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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Buğdayda Farklı *Fusarium culmorum* İzolatları ile *Pratylenchus thornei* Etkileşimi

Interaction of Different *Fusarium culmorum* Isolates and *Pratylenchus thornei* on Wheat

Fatma Gül GÖZE ÖZDEMİR[1]* Şerife Evrim ARICI[2] İbrahim Halil ELEKÇİOĞLU[3]

Öz

Çalışmada Türkiye'nin Isparta ve Burdur illerinden izole edilen on iki *Fusarium culmorum* (W. G. Sm.) Sacc. izolatı ile *Pratylenchus thornei* (Sher and Allen),1953 etkileşimi İkizce buğday çeşidinde kontrollü koşullar altında (25±2°C ve %60±5 nem) araştırılmıştır. Buğdaylarda ilk kardeş yapraklar oluştuktan sonra deneme kurulmuş ve 4 uygulamada denemeler yapılmıştır. Uygulamalar; sadece *P. thornei* uygulaması (N), sadece *F. culmorum* uygulaması (FCUL), eş zamanlı *P. thornei* ve *F. culmorum* uygulaması (N+FCUL) ve *P. thornei* uygulamasından 2 hafta sonra *F. culmorum* uygulaması (N+2FCUL) olarak yapılmıştır. *Fusarium culmorum* izolatlarının inokulasyonunda her saksıya %50 oranında seyreltilmiş kültür filtratı konsantrasyonundan 5 ml, *P. thornei* popülasyonu için ise 1000 larva+ergin birey inokulum yoğunluğu kullanılmıştır. Değerlendirme işlemi buğdayda hastalık şiddeti ve nematod üreme oranı üzerinden denemenin kurulumundan 8 hafta sonra gerçekleştirilmiştir. Çalışmada N+FCUL ve N+2FCUL uygulamalarına bakıldığında *P. thornei*'nin sadece *F. culmorum*'un YLVC16 izolatında hastalık şiddetinin artışına katkısının olduğu görülmüştür. YLVC16 izolatında hastalık şiddeti skala değeri FCUL uygulamasında 2.4 belirlenirken, N+FCUL ve N+2FCUL uygulamalarında sırasıyla 3.4 ve 3.6 tespit edilmiştir. *Pratylenchus thornei* üreme oranı N uygulamasında 2.5 bulunmuştur. *Fusarium culmorum*'un YLVC16, T21 ve K17 izolatları ile kurulan denemelerinde *P. thornei* üreme oranı N+FCUL uygulamasında sırasıyla 3.1, 3.0 ve 3.3 tespit edilirken, N+2FCUL uygulamasında 3.1, 3.2 ve 3.4 saptanmıştır. Ancak *P. thornei* üreme oranı açısından YLVC16, T21 ve K17 izolatları ile kurulan denemelerde N+FCUL ve N+2FCUL uygulamaları arasında önemli bir farklılık belirlenememiştir. Çalışmada 12 *F. culmorum* izolatı içerisinden sadece üç tanesinin (YLVC16, T21 ve K17) *P. thornei* üreme oranına pozitif katkısı belirlenirken, *P. thornei*'nin ise sadece bir *F. culmorum* izolatının (YLVC16) hastalık şiddetine katkısının olduğu belirlenmiştir.

Anahtar Kelimeler: Buğday, *Pratylenchus thornei*, *Fusarium culmorum*, Patojenisite, İnteraksiyon, Sinerjistik etki

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Abstract

In present study, the interaction of twelve *Fusarium culmorum* (W. G. Sm.) Sacc. isolates from Isparta, Burdur in Turkey and *Pratylenchus thornei* (Sher and Allen),1953 were investigated under controlled conditions (25±2°C and 60±5% RH) in Ikizce wheat cultivar. The experiment was established after the first leaves at tillering on wheat and working with four applications. Applications; only *P. thornei* inoculation (N), only *F. culmorum* inoculation (FCUL), simultaneous inoculation of *P. thornei* and *F. culmorum* (N+FCUL), and *R. solani* inoculation two weeks after *P. thornei* application (N+2FCUL) were made. In the inoculation of *F. culmorum* isolates, 5 ml of 50% diluted culture filtrate concentration was used for each pot, and 1000 larva+adult inoculum density was used for the *P. thornei* population. Evaluation was carried out 8 weeks after the establishment with disease severity and nematode reproduction rate on wheat. When N+FCUL and N+2FCUL applications were examined in the study, it was observed that *P. thornei* contributed to the increase of disease severity only in the YLVC16 isolate of *F. culmorum*. The disease severity scale of YLVC16 isolate was 2.4 in FCUL application, while 3.4 and 3.6 were in N+FCUL and N+2FCUL applications, respectively. The reproduction rate of *P. thornei* was found to be 2.5 in N application. In the experiment established with YLVC16, T21 and K17 isolates of *F. culmorum*, the reproduction rate of *P. thornei* was determined as 3.1, 3.0 and 3.3 in N+FCUL application, while 3.1, 3.2 and 3.4 in N+2FCUL application. Also, in terms of *P. thornei* reproduction rate, no significant difference was determined between N+FCUL and N+2FCUL applications in the experiment established with YLVC16, T21 and K17 isolates. In the present study, it was determined that only three of the 12 *F. culmorum* isolates (YLVC16, T21 and K17) contributed positively to the *P. thornei* reproduction rate, while *P. thornei* contributed to only one *F. culmorum* isolate (YLVC16) disease severity.

Keywords: Wheat, *Pratylenchus thornei*, *Fusarium culmorum*, Pathogenicity, Interaction, Synergistic effect

1. Giriş

Dünya toplam tahıl üretimi 2.7 milyar ton olup USDA'nın 2020/21 üretim sezonu projeksiyonlarına göre bunun %28'ini buğday üretimi oluştururken, 464 milyon ton olan dünya toplam tahıl ihracatının %42'sini buğday oluşturmaktadır. Buğday ekim alanının %55.3'ünü Hindistan, Rusya, AB, Çin ve ABD oluştururken, bu ülkeler dünya buğday üretiminin %65.4'ünü oluşturmaktadır (USDA, 2021). Son dönemlerde dünyada yaşanan COVID-19 salgını sebebiyle buğday ürünlerine olan talep çok fazla artmaktadır ve buğday, strateji uzmanlarına göre 21. yüzyılın en önemli jeo-ekonomik gücüdür (Koca, 1999; Akdağ ve Zengin, 2020). Türkiye ve gelişmekte olan ülkelerde ekmeklik buğday (*Triticum aestivum* L.) ve makarnalık buğday (*Triticum durum* Desf.) temel besin kaynaklarını oluşturmaktadır. TÜİK verilerine göre Türkiye buğday ekim alanı 2019/20 üretim sezonu itibariyle dünya buğday ekim alanının %3.2'sini oluşturmaktadır. Bu toplam ekilen tahıl alanın %44'ünü teşkil etmektedir. Türkiye'de 2019/20 üretim sezonunda 68.5 milyon da buğday üretimi yapılmıştır (TUİK, 2020).

Buğday üretimini bazı abiyotik ve biyotik faktörler sınırlandırmaktadır. Bunlardan abiyotik faktörler; uygun olmayan meteorolojik koşullar, elverişsiz toprak şartları, çevre kirliliği ve hatalı tarımsal işlemlerdir. Biyotik faktörler ise yabancı otlar, zararlılar, nematodlar ve hastalık etmenleridir. Buğdayda birim alandan elde edilecek verimi arttırmak için, verimli ve kaliteli çeşitler uygun şartlarda yetiştirilmeli ve bitki hastalık etmenleri ile mücadeleye de dikkat edilmelidir. Buğday da her yıl hasat edilen ürünün yaklaşık % 20'sinin hastalıklar nedeniyle kaybolduğu tahmin edilmektedir (Araz ve ark., 2009; Köycü ve Sükut, 2018). Buğdayda en çok *Fusarium* spp. (*F. graminearum, F. culmorum, F. nivale, F. avenaceum, F. poae*), *Rhizoctonia* spp. (*R. solani, R. cerealis* ve *R. oryzae*), *Pythium* spp., *Gaeumannomyces graminis* var. *tritici, Bipolaris sorokiniana, Pseudocercosporella herpotrichoides* ve *Alternaria* spp.'nin neden olduğu kök ve kök boğazı hastalıkları görülmektedir. Yapılan araştırmalarda Fusarium cinsi fungusların infeksiyonu sonucu ürün kayıplarının %50'ye ulaştığı saptanmıştır (Hekimhan ve ark., 2004; Araz ve ark., 2009; Arıcı ve ark., 2013).

Fusarium cinsi içerisinde *F. pseudograminearum, F. graminearum, F. culmorum ve F. avenaceum* virulensi en yüksek türler olarak tespit edilmiştir (Parry, 1990). Bu türler arasında *F. culmorum* (W. G. Sm.) Sacc. Dünyada ve Türkiye'de buğdayda en önemli patojenlerden biri olarak tespit edilmiştir (Wagacha ve Muthomi, 2007; Hogg ve ark., 2010; Treikale ve ark., 2010; Miedaner ve ark., 2008; Arıcı ve ark., 2013; Köycü ve Sukut, 2018; Erginbas Orakcı ve ark., 2018). Fusarium kök çürüklüğü, taç ve alt gövde dokusunun çürümesi ile karakterize edilir, bu da hastalık için uygun koşullar altında buruşmuş veya tanesiz dağınık beyaz başlarla ve sonuçta tane kalitesi ve miktarında azalma ile sonuçlanır (Scherm ve ark., 2013). *Fusarium culmorum*, büyük bir moleküler ve fenotipik çeşitlilik gösterir. Virülenslik, mikotoksin profilleri/üretimi ve konsantrasyonlar izolatlar arasında farklı olabilmektedir (Miedaner ve ark., 1996; Gang ve ark., 1998; Muthomi ve ark., 2000). *Fusarium culmorum* izolatları arasında görülen virülenslik yüksek kalıtsallığa sahip, genetik olarak kararlı bir özelliktir (Miedaner ve ark., 1996). Sıcaklık, yağış ve nem gibi çevresel faktörlerin *Fusarium* spp. popülasyonu ve hastalık şiddeti üzerinde önemli bir etkisi vardır (Vigier ve ark., 1997). Agresif Fusarium ırklarının buğdayı hastalandırma yeteneği, kültürde veya enfekte dokularda büyük miktarlarda trikotesen üretme yetenekleriyle ilgilidir (Hestbjerg ve ark., 2002; Scherm ve ark., 2011). *Fusarium culmorum* tarafından üretilen trikotesen mikotoksinleri (DON, nivalenol (NIV), 3-acetyldeoxynivalenol, acetyl T-2 toxin, zearalenone (ZON) ve fusarins), konukçu bitkiler tarafından aktive edilen savunma mekanizmalarını engelleyerek hastalığın yayılmasından sorumludur (Demeke ve ark., 2005; Llorens ve ark., 2006; Wagacha ve Muthomi, 2007).

Pratylenchus thornei (Sher and Allen), 1953 (Tylenchida: Pratylenchidae) dünyada ve Türkiye'de ekonomik olarak önemli bir bitki paraziti nematod türü olarak tespit edilmiştir (Mokrini ve ark. 2019; Fanning ve ark., 2020; Kasapoğlu ve ark., 2014; Kasapoğlu Uludamar ve ark., 2018; Yavuzaslanoglu ve ark., 2012, 2020; Toktay ve ark., 2020; Göze Özdemir, 2021; Göze Özdemir ve ark., 2021). *Pratylenchus thornei* stileti yardımıyla bitki kök dokusuna giriş yapan ve kök korteks hücrelerinin sitoplazmasından besinleri çekmek için hücre içine göç eden hareketli endoparazit bir nematod türüdür (Channale ve ark., 2021). Beslenmenin ve kök hücrelerinin içinde üremenin neden olduğu hasar nedeniyle su stresi, bodurluk, solma, klorozlu yapraklar gibi besin eksikliğinde görülen belirtiler ortaya çıkmaktadır (Castillo ve Vovlas, 2007; Thompson ve ark., 2012; Whish ve ark., 2014). Ayrıca kök lezyon nematodlarının bitkilerde penetrasyon ve beslenme sürecinde açtığı yaraların toprak kaynaklı patojenler için giriş kaynağı olduğu belirtilmektedir (LaMondia, 2003; Hoseini ve ark., 2010; Da Silva, 2010; Mallaiah ve ark., 2014).

Bitki paraziti nematodlar ve fungusların etkileşimleri nematod ve fungus türü, yoğunluğu, üreme gücü, patojenite özelliği, bitki türü/çeşidi, bitki yaşı ve toprak tipi gibi birçok faktöre bağlı olarak değişmektedir (Saeed ve ark.,1998; Hafez ve ark., 1999; Agu ve Ogbuji, 2000; Back ve ark., 2002; Antoon ve ark., 2009; Hoseini ve ark., 2010; Charegani ve ark., 2012; Hassan ve ark., 2012; Hajihassani ve ark., 2013a,b). Nematod ve fungus arasındaki sinerjistik etkileşimde bitki zarar görürken, antagonistik etkileşim ise bitkiye olumlu yansımaktadır (Back ve ark., 2002). 4,15-diacetylnivalenol ve 4,15 diacetoxyscirpenol (DON) bileşiklerini üreten *Fusarium* türlerinin bitki paraziti nematodlara karşı toksik etkisinin olduğu tespit edilmiştir (Rotter, 1996; Nitao ve ark., 2001). Taheri ve ark. (1994), buğdayda *P. neglectus* varlığında *F. oxysporum, F. equiseti* ve *F. acuminatum*'un köklerdeki hastalık şiddetinin arttığı ancak; nematod yoğunluğunun başlangıç inokulasyon yoğunluğundan daha düşük olduğunu bildirmiştir. Başka çalışmada Hoseini ve ark. (2010), çay bitkisinde *Rhizoctania solani* ve *F. proliferatum*'un *P. loosi* yoğunluğunda önemli artışa neden olurken, *F. pallidorum* ve *Sclertotium rolfsii*'nin *P. loosi* popülasyon yoğunluğuna etkisinin olmadığını ve *R. solani*'nin *P. loosi* ile yüksek sinerjistik ilişki içerisinde olduğunu saptamışlardır. Göze Özdemir ve ark. (2022a), İkizce buğday çeşidinde *P. thornei, P. neglectus* ve *P. penetrans* ile *F. culmorum* B4 izolatı ile eş zamanlı ve ardışık inokulasyonlar ile yürütttüğü çalışmada aralarındaki etkileşimde, kök lezyon nematodlarının türleri arasında farklılıklar tespit etmiş ve buğdayda nematod gelişiminde *F. culmorum* uygulama zamanının önemli olduğunu belirtmiştir. Ayrıca buğdayda kontrollü koşullarda üç *P. thornei* popülasyonu (SK11, SK24 ve YLVC24) ile *F. culmorum* B4 izolatı'nın interaksiyonunun araştırıldığı çalışmada sadece SK24 popülasyonu ile *F. culmorum* arasında sinerjistik etkileşim bulunmuştur (Göze Özdemir ve ark., 2022b). *Fusarium culmorum* izolatları arasında görülen patojenite farklılıklarının bitki paraziti nematodlarla ilişkileri değiştirebileceği düşünülmektedir. Bu çalışmada kontrollü koşullar altında İkizce buğday çeşidinde *P. thornei* popülasyonu ile on iki *F. culmorum* izolatı arasındaki etkileşimin eşzamanlı ve ardışık inokulasyonlarla belirlenmesi amaçlanmıştır.

2. Materyal ve Metot

2.1. Materyal

Çalışma buğday tarlalarından izole edilen on iki *F. culmorum* izolatı (G14, K8, YLVC16, SK20, CAV6, T21, GOL2, GOL18, YOVA22, YOVA27, YOVA21, K17) ve *P. thornei* SK24 izolatı ile İkizce buğday çeşidi kullanılarak yürütülmüştür. *Pratylenchus thornei* popülasyonu daha önce yürütülen çalışmadan sağlanmış (Göze Özdemir, 2021) ve kitle üretimleri ISUBU Ziraat Fakültesi Bitki Koruma Bölümü Nematoloji Laboratuarında Zuckerman (1985) yöntemiyle havuç disklerinde devam ettirilmiştir. *F. culmorum* izolatları Isparta ve Burdur illerinden buğday ve arpa tarlalarından kök ve kökboğazı ile sap bölgesinde çürüklük şeklinde hastalık belirtileri gösteren bitki materyallerinden izolasyonu gerçekleştirilmiş ve morfolojik teşhisleri yapılmıştır (Booth, 1971; Nelson ve ark., 1983; Leslie ve Summerell, 2006). Çalışmada kullanılan *F. culmorum* izolatları'nın orijinleri *Tablo 1'* de verilmiştir.

2.2. Metot

2.2.1.Nematod İnokulumunun Hazırlanması

Pratylenchus thornei SK24 izolatının kitle üretimin gerçekleştirildiği havuç diskleri ayrı ayrı 120 mm petri kaplarına aktarılmıştır. Aktarılan havuç diski küçük parçalara bölünmüş ve petri kabını kaplayacak şekilde steril saf su eklenmiştir. Altı saat sonra nematodlar geliştirilmiş Baermann huni yöntemi kullanılarak elde edilmiştir. Mezurlar içerisinde elde edilen nematod süspansiyonlarının her bir tekrarı 15 ml'ye düşürülmüş ve santrifüj tüplerine alınmıştır (Mudiope ve ark., 2004). Santrifüj tüplerinde nematodların dibe çökmesi için 4 saat beklendikten sonra üstteki sıvı atılarak 1 ml ye düşürülmüş ve dipteki kısımdan ergin+larva ışık mikroskobu altında 40X büyütmede sayılmıştır. Daha sonra çalışmada kullanılacak nematod yoğunluğu ayarlanarak saf su içeren eppendorf tüpler içerisinde +4 °C de buzdolabında bekletilmiştir.

2.2.2.Fungus İnokulumunun Hazırlanması

On iki *F. culmorum* izolatının kültür filtratı hazırlanmıştır. Kültür filtratında PDB (Potato Dextrose Broth, Neogen®) ortamı kullanılmış olup, 50 ml PDB içeren 250 ml'lik erlenlerde otoklavda 1.2 atm basınçta, 121 °C'de 20 dk. sterilize edilmiştir. Daha önce Patates Dekstroz Agar (PDA-Merck ®) ortamında gelişen 7-10 günlük her bir *F. culmorum* izolatının fungus kolonisinden 5-7 adet (1 cm'lik) erlenmayer içerisine konulmuş ve laboratuvarda 25 °±1 C'de karanlıkta 21 gün boyunca bekletilmiştir (Bhagawati ve ark., 2000; Arıcı, 2006). İnkübasyon süresince her gün elle çalkalama işlemi gerçekleştirilmiştir. Daha sonrada fungus misel ve sporlarını uzaklaştırmak için önce

iki kat filtre kağıdından (Whatman No. 1) geçirildikten sonra aspiratör yardımıyla steril nuçe erlenmayeri içerisine çekilmiştir. Saf kültür filtratı, distile su yardımıyla %50 oranında seyreltilmiş ve denemede bu konsantrasyon kullanılmıştır (Göze Özdemir, 2020).

Tablo1. Denemede kullanılan Fusarium culmorum izolatları

Table 1. Fusarium culmorum isolates used in the experiment

İzolat	İzole edildiği yer	İzole edildiği bitki	Koordinat	Yükseklik (m)
G14	Gelendost/Isparta	Buğday	N: 38˚12'02.7''/ E: 030˚59'30.7''	1064
K8	Keçiborlu/Isparta	Buğday	N: 37˚58'48.6''/ E: 030˚17'45.0''	1163
YLVC16	Yalvaç/Isparta	Arpa	N: 38˚19'54.8''/ E: 031˚09'50.7''	1143
SK20	Şarkikaraağaç/Isparta	Arpa	N: 38˚04'59.9''/ E: 031˚24'14.5''	1211
CAV6	Çavdır/Burdur	Buğday	N: 37˚06'55.8'' / E: 029˚42'41.5''	1066
T21	Tefenni/Burdur	Buğday	N: 37˚15'14.0"/ E: 029˚45'13.3"	1178
GOL2	Gölhisar/Burdur	Arpa	N: 37˚05'00.8''/ E: 029˚31'39.1''	985
GOL18	Gölhisar/Burdur	Buğday	N: 37˚09'04.5''/ E: 029˚36'59.7''	970
YOVA21	Yeşilova/Burdur	Arpa	N: 37˚31'25.2"/ E: 029˚39'7.3"	1169
YOVA22	Yeşilova/Burdur	Arpa	N: 37˚31'19.8"/ E: 029˚38'55.3"	1158
YOVA27	Yeşilova/Burdur	Buğday	N: 37˚32'10.6"/ E: 029˚37'11.6"	1183
K17	Karamanlı/Burdur	Arpa	N: 37˚22'58.4"/ E: 029˚53'36.8"	1118

2.2.3. Buğdayda *Fusarium culmorum* İzolatlarının *Pratylenchus thornei* Popülasyonu ile Etkileşimlerinin Belirlenmesi

Denemede kullanılan toprak karışımı (% 68 kum, % 21 Silt ve %11 kil) otoklavda steril edildikten sonra 500 cc'lik plastik saksılara 500 g toprak karışımı konulmuş ve kontrollü koşullar altında 25±2°C sıcaklık ve %60±5 orantılı nem içeren iklim odasına yerleştirilmiştir. Her saksıya 3 adet İkizce buğday tohumu atılmış ve 3 buğday bitkisi 1 tekerrür olarak kabul edilmiştir. Deneme, tesadüf parselleri deneme desenine göre 5 tekerrürlü olacak şekilde kurulmuştur. *Pratylenchus thornei* popülasyonu için inokulum yoğunluğu 1000 larva+ergin birey kullanılırken, *F. culmorum* izolatlarının inokulumunda her saksıya 5 ml konsantrasyon kullanılmıştır (Göze Özdemir, 2020). Her *F. culmorum* izolatı için deneme ayrı ayrı kurulmuş ve 4 uygulamadan oluşmuştur. Ayrıca buğday bitkilerine sadece *F. culmorum* uygulaması ile izolatların patojeniteleri araştırılmıştır. Uygulamalar; sadece *P. thornei* uygulanmış bitki (N), sadece *F. culmorum* uygulanmış bitki (FCUL), eş zamanlı *P. thornei* ve *F. culmorum* uygulanmış bitki (N+FCUL), ve *P. thornei* uygulamasından 2 hafta sonra *F. culmorum* uygulanmış bitki (N+2FCUL) şeklinde planlanmıştır (Hoseini ve ark., 2010). Buğdaylarda ilk kardeş yapraklar oluştuktan sonra deneme kurulmuştur. Nematod inokulasyonu buğday kök bölgesi etrafına 2-3 cm toprak derinliğine açılan deliklere plastik puarlı pipetler yardımıyla yapılırken, fungus inokulumu toprak yüzeyine mezür yardımıyla dökülmüştür. Bitkiler yaklaşık 8 hafta sonra sökülerek değerlendirme işlemi yapılmıştır. Değerlendirme işlemi; 0-4 hastalık şiddeti (0 = sağlıklı, 1 = %25'den az nekroz, 2 = %25–50 arasında nekroz nekroz,3=%50-75 arasında nekroz ve 4 = % 75'den fazla nekroz) (Wildermuth ve McNamara, 1994) ve nematod üreme oranı (RF=PF (final)/ Pİ (ilk)) üzerinden gerçekleştirilmiştir. Üreme oranı hesaplamak için kullanılan PF değeri toprak ve kökten geliştirilmiş Baerman huni yöntemiyle elde edilen nematodların yoğunluğudur (Göze Özdemir, 2020).

2.2.4. İstatistiksel Analiz

Çalışmada elde edilen verilerin istatistiksel analizi için SPSS (versiyon 20.0) programı kullanılmış ve ilgili çalışma tesadüf parselleri deneme modeline göre yapılmıştır. Farklı grup ortalamalarını belirlemek için varyansların homojen olduğu durumlarda "Tukey testi" kullanılmıştır (P≤0,05).

3. Araştırma Sonuçları ve Tartışma

Yapılan bu araştırmada sadece *F. culmorum* uygulamasında (FCUL), buğdayda *F. culmorum* izolatlarının patojenitelerinde farklılıklar belirlenmiştir. FCUL uygulaması değerlendirildiğinde en düşük hastalık şiddeti skala değeri 1.0 ile G14 izolatında belirlenirken, en yüksek skala değeri 3.6 ile K17 izolatında bulunmuş, bunu YOVA27 (3.4) ve CAV6 (3.4) izolatları takip etmiştir. Isparta ilinden elde edilen *F. culmorum* izolatlarının (G14, K8, YLVC16, SK20) hastalık şiddeti skala değeri 1.0-2.4 aralığında belirlenmiştir. Burdur ilinden elde edilen *F. culmorum* izolatlarının 4'ünün (CAV6, T21, YOVA27, K17) hastalık şiddeti skala değerleri 3.0-3.6 arasında bulunmuştur. GOL2, GOL18, YOVA21 ve YOVA22 izolatlarının skala değerleri 1.2-2.2 arasında saptanmıştır. Burdur ili Gölhisar ilçesinden izole edilen GOL2 (1.8) ve GOL18 (2.2) izolatların patojeniteleri birbirine yakın bulunurken, Yeşilova ilçesinden arpa bitkisinden izole edilen YOVA22 (2.2) ve YOVA21 (2.2) ile buğdaydan izole edilen YOVA27 (3.4) izolatlarının patojenitelerinde önemli farklılık belirlenmiştir. Burdur ili Yeşilova ilçesinde buğdaydan izole edilen YOVA27 *F. culmorum* izolatının daha patojenik olduğu saptanmıştır (*Tablo 2*).

Eş zamanlı *P. thornei* ve *F. culmorum* uygulaması (N+FCUL) ve *P. thornei* uygulamasından 2 hafta sonra *F. culmorum* uygulaması (N+2FCUL) sadece FCUL uygulamasıyla karşılaştırıldığında hastalık şiddetinde artış olmasına rağmen YLVC16 izolatı hariç diğer 11 izolatta uygulamalar arasında istatistiki bir fark belirlenememiştir (P≥0,05). YLVC16 izolatında hastalık şiddeti skala değeri N+FCUL uygulamasında 3.4 bulunurken, N+2FCUL uygulamasında 3.6 tespit edilmiş ve aralarındaki fark istatistiki olarak anlamlı bulunmamıştır (P≥0,05). Ancak YLVC16 izolatında FCUL (2.4/0-4 skala) uygulamasının hastalık şiddeti skala değeri 2.4 bulunmuş ve N+FCUL ile N+2FCUL uygulamalarından düşük değerde tespit edilmiştir. İkizce buğday çeşidinde sadece YLVC16 *F. culmorum* izolatında *P. thornei*'nin hastalık şiddetine katkısı olduğu belirlenmiştir (*Tablo 2*).

Tablo 2. Ikizce Buğday Bitkisinde Fusarium culmorum İzolatları ve Pratylenchus thornei Etkileşiminde Hastalık Şiddeti

Table 2. Disease Severity in the Interaction of Fusarium culmorum Isolates and Pratylenchus thornei in İkizce Wheat Cultivar

***Fusarium culmorum* izolatları**	**Uygulama**		
	***Fusarium culmorum* hastalık şiddeti ortalaması ±Standart Hata**		
	FCUL	**N+FCUL**	**N+2FCUL**
G14	1.0±0.3 e*	1.4±0.2 e	1.6±0.2 d
K8	2.2±0.3 b-e	2.6±0.2 b-e	2.6±0.2 bc
YLVC16	2.4±0.2 a-d B	3.4±0.2 abc A	3.6±0.2 ab A
SK20	1.8±0.2 c-e	2.0±0.0 e	2.4±0.2 cd
CAV6	3.4±0.2 ab	3.6±0.2 ab	4.0±0.0 a
T21	3.0±0.3 abc	3.2±0.2 a-d	3.6±0.2 ab
GOL2	1.8±0.2 c-e	2.2±0.2 de	2.6±0.2 bc
GOL18	2.2±0.2 b-e	2.4±0.2 cde	2.6±0.2 bc
YOVA21	1.2±0.3 de	1.8±0.2 e	2.2±0.2cd
YOVA22	2.2±0.3 b-e	2.4±0.2 cde	2.6±0.2 bc
YOVA27	3.4±0.2 ab	3.8±0.8 a	4.0±0.0 a
K17	3.6±0.2 a	4.0±0.0 a	4.0±0.0 a

FCUL: Sadece *F. culmorum* uygulanmış bitki, N+FCUL: Eş zamanlı *P. thornei* ve *F. culmorum* uygulanmış bitki, N+2FCUL: *P. thornei* uygulamasından 2 hafta sonra *F. culmorum* uygulanmış bitki
* Küçük harfler aynı sütunda ortalamalar arasındaki farklılıkları, büyük harfler aynı satırdaki ortalamalar arasındaki farklılıkları göstermektedir (P≤0.05)

İkizce buğday çeşidinde sadece *P. thornei* uygulamasında üreme oranı 2.5 belirlenmiştir. YLVC16, T21 ve K17 izolatları ile kurulan denemelerde eş zamanlı nematod ve fungus uygulaması (N+FCUL) ile nematod

uygulamasından 2 hafta sonra fungus uygulamalarında (N+2FCUL) *P. thornei* üreme oranında artış tespit edilmiştir. Ancak *P. thornei* üreme oranı YLVC16, T21 ve K17 izolatları ile kurulan denemelerde N+FCUL ve N+2FCUL uygulamaları arasında istatistiki fark bulunamamıştır. Diğer dokuz izolatta N, N+FCUL ve N+2FCUL uygulamalarında *P. thornei* üreme oranlarında bir değişim belirlenememiştir. *Fusarium culmorum* YLVC16 (3.1), T21 (3.2) ve K17 (3.4) izolatları'nın *P. thornei* gelişimine pozitif katkısı olduğu belirlenmiştir ve *P. thornei* popülasyonunun üreme oranında artış gözlenmiştir (*Tablo 3*).

Tablo 3. İkizce Buğday Çeşidinde Fusarium culmorum İzolatları ve Pratylenchus thornei Etkileşiminde Nematod Üreme Oranı

Table 3. Nematode Reproduction Rate in the Interaction of Fusarium culmorum Isolates and Pratylenchus thornei in İkizce Wheat Cultivar

***Fusarium culmorum* izolatları**	**Uygulama (*Pratylenchus thornei* üreme oranı ortalaması±Standart hata)**		
	N	**N+FCUL**	**N+2FCUL**
G14	2.5±0.1 a*	2.6±0.0 b	2.6±0.1 c
K8	2.5±0.1a	2.6±0.2 b	2.6±0.0 c
YLVC16	2.5±0.1a B	3.1±0.1 ab A	3.1±0.0 abc A
SK20	2.5±0.1a	2.6±0.1 b	2.7±0.1 bc
CAV6	2.5±0.1a	2.7±0.1 b	2.8±0.1 bc
T21	2.5±0.1 aB	3.0±0.0 ab A	3.2±0.1 ab A
GOL2	2.5±0.1a	2.6±0.2 b	2.7±0.0 bc
GOL18	2.5±0.1a	2.7±0.0 b	2.8±0.0 bc
YOVA21	2.5±0.1a	2.8±0.0 b	2.8±0.1 bc
YOVA22	2.5±0.1a	2.7±0.2 b	2.7±0.1 bc
YOVA27	2.5±0.1a	2.6±0.1 b	2.8±0.1 bc
K17	2.5±0.1a B	3.3±0.0 a A	3.4±0.0 a A

N: Sadece *P. thornei* uygulanmış bitki, N+FCUL: Eş zamanlı *P. thornei* ve *F. culmorum* uygulanmış bitki, N+2FCUL: *P. thornei* uygulamasından 2 hafta sonra *F. culmorum* uygulanmış bitki

* Küçük harfler aynı sütunda ortalamalar arasındaki farklılıkları, büyük harfler aynı satırdaki ortalamalar arasındaki farklılıkları göstermektedir (P≤0.05)

Çalışmada *F. culmorum* YLVC16 izolatı'nın buğdayda *P. thornei* üreme oranına pozitif katkısı belirlenirken, *P. thornei*'nin de YLVC16 hastalık şiddetini arttırdığı tespit edilmiştir (*Tablo 2;3*). Buğdayda YLVC16 izolatı ve SK24 *P. thornei* izolatı arasında sinerjistik ilişki belirlenmiştir. *Pratylenchus thornei*'nin buğdayda *F. culmorum* T21 izolatı'nın hastalık şiddetine pozitif katkısı belirlenememiş, ancak T21 izolatı'nın *P. thornei* üreme oranını artırdığı saptanmıştır (*Tablo 3*). K17 izolatının buğdayda sadece *F. culmorum* uygulamasında yüksek patojenite gösterdiği dolayısıyla nematodla birlikte olduğu uygulamalarda da en yüksek skala değerini aldığı için aralarında istatistiki olarak fark bulunamamıştır. Ayrıca K17 izolatı'nın SK24 *P. thornei* izolatı'nın üreme oranına pozitif katkısı belirlenmiştir (*Tablo 3*). *Fusarium culmorum* K17 izolatı ve SK24 *P. thornei* izolatı arasında da sinerjistik ilişki olduğu düşünülmektedir.

Bu çalışmada üç *F. culmorum* (YLVC16, T21 ve K17) izolatının buğdayda *P. thornei* ile eş zamanlı inokulasyonu ve nematod inokulasyonundan 2 hafta sonra uygulanması durumunda nematod yoğunluğunu artırması sonucu üreme oranının arttığı saptanmıştır. Rotenberg ve ark. (2004) Russet Burbank patates köklerinde inokulasyondan 16 gün sonra yalnız *P. penetrans* uygulamasında nematod yoğunluğunu eş zamanlı *P. penetrans* ve *Verticillium dahliae* uygulamasından daha düşük tespit etmişlerdir. Hoseini ve ark. (2010), çay bitkisinde *F. proliferatum*'un *P. loosi* yoğunluğunda önemli artışa neden olduğunu bulmuştur. Mallaiah ve ark. (2014), kontrollü koşullarda crossandra çiçeğinde *P. delattrei* (1 adet/g) ve *F. incarnatum* (%3)'un patojen uygulamasından 7 gün önce nematod uygulandığında 150 gün sonra nematod popülasyonunda %90.5 artış bulurken, yüzde solgunluk oranını 58.3 olarak saptamışlar ve denemedeki en yüksek oran olduğunu belirtmişlerdir.

Bu çalışmada buğdayda *P. thornei*'nin *F. culmorum*'un sadece YLVC16 nolu izolatında hastalık şiddetine katkısı olduğu bulunmuştur. Dokuz *F.culmorum* izolatında (G14, K8, SK20, CAV6, GOL2, GOL18, YOVA21, YOVA22,YOVA27) ise buğdayda eş zamanlı *P. thornei* ve *F. culmorum* uygulaması ile *P. thornei* uygulamasından 2 hafta sonra *F. culmorum* uygulamasında hastalık şiddeti skala değerinin artmadığı saptanmıştır.

Kök lezyon nematodlarının açtığı yaraların toprak kaynaklı patojenlerin enfeksiyon oranını artırdığı bildirilmiştir (Hoseini ve ark., 2010; Da Silva, 2010; Mallaiah ve ark., 2014). Göze Özdemir ve ark. (2022a), İkizce buğday çeşidinde *P. thornei*'nin *F. culmorum* B4 izolatın'dan önce ve eş zamanlı olarak bitkiye inokulasyonunda hastalık şiddetine olumlu etki yaptığını belirlemişlerdir. Ancak bu çalışmada *P. thornei*'nin tüm denemelerde buğday köklerinde enfeksiyon oluşturmasına rağmen *F. culmorum* izolatlarının hastalık şiddetine olumlu katkısı belirlenememiştir. Ayrıca buğdayda SK11, SK24 ve YLVC24 *P.thornei* popülasyonları ile kurulan denemelerde hastalık şiddeti parametresinde yalnız fungus, eş zamanlı ve ardışık nematod fungus uygulamaları arasında önemli bir farklılık bulunamamıştır (Göze Özdemir ve ark., 2022b). Bazı çalışmalarda laboratuvar koşullarında bazı *Fusarium* türlerinin ve *F. culmorum*'un bitki paraziti nematodlara karşı toksik etkisinin olduğu tespit edilmiştir (Rotter ve ark., 1996; Nitao ve ark., 2001; Athman, 2006; Vu ve ark., 2006; Göze Özdemir ve ark., 2018, 2021). Ancak çalışmada *F. culmorum* izolatları ile *P. thornei* arasında antagonistik bir ilişki de saptanmamıştır.

Çalışmada *F. culmorum* yüksek virülensliği ile nematod-fungus etkileşimlerinde doğrudan ilişki bulunamamıştır. Patojenite denemesinde virülent bulunan CAV6 ve YOVA27 izolatları'nda beklenenin aksine *P. thornei* ile herhangi bir interaksiyon belirlenememiştir. YLVC16 izolatı'nın virülensi FCUL uygulamasında CAV6 ve YOVA27 izolatlarından daha düşük olmasına rağmen *P. thornei* ile sinerjistik etkileşim kurduğu belirlenmiştir (*Tablo 2;3*). Bu durum nematod ve fungus ilişkilerinin oldukça spesifik ve birçok faktöre bağlı olarak değişebileceğini göstermektedir. Ayrıca yapılan çalışmalarda mikotoksin profilleri ve konsantrasyonlarının *F. culmorum* izolatları arasında farklılık gösterdiği belirtilmektedir (Miedaner ve ark., 1996; Gang ve ark., 1998; Muthomi ve ark., 2000). Bu farklılıkların nematod etkileşimlerinde önemli olabileceği düşünülmektedir. Yapılan araştırmalarda fungusun virülenslik derecesi buğdayı enfekte etme yeteneği, kültürde veya enfekte dokularda büyük miktarlarda trikotesen üretme yetenekleriyle ilgili olduğu belirlenmiş olmasına rağmen (Hestbjerg ve ark., 2002; Scherm ve ark., 2011), korelasyonun her zaman doğrudan olmadığı belirtilmiştir (Gang ve ark., 1998).

4. Sonuç

Fusarium culmorum YLVC16 ve K17 izolatları ile *P. thornei* arasında buğdayda sinerjistik ilişki bulunurken, diğer izolatlarda herhangi bir etkileşim saptanamamıştır. *Fusarium culmorum*'un virülent olarak belirlenen tüm izolatları ile *P. thornei* arasında bir etkileşim belirlenememiştir. Buğdayda *F. culmorum* ve *P. thornei* etkileşiminin oldukça spesifik, kompleks ve birden çok faktöre bağlı olduğu düşünülmektedir. *Pratylenchus thornei* ve *F. culmorum* etkileşiminde fungus virülensliğinin doğrudan ilişkili olduğu düşünülmemektedir. Ancak *F. culmorum* izolat farklılığının *P. thornei* ile kurulan etkileşimde önemli olduğu saptanmıştır. *Fusarium culmorum* izolatına bağlı olarak *P. thornei* ile kurulan sinerjistik veya antogonistik ilişki düzeyinin değişebileceği belirlenmiştir. İzolatların mikotoksin profilleri ve konsantrasyonlarının farklılık gösterebileceği bilinmekte ve bu farklılıkların nematod-fungus etkileşimlerinde daha önemli olduğu düşünülmektedir. Bu yüzden *F. culmorum* izolatlarının mikotoksin profillerinin belirlenmesi ve ayrı ayrı nematod etkileşimlerinin değerlendirilmesi önem taşımaktadır.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

İkinci Ürün Olarak Yetiştirilen Silajlık Mısır Çeşitlerinin Silaj Verimi ve Bazı Kalite Özellikleri*

Silage Yield and Some Quality Traits of Silage Maize Varieties Growing as Second Crop

Levent BURGU[1*], Hanife MUT[2]

Öz

Bu çalışma Bilecik ili ekolojik koşullarında ikinci ürün olarak ekilen 22 adet farklı hibrit silajlık mısır çeşidinin (ADA-9510, ADA-9516, ADA-523, AGA, Arifiye, Kalideas, Keravnos, Kerbanis, Kolessous, Kilowatt, Larigal, Sakarya, Samada-07, Simpatico, SY-Antex, SY-İnove, SY-Gladius, Dragma, Pioneer PR31G98, Pioneer P9027, Dekalp 6308 ve Dekalp 6442) silaj verimi ve kalite özelliklerinin belirlenmesi amacıyla 2020 yıllında yürütülmüştür. Deneme Tesadüf Blokları Deneme Desenine göre 3 tekerrürlü olarak kurulmuştur. Denemeye alınan tüm bitkiler hamur olum döneminde hasat edilmiştir. Hasat edilen bitki örnekleri parçalanmış, 2 kg'lık plastik bidonlara 3 tekrar olacak şekilde doldurulmuş ve fermantasyon süresi boyunca, doğrudan güneş ışığı almayan kapalı ve kuru bir ortamda, 25±2 °C sıcaklıkta muhafaza edilmiştir. Silajlık mısır çeşitlerinde silaj verimi, fiziksel kalite özellikleri (renk, koku ve strüktür), Flieg puanı, laktik asit, asetik asit, bütrik asit içeriği, pH düzeyi, kuru madde miktarı, ham protein oranı, kondanse tanen içeriği, nispi yem değeri (NYD) ve bazı mineral madde içerikleri belirlenmiştir. Çeşitlerin silaj verimleri 5665.43 kg da^{-1} (Kalideas) ile 9971.30 kg da^{-1} (Sakarya), Flieg puanı 46.52 (Kolessous) ile 98.59 (PR31G98), ham protein oranı % 6.45 (Samada-07) ile 8.95 (Ada-9510), nispi yem değeri ise 82.79 (Kolessous) ile 137.19 (ADA-9516) arasında değişmiştir. En yüksek laktik asit içeriği Arifiye (% 3.316), Sakarya (% 2.636), Larigal (% 3.064), Sy-Gladius (% 3.062) ve Dekalp 6308 (% 3.154) çeşitlerinde belirlenmiştir. Silajlık mısır çeşitlerinden elde edilen silajların K içeriği % 1.867 (Kerbanis) ile % 3.203 (Kolessous), P içeriği % 4.453 (Kalessous) ile, % 0.320 (SY-İnove), Ca içeriği % 0.213 (Kerbanis)-0.490 (Kolessous) ve Mg içeriği ise % 0.110 (Kerbanis)–0.217 (Dekalp 6308) arasında değişmiştir. Çalışma sonucunda, Bilecik ekolojik koşullarında Arifiye, Sakarya, Larigal, Sy-Antex, Sy-Gladius, PR31G98, P9027 ve Dekalp çeşitlerinden yapılan silajların diğer mısır çeşitlerinden elde edilen silajlara kıyasla silaj verimi ve araştırılan kalite özellikleri bakımından öne çıktığı görülmüştür.

Anahtar Kelimeler: Silajlık mısır, İkinci ürün, Silaj verimi, Kalite, Bilecik

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Abstract

This study was conducted to determine silage yield and quality characteristics of 22 silage maize varieties (ADA-9510, ADA-9516, ADA-523, AGA, Arifiye, Kalideas, Keravnos, Kerbanis, Kolessous, Kilowatt, Larigal, Sakarya, Samada-07, Simpatico, SY-Antex, SY-İnove, SY-Gladius, Dragma, Pioneer PR31G98, Pioneer P9027, Dekalp 6308 ve Dekalp 6442) in Bilecik ecological conditions during the 2020 year. The experiments were arranged in randomized blocks design with three replications. The harvest was done when the plants reached at dough stage. The harvested plant were chopped, filled in 2 kg plastic drums in 3 repetitions and stored during the fermentation period, at 25±2 °C in a dry and out of direct sunlight indoor environment. Silage yield, physical quality characteristics, Flieg score, lactic acid, acetic acid, butyric acid content, pH level, dry matter content, crude protein content, condensed tannin content, relative feed value (RFV), and some minerals contents were determined. Silage yields of the varieties were 5665.43 kg da^{-1} (Kalideas) 9971.30 kg da^{-1} (Sakarya), Flieg score 46.52 (Kolessous) - 98.59 (PR31G98), crude protein ratio 6.45% (Samada-07) – 8.95 (Ada-9510), relative feed value varied between 82.79 (Kolessous)-137.19 (ADA-9516). The highest lactic acid was from Arifiye (3.316), Sakarya (2.636%), Larigal (3.064%), Sy-Gladius (3.062%), and Dekalp 6308 (3.154%) varieties. The silages obtained from silage corn varieties, K content are between 1.867% (Kerbanis) and 3.203% (Kolessous), P content is 4.453% (Kalessous), 0.320% (SY-İnove), Ca content is 0.213% (Kerbanis)-0.490 (Kolessous) and The Mg content varied between 0.110% (Kerbanis)–0.217 (Dekalp 6308). As a result of the study, it was determined that silages made from Arifiye, Sakarya, Larigal, Sy-Antex, Sy-Gladius, PR31G98, P9027 and Dekalp varieties outperformed in terms of silage yield and quality characteristics which was investigated from other maize varieties in Bilecik ecological conditions.

Keywords: Silage maize, Variety, Morphological, Hay yield, Quality, Bilecik

1. Giriş

Hayvansal üretimin verimli bir şekilde sürdürülebilmesi ve arttırılabilmesi için kaba yem ihtiyacının karşılanması önemli bir unsurdur. Ülkemizde bu amaçla silajlık mısır, yonca, fiğ, korunga, yem şalgamı, yem bezelyesi ve İtalyan çimi gibi yem bitkileri ile buğday, yulaf ve arpa gibi yeşil ota yönelik tahıllar yetiştirilmektedir. 2020 yılında ülke genelinde 55.206.285 ton kaba yem üretimi yapılmış olup, bu üretimin 17.949.764 tonu yonca, 4.303.868 tonu fiğ, 17.81.789 tonu korunga, 3.155.197 tonu yulaf ve 616.709 tonluk kısmı ise İtalyan çimi tarımı ile elde edilmiştir. Silajlık mısır üretimi ise 25.499.870 ton 'dur. Toplam kaba yem üretimin % 46'lık kısmını oluşturan silajlık mısır üretimi 507.412,7 ha alanda gerçekleştirilmiştir (TUİK, 2020). Bu veriler silajlık mısır üretimin Türkiye'nin hayvansal üretimi açısından ne kadar önemli olduğunu ortaya koymaktadır.

Ülkemizde silaj üretimine uygun birçok yem bitkisi olmasına rağmen, en çok kullanılan bitki mısırdır. Kuru madde içeriğinin yüksek ve laktik asit fermantasyonunda rol alan suda çözünebilir karbonhidratlar bakımından zengin olması silaj yapımında avantaj oluşturmaktadır. Üstelik silaj yapıldığında kaba yeme göre daha kolay ve uzun süreli depolanabilmesi, depolanırken daha az besin maddesi kaybı görülmesi, yeşil yem kaynaklarının kısıtlı olduğu zamanlarda hazır yeşil yem olarak kullanılabilmesi, lezzetli ve besleyici olması da diğer tercih sebeplerindendir (Karadeniz, 2019).

Silaj yapımında temel amaç, yüksek besleme değerine sahip yeşil yem materyalinin en az besin madde kaybı ile saklanabilmesidir. Nitekim kuru ot olarak saklanan kaba yemlerde kuru madde kaybı % 15–30, sindirilebilir protein kaybı % 25–35 düzeyinde iken, her iki kayıp oranı silo yeminde % 5'e, kadar düşmektedir. Nişasta değerinde ise kuru otta % 50'ye yakın kayıp olurken, silo yemlerinde en fazla % 10 kayıp görülmektedir. (Bingöl ve ark., 2008). Bunun yanında, daha lezzetli olmaları ve iştah açıcı özellikleri nedeniyle de avantaj sağlamaktadır.

Aynı alanda yapılan ana ürün ve ikinci ürün tarımında ekim tarihi, hasat tarihi, vejetasyon süresi, toprak sıcaklığı, gece-gündüz hava sıcaklıkları, nem oranı ve yağış gibi önemli etmenler farklılık gösterir. İkinci ürün döneminde oluşan farklı koşullar, çeşitlerin verimliliğini ve silaj kalitesini önemli ölçüde etkileyebilen etmenlerdir. Bu nedenle ikinci ürün silajlık mısır çalışmalarının ayrıca yürütülmesi ve sonuçlarının değerlendirilmesi önemlidir.

Bu çalışmada Bilecik ekolojik koşullarında ikinci ürün olarak ekilen 22 farklı silajlık mısır çeşidinin silaj verimi ve bazı kalite özelliklerinin tespit edilerek, bölge şartlarında 2. ürün olarak verimli ve silaj kalitesi yüksek silajlık mısır çeşit veya çeşitlerinin belirlenmesi amaçlanmıştır.

2. Materyal ve Metot

Çalışma 2020 yılında Bilecik Şeyh Edebali Üniversitesi, Tarımsal Araştırma ve Uygulama Merkezi arazisinde yürütülmüştür. Araştırmada kullanılan silajlık mısır çeşitleri *Tablo 1* 'de sunulmuştur.

Bilecik İlinin uzun yıllar ve 2020 yılı vejetasyon dönemine ait (Temmuz-Ekim) iklim verileri Meteoroloji Bölge Müdürlüğünden alınmıştır. Buna göre, uzun yıllar ve 2020 yılı vejetasyon dönemi sıcaklık ortalaması sırasıyla 19.2 °C ve 21.2 °C olarak gerçekleşmiştir. Toplam yağış miktarı uzun yıllar ortalamasında 94.8 mm, 2020 yılında 50.8 mm olmuştur (*Tablo 2*).

Çalışmanın yürütüldüğü arazinin toprak özelliklerinin belirlenmesi amacı ile analiz yaptırılmış, toprağın killi tınlı yapıda, hafif alkali (pH=7.78), orta düzeyde kireçli (% 6.84) ve hafif tuzlu (% 0.045) olduğu belirlenmiştir. Ayrıca toprağın fosfor (22.16 kg da^{-1}) ve potasyum (66.9 kg da^{-1}) bakımından zengin ve organik madde içeriğinin ise orta seviyede (% 2.26) olduğu tespit edilmiştir.

Deneme ikinci ürün olarak 03.07.2020 tarihinde Tesadüf Blokları Deneme Desenine göre 3 tekerrürlü kurulmuştur. Ekim mibzer ile yapılmış olup, sıra üzeri 17 cm, sıra arası 70 cm, parsel uzunluğu 5 m ve 4 sıradan oluşmuştur. Ekim normu bir dekar alanda 12000 tohum olacak şekilde hesaplanmıştır. Ekim ile birlikte dekara 8 kg P_2O_5 gelecek şekilde DAP gübresi ve uygulanması planlanan azotlu gübrenin yarısı olan 5 kg da^{-1}N gelecek şekilde üre (% 46 N) gübresi uygulanmıştır. Azotlu gübrenin diğer yarısı ise bitkiler 40-50 cm (Kırtok, 1998) boylandıklarında, yine dekara 5 kg N gelecek şekilde üre (% 46 N) uygulaması ile verilmiştir. Sulama tohumların çimlenmesine kadar yağmurlama sulama şeklinde, sonrasında damla sulama olarak yapılmıştır. Yabancı ot mücadelesi ve boğaz doldurma yapmak amacıyla 2 kez elle çapa yapılmıştır. Mısırlar hamur olum dönemine geldiğinde silaj için hasatları yapılmıştır.

Tablo 1. Araştırmada kullanılan silajlık mısır çeşitleri

Table 1. The silage corn varieties used in the study

Çeşit adı	Tescil sahibi	FAO olum grubu
Samada-07	Sakarya Mısır Araştırma Enstitüsü	700
Arifiye	Sakarya Mısır Araştırma Enstitüsü	650
Sakarya	Sakarya Mısır Araştırma Enstitüsü	650
ADA-9510	Sakarya Mısır Araştırma Enstitüsü	650
ADA-9516	Sakarya Mısır Araştırma Enstitüsü	650
ADA-523	Sakarya Mısır Araştırma Enstitüsü	650
AGA	Sakarya Mısır Araştırma Enstitüsü	720
Kerbanis	KWS Türk Tarım ve Ticaret A.Ş.	550
Keravnos	KWS Türk Tarım ve Ticaret A.Ş.	700
Kolessous	KWS Türk Tarım ve Ticaret A.Ş.	680
Simpatico	KWS Türk Tarım ve Ticaret A.Ş.	200
Kilowatt	KWS Türk Tarım ve Ticaret A.Ş.	700
Kalideas	KWS Türk Tarım ve Ticaret A.Ş.	250
Larigal	Agromar San. ve Tic. A. Ş.	600
SY-Antex	Sygenta Tohumculuk Ticaret Ltd. Şti.	400
SY-İnove	Sygenta Tohumculuk Ticaret Ltd. Şti.	450
SY-Gladius	Sygenta Tohumculuk Ticaret Ltd. Şti.	600
Dragma	Sygenta Tohumculuk Ticaret Ltd. Şti.	450
PR31G98	Pioneer Tohumculuk San. Tic. A.Ş.	700
P9027	Pioneer Tohumculuk San. Tic. A.Ş.	300
Dekalp 6308	Bayer Crop Science Türkiye	650
Dekalp 6442	Bayer Crop Science Türkiye	650

Tablo 2. Bilecik İli Uzun Yıllar ve 2020 Yılı İklim Verileri

Table 2. Bilecik Province Long Years and 2020 Climate Data

Aylar	Sıcaklık (°C)		Yağış (mm)		Nem (%)	
	UYO	2020	UYO	2020	UYO	2020
Temmuz	22.1	22.9	19.1	1.20	58.0	63.0
Ağustos	22.1	23.3	13.0	6.50	57.0	56.7
Eylül	18.5	21.4	22.5	8.00	61.0	65.2
Ekim	13.9	17.1	40.2	35.1	69.0	66.6
Ortalama	**19.2**	**21.2**			**61.3**	**62.9**
Toplam			**94.8**	**50.8**		

UYO: Uzun yıllar ortalaması

Her parselden rastgele seçilen 10 bitkinin ağırlıklarının ortalaması, parseldeki bitki sayısı ile çarpılarak çeşitlerin yeşil ot verimleri belirlenmiştir. Hasat, silolama ve yemleme aşamalarında oluşması muhtemel kayıplar da dikkate alınmış ve yeşil ot veriminin % 25 azaltılması (Kutlu, 2022) ile çeşitlerin silaj verimi belirlenmiştir.

Hasat sonrası silaj makinası ile parçalanan bitki örnekleri 2 kg'lık plastik bidonlara 3 tekerrürlü olacak şekilde doldurulmuş, kapalı ve kuru bir ortamda 25±2 °C sıcaklıkta fermantasyona bırakılmıştır. Silaj yapımından yaklaşık altı ay sonra açılan silajlardan alınan örneklerin fiziksel kalite özellikleri Yalçınkaya ve ark. (2012)'nın bildirdiği kriterlere (renk, koku ve strüktür) göre iki kişi tarafından değerlendirilmiştir. Buna göre silajlarda beklenen aromatik kokuya sahip olan silaj örnekleri 14, hafif kızışma ve kokuda değişim görülen silaj örnekleri 8, kuvvetli kızışma ve kokuda kuvvetli değişim olanlar 4, amonyak kokusu ve çok ekşi koku hissedilenler 2 ve çürük küf kokusu belirgin görülenler 0 puan almıştır. Strüktür değerlendirmesinde yapısı bozulmamış silaj 4, biraz bozulmuş silajlar 2, çok bozulmuş ve küflü olan silajlar 1, çürümüş ve aşırı bozulmuş olan silajlar ise 0 puan almıştır. Silaj örneklerinin renk değerlendirmesinde ise 0–2 arası puan kullanılmış, hasat aşamasındaki rengini koruyan silaj örneklerine 2, rengi az değişmiş silaj örneklerine 1 ve rengi çok değişen silaj örneklerine 0 puan verilmiştir. Burada

aktarılan fiziksel gözlemler neticesinde verilen toplam puanlara göre denemeye alınan çeşitlerden elde edilen silajların yem nitelik sınıfları belirlenmiştir. Buna göre; toplam fiziksel değerlendirme puanı 0-4 olan silajlar kötü, 5-9 olan silajlar değeri az, 10-13 olan silajlar orta, 14-17 olan silajlar iyi ve 18-20 olan silajlar ise çok iyi sınıfta yer almıştır.

Silajlar açılıp, alınan örnekler yaş olarak tartılmış daha sonra etüve konularak 105 °C derecede 48 saat süreyle kurutulmuştur. Kuru örnek ağırlığının yaş örnek ağırlığına oranlanması ile kuru madde oranı belirlenmiştir. Organik asit içeriklerinin belirlenmesi için hazırlanan silaj örneklerinin pH'sı dijital pH metre ile ölçülmüştür. Kuru madde oranı ve pH'ları belirlenen silajların aşağıda verilen ve Kılıç (1984)'ın, belirlemiş olduğu formül yardımıyla Fleig puanları da hesaplanmıştır.

Flieg Puanı: 220+(2 x % Kuru Madde – 15) – 40 x pH (Kılıç, 1984).

Açılan silajlardan 20 g örnek alınarak üzerine 100 ml saf su ilave edilmiş ve blender yardımı ile iyice karıştırılarak filtre kâğıdından süzülmüştür (Başaran ve ark., 2018). Süzülen bu örneklerin laktik, asetik ve bütrik asit içerikleri yüksek performanslı sıvı kromatografi (HPLC) cihazı kullanılarak ölçülmüştür.

Ham protein, asit deterjanda çözünmeyen lif (ADF) ve nötr deterjanda çözünmeyen lif (NDF) analizlerinin yapılabilmesi için kurutulan örnekler 1 mm çapındaki elekten geçecek şekilde laboratuar değirmeninde öğütülmüştür. Daha sonra bu örneklerin ham protein oranları Near Infrared Reflectance Spectroscopy (NIRS) (Foss 6500) cihazı ve IC-0904FE paket programı kullanılarak belirlenmiştir. ADF ve NDF analizi ise ANKOM Fiber Analyzer cihazı ile yapılmıştır. (Van Soest ve ark., 1991)

Nispi yem değerinin (NYD) belirlenmesi için ise aşağıda da verilen Rohweder ve ark. (1978)'nın belirlemiş olduğu formül kullanılmıştır.

Sindirilebilir Kuru Madde (SKM): (88.9 - (0.779 * % ADF).

Kuru Madde Tüketimi (KMT): ($120\ NDF^{-1}$)

Nispi Yem Değeri (NYD): (% SKM * % KMT) 1.29^{-1} (Rohweder ve ark., 1978).

Silaj örneklerinin potasyum (K), kalsiyum (Ca) ve magnezyum (Mg) içerikleri Kacar (1972)'ın belirtmiş olduğu yaş yakma yöntemine göre ve Atomik absorpsiyon spektrofotometre cihazında, fosfor (P) içerikleri ise Kitson ve Mellon (1944)'un belirtmiş olduğu kuru yakma yöntemine göre ve spektrofotemetre cihazında belirlenmiştir.

Silajlardan 0.01 gr örnek tartılarak üzerine 6 ml tanen çözeltisi (1.5 ml Bütanol-HCl ayracı, 250 µl tanen ekstraktı, 50 µl Fe FeCl3 çözeltisi) eklenmiş ve bir tüpe konularak vortexte karıştırılmıştır. Test tüpünün ağzı sıkıca kapatılıp 1 saat 100 °C de tutulmuş ve örnekler soğutulmuştur. Daha sonra örnekler spektrofotometrede 550 nm absorbans değerinde okutulmuştur (Bate-Smith,1975). Absorbans değerleri belirlenen örneklerin kondanse tanen içerikleri ise aşağıdaki formül yardımıyla hesaplanmıştır.

Kondanse tanen: Absorbans (550 nm x 156,5 x seyreltme faktörü) Kuru ağırlık $(\%)^{-1}$

Araştırmadan elde edilen verilerde SPSS 20.0 paket programı kullanılarak yapılan Anova analizleri sonunda faktör ortalamalarının kıyaslanması Duncan çoklu karşılaştırma testine göre değerlendirilmiştir.

3. Araştırma Sonuçları ve Tartışma

Farklı silajlık mısır çeşidine ait silaj örneklerinin renk, koku, strüktür, toplam puanlamaları ve yem nitelik sınıflarına ait veriler *Tablo 3*'de verilmiştir.

İyi silolanmış ve korunmuş bir silaj yeminin mümkün olduğunca silolandığı andaki rengini koruması istenir. Silo yeminin rengi yapıldığı bitkiye göre değişmekle birlikte açık yeşilden, açık kahve veya daha koyu tonlara kadar değişebilir. Silajların çok koyu renge sahip olması ya da renk değiştirmiş olması istenmeyen bir durumdur. Eğer silo yeminde koyu yeşilden koyu siyaha kadar renkler gözleniyorsa bu durum protein ve selülozun parçalandığına işaret eder (Uygur, 2022). Çalışmada SY-İnove çeşidi hariç tüm çeşitlerin silolandığı andaki rengini koruduğu tespit edilmiş olup silajlarda herhangi bir bozulmanın olmadığı görülmüştür. Bu durum, hasadın doğru

zamanda yapılmış olması nedeniyle kuru madde içeriğinin silaj yapımı için istenen seviyede olması, sıkıştırma işleminin ve fermantasyonun uygun bir şekilde gerçekleşmesinden kaynaklanmıştır.

İyi fermente olmuş silajlar, açıldığı anda rahatlıkla alınabilen, silaja özgü bir kokuları vardır. Bu koku özelliği silaj kalitesinin belirlenmesinde ele alınan özelliklerden birisidir. Silaj açıldığında aşırı keskin ya da istenmeyen asit benzeri kokular alınması durumunda fermantasyonun istenilen şekilde gerçekleşmediği ve silolama aşamasında silaj içerisine karışan havanın silajı olumsuz etkilediği düşünülür (Aykan ve Saruhan, 2018). Denemeye alınan çeşitler arasında silaj kokusu bakımından farklılıklar tespit edilmiştir. Renk kriterinde olduğu gibi SY-İnove çeşidi hariç çeşitlerin çoğunluğunda tereyağ asidi kokusunun olmadığı, hafif ekşimsi, meyvemsi ve aromatik kokuya sahip oldukları tespit edilmiştir. SY-İnove ile kurulan silajda ise asidik kokular bulunduğu görülmüştür. Silolanmış yemler açıldıklarında kullanılan bitkilerin yaprak ve saplarının bozulmadan kalması bir diğer önemli husustur.

İyi silolanma şartlarında silo içerisinde oluşan laktik asit sayesinde bitkilerin yaprak ve saplarının fiziksel görüntüsü korunabilmektedir. Silajların strüktür ortalamaları incelendiğinde, SY-İnove, Keravnos ve Kolesseus çeşitleri hariç tüm çeşitlerde yaprak ve sapların bozulmadan kaldığı ve strüktür değerlendirmesinden 4.0 puan aldığı tespit edilmiştir. Çeşitlerin toplam fiziksel puanlamaları değerlendirildiğinde; 9-20 arasında, yem nitelik sınıfları ise orta ve çok iyi düzey arasında değişmiştir. Kavut ve Soya (2012), bazı mısır çeşitlerinin silaj kalite özellikleri üzerinde yaptığı çalışmada, çeşitlerin fiziksel gözlemlerine ait toplam puanın 18.22-19.06 arasında değiştiğini bildirmişlerdir.

Tablo 3. Farklı Silajlık Mısırlara Ait Silajların Fiziksel Gözlemleri İle Yem Nitelik Sınıfları

Table 3. Physical Observations and Feed Quality Classes of Silage Belonging to Different Silage Corns

Çeşitler	Renk	Koku	Strüktür	Toplam	Yem nitelik sınıfı
Samada-07	2.0	11.00	4.0	17.00	İyi
Arifiye	2.0	14.00	4.0	20.00	Pek iyi
Sakarya	2.0	14.00	4.0	20.00	Pekiyi
ADA-9510	2.0	11.00	4.0	17.00	İyi
ADA-9516	2.0	14.00	4.0	20.00	Pekiyi
ADA-523	2.0	11.00	4.0	17.00	İyi
AGA	2.0	14.00	4.0	20.00	Pekiyi
Kerbanis	2.0	11.00	4.0	17.00	İyi
Keravnos	2.0	11.00	3.0	16.00	İyi
Kolessous	2.0	11.00	3.0	16.00	İyi
Simpatico	2.0	11.00	4.0	17.00	İyi
Kilowatt	2.0	11.00	4.0	17.00	İyi
Kalideas	2.0	8.00	4.0	14.00	İyi
Larigal	2.0	14.00	4.0	20.00	Pekiyi
SY-Antex	2.0	14.00	4.0	20.00	Pekiyi
SY-İnove	1.0	6.00	2.0	9.00	Değeri Az
SY-Gladius	2.0	14.00	4.0	20.00	Pekiyi
Dragma	2.0	14.00	4.0	20.00	Pekiyi
PR31G98	2.0	14.00	4.0	20.00	Pekiyi
P9027	2.0	14.00	4.0	20.00	Pekiyi
Dekalp 6308	2.0	14.00	4.0	20.00	Pekiyi
Dekalp 6442	2.0	11.00	4.0	17.00	İyi

Silajların kuru madde oranı, pH ve Flieg puanları ile kalite sınıfları *Tablo 4*'de verilmiştir. Buna göre çeşitler arasında pH ve Flieg puanı arasında önemli farklılıklar ($P>0.05$) belirlenirken, kuru madde oranları arasında farklılık tespit edilmemiştir.

Tablo 4. Silajlık mısır çeşitlerinin % kuru madde, pH, Flieg puanları ve kalite sınıfları

Table 4. Dry matter %, pH, Flieg scores and quality classes of silage corn varieties

Çeşitler	Kuru madde (%)	pH*	Flieg puanı*	Kalite sınıfı
Samada-07	33.29	4.46 cd	93.05 ab	Pekiyi
Arifiye	32.32	4.61 bcd	85.10 ab	Pekiyi
Sakarya	34.62	4.59 cd	90.78 ab	Pekiyi
ADA-9510	34.66	4.63 bcd	89.25 ab	Pekiyi
ADA-9516	35.89	4.48 cd	97.45 a	Pekiyi
ADA-523	34.12	5.31 ab	60.84 bc	İyi
AGA	34.53	4.90 a-d	78.19 ab	İyi
Kerbanis	33.15	5.03 a-d	69.96 abc	İyi
Keravnos	32.70	4.83 bcd	77.07 abc	İyi
Kolessous	31.83	5.55 a	46.52 c	Orta
Simpatico	37.24	4.71 bcd	91.07 ab	Pekiyi
Kilowatt	32.94	4.93 a-d	73.55 abc	İyi
Kalideas	37.23	4.78 bcd	88.27 ab	Pekiyi
Larigal	35.85	4.46 cd	98.31 a	Pekiyi
SY-Antex	34.19	4.52 cd	92.58 ab	Pekiyi
SY-İnove	35.91	5.17 abc	70.03 abc	İyi
SY-Gladius	34.46	4.52 cd	93.26 ab	Pekiyi
Dragma	35.64	4.47 cd	97.35 a	Pekiyi
PR31G98	35.66	4.44 d	98.59 a	Pekiyi
P9027	35.05	4.44 d	97.64 a	Pekiyi
Dekalp 6308	34.47	4.47 cd	95.27 a	Pekiyi
Dekalp 6442	36.05	4.67 bcd	90.43 ab	Pekiyi

(*p>0.05); Aynı harfle gösterilen ortalamalar arasında p>0.05 seviyesinde farklılık yoktur.

Kaliteli olarak nitelenebilmesi için silajda kuru madde oranının % 25-40 arasında olması gerekmektedir (Klamem ve ark., 2005, Panyasak ve Tumwasorn, 2015). Kuru madde oranının % 40'tan fazla olması, yemde yüksek selüloz ve hemiselüloz içeriğinin yüksek olduğu anlamına gelirken, bu durumun yemin sindirilmesini güçleştirdiği ve lezzetini azalttığı da bilinmektedir. Ayrıca yüksek kuru madde içeriği silajın sıkıştırılmasını zorlaştırdığından, bozulma riskini ortadan kaldırmak için silolamanın daha hassas bir şekilde yapılmasını gerektirmektedir. Diğer taraftan düşük kuru madde oranı ise silajın karbonhidrat içeriğini düşürür ve bozulmasına neden olur (Panyasak ve Tumwasorn, 2015). Çalışmada silajların kuru madde oranı % 31.83-37.24 arasında değişmiş olup, istenen seviyenin arasında olmuştur. Öztürk ve Budaklı Çarpıcı (2019) Bursa ekolojik koşullarında yürüttükleri çalışmada 10 farklı silajlık mısır çeşidinden (AS 160 Silaz, Colonia, P 3394, Hacıbey, 94MAY66, Macha, Sy Jullen, Sy Atomic ve Temuco) elde ettikleri silajların kuru madde oranının % 25.58-31.46 arasında, Özdüven ve ark. (2009) tarafından Akdeniz, Gözdem, Pioneer 3167 ve Ada 9510 hibrit mısır çeşitleri ile yürütülen çalışmada ise hamur olum döneminde hasat edilerek yapılan silajların kuru madde içeriğinin % 29.03-30.99 arasında değiştiği bildirilmiştir.

Silo yemi kalitesinin belirlenmesinde kullanılacak en önemli kriterlerden birisi de pH değeridir. Silo içi fermantasyon düzeyinin belirlenmesinde silo yemi pH içeriği önemli bir parametredir. Silajın yeterince olgunlaşıp olgunlaşmadığı yemin pH değerine bakılmak suretiyle belirlenmektedir (Uygur, 2022). Kaliteli bir silaj elde etmek için silo içerisinde mutlaka asidik bir ortam dolayısıyla düşük pH değeri istenmektedir. Laktik asit bakterilerinin aktif çalışması sonucunda siloda pH'nın 4.2-4.5 düzeylerine düşmesinden sonra silolanan materyal stabil bir devreye girmektedir (Açıkgöz, 2021). Çalışmada kullanılan çeşitlerin pH değeri 4.44 ile 5.55 arasında değişmiştir (*Tablo 4*). Bu değerlerin Kavut ve Soya (2012) tarafından Bornova ve Ödemiş koşullarında gerçekleştirilen çalışmada elde edilen değerlerden (pH 3.98-4.04) daha yüksek, Aykız (2019) tarafından Tekirdağ koşullarında tespit edilen değerlerden ise daha düşük (pH 4.80 – 5.93) olduğu görülmüştür. Farklılıkların kullanılan çeşitlerden, hasat zamanından ve uygulanan kültürel işlemlerden kaynaklandığı tahmin edilmektedir. Diğer taraftan silaj

üzerine olumsuz etkide bulunan enterobacteria mikroorganizmaları ile clostridial sporlarının çoğalmaması için pH'nın 5'in altına düşmesi gerekmektedir (Filya, 2001). Buna göre, çalışmada ADA-523 (5.31), Kerbanis (5.03), Kolessous (5.55) ve SY-İnove (5.17) dışında kalan çeşitlere ait silajların pH'ları bu seviyenin altında olmuştur. Korkmaz ver ark. (2016), Çukurova koşullarında yürüttükleri çalışmada silajlık mısır çeşitlerinin pH'sının 3.52-3.73, Tantekin (2016) ise Diyarbakır ekolojik koşullarında 3.67-3.90, Kaya ve Polat (2010) Tekirdağ koşullarında 3.58-3.66 arasında değiştiğini bildirmiştir.

Silajların pH ve kuru madde içeriğinden yararlanılarak belirlenen Flieg puanı mevcut çalışmada 46.52 ile 98.59 arasında değişmiştir (*Tablo 4*). Flieg puanı ile kalite sınıfı arasında pozitif yönlü bir korelasyon vardır. Çalışmada kullanılan çeşitlerin kalite sınıfları orta ve pekiyi arasında değişirken, çoğu çeşit pekiyi kalite sınıfında yer almıştır. Korkmaz ve ark. (2019) Çukurova ekolojik koşullarında ikinci ürün yetiştirdikleri farklı silajlık mısır çeşitlerinin en yüksek ve en düşük Flieg puanının sırasıyla 122.60 ve 114.53 olduğunu belirtmişlerdir.

İkinci ürün olarak yetiştirilen çeşitlerin silaj verimi ham protein oranı, kondanse tanen içerikleri ile NYD üzerinde çeşitlerin etkisi çok önemli ($p<0.01$) bulunmuştur (*Tablo 5*).

Silajlık mısır çeşitlerinin silaj verimi 5665.43 kg da^{-1} ile (Kalideas) - 9971.30 kg da^{-1} (Sakarya) arasında değişmiştir (*Tablo 5*). Çeşitlerin sergilemiş oldukları silaj verimleri dikkate alındığında, bölge ekolojik koşullarında ikinci ürün yetiştiriciliğinde FAO olum gruplarının belirleyici olmadığı tespit edilmiştir. Güneş ve Acar (2006) Karaman ekolojik koşullarında yürüttükleri çalışmada çeşitlerin silaj verimini 6892.8-8488.0 kg da^{-1}, Şimşek (2006) Antalya koşullarında 7773.8-13297.6 kg da^{-1}, Balmuk (2012) Konya şartlarında 3576.2-50476 kg da^{-1}, Ayaz ve ark. (2013) Şanlıurfa koşullarında 4831.75-6453.49 kg da^{-1}, Seydoşoğlu ve Saruhan (2017) Diyarbakır şartlarında 6001-10373 kg da^{-1}, Karaalp (2015) ise Yozgat Boğazlıyan koşullarında 3065.7-4495.5 kg da^{-1} arasında değiştiğini bildirmişlerdir. Çalışmada belirlenen silaj verimleri farklı araştırmacıların bulguları ile benzer olmuştur.

Silajlık mısır çeşitlerinin ham protein oranı % 6.45 (Samada-07) – 8.95 (Ada-9510) arasında değişmiştir (*Tablo 5*). Ham protein oranı genetik farklılıklara bağlı olarak değişmekle beraber, ekolojik koşullar ile kültürel işlemlerden de (ekim zamanı, hasat zamanı, sulama ve gübreleme) etkilenebilmektedir. Yozgat ekolojik koşullarında iki yıl süreyle yürütülen çalışmada farklı silajlık mısır çeşitlerinin ham protein oranı % 7.05-9.53 (Yozgatlı, 2017), Ordu ekolojik koşullarında % 7.63-9.32 (Güneş, 2017) ve İzmir ekolojik koşullarında % 6.16-8.61 (Yıldız ve ark., 2017) arasında değişmiştir. Kaba yemlerin besleme değerlerinin belirlenmesinde en önemli faktörlerden biri olan ham protein oranının yemlerde en az % 6 civarında olması istenmektedir (Şenel, 1986; Tan ve Serin, 1997). Araştırmada yer alan çeşitlerin ham protein oranları belirtilen değerin üzerinde bulunmuştur (*Tablo 5*). Çalışmada, en yüksek kondanse tanen içeriği Arifiye (% 1.178), Dragma (% 1.271) ve Dekalp 6308 (% 1.277), en düşük ise % 0.825 ile PR31G98 çeşidinde belirlenmiştir (*Tablo 5*). Bitkilerde bulunan kondanse tanenler rumenden salınan metan gazı üreticilerini engellemekte ve sera gazı salınımını azaltmaktadır (Martin ve ark., 2012), (Lascano ve Cardenas, 2010). Küresel ısınmanın 1/4'ünün ruminantların sindirim sisteminde üretilen ve doğaya salınan metan gazından kaynaklandığı bildirmektedir. Diğer taraftan kondanse tanenler antihelmintik etki göstererek hayvanların iç parazitlerini azaltmakta ve hayvanlarda verim ve kalite artışı sağlamaktadır (Lüscher ve ark., 2016). Buna göre ruminant rasyonlarında yer alan yemlerin kondanse tanen içeriğinin en fazla % 2-3 arasında olması gerekmektedir (Barry, 1987). Silajlık mısır çeşitlerinin kondanse tanen içeriğinin % 1 civarında yoğunlaştığı ve kritik seviyenin altında olduğu görülmüştür (*Tablo 5*). Yalçın (2013) baklagillerde diğer yem bitkilerine oranla daha çok kondanse tanen bulunduğunu ve miktarının % 0.15-18.70 arasında değiştiğini bildirmiştir.

Silajlık mısır çeşitlerinin NYD 82.79 ile 137.19 arasında değişmiştir (*Tablo 5*). NYD Rohweder ve ark. (1978) tarafından yem bitkilerinin pazar değerlerinin belirlenmesi amacıyla belirlenmiş bir formül olup, 6 kalite sınıfına ayrılmaktadır. Buna göre yemin NYD değeri 151'den büyük ise yem başlangıç sınıfında, 125-151 arasında ise 1. sınıfta, 103-124 arasında ise 2. sınıfta, 87-102 arasında ise 3. sınıfta, 75-86 ise 4. sınıfta ve 75'den küçük olduğunda ise 5. sınıfta yer almaktadır. Bu sonuçlara göre çalışmada kullanılan silajlık mısır çeşitleri NYD bakımından 1-4. sınıflar arasında yer almıştır. Yılmaz ve ark. (2020) Samsun ekolojik koşullarında farklı silajlık mısır çeşitlerinin nispi yem değerlerinin 102.4.-137.19 arasında değiştiğini bildirmiştir. Denemede ikinci ürün olarak ekilen 22 farklı silajlık mısır çeşidinden elde edilen silajlara ait laktik, asetik ve bütrik asit değerleri *Tablo 6*'da verilmiştir.

Tablo 5. Silajlık mısır çeşitlerinin silaj verimi, ham protein oranı, kondanse tanen içeriği ile nispi yem değeri

Table 5. Silage yield, crude protein content, condensed tannin content and relative feed value of silage corn varieties

Çeşitler	Silaj verimi (kg da^{-1})**	Ham protein oranı (%)**	Kondanse tanen içeriği (%)**	Nispi Yem Değeri
Samada-07	8645.00 abc	6.45 f	0.901 d-g	85.91 e
Arifiye	7766.67 a-d	7.53 b-f	1.178 ab	85.44 e
Sakarya	9971.30 a	8.39 a-e	0.835 fg	119.15 abc
ADA-9510	8765.80 abc	8.95 a	0.888 d-g	100.62 cde
ADA-9516	9538.33 ab	7.79 a-e	0.837 fg	137.19 a
ADA-523	7780.50 a-d	8.27 a-e	0.915 c-g	107.83 cde
AGA	8753.53 abc	8.73 ab	0.948 c-g	118.33 abc
Kerbanis	7995.17 a-d	8.64 abc	0.839 fg	135.23 ab
Keravnos	6510.33 cd	7.60 b-f	0.936 c-g	85.67 e
Kolessous	6629.87 cd	7.56 b-f	0.925 c-g	82.79 e
Simpatico	6118.70 cd	7.69 b-e	0.956 c-g	99.19 cde
Kilowatt	6480.60 cd	8.33 a-e	0.866 efg	107.38 cde
Kalideas	5665.43 d	7.23 ef	0.866 efg	104.84 cde
Larigal	7830.20 a-d	8.93 a	1.026 b-f	112.19 bcd
SY-Antex	7700.93 a-d	7.85 a-e	1.070 bcd	104.23 cde
SY-İnove	9398.53 ab	8.53 a-d	1.094 bc	90.75 de
SY-Gladius	9437.03 ab	7.39 def	0.923 c-g	111.64 bcd
Dragma	8846.13 abc	7.48 c-f	1.271 a	116.84 abc
PR31G98	8852.30 abc	8.46 a-e	0.825 g	102.33 cde
P9027	7132.23 bcd	8.52 a-d	1.041 b-e	119.69 abc
Dekalp 6308	9308.80 ab	8.15 a-e	1.277 a	103.90 cde
Dekalp 6442	9192.60 ab	8.15 a-e	0.923 c-g	117.42 cde

(**p>0.01); Aynı harfle gösterilen ortalamalar arasında p>0.05 seviyesinde farklılık yoktur.

Tablo 6. Silajlık mısır çeşitlerinin organik asit içerikleri

Table 6. Organic acid content of silage corn varieties

Çeşitler	Laktik asit (%)**	Asetik asit (%)**	Bütrik asit (%)
Samada-07	1.332 fg	0.033 ıi	0.009
Arifiye	3.316 a	0.072 e-ı	0.018
Sakarya	2.636 abc	0.112 a-e	0.044
ADA-9510	1.351 fg	0.054 g-i	0.021
ADA-9516	1.732 d-g	0.118 abc	0.012
ADA-523	1.140 g	0.034 ıi	0.003
AGA	1.387 efg	0.086 c-g	0.010
Kerbanis	1.336 fg	0.091 c-g	0.008
Keravnos	1.791 d-g	0.102 b-f	0.005
Kolessous	1.403 efg	0.015 i	0.002
Simpatico	1.512 efg	0.044 hıi	0.009
Kilowatt	1.662 d-g	0.089 c-g	0.020
Kalideas	1.118 g	0.076 d-h	0.004
Larigal	3.064 ab	0.077 d-h	0.006
SY-Antex	2.152 cde	0.140 ab	0.031
SY-İnove	1.143 g	0.034 ıi	0.017
SY-Gladius	3.062 ab	0.070 f-ı	0.011
Dragma	1.485 efg	0.112 a-e	0.008
PR31G98	2.084 c-f	0.116 a-d	0.012
P9027	2.380 bcd	0.150 a	0.021
Dekalp 6308	3.154 a	0.087 c-g	0.018
Dekalp 6442	1.518 efg	0.058 ghı	0.010

(**p>0.01); Aynı harfle gösterilen ortalamalar arasında p>0.05 seviyesinde farklılık yoktur.

Buna göre laktik ve asetik asit bakımından çeşitler arasında % 1 önemlilik seviyesinde farklılık varken, bütrik asit bakımından ise silajlar arasında farklılık olmamıştır. En yüksek laktik asit Arifiye (% 3.316), Sakarya (% 2.636), Larigal (% 3.064), Sy-Gladius (% 3.062) ve Dekalp 6308 (% 3.154), en düşük ise ADA-523 (% 1.140), Kalideas (% 1.118) ve SY-İnove (% 1.143) çeşitlerinde belirlenmiştir. Laktik asit silajda istenen bir organik asit olup, silajda en az % 2 olması istenir (Alçiçek ve Özkan, 1996). Çalışmada Arifiye (% 3.316), Sakarya (% 2.636), Larigal (% 3.064), Sy-Antex (% 2.152), Sy-Gladius (% 3.062), PR31G98 (% 2.084), P9027 (% 2.380) ve Dekalp 6308 (% 3.154) çeşitleri bu değerin üzerinde olmuştur Yozgatlı (2017) farklı silajlık mısır çeşitlerinin laktik asit içeriğini % 1.504-2.571 arasında değiştiğini bildirmiştir.

Silaj kalitesinin belirlenmesinde ele alınan bir kriter de asetik asittir. Silolama işleminin doğru yapılmasında önemli bir yere sahiptir. Asetik asit silajda daima var olup fazla olması istenmez. Silajda asetik asit değeri % 0.8 düzeyine kadar tolere edilebilir (Alçiçek ve Özkan 1996). Silajlık mısır çeşitlerinin asetik asit değerleri % 0.015 (Kolessous) – 0.150 (P9027) arasında değişmiştir. Analiz sonuçlarına göre mevcut çalışmadaki silajlık mısır çeşitlerinin asetik asit değerleri bu kritik seviyenin altında olmuştur (*Tablo 6*).

Bütrik asit bakterileri proteinleri parçalayarak amin ve amonyağın açığa çıkmasına, böylece proteinlerin biyolojik değerinin düşmesine neden olurlar. Bu yüzden silo yemlerinde bütrik asit hiç istenmez. Nitelikli silo yemleri bu asidi çoğu zaman içermezler. Genelde % 0.1-0.7 arasında bir değere sahiptirler (Uygur, 2022). Çalışmada en yüksek bütrik asit içeriği % 0.044 ile Sakarya, en düşük ise % 0.002 ile Kolessous çeşidinde tespit edilmiştir. Çalışmada silajlık mısır çeşitlerinin bütrik asit içerikleri bu düzeyin de oldukça altında olmuştur. Çeşitler arasında K ve Ca bakımından istatistiksel olarak çok önemli ($p<0.01$), Mg bakımından önemli ($p<0.05$) fark varken, P bakımından fark olmamıştır *(Tablo 7*).

Tablo 7. Silajlık mısır çeşitlerinin K, P, Ca ve Mg İçerikleri

Table 7. K, P, Ca and Mg Contents of Silage Corn Varieties

Çeşitler	K (%)**	P (%)	Ca (%)**	Mg (%)*
Samada-07	2.583 b-g	0.370	0.363 c-f	0.143 bcd
Arifiye	2.940 a-d	0.413	0.407 a-e	0.133 bcd
Sakarya	2.393 d-h	0.373	0.347 c-f	0.150 bcd
ADA-9510	2.597 b-g	0.360	0.370 b-f	0.157 bcd
ADA-9516	2.010 gh	0.360	0.270 fg	0.137 bcd
ADA-523	2.560 b-g	0.377	0.323 d-g	0.130 bcd
AGA	2.370 d-h	0.387	0.320 d-g	0.133 bcd
Kerbanis	1.867 h	0.383	0.213 g	0.110 d
Keravnos	2.617 b-f	0.380	0.420 a-d	0.170 abc
Kolessous	3.203 a	0.453	0.490 a	0.157 bcd
Simpatico	2.477 c-g	0.380	0.367 c-f	0.137 bcd
Kilowatt	2.423 c-h	0.367	0.343 c-f	0.147 bcd
Kalideas	3.097 ab	0.433	0.477 ab	0.177 ab
Larigal	2.277 e-h	0.370	0.357 c-f	0.167 a-d
SY-Antex	2.457 c-g	0.370	0.320 d-g	0.127 bcd
SY-İnove	2.990 abc	0.320	0.443 abc	0.160 bcd
SY-Gladius	2.233 e-h	0.360	0.297 efg	0.130 bcd
Dragma	2.073 fgh	0.330	0.283 fg	0.143 bcd
PR31G98	2.693 a-e	0.380	0.340 c-f	0.117 cd
P9027	2.277 e-h	0.350	0.323 d-g	0.150 bcd
Dekalp 6308	2.127 e-h	0.347	0.313 d-g	0.217 a
Dekalp 6442	2.157 e-h	0.357	0.307 d-g	0.143 bcd

(**p>0.01; *p>0.05); Aynı harfle gösterilen ortalamalar arasında p>0.05 seviyesinde farklılık yoktur.

Silajlık mısır çeşitlerinin K içeriği % 1.867 (Kerbanis) ile % 3.203 (Kolessous) arasında değişmiştir (*Tablo 7).* Yozgatlı (2017: 13-22) farklı silajlık mısır çeşitlerinin K içeriğin % 1.91 ile % 2.24 arasında değiştiğini bildirmiştir. En yüksek P içeriği % 4.453 ile Kalessous, en düşük ise % 0.320 ile SY-İnove çeşidinden yapılan silajda belirlenmiştir (*Tablo 7*). Meşe (2020) Bilecik ekolojik koşullarında ana ürün olarak 18 farklı silajlık mısır çeşidinin,

P içeriğinin % 0.238-0.315 arasında değiştiğini bildirmiştir. Silajların Ca içeriği % 0.213-0.490 arasında olmuştur (*Tablo 7*). Silajların Mg içeriği ise % 0.110 (Kerbanis) – 0.217 (Dekalp 6308) arasında değişmiştir. Yapılan bir çalışmada, farklı silajlık mısır çeşitlerinin Mg içeriği ortalama % 0.19 olarak belirlenmiştir (Özata, 2017). Ruminant sağlığı açısından kaliteli kaba yemlerde K oranının en az % 0.8, P oranının % 0.21, Ca içeriğinin % 0.18 - 0.44 ve Mg içeriğinin ise % 0.04 - 0.10 arasında olması gerekmektedir (Kidambi ve ark., 1989; Yozgatlı, 2017). Mevcut çalışmada, tüm silajlık mısır çeşitlerinden elde edilen silajların % mineral madde içeriklerinin istenilen seviyede olduğu belirlenmiştir (*Tablo 7*).

4. Sonuç

Silajlık mısır üretiminde başarının arttırılabilmesi için mevcut çeşitlerin hangi ekolojilerde daha iyi performans gösterdiği, çeşitlerden elde edilen silajların yem kaliteleri ve ikinci ürün üretimindeki performansları tüm farklı ekolojilerde araştırılmalıdır. Bu tür çalışmalar sonucunda farklı bölgelerdeki üreticilerimize bölge koşullarında üstün performans gösteren çeşitler önerilebilecektir. Bölgeye uygun çeşitlerin yetiştirilmesi ile de silajlık mısır üretimi daha verimli bir şekilde gerçekleştirilecek ve hayvansal üretimin ihtiyacı olan kaliteli kaba yem sağlanabilecektir.

Bu çalışmada Bilecik ili ekolojik koşullarında, 22 silajlık mısır çeşidi ikinci ürün olarak yetiştirilmiş ve çeşitlerin silaj verimi ile silajların bazı kalite özellikleri karşılaştırılmıştır. Silaj verimi ve kalite özellikleri birlikte ele alındığında; Arifiye, Sakarya, Larigal, Sy-Antex, Sy-Gladius, Pioneer PR31G98, Pioneer P9027 ve Dekalp 6308 çeşitlerinin diğer mısır çeşitlerinden daha üstün performans sergilediği görülmüştür.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Examination of Soil Analysis Applications and Soil Analysis Subsidies in terms of Producers in Edirne and Tekirdağ Provinces

Edirne ve Tekirdağ İllerinde Toprak Analizi Uygulamaları ve Toprak Analiz Desteğinin Üreticiler Yönünden İncelenmesi

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Abstract

The aim of this study was to determine the differences and the importance of the differences in terms of some socio-economic factors and agricultural practices of the producers who had soil analysis in Edirne and Tekirdağ provinces and to evaluate the opinions of the producers about soil analysis and soil analysis subsidies. Three laboratories were selected among the laboratories with the highest number of sample acceptances for soil analysis in the provinces determined in the study. For each province, total of 60 producers who applied to the laboratories in 2015 and who utilized from soil analysis subsidies, and consequently, total of 120 producers were interviewed. The analysis of the differences of the producers who had soil analysis in Edirne and Tekirdağ provinces was determined by the regression tree model (CHAID analysis). According to the CHAID analysis, in which the provinces were taken as the dependent variable, it was seen that the first most distinctive feature was the state-supported agricultural insurance. Of the producers who stated that they did not have agricultural insurance, 31% were located in Edirne and 69% were located in Tekirdağ. It was seen that 56% of the producers in Edirne and 44% of the producers in Tekirdağ had agricultural insurance. The most important feature of the second node was the education level of the producers, the third sub-node decision point was whether the producers had training on fertilization, and the fourth decision point was whether the producers faced risks in agriculture in the last three years. The four most important reasons for the producers to have soil analysis in Edirne province were to increase the product yield, to reduce the cost, to increase product quality and protect the environment, respectively. In the province of Tekirdağ, the criteria of increasing the product yield was on the first rank, increasing the product quality in the second rank, reducing the cost in the third rank and protecting the environment in the fourth rank. It is expected that it will be beneficial to introduce soil analysis conditions to the producers at the stage of purchasing fertilizers, and thus to ensure that the producer purchases fertilizer by determining the type and amount of fertilizer to be disposed of according to the analysis results.

Keywords: Regression tree, Soil analysis, Soil analysis subsidy, Producer opinion

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Öz

Bu çalışmanın amacı Edirne ve Tekirdağ illerinde toprak analizi yaptıran üreticilerin bazı sosyo ekonomik faktörler ve tarımsal uygulamalar yönünden farklılıklarının ve farklılıkların önem düzeylerinin belirlenmesi ve üreticilerin toprak analizi ve toprak analizi destekleri ile ilgili görüşlerinin değerlendirilmesidir. Araştırmada belirlenen illerde toprak analizi için numune kabul sayısı en fazla olan laboratuvarlar arasından 3 adet laboratuvar seçilmiştir. Her il için 2015 yılında laboratuvarlara başvuran ve toprak analiz desteğinden yararlanan üreticilerden toplamda 60 üretici olmak üzere, toplamda 120 üretici ile görüşülmüştür. Edirne ve Tekirdağ illerinde toprak analizi yaptıran üreticilerin farklılıklarının analizi regresyon ağacı modeli (CHAID analizi) ile belirlenmiştir. İllerin bağımlı değişken olarak alındığı CHAID analizine göre, birinci en belirgin özelliğin devlet destekli tarım sigortası yaptırma olduğu görülmüştür. Tarım sigortası yaptırmadığını ifade eden üreticilerin %31'i Edirne ilinde, %69'u Tekirdağ ilinde yer almaktadır. Edirne ilinde üreticilerin %56'sının, Tekirdağ ilinde üreticilerin %44'ünün tarım sigortası yaptırdıkları görülmektedir. İkinci düğüm noktasının en önemli özelliği, üreticilerin eğitim düzeyleri, üçüncü alt düğüm karar noktasında üreticilerin gübreleme ile ilgili eğitim alıp almama durumları, dördüncü karar noktasında ise üreticilerin son üç yıl içinde tarımda riskle karşılaşıp karşılaşmama durumları yer almaktadır. Edirne ilinde üreticilerin toprak analizi yaptırmalarındaki en önemli dört nedenin sırasıyla ürün verimini arttırmak, maliyeti düşürmek, ürün kalitesini arttırmak ve çevreyi korumak olduğu belirlenmiştir. Tekirdağ ilinde de ilk sırayı ürün verimini arttırmak kriteri almakta olup, ikinci sırayı ürün kalitesini arttırmak, üçüncü sırayı maliyeti düşürmek ve dördüncü sırayı çevreyi korumak kriterleri almaktadır. Üreticilere gübre satın alma aşamasında toprak analizi şartının getirilmesinin, dolayısıyla analiz sonuçlarına göre atılması gereken gübre cinsi ve miktarının belirlenerek üreticinin gübre satın almasının sağlanmasının faydalı olacağı beklenmektedir.

Anahtar Kelimeler: Regresyon ağacı, Toprak analizi, Toprak analiz desteği, Üretici görüşü

1. Introduction

The main factor of agricultural production is soil. As long as the fertility of the soil is at an appropriate level, the amount and quality of the product to be taken from the unit area will be high. Therefore, it is extremely important to increase and protect the productivity levels of soils. It is obligatory to restore the plant nutrients that are depleted from the soil in various ways (Özyazıcı et al., 2013). Soil pollution usually occurs as a result of activities (fertilization, spraying, irrigation, etc.) performed by people unconsciously, reducing the sustainable yield capacity of the soil and causing soil fatigue. Although soil fatigue is not as well known as environmental pollution, it is one of the most important issues in terms of the economic life of soils (Bellitürk, 2011).

The main aim in agriculture is to obtain the highest possible yield and quality product from the cultural lands. Achieving this aim is possible, first of all, by taking a series of cultural measures that will increase the productivity of the soils. Among these cultural measures, fertilization takes the first place. However, fertilizing does not indicate that high quality and high yield power can be achieved. As a matter of fact, unconsciously, excessive fertilization of the soil not only disrupts the structure of the soil, but also disrupts the ecological balance (Güçdemir and Kalınbacak, 2009).

Soil analysis should be taken as a basis for effective and correct fertilization. Farmers, who apply the fertilizer recommendations made according to the results of the samples which are duly taken and analyzed, will make a significant contribution to both their own budgets and the country's economy by making a balanced and conscious fertilization. Before fertilizing, it is extremely important technically and economically to learn the amount and application manner of the fertilizer. Profitable fertilization can only be done by using the most appropriate methods to supply the plant nutrients needed by the plant as much as necessary. At this point, the importance of soil analysis emerges. The purpose of soil analysis is to determine the soil structure and the amount of nutrients available to the plants in its content, and to complete the missing part of the nutrients needed by the plants to be grown in that soil with fertilization.

In order to protect the agricultural sector, encourage agricultural activities and promote its sustainability, support payments are made by the state in different subjects (Sayın et al., 2021). In order to ensure adequate and economical fertilization with the fertilization programs created in accordance with the analysis results by encouraging the producers to have soil analysis, it was decided to give soil analysis subsidies with the decree dated 28.03.2005 and numbered 2005/8629 in addition to the direct income support by the Ministry of Agriculture and Forestry.

In this context, the principles regarding soil analysis subsidies are explained in subparagraph b of article 11 of the Communiqué numbered 2005/21 published in the Official Gazette dated 30.04.2005. Soil samples declared by the farmers to the laboratory were analyzed and reported by the laboratories authorized by the Ministry of Agriculture and Forestry, and their support began to be given as of 2006 and the payment was made at a maximum of 60 da. Communiqué dated 31.12.2008 and numbered 27097 published in the Official Gazette and 2008/70 communique dated 18.03.2010 were revised as a maximum of 50 support payments for each soil analysis. According to the communiqué numbered 29019 dated 03.06.2014 and the communiqué numbered 29368 dated 27.05.2015, soil analysis support payments were given to the farmers with diesel and fertilizer support. In accordance with the decision on agricultural supports to be made in 2016 No. 2016/8791, soil analysis support payments were abolished. In accordance with the communiqué numbered 30183 published in the Official Gazette dated 17.09.2017, it was stated that the soil samples will be taken by the technical staff of the authorized soil analysis laboratories using a coordinate determining device. Finally, in the 10th article of the Communiqué on the Payment of Support to Plant Production, published with the communiqué number 2019/46 dated 9.11.2019, the application principles for soil analysis support payments and the issues related to soil analysis laboratories that want to benefit from these payments are included.

In this study, the differences and importance levels of the differences in terms of some socio-economic factors and agricultural practices of the producers who had soil analysis in Edirne and Tekirdağ provinces were determined, and the opinions of the producers on soil analysis and soil analysis subsidies were given. Evaluations were made separately for the producers in Tekirdağ and Edirne provinces, and the provinces were compared.

2. Materials and Methods

2.1. Materials

The material of the research consisted of data obtained from primary and secondary sources. The primary data of the research consisted of the data obtained from the survey studies conducted with the producers who had soil analysis in 2015 in the laboratories that accepted the most sampling for soil analysis and gave fertilizer advice in the provinces of Edirne and Tekirdağ, which had the largest number of laboratories in the Thrace Region. Secondary data in the research was obtained from Turkish Statistical Institute, TR Ministry of Agriculture and Forestry, FAO, domestic and foreign universities and publication services' reports and previous studies and websites. The selected laboratories in the research area are given in *Table 1*.

Table 1. Laboratories in the research area

Provinces	Districts	Laboratories
Tekirdağ	Çorlu	Tua Agriculture Industry and Trade Limited Company
	Çorlu	Tekirdağ Thrace Oilseeds Agricultural Soil Analysis Laboratory
	Hayrabolu	Tekirdag Hayrabolu Commodity Exchange Soil Analysis Laboratory
	Central District	Namık Kemal University, Faculty of Agriculture, Soil Plant Analysis Laboratory
	Central District	Tekirdag Commodity Exchange Soil Analysis Laboratory
	Malkara	Tekirdağ Malkara Soil Plant and Irrigation Water Analysis Laboratory
Edirne	Keşan	Simcan Laboratory Services Industry and Trade Limited Company
	Keşan	Edirne Keşan Commodity Exchange Soil-Plant Analysis Laboratory
	Uzunköprü	Edirne Uzunköprü Commodity Exchange Soil Plant Analysis Laboratory
	Central District	Edirne Commodity Exchange Agricultural Analysis Laboratory

2.2. Methods

In the provinces determined in the research, 3 laboratories were selected among the laboratories with the highest number of sample acceptances for soil analysis. For each province, total of 60 producers who applied to the laboratories in 2015 and who utilized from soil analysis subsidies, and consequently, total of 120 producers were interviewed.

The compiled data were coded, loaded into the computer and evaluated with the widely used SPSS program. Descriptive statistics and cross tables were used in the analysis of the data obtained. The chi-square test in cross-sectional data was used to determine whether there was a difference between the groups in terms of the variables examined. The analysis of the differences of the producers who had soil analysis in Edirne and Tekirdağ provinces was determined by the regression tree model (CHAID analysis), one of the data mining methods.

Data mining is a method that can make predictions using meaningful information from complex data sets (Küçükönder et al., 2014). The most widely used method in data mining is classification and regression tree algorithms based on tree structure. The structure formed by the continuous dependent variable is called the “Regression Tree” (Koç, 2016). The structure formed by the categorical dependent variable is defined as the "Classification Tree" (Oruçoğlu, 2011).

It is a very useful technique with its tree structure and easy rule extraction. In this context, it is known that decision trees are widely used in medicine, industry, agriculture and engineering sciences (Kayri and Boysan, 2008, Sugumaran et al., 2007).

The regression tree method is a method that does not require assumptions that are important for parametric tests (such as normality, homogeneity), and has a visual superiority that is not affected by multiple correlations, missing observations and extreme values (Mendeş and Akkartal, 2009). With the diagram created by the regression tree method, the interaction between the independent variables and which independent variables affect the dependent variables can be easily seen. At the same time, the regression tree method allows the decision rules used in the creation of tree structures to be easily understood (Akşahan and Keskin, 2015).

The most frequently used decision tree models are called CART (Classification and Regression Trees) analysis and CHAID (Chi-Square Automatic Interaction Detector). Both are used for the same purposes, but there are differences in the decision tree creation stage. However, the CHAID method is preferred over the other

method. CHAID analysis is a sub-analysis within the classification and regression tree method (Albayrak and Kotlan-Yılmaz, 2009). The most important difference between CHAID analysis and other decision tree methods is due to tree formation. While the other method generates binary trees, CHAID analysis generates multiple trees (Türe et al., 2009). A regression equation to be obtained by CHAID analysis is kept independent of known classical assumptions (normality, linearity, homogeneity, etc.). Because with a strong translation algorithm, the whole universe can be divided into stable sub-nodes. This process can also ensure normality and homogeneity in the distribution of the data. In addition, continuous and categorical data can be included in the model at the same time with CHAID analysis (Doğan, 2003). For this reason, CHAID analysis removes the distinction between parametric and non-parametric and has a statistically semi-parametric feature in the method algorithm (Kayri and Boysan, 2008). In CHAID analysis, especially the relationships and interactions of independent variables with each other are examined. For this reason, it also tests the relationships between variables. If the dependent variable is categorical, the relationship between the variables is tested with chi-square analysis, and if the dependent variable is continuous, it is tested with the F test. (Kayri and Boysan, 2008).

3. Results and Discussion

3.1. Anaylsis of the differences of the producers

In this part of the study, the differences and the importance of the differences in terms of some socio-economic factors and agricultural practices of the producers who had soil analysis in Edirne and Tekirdağ provinces were examined with the help of CHAID analysis. The distribution of the variables used in the analysis in the provinces is given in *Table 2*.

Producers who had analysis in Edirne and Tekirdağ provinces were predominantly in the middle-aged group (41-60 years old). While it was seen that the ratio of the producers who were primary school graduates in Edirne province was higher than Tekirdağ province, the ratio of producers who were secondary school, high school and university graduates was higher in Tekirdağ province. While it was determined that 45% of the producers in Tekirdağ province had less than 25 years of agricultural experience, this ratio was lower in Edirne province as 33.33%.

The ratio of obtaining agricultural insurance was 85% in Edirne and 66.67% in Tekirdağ. It was seen that the ratio of the producers who stated that they had non-agricultural income in Edirne (66.67%) was higher than those in Tekirdağ (48.33%). It was seen that the ratio of the producers who stated that they faced risks in agriculture in the last three years was quite close to each other in Edirne and Tekirdağ provinces.

It was determined that the ratio of the producers (23.33%) who were engaged in animal husbandry as well as plant production in Edirne province was slightly higher than the producers in Tekirdağ (15%). The ratio of the producers who stated that they cultivated more than 250 decares of land in Edirne and Tekirdağ provinces were found to be quite close to each other in both provinces. 68.33% of the producers in Edirne and 55% of the producers in Tekirdağ stated that they used fertilizer support to buy fertilizer.

While the rate of producers who stated that they received training on fertilization in Edirne was 33.33%, this ratio was found to be 50% for producers operating in Tekirdağ. 46.67% of the producers in Edirne and 51.67% of the producers in Tekirdağ stated that they had separate analyzes for each parcel. While 58.33% of the producers operating in both provinces stated that they complied with the recommended fertilization program, 10% of the producers in Edirne and 28.33% of the producers in Tekirdağ stated that they always complied with the fertilization program (*Table 2*).

The regression tree created with the CHAID algorithm to determine the differences of the producers who had soil analysis in Edirne and Tekirdağ provinces is given in *Figure 1*. According to the CHAID analysis, in which the provinces were taken as the dependent variable, it was seen that the first most distinctive feature was the state-supported agricultural insurance. Of the producers who stated that they did not have agricultural insurance, 31% were located in Edirne and 69% were located in Tekirdağ. It was seen that 56% of the producers in Edirne and 44% of the producers in Tekirdağ had agricultural insurance. The most important feature of the second node was the education level of the producers, the third sub-node decision point was whether the producers had received training on fertilization, and the fourth decision point was whether the producers faced risks in agriculture in the last three years.

Table 2. Descriptive statistics of the variables used in the analysis

Variables	Edirne		Tekirdağ	
	Number	%	Number	%
Age				
Young (20-40 years old)	4	6.67	10	16.67
Middle-aged (41-60 years old)	36	60.00	37	61.67
Elderly (61 years and older)	20	33.33	13	21.67
Young (20-40 years old)	4	6.67	10	16.67
Education level				
Primary school	29	48.33	16	26.67
Middle school	5	8.33	11	18.33
High school	16	26.67	21	35.00
College/University	10	16.67	12	20.00
Agricultural experience				
Less than 25 years	20	33.33	27	45.00
25 years and above	40	66.67	33	55.00
Agricultural insurance				
Yes	51	85.00	40	66.67
No	9	15.00	20	33.33
Non-agricultural income				
Yes	40	66.67	29	48.33
No	20	33.33	31	51.67
Encountering risks in agriculture				
Yes	24	40.00	22	36.67
No	36	60.00	38	63.33
Type of activity				
Vegetative	46	76.67	51	85.00
Vegetative + animal	14	23.33	9	15.00
Total land size				
0-250 da	16	26.67	15	25.00
251 da and above	44	73.33	45	75.00
Purpose of use of fertilizer support				
To get fertilizer	41	68.33	33	55.00
Out of agriculture	0	0.00	2	3.33
Apart from fertilizer but still in agricultural production	19	31.67	25	41.67
Getting training on fertilization				
Yes	20	33.33	30	50.00
No	40	66.67	30	50.00
Performing analysis for each parcel				
Yes	28	46.67	31	51.67
No	32	53.33	29	48.33
Comply with the fertilization recommendation program				
Always	6	10.00	17	28.33
Generally	35	58.33	35	58.33
Rarely	11	18.33	4	6.67
Very rare	6	10.00	1	1.67
No	2	3.33	3	5.00

The situation of not having agricultural insurance was affected by the education level variable and divided into two juvenile nodes. 61.5% of the producers who did not have agricultural insurance in Edirne and 38.5% of those who did not have agricultural insurance in Tekirdağ were primary school graduates. While the ratio of the producers who were above primary school graduates in the producer group who did not have agricultural insurance in Edirne province was determined as 6.2%, this ratio was found as 93.8% in Tekirdağ province.

Agricultural insurance was affected by the total land size variable and divided into two juvenile nodes. The total land size of 51.4% of the producers who had agricultural insurance in Edirne and 48.6% of those who had agricultural insurance in Tekirdağ province was over 250 decares.

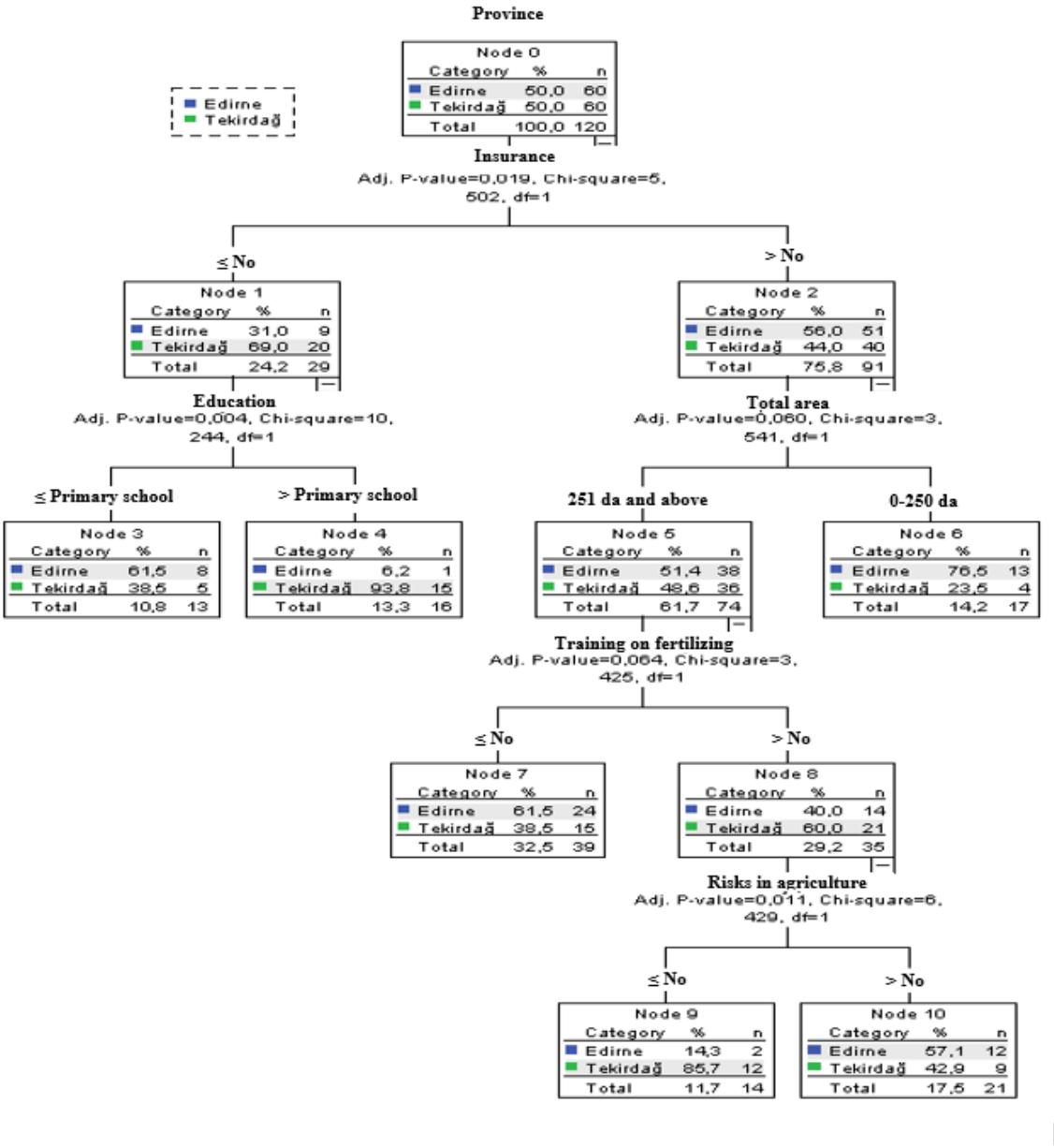

Figure 1. Regression tree for provinces using CHAID algorithm

The variable of land size over 250 decares was divided into two juvenile nodes by being affected by the variable of training on fertilization. While it was determined that 61.5% of the producers working on 250 decares of land in Edirne province did not receive training on fertilization, this ratio was found as 38.5% in Tekirdağ province. The rate of training with fertilization by the producers who cultivated a land of more than 250 decares was found to be 40% for Edirne province and 60% for Tekirdağ province. The variable of receiving education about fertilization was affected by the risk exposure variable in agriculture in the last three years and divided into two juvenile nodes. 14.3% of the producers who received fertilization training in Edirne and 85.7% of the producers who received fertilization training in Tekirdağ stated that they did not encounter any risk in agriculture in the last three years. In the provinces of Edirne and Tekirdağ, the ratio of encountering any risk in agriculture in the last three years was found to be 57.1% and 42.9%, respectively (*Figure 1*).

3.2. Opinions of the producers on soil analysis and analysis subsidies

In this part of the research, the opinions of the producers about soil analysis and soil analysis subsidies are given. Evaluations were made separately for the producers in Tekirdağ and Edirne provinces, and the provinces were compared. The reasons for the soil analysis of the producers were determined (*Table 3*). Producers were asked to rank the reasons for having soil analysis in order of importance (1 = lowest; 5 = highest). The total scores of the criteria were obtained by multiplying the degree of importance given to the reasons for the soil analysis by the producers and the number of producers responding, and adding the obtained values.

In Edirne province, 91.67% of the producers stated that they had soil analysis done to increase product yield, 71.67% to increase product quality, 78.33% to reduce costs, and 61.67% to protect the environment. In Tekirdağ, 88.33% of the producers stated that they had soil analysis done to increase product yield, 60% to increase product quality, 43.33% to reduce costs, and 36.67% to protect the environment. Producers listed the reasons for having soil analysis according to the degree of importance, and it was determined that the four most important reasons for producers to have soil analysis in Edirne province were to increase the product yield, reduce the cost, increase the product quality and protect the environment, respectively. In the province of Tekirdağ, the criteria of increasing the product yield was the first rank, increasing the product quality in the second rank, reducing the cost in the third rank and protecting the environment in the fourth rank. It was determined that the last three criteria that were effective in soil analysis by producers in both provinces were getting subsidies, learning about the condition of the soil and protecting the soil.

In the study conducted by Küçükkaya and Özçelik (2014), it was determined that wheat producers had soil analysis done in order to use less fertilizer, increase product yield, benefit from support and learn the condition of the soil, respectively. In the study of Çönoğlu et al. (2016), producers who benefited from soil analysis subsidies and those who did not, stated that the most important purpose of soil analysis was to use the right fertilizer and increase product yield. In the study conducted by Tanrıverdi (2017), the majority of the producers stated that they had soil analysis done to benefit from the supports. The result of this research was similar to the results of Küçükkaya and Özçelik (2014) and Çönoğlu et al. (2016) literature.

Table 3. Reasons for producers to have soil analysis

Reasons for soil analysis*	Edirne				Tekirdağ			
	Number	%	Total Points	Order of importance	Number	%	Total Points	Order of importance
To increase product yield	55	91.67	245	1	53	88.33	249	1
To improve product quality	43	71.67	158	3	36	60.00	139	2
To reduce the cost	47	78.33	182	2	26	43.33	94	3
To protect the environment	37	61.67	86	4	22	36.67	64	4
For supporting	8	13.33	20	5	14	23.33	45	5
To know the condition of the soil	5	8.33	16	6	7	11.67	30	6
To protect the soil	4	6.67	10	7	7	11.67	28	7

* More than one option marked

The sources of information about the soil analysis of the producers were also determined (*Table 4*). Producers were asked to rank their sources of information on soil analysis in order of importance (1 = lowest; 5 = highest).

In the province of Edirne, 81.67% of the producers stated that their information sources about soil analysis were employees of the provincial/district directorate, 83.33% were laboratory workers, 31.67% were research institutes, 30% were friends-neighbours, 25% were fertilizer dealers, 21.67% were cooperatives, 15% were newspapers/TV and brochures, and 13.33% were social media sites. In Tekirdağ, 66.67% of the producers stated that their information sources about soil analysis were employees of the provincial/district directorate of the information sources on soil analysis, 38.3% were laboratory workers, 30% were friends-neighbours, 26.67%

were cooperatives, 25% were newspaper/TV and brochures, 20% were fertilizer dealers, %16.67 were social media sites and 11.67% were research institutes.

When the producers ranked the soil analysis information sources according to their importance, it was determined that the two most important sources of information about soil analysis of the producers in Edirne and Tekirdağ provinces were the employees of the provincial/district directorate and laboratory workers. While the research institute option was in the third place in Edirne province, it was in the last place in Tekirdağ province.

In the studies conducted by Gülaç (2011), Küçükkaya and Özçelik (2014), and Tanrıverdi (2017), it was determined that the majority of the producers who had soil analysis received information from the district agriculture directorate about soil analysis, which showed similarities with the research result.

Table 4. Information resources of the producers on soil analysis

Soil analysis information resources*	Edirne				Tekirdağ			
	Number	%	Total Points	Order of importance	Number	%	Total Points	Order of importance
Provincial/District directorate of agriculture employees	49	81.67	228	1	40	66.67	178	1
Laboratory	50	83.33	211	2	23	38.33	100	2
Friend-neighbor	18	30.00	38	5	18	30.00	60	3
Research institute	19	31.67	67	3	7	11.67	27	8
Fertilizer dealer	15	25.00	48	4	12	20.00	42	6
Cooperative	13	21.67	26	6	16	26.67	59	4
Newspaper/TV and brochures	9	15.00	15	8	15	25.00	54	5
Social media sites	8	13.33	16	7	10	16.67	29	7

* More than one option marked

Information sources on soil analysis subsidies of producers were also determined (*Table 5*). Producers were asked to rank their sources of information on soil analysis subsidies in order of importance (1 = lowest; 5 = highest).

Almost all of the producers in Edirne and Tekirdağ provinces stated that the information sources on soil analysis subsidies were the publication and training activities of the provincial/district directorate of agriculture. While 45% of the producers in Edirne stated that the information sources about soil analysis subsidies were friends-neighbours, 41.67% of them were newspapers/TV, these ratios were found to be 25% and 23.33% in Tekirdağ. The ratio of producers who stated that their source of information about soil analysis subsidies was the village headman was very close to each other in Edirne and Tekirdağ provinces. While 33.33% of the producers in Edirne stated that they learned about the supports through cooperatives, this ratio was determined as 16.67% for Tekirdağ province. While the ratio of producers who stated that they received information about soil analysis subsidies from the research institute in Edirne province was 33.33%, this ratio was determined as 1.67% in Tekirdağ province. While 6.67% of the producers in Tekirdağ stated that they obtained information about the support from the internet, no producers were found in Edirne who stated that they obtained information via the internet.

When the producers ranked the soil analysis subsidies information sources according to the degree of importance, it was determined that the most important source of information on soil analysis of the producers in Edirne and Tekirdağ provinces was the publication and training activities of the provincial/district directorate of agriculture, and the second and the third information sources were friend-neighbor and newspaper/TV options.

In the studies conducted by Gülaç (2011), Küçükkaya and Özçelik (2014), Güldal (2016) and Tanrıverdi (2017), it was determined that the most important information sources about the soil analysis subsidies of the producers who had soil analysis were the education and publication activities of the provincial-district directorate which showed similarities with the research result.

The distribution of the producers according to the years (2010-2015) in which they benefited from the soil analysis subsidies is given in *Table 6*. It was seen that the ratio of the producers receiving support in 2010 was quite close to each other in both provinces. The ratio of the producers benefiting from soil analysis support in the province of Edirne in 2011, 2012 and 2013, and the ratio of the producers benefiting from soil analysis support in Tekirdağ in 2014 and 2015 was higher. It was seen that the year that benefited the most from soil analysis support between 2010 and 2015 was 2015, according to the provincial average.

Table 5. Information resources on soil analysis support

Soil analysis support information resources*	**Edirne**				**Tekirdağ**			
	Number	**%**	**Total Points**	**Order of importance**	**Number**	**%**	**Total Points**	**Order of importance**
Provincial/District directorate of agriculture extension and training activities	59	98.33	290	1	57	95.00	276	1
Friend-neighbor	27	45.00	84	2	15	25.00	57	2
Newspaper/TV	25	41.67	75	3	14	23.33	48	3
Headman	11	18.33	41	6	13	21.67	43	4
Cooperative	20	33.33	57	4	10	16.67	24	5
Research institute	20	33.33	55	5	1	1.67	2	8
Internet	0	0.00	0	9	4	6.67	14	6
Faculty of agriculture	4	6.67	6	8	2	3.33	5	7
Laboratory	2	3.33	9	7	1	1.67	2	9

* More than one option marked

Table 6. Years of producers benefiting from soil analysis subsidies

Years*	**Edirne**		**Tekirdağ**		**Total**	
	Number	**%**	**Number**	**%**	**Number**	**%**
2010	42	70.00	43	71.67	85	70.83
2011	53	88.33	45	75.00	98	81.67
2012	54	90.00	48	80.00	102	85.00
2013	57	95.00	51	85.00	108	90.00
2014	55	91.67	56	93.33	111	92.50
2015	56	93.33	60	100.00	116	96.67

* More than one option marked

It was also asked whether the producers had separate analyzes for each parcel (*Table 7*). 46.67% of the producers in Edirne and 51.67% of the producers in Tekirdağ stated that they had soil analysis done for each parcel. As a result of the chi square test, it was determined that the status of the producers to have soil analysis for each parcel did not change according to the provinces.

Table 7. Status of manufacturers to have separate analysis for each parcel

Making analysis for each parcel	**Edirne**		**Tekirdag**		**Total**	
	Number	**%**	**Number**	**%**	**Number**	**%**
Yes	28	46.67	31	51.67	59	49.17
No	32	53.33	29	48.33	61	50.83
Total	60	100.00	60	100.00	120	100.00
Chi-square: 0.300 p: 0.584						

It was also determined whether the producers complied with the recommended fertilization program according to the soil analysis results (*Table 8*). 58.33% of the producers operating in both provinces stated that they complied with the recommended fertilization program. While 10% of the producers in Edirne stated that they always complied with the fertilization program, this ratio was found as 28.33% for Tekirdağ province. The ratio of compliance with the fertilization program of the producers in Tekirdağ province was higher than the producers in Edirne province. As a result of the chi square test, it was determined that the producers' compliance with the recommended fertilization program according to the soil analysis results varied according to the provinces.

In the study conducted by Ataseven et al. (2014) in the province of Ankara, 39.3% of the producers, in the study conducted by Ceyhan (2010) in Samsun, 7% of the producers, in the study conducted by Olhan et al. (2010), 25.9% of the producers, in the study conducted by Küçükkaya and Özçelik (2014), 43.33% of the producers, in the study conducted by Çarkacı et al. (2016) in Konya province, 16.66% of the producers, in the study conducted by Güldal (2016), 33.33% of the producers and 30.19% of the producers in the study conducted by Tanrıverdi (2017) stated that they applied fertilizers according to the results of soil analysis. According to the results of the research, the ratio of producers who stated that they applied fertilizers according to the results of soil analysis was quite high when compared to the literature.

Table 8. Compliance with the recommended fertilization program according to the soil analysis results of the producers

Compliance with fertilization program	Edirne		Tekirdağ		Total	
	Number	%	Number	%	Number	%
Always	6	10.00	17	28.33	23	19.17
Generally	35	58.33	35	58.33	70	58.33
Rarely	11	18.33	4	6.67	15	12.50
Very rare	6	10.00	1	1.67	7	5.83
No	2	3.33	3	5.00	5	4.17
Total	60	100.00	60	100.00	120	100.00
Chi-square: 10.097 p: 0.039						

The producers who stated that they seldom or did not comply with the fertilization program were asked about the reasons for not complying with the program (*Table 9*). 52.63% of the producers operating in Edirne province and 37.50% of the producers operating in Tekirdağ province stated that they did not consider the recommended amount of fertilizer sufficient. While 31.58% of the producers in Edirne stated that they had soil analysis done only to benefit from the support, this ratio was lower for Tekirdağ province and was found as 12.50%. While 75% of the producers in Tekirdağ stated that they did not trust the results, this ratio was lower for Edirne and was determined as 31.58%.

Table 9. Reasons for non-compliance with the recommended fertilization program according to the soil analysis results of the producers

Reasons for non-compliance with the fertilization program*	Edirne		Tekirdağ		Total	
	Number	%	Number	%	Number	%
The amount of fertilizer was insufficient	10	52.63	3	37.50	13	48.15
I'm getting analysis to take advantage of support	6	31.58	1	12.50	7	25.93
I don't trust the result	6	31.58	6	75.00	6	22.22
Due to financial difficulties	1	5.26	1	12.50	2	7.41

* More than one option marked

In the study conducted by Gülaç (2011), financial impossibilities took the first rank among the reasons for not using fertilizers according to the results of soil analysis, and the second rank was the insufficient amount of fertilizer written in the analysis. In the study conducted by Küçükkaya and Özçelik (2014), it was determined that the producers did not comply with the fertilization program primarily due to financial impossibilities and they had an analysis done only to benefit from the subsidies. Çönoğlu et al. (2016) stated that the biggest factor

in not using fertilizers according to soil analysis was the low amount of fertilizer obtained as a result of the analysis. In the study conducted by Güldal (2016), the reasons for not using fertilizers according to the soil analysis results of the producers in the enterprises that had soil analysis were determined as performing analysis to benefit from fertilizer support, not relying on the analysis results, and insufficient amount of fertilizer in the analysis. In the study conducted by Şahinli et al. (2016), the first three reasons for not using fertilizers according to the analysis results of the producers who had soil analysis were to benefit only from the subsidies, not to trust the analysis results, and to have insufficient amount of fertilizer. In the study conducted by Tanrıverdi (2017), the vast majority of producers stated that they had soil analysis done only to benefit from support. The result of this research was similar to the results of Çönoğlu et al. (2016) literature.

The reasons for choosing the laboratory where the producers had soil analysis were also determined (*Table 10*). 68.33% of the producers operating in Edirne and 58.33% of the producers operating in Tekirdağ stated that they preferred the laboratory because it wasclose. While the ratio of the producers who stated that they preferred the laboratory because they found the laboratory reliable in Tekirdağ province was 38.33%, this ratio was determined as 26.67% for Edirne province. As a result of the chi square test, it was determined that the reasons for choosing the laboratory where the producers had soil analysis did not differ according to the provinces.

Table 10. Reasons for the producers to choose the soil analysis laboratory

Reasons for choosing a laboratory	**Edirne**		**Tekirdağ**		**Total**	
	Number	**%**	**Number**	**%**	**Number**	**%**
Near	41	68.33	35	58.33	76	63.33
Trustworthy	16	26.67	23	38.33	39	32.50
Fast	3	5.00	2	3.33	5	4.17
Total	60	100.00	60	100.00	120	100.00
Chi-square: 1.930 p: 0.379						

The producers were asked who took the soil sample for soil analysis, and their distribution according to the answers they gave is given in *Table 11*. While almost all of the producers in Tekirdağ (98.33%) stated that they took the soil sample themselves, only one producer stated that their relatives took it. In Edirne province, the ratio of producers who stated that they took the soil sample was lower than Tekirdağ province and was found to be 86.67%. Four producers operating in the province of Edirne stated that the laboratory staff took the soil samples, and two producers each stated that their relatives or the workers they employed. As a result of the chi square test, it was determined that the people who took soil samples for soil analysis varied according to the provinces. In the study conducted by Özçelik and Güldal (2014) in the province of Ankara, it was determined that 91.32% of the producers took the soil sample themselves, which was similar to the research result.

The information on how the producers took soil samples for soil analysis and from which depth they took the soil sample is given in *Table 12*. It was determined that the ratio of the producers who stated that they took the soil samples by drawing zigzags according to the shape of the land in both provinces was the same (95%).

All of the producers operating in Edirne stated that they took the soil sample from 0-30 cm depth. For Tekirdağ province, this ratio was found to be 98.33%. Only one producer operating in Tekirdağ stated that he took the soil sample from a depth of 30-60 cm.

It was also determined whether the producers had regularly soil analysis done every year (*Table 13*). It was determined that 48.33% of the producers operating in the province of Edirne and 26.67% of the producers operating in the province of Tekirdağ stated that they had a soil analysis done every year. As a result of the chi square test, it was determined that the status of the producers to make soil analysis every year varied according to the provinces. In the study conducted by Gülaç (2011), 34% of the producers, in the study conducted by Ataseven et al. (2014), 59% of the producers in Ankara, and 56.1% of the hazelnut producers in the study conducted by Aydoğan and Demiryürek (2012) in Samsun stated that they had soil analysis done regularly.

Table 11. Soil sampling for soil analysis

Who takes soil sample?	Edirne		Tekirdağ		Total	
	Number	%	Number	%	Number	%
Myself	52	86.67	59	98.33	111	92.50
laboratory staff	4	6.67	0	0.00	4	3.33
Relatives	2	3.33	1	1.67	3	2.50
Workers	2	3.33	0	0.00	2	1.67
Total	60	100.00	60	100.00	120	100.00
Chi-square: 9.099 p: 0.039						

Table 12. How and depth of soil sampling by producers for soil analysis

Soil sampling method	Edirne		Tekirdağ		Total	
	Number	%	Number	%	Number	%
By drawing zigzags according to the shape of the land	57	95.00	57	95.00	114	95.00
Straight from one end of the field to the other	3	5.00	3	5.00	6	5.00
Total	60	100.00	60	100.00	120	100.00
Soil sampling depth						
0-30cm	60	100.00	59	98.33	119	99.17
30-60cm	0	0.00	1	1.67	1	0.83
Total	60	100.00	60	100.00	120	100.00

Table 13. Status of producers to have soil analysis performed every year

Status of soil analysis every year	Edirne		Tekirdağ		Total	
	Number	%	Number	%	Number	%
Yes	29	48.33	16	26.67	45	37.50
No	31	51.67	44	73.33	75	62.50
Total	60	100.00	60	100.00	120	100.00
Chi-square: 5.120 p: 0.024						

Table 14. Soil analysis criteria of the producers

Soil analysis criteria	Edirne		Tekirdağ		Total	
	Number	%	Number	%	Number	%
For soil control	34	56.67	30	50.00	64	53.33
If the yield decreases	9	15.00	15	25.00	24	20.00
To get support	9	15.00	8	13.33	17	14.17
As far as I can think of	5	8.33	6	10.00	11	9.17
When i change the product	2	3.33	1	1.67	3	2.50
If necessary	1	1.67	0	0.00	1	0.83
Total	60	100.00	60	100.00	120	100.00
Chi-square: 3.284 p: 0.701						

The criteria for soil analysis were also asked to the producers (*Table 14*). Majority of the producers in both provinces stated that they had soil analysis done for soil control. In Edirne province, the ratio of producers who stated that they had soil analysis done in case of decrease in yield or to get support was found to be 15%, while in Tekirdağ province, 25% of the producers stated that they had it done in case of decrease in yield, and 13.33% to get support. While 8.33% of the producers in Edirne and 10% of the producers in Tekirdağ answered this question whenever they came to my mind, two producers operating in Edirne and one producer operating in Tekirdağ stated that they had a soil analysis done when they were going to change the product they were planting. A producer operating in Edirne stated that he had soil analysis done if necessary while it was determined that there was no producer who preferred this criterion in Tekirdağ province. In the study conducted

by Gülaç (2011), it was concluded that the majority of the producers had soil analysis done in case the yield decreased.

4. Conclusions

It was seen that some of the producers who had soil analysis did not comply with the recommended fertilization program according to the soil analysis results. In order to increase the fertilizing status according to the results of the analysis report, it is thought that it would be appropriate to introduce the soil analysis condition in fertilizer sales in order to increase the use of fertilizers, or the soil analysis condition in fertilizer support for lands of 50 decares or more, as well as the requirement to purchase fertilizer according to the analysis results.

In terms of the reliability of the soil analysis, it is very important to take the soil sample to be analyzed correctly. The majority of the producers in the research area stated that they took the soil sample as a result of their own knowledge. It would be more appropriate for the privately authorized soil analysis laboratories, together with the laboratories belonging to the Ministry of Agriculture and Forestry in the region, to inform the producers more about the soil sampling, and if possible, the soil samples should be taken by the personnel in the laboratory where the analyzes were made, not the producers.

It is important to give practical training to the producers on sampling, not to take fertilizer without soil analysis results, to make supports mandatory and to remove the area limitation. In addition to these, it is thought that it would be beneficial to implement fertilizer sales according to the analysis reports of the laboratories, to expand the training and extension studies, and to explain the necessity of having analysis done by the producers who make a living from the fields. It is expected that it will be beneficial to introduce soil analysis conditions to the producers at the stage of purchasing fertilizers, and thus to ensure that the producer purchases fertilizer by determining the type and amount of fertilizer to be disposed of according to the analysis results.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Optimization of Drying Conditions of Kiwi Rings with Osmo-solar Dehydration*

Ozmo-solar Dehidrasyon Kurutma ile Kivi Halkalarının Kurutma Koşullarının Optimizasyonu

Zehra YILDIZ[1*], Sabri Furkan GENCER[2]

Abstract

It is the oldest and most common traditional food preservation method known to dry by laying food products under the sun. However, if the food product is in direct contact with the sun light, there is a decrease in the color and nutrient values of the product. To solve these problems, solar dryers have been developed which can be utilized due to indirectly the effect of the sun. In this study, kiwi rings were dried by using osmosolar dehydration as a combination of osmotic dehydration and solar drying. Kiwi rings were first immersed in sucrose solutions and then dried in a solar dryer. Response Surface Methodology used to determine effects of the conditions ondrying performance and find out optimum levels drying conditions for the responses to a safe level. In the response surface method, the drying conditions were selected as the kiwi slice thickness (A), sucrose concentrations (B), immersed time (C) and solar drying time (D). The response to be optimized was chosen as water loss, diameter shrinkage ratio and greenness (*a*) color change. A successful mathematical model was obtained by the response surface method between the drying conditions and the responses. The suitable model is chosen quadratic for water loss, 2FI model for color change model and shrinkage ratio. The model R^2 value is 0.952 for water loss, 0.737 for *a* color change and 0.856 for shrinkage ratio. The regression coefficients, along with the corresponding P-values, for the model of production water loss, *a* color change and shrinkage ratio are described by ANOVA. Values of "Prob>F" less than 0.0500 indicate model terms are significant. In this case B, C, C^2 are significant model terms for water loss. A, B, C, AB, AC, AD, BC and CD are significant model terms for color change and B, C, AC, AD, BD, CD are significant model terms for shrinkage ratio. The optimum drying conditions levels was determined to sucrose concentration 12.7 %w/v, ring slice thickness 4.06 mm, solar drying time 125 min and immersed time 70.9 min, respectively. In addition, pretreatment of osmotic dehydration was found to be effective in drying kiwi rings with solar tray dryer.

Keywords: Kiwi drying; Solar dryer; Response surface method; Osmotic dehydration; Osmosolar dehydration

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Öz

Gıda ürünlerinin güneş altına serilerek kurutulduğu bilinen en eski ve en yaygın geleneksel gıda muhafaza yöntemidir. Ancak gıda ürünü güneş ışığı ile direkt temas ederse ürünün renginde ve besin değerlerinde azalma olur. Bu sorunları çözmek için güneşin dolaylı olarak etkisinden yararlanılabilen güneş kurutucuları geliştirilmiştir. Bu çalışmada kivi halkaları, ozmotik dehidrasyon ve güneşte kurutmanın bir kombinasyonu olarak ozmosolar dehidrasyon kullanılarak kurutulmuştur. Kivi halkaları önce sakaroz çözeltilerine daldırılmış ve ardından bir güneş kurutucusunda kurutulmuştur. Yanıt Yüzey Yöntemi metodu, koşulların kurutma performansı üzerindeki etkilerini belirlemek ve güvenli bir seviyeye tepkiler için optimum kurutma koşullarını bulmak için kullanılır. Yanıt Yüzey Yönteminde kurutma koşulları kivi dilimi kalınlığı (A), sakaroz konsantrasyonları (B), daldırma süresi (C) ve güneşte kurutma süresi (D) olarak seçilmiştir. Optimize edilecek yanıtlar nem kaybı, çapsal büzülme oranı ve yeşillik (a) renk değeri olarak seçilmiştir. Kurutma koşulları ile tepkiler arasında yanıt yüzeyi yöntemi ile başarılı bir matematiksel model elde edilmiştir. Nem kaybı için kuadratik model, renk değişimi ve büzülme oranı için ikili etkileşim modeli seçilmiştir. Model R^2 değerleri nem kaybı için 0.952, renk değişimi için 0.737 ve büzülme oranı için 0.856 dır. P değerine karşılık regrasyon katsayıları, nem kaybı, a renk değişimi ve büzülme oranı için ANOVA ile ifade edilmiştir. "Prob>F" değerleri 0.0500 de daha az ise model terimleri önemli bulunmuştur. Bu durumda B, C, C^2 nem kaybı için önemlidir. A, B, C, AB, AC, AD, BC ve CD renk değişimi için önemlidir. B, C, AC, AD, BD, CD büzülme oranı iiçin önemlidir. Optimum kurutma koşulları seviyesi sakaroz çözelti derişimi için %12.7, dilim kalınlığı için 4.06 mm, güneş kurutma süresi için 125 dakika ve ozmotik dehidrasyon süresi için 70.9 dakika belirlenmiştir. Ayrıca ozmotik dehidrasyon ön işleminin güneş enerjili raflı kurutucu ile kivi halkaları kurutma da etkili olduğu bulunmuştur.

Anahtar Kelimeler: Kivi kurutma, Güneş enerjili kurutucu, Yanıt yüzey yöntemi, Ozmotik dehidrasyon, Ozmosolar dehidrasyon

1. Introduction

Both efficient and economical drying methods are required to meet the increasing need for dry food products and to produce quality marketable products. Traditional solar is carried out loss of color and nutritional values, non-hygienic drying, and long drying time in the large areas (Yıldız and Akkari, 2021). The pre-treatments to be applied before drying have important effects on the quality and operating cost of the product to be dried (Yokuş, 2014; Gürel et al., 2016; Fernandes et al., 2006). Research on the application of osmotic dehydration as a drying pretreatment technique has attracted attention in recent years. This process is the partial removal of water from the tissues of the product immersed in an osmotic solution such as sugar, salt, honey, fruit juice, lemon juice, ascorbic acid and citric acid solutions (Abano and Sam-Amoah, 2011; Pandya and Yadav, 2014; Gürel et al., 2016). It is stated that the samples dried after osmotically dehydrated are products with high-water absorption ability and high sensory properties such as color, texture, appearance and are at an acceptable level in terms of aroma and taste. Solar dryers are becoming increasingly important as fresh and durable dried fruit is obtained as much as possible (Torringa et al., 2001; Lombard et al., 2008; Bórquez et al., 2010; Amer et al., 2010; Karaaslan, 2012; Akar, 2017). Studies are carried out on combining osmotic drying with new techniques to shorten the processing time. In addition, many studies have been carried out on hybrid drying techniques, where various drying methods are used together, such as vacuum drying, microwave drying and osmotic dehydration (Bórquez et al., 2010). It can be used in conjunction with osmotic dehydration to increase the efficiency of the solar drying process.

The drying process in which osmotic dehydration and solar dryer are used together can be called osmosolar dehydration drying process. Due to the loss of water during osmotic dehydration applied before drying, the water removal load of the dryer decreases, samples enter the dryer with a higher dry matter content. Thus, the osmotic dehydration pretreatment enables shortening the drying time and increasing the drying potential. In addition, osmosolar dehydration drying process takes place at low temperatures, and heat damage such as aroma change and oxidation in food is less. In this way, denser, quality in color, texture and appearance, and a dry product acceptable in terms of aroma and taste can be obtained. By drying the kiwi rings, both the spread of consumption to a wider area and the diversity and added value in the food industry and trade will be achieved. Studies on osmotic dehydration have focused on drying kinetics, optimization, modeling, mass and heat transfer.

Response surface methodology (RSM) usually has been used for optimization of drying process of vegetables and fruits (Uddin et al. 2004; Corzo and Gomez, 2004; Eren and Ertekin, 2007; Singh et al., 2007; Han et al., 2010; Abano et al., 2014; Sadeghi et al., 2020). RSM combines mathematics with statistics, modeling, evaluating the controlling drying conditions and optimization of the drying conditions. This method can be optimized with less experiments number with not need to any mathematical model. The experimental results statistically are employed on by using the analysis of variance (ANOVA). It is determined the optimum values which maximized the water loss, shrinkage ratio and color change in the study on the optimization of solar drying of kiwi slice by RSM. The condition levels such as kiwi slice thickness, drying time and kiwi slice load should be optimized.

2. Materials and Methods

2.1. Experimental analysis

Drying experiments were carried out with natural heat convection in the solar tray dryer and the effect of drying conditions on drying process was determined. The fresh organic kiwis were dried by using solar tray dryer in local market. Fresh kiwis were obtained from a local market, sorted visually for size, maturity level and physical damage. The product was stored at 4°C under refrigeration until used. The dirt, flower pit, shell, core house remnants, stalk, leaf parts, core, etc. found in or on the kiwi were cleaned. For these reasons, the kiwi samples were thoroughly washed with water to remove adhering soil and other debris. Kiwi samples were peeled and sliced to a ring shape form according to RSM experiment conditions as five kiwi samples. Kiwi rings were immerged in sucrose solution in order to osmotic dehydration. Solar drying trials were performed with the solar tray dryer shown in *Figure 1*.

Figure 1. Solar tray dryer

Shrinkage ratio was determined by measuring of diameter. These experiments were replicated five samples and obtain a reasonable average. The water loss, *a* color change and shrinkage ratio were calculated according to the following Eq. 1 and Eq. 2 (Aboud, 2013; Ochoa-Martinez et al. 2006).

$$\text{Water Loss} = \frac{M_0 - M_t}{M_0} \quad \text{(Eq. 1)}$$

$$\text{Shrikange Ratio} = \frac{D_0 - D_t}{D_0} \quad \text{(Eq. 2)}$$

Where M_0 and M_t are the sample mass (g), D_0 and D_t are the sample diameter (mm), at the beginning and at time t, respectively. Air temperature and humidity in the drying cabinet were monitored by CEM brand DT-802 model air quality measuring device.

The color change of kiwi rings is a parameter that negatively affects the quality. In order to prevent the kiwi rings from darkening as a result of oxidation and to reduce the drying time, the kiwi rings were first immersed in sucrose solution at the determined concentrations. Color parameters are *L, a* and *b* values. *L* is the luminance value and it varies between 0-100. An *L* value of 100 indicates white, *a* 0 value indicates black. *b*-value gives information about the blue-yellow colors. The positive value of *b* denotes the yellow and the negative value the blue color (Yıldız et al., 2015). The *a* value ranges from (-60) to (+ 60) and gives the red-green color value. a positive value gives red (+60) and a negative value (-60) the green color (Askari et al., 2008, Çelen et al., 2016, Arslan et al., 2021). Kiwi rings are green in color and turn green-brown over time. Therefore, *a* value (greenness) for kiwi is important in color analysis. Color parameters *a* value of kiwi rings before and after drying were determined with the FRU marka WR18 Colormeter. Color measurement was made three times and the average value was taken. *a* color change was calculated according Eq. 3. a_0 indicates the color parameter of fresh kiwi rings and a after the drying period.

$$\frac{\Delta a}{a_0} = \frac{a_0 - a}{a_0} \quad \text{(Eq. 3)}$$

2.2. Statistical analyses

The response surface methodology was described as the optimization of the experimental results by using binary combination of mathematical and statistical methods in the analysis and modeling of problems. The parameters affecting the process are called independent variables and the responses are called dependent variables. A mathematical model, describing the relations between the drying conditions and the responses in a second-order equation, was developed. Code value of the variables was done according to the following Eq. 4:

$$y = b_0 + \sum_{i=1}^{k} b_i X_i + \sum_{i=1}^{k} b_{ij} X_i^2 + \sum_{i_j<j}^{k} \sum_{j}^{k} b_{ij} X_i X_j + e \quad \text{(Eq. 4)}$$

Where *i* and *j* are linear and quadratic coefficients, respectively, *b* is a regression coefficient, *k* is the factor optimized in the experimental design, and *e* is random error. The suitable value of the equation was expressed by the coefficient of determination R^2 and its statistical significance was determined by the F-test. The coefficients of the equation were determined by employing Design Expert software. It was done ANOVA for the final predictive equation by the design expert software. The equation was optimized for maximum yield in the range of the variables by using the software.

3. Results and Discussion

3.1. RSM analysis

RSM was used to decide the optimum levels of drying conditions. Face centered design for three independent variables was used. The independent variables selected for the optimization were the influence of drying conditions (kiwi ring load, drying time and kiwi ring thickness) and come out optimal drying conditions for the water loss (WL), shrinkage ratio (SR) and *a* color change (CC). The response was selected Y_{WL}, Y_{SR} and Y_{CC}. A five level central composite rotatable design (CCRD) design was used with kiwi ring thickness (2-6 mm), B sucrose concentrations (0- 40 %w/v), C immersed time (60-150 min) and D solar drying time (60-480 min), were chosen independent variables as drying conditions. The five levels chosen were -α, -1, 0, 1 and α as shown in *Table 1*.

Table 1. Codes and actual levels of the input variables for design of experiment

		Codes levels				
Inpendent Variables	**Symbols**	**-2**	**-1**	**0**	**1**	**+2**
Kiwi ring thickness (mm)	A	2	3	4	5	6
Sucrose concentrations (%w/v)	B	0	10	20	30	40
Immersed time (min)	C	30	60	90	120	150
Solar drying time (min)	D	60	120	240	360	480

The correct spacing for the axial parameter (α) is chosen for the CCRD experiment design. It is α=2 for our experimental design (input variables, k=4). The input variables and their ranges were selected on the basis of the preliminary experiments avoiding that any experimental point get burn (Yıldız, 2017; Bilen et al. 2018). The experimental design consisted of a total of 30 experimental runs ($n=2^k+2k+m$, n=total experimental points, k=4 and central point, m=6) which included eight factorial points, six axial points, and six replicated central points as shown in *Table 2*. The results of experiments in the design expert are shown in *Table 2*.

Based on the experimental response, Y_{WL} produced by the water loss ranged from 0.009 to 0.819, Y_{SR} produced by shrinkage ratio ranged from 0.006 to 0.823 and Y_{CC} produced by color change the ranged from 0.006 to 0.389. Standard no 13 and no 21 had the maximum and minimum for the water loss and shrinkage ratio respectively. Standard no 15 and no 14 had the maximum and minimum for shrinkage ratio respectively. Standard no 2 and no 3 had the maximum and minimum for color change ratio respectively.

An F-value several times greater than the tabulated F-value shows that the model predicts the experimental results well and the estimated factors effects were real. The R^2 is one of the measures of degree of fit of a model. There is only a 0.01% chance that a Model F-Value this large could occur due to noise. ANOVA suggests the model to be significant at $P<0.0001$. All the variables have significant effects on the water loss, color change and shrinkage ratio. The suitable model is chosen among linear, 2FI, quadratic, cross-product, cubic. The suitable model is chosen quadratic for water loss. It is determined 2FI model for color change model and shrinkage ratio. The cubic model is not aliased. Adjusted R^2 (Adj R^2) and the Predicted R^2 (Pred R^2) focus on the model. A negative Pred R^2 implies that the overall mean is a better predictor of the response than the current model. Adeq precision measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 18.802, 11.216 and 12.723 indicates an adequate signal for water loss, color change and shrinkage ratio respectively. The Pred R^2 of 0.7510 is in reasonable agreement with the Adj R^2 of 0.9072 for water loss. A negative Pred R^2 implies that the overall mean is a better predictor of your response than the current model for *a* color change. The Pred R^2 of 0.4494 is not as close to the Adj R^2 of 0.7804 as one might normally expect for the shrinkage ratio *(Table 3*). This may indicate a large block effect or a possible problem with your model and/or data. Things to consider are model reduction, response tranformation, outliers, etc. This model can be used to navigate the design space. The quadratic model

showed for Y_{WL} and $Y_{SR,}$ and the 2FI model for $Y_{CC,}$ a good fit and effectively represented the relationship among the variables selected.

Table 2. Four-level CCRD and the experimental responses

Std No	A	B	C	D	Y_{WL}	Y_{SR}	Y_{CC}
1	-1	-1	-1	-1	0.412	0.063	0.201
2	1	-1	-1	-1	0.265	0.187	0.389
3	-1	1	-1	-1	0.209	0.105	0.006
4	1	1	-1	-1	0.246	0.035	0.102
5	-1	-1	1	-1	0.607	0.053	0.245
6	1	-1	1	-1	0.735	0.168	0.253
7	-1	1	1	-1	0.545	0.234	0.131
8	1	1	1	-1	0.635	0.070	0.149
9	-1	-1	-1	1	0.361	0.039	0.069
10	1	-1	-1	1	0.451	0.079	0.067
11	-1	1	-1	1	0.218	0.014	0.042
12	1	1	-1	1	0.249	0.071	0.083
13	-1	-1	1	1	0.819	0.244	0.266
14	1	-1	1	1	0.774	0.006	0.236
15	-1	1	1	1	0.711	0.823	0.212
16	1	1	1	1	0.679	0.113	0.170
17	-2	0	0	0	0.621	0.207	0.107
18	2	0	0	0	0.548	0.136	0.152
19	0	-2	0	0	0.637	0.009	0.197
20	0	2	0	0	0.469	0.201	0.100
21	0	0	-2	0	0.009	0.232	0.023
22	0	0	2	0	0.779	0.221	0.252
23	0	0	0	-2	0.515	0.096	0.112
24	0	0	0	2	0.475	0.128	0.121
25	0	0	0	0	0.556	0.137	0.169
26	0	0	0	0	0.584	0.136	0.179
27	0	0	0	0	0.548	0.138	0.168
28	0	0	0	0	0.586	0.138	0.165
29	0	0	0	0	0.584	0.142	0.174
30	0	0	0	0	0.584	0.146	0.175

Table 3. ANOVA values of the regression parameters for RSM

Response	Regression	df	R^2	Adj R^2	Pred R^2	F value	Pr > F
	Linear	4	0.891	0.873	0.837	50.853	< 0.0001
	2FI	6	0.902	0.850	0.723	0.363	0.894
	Quadratic	4	0.952	0.907	0.751	3.926	0.0225
	Cubic	8	0.988	0.950	0.168	2.607	0.112
	Residual	7					
WL	Total	30					
	Linear	4	0.236	0.114	-0.193	1.936	0.136
	2FI	6	0.737	0.599	-0.160	6.034	0.00114
	Quadratic	4	0.770	0.555	-0.326	0.530	0.716
	Cubic	8	0.983	0.928	-1.51	10.684	0.00267
	Residual	7					
CC	Total	30					
	Linear	4	0.566	0.496	0.324	8.144	0.000239
	2FI	6	0.856	0.780	0.449	6.388	0.000823
	Quadratic	4	0.868	0.744	0.237	0.324	0.858
	Cubic	8	0.966	0.859	-3.90	2.535	0.119
	Residual	7					
SR	Total	30					

Table 4. ANOVA for the model on responses

Source	Sum of Squares	df	F	P > F
Water Loss				
Model	1.0411	14	21.2587	< 0.0001
A	0.0000	1	0.0002	0.990
B	0.0671	1	19.1914	0.000537
C	0.8951	1	255.8972	< 0.0001
D	0.0116	1	3.3161	0.0886
A^2	0.0013	1	0.3580	0.559
B^2	0.0000	1	0.0121	0.914
C^2	0.0462	1	13.2102	0.00245
D^2	0.0068	1	1.9389	0.184
AB	0.0006	1	0.1787	0.678
AC	0.0010	1	0.2944	0.595
AD	0.0002	1	0.0699	0.795
BC	0.0026	1	0.7357	0.405
BD	0.0017	1	0.4811	0.499
CD	0.0061	1	1.7550	0.205
Residual	0.0525	15		
Lack of Fit	0.0455	10	3.2820	0.101
Pure Error	0.0069	5		
Cor Total	1.0935	29		
$R^2 = 0.952$				
Color Change				
Model	0.1661	10	11.3034	< 0.0001
A	0.0056	1	3.7808	0.0668
B	0.0437	1	29.7465	< 0.0001
C	0.0565	1	38.4452	< 0.0001
D	0.0040	1	2.7301	0.115
AB	0.0002	1	0.1125	0.741
AC	0.0086	1	5.8258	0.0261
AD	0.0073	1	4.9736	0.0380
BC	0.0015	1	1.0302	0.323
BD	0.0202	1	13.7581	0.00149
CD	0.0186	1	12.6307	0.00212
Residual	0.0279	19	11.3034	
Lack of Fit	0.0279	14	3.7808	
Pure Error	0.0000	5	29.7465	
Cor Total	0.1661	29	38.4452	
$R^2 = 0.737$				
Shrinkage Ratio				
Model	0.4534	10	5.3307	0.000882
A	0.0407	1	4.7868	0.0414
B	0.0426	1	5.0102	0.0374
C	0.0501	1	5.8889	0.0254
D	0.0120	1	1.4143	0.249
AB	0.0536	1	6.3072	0.0212
AC	0.0824	1	9.6861	0.00574
AD	0.0458	1	5.3887	0.0315
BC	0.0520	1	6.1086	0.0231
BD	0.0290	1	3.4123	0.0803
CD	0.0451	1	5.3040	0.0327
Residual	0.1616	19		
Lack of Fit	0.1616	14	1392706.5856	< 0.0001
Pure Error	0.0000	5	5.3307	
Cor Total	0.6150	29	4.7868	
$R^2 = 0.856$				

The P-values confirmed the significance of each of the coefficients, which are essential to recognize the pattern of the common interactions between the independent variables. Values of P less than 0.0001 indicate that the model terms are significant. The P-values used as a tool to check the significance of each of the coefficients in turn

indicate the pattern of interactions between the variables. A smaller value of P was more significant to the corresponding coefficient. ANOVA of the regression model for Y_{WL}-Y_{CC}-Y_{SR} response established that the model was significant due to a very low probability value (P model >F-0.001). ANOVA (F-test) for the model explained the response of the dependent variable. The regression coefficients, along with the corresponding P-values, for the model of production water loss, *a* color change and shrinkage ratio are described by ANOVA. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case B, C, C^2 are significant model terms for water loss. A, B, C, AB, AC, AD, BC and CD are significant model terms for *a* color change and B, C, AC, AD, BD, CD are significant model terms for shrinkage ratio (*Table 4*). Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms that not counting those required to support hierarchy, model reduction may improve the model.

ANOVA results of the models, indicating a good model performance with an R^2 value of 0.952 and an F value of 21.259 for water loss. The Model F-value of 21.26 implies the model is significant. R^2 value of 0.737 and F value of 11.303 for color change and with an R^2 value of 0.856 and an F value of 5.33 for shrinkage ratio. The model R^2 values of 0.952 (for water loss), 0.737 (for color change) and 0.856 (for shrinkage ratio) imply that the variations of 95% for water loss, and 74% for *a* color change and 86% for shrinkage ratio can be attributed to the independent variables. The corresponding second-order model and 2FI models in coded variables were assembled for each response (Eq. 5-7).

$$Y_{WL}=0.550-0.000159A-0.05289B+0.193124C+0.021984D+0.006756A^2-0.00124B^2-0.04105C^2-0.01572D^2+0.006251AB+0.008022AC-0.00391AD+0.012682BC-0.01026BD+0.019588CD \quad \text{(Eq. 5)}$$

$$Y_{cc}=0.1452-0.04119A-0.042138B+0.045683C+0.0223888D-0.0519AB-0.07176AC-0.05352AD+0.056985BC+0.04259BD+0.053099CD \quad \text{(Eq. 6)}$$

$$Y_{SR}=0.1566-0.0152A-0.0427B-0.0485C-0.0129D-0.0032AB-0.0231AC-0.0214AD+0.0097BC+0.0355BD+0.0341CD \quad \text{(Eq. 7)}$$

A statistically significant multiple regression relationship between A, B, C, D and the $Y_{WL,}$ Y_{CC}, Y_{SR} can be established. The optimum drying condition levels were obtained for the water loss, the color change and the shrinkage ratio values predicted by RSM optimization tool box. The optimum parameter levels were selected according to desirability from different solutions with a (desirability) value of 1, considering their cost. The optimum drying point was chosen for the corresponding experimental values were sucrose concentration 12.7 %w/v, ring slice thickness 4.06 mm, solar drying time 125 min and osmotic dehydration time 70.9 min, respectively.

4. Conclusions

In the solar dryer, the kiwi rings dry out in a shorter period of time due to the fact that it is more heat and less water loss than drying in the sunshine and drying in the shadows. The air humidity in solar drying is an important problem in the regions where the air humidity is high. The air humidity is less in the drying cabinet, and to solve the problem by using the solar dryer. In addition, the parameters of the drying process are optimized to make process designs and process efficient and solar dryers can be expanded by increasing their applicability in the industry. The present study aims to model the water loss, shrinkage ratio and color change as a function of the drying conditions and to find the optimum drying conditions that maximize the water loss, minimum shrinkage ratio and minimum *a* color change by using RSM. The method experimentally was optimized and modelled with 30 experiments number. RSM analysis results statistically are suitable for the experimental results. The quadratic model a good fit and effectively represented for water loss (R^2 = 0.952) and shrinkage ratio (R^2 = 0.856), and the 2FI model selected for *a* color change (R^2 = 0.737). Optimum results of solar tray dryer parameters were determined to be 12.7 %w/v for sucrose concentration, 4.06 mm for ring slice thickness, 125 min for solar drying time and 70.9 min for osmotic dehydration time for maximum water loss, minimum both shrinkage ratio and color change. It was significantly found that sucrose concentration and osmotic dehydration time had effect on the responses. This result showed that osmotic dehydration has a positive effect on the solar drying process.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Benchmarking of Irrigation Performance in Karataş and Karaçal Irrigation Associations*

Karataş ve Karaçal Sulama Birliklerinde Performansının Karşılaştırmalı Değerlendirilmesi

Ahmed Qadar ABDISAMAD[1], Mehmet ŞENER[2*]

Abstract

This study was carried out to evaluate the system performances of Karataş and Karaçal irrigation associations located in Burdur province. Karataş irrigation association was put into operation in 1982 and Karaçal irrigation association in 2015 with irrigation areas are 5476 and 4975 ha, respectively. The same public personnel were appointed to both irrigation associations as the Head of the Association in 2018, and as of 2019, both irrigation Associations were gathered under the management of Karataş irrigation association. In this study, the performances of Karataş irrigation, which has an old and predominantly open canal system, and Karaçal irrigation systems, which are relatively new and have a pressurized irrigation system, between the years 2015-2019 have been evaluated. In the performance evaluation, a set of indicators under two main headings as water use efficiency, and financial efficiency recommended by the International Technology and Research Program in Irrigation and Drainage (IPTRID) was used. According to the results of the research, when the water use efficiency is examined, especially Annual relative irrigation supply (0.53-0.73 for Karataş; 0.47-0.96 for Karaçal) and irrigation ratio (20-72% for Karataş; 36% for Karaçal) 55) values were not at the desired levels. In terms of Financial Efficiency, cost recovery ratio (119-401% for Karataş; 144-311 for Karaçal) and revenue collection performance (78-442% for Karataş; 10-130 for Karaçal) were found to be high. Although this is a new irrigation, Karaçal irrigation shows that relatively high maintenance costs are incurred. Total operating maintenance and management (MOM) cost per unit area is US$ 9.60-14.98/ha for Karataş and as 1.32-22.92 US$/ha for Karaçal. These values showed that, in general, both irrigations have sufficient financial strength.

Keywords: Water use efficiency, Economic efficiency, Irrigation system performance, Irrigation association, Performance indicators.

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*This study is summarized from the MSc. thesis.

Öz

Bu çalışma, Burdur ilinde yer alan, Karataş ve Karaçal Sulama Birliklerinin sistem performanslarını değerlendirmek amacıyla yapılmıştır. Araştırma alanlarından, Karataş Sulama birliği 1982 yılında, Karaçal sulama birliği ise 2015 yılında işletmeye açılmış ve sırasıyla sulama hizmet alanları 5476 ve 4975 ha'dır. Her iki sulama birliğine 2018 yılında DSI tarafından alınan karara istinaden aynı kamu personeli birlik başkanı olarak atanmıştır. Ayrıca, 2019 yılı itibariyle de her iki sulama, Karataş sulama birliği çatısı altında toplanmışlardır. Bu çalışma ile eski ve ağırlıklı olarak açık kanal sisteme sahip Karataş sulaması ile nispeten yeni ve kapalı sisteme sahip Karaçal sulama sistemlerinin karşılaştırmalı olarak 2015-2019 yılları arası performansları değerlendirilmeye çalışılmıştır. Performans değerlendirmesinde Sulama ve Drenajda Uluslararası Teknoloji ve Araştırma Programı (IPTRID) tarafından tavsiye edilen gösterge setleri kullanılmıştır. Bu amaçla, su kullanım etkinliği ve finansal etkinlik olmak üzere iki ana başlık halinde hazırlanan bir gösterge seti kullanılmıştır. Araştırma sonuçlarına göre, su kullanım etkinliği incelendiğinde özellikle sulama suyu temin oranı (Karataş için 0,53-0,73; Karaçal için 0,47-0,96) ve sulama oranı (Karataş için %20-72; Karaçal için %36-55) değerleri istenen seviyelerde olmadığı görülmüştür. Finansal Etkinlik açısından, masrafların karşılanma oranı (Karataş için %119-401; Karaçal için %144-311) ve Tahsilat oranları (Karataş için %78-442; Karaçal için 10-130) yüksek bulunmuştur. Bakım masrafların gelire oranı Karataş için %7-43; Karaçal için %17-48 bulunmuştur. Bu durum yeni bir sulama olmasına rağmen Karaçal sulamasında nispeten yüksek miktarda bakım masrafı yapıldığını göstermektedir. Birim alana düşen toplam işletme bakım yönetim masrafı Karataş için 9,60-14,98 US$/ha; Karaçal için 1,32-22,92 US$/ha olarak belirlenmiştir. Bu değerler, genel olarak her iki sulamanın finansal açıdan yeterli güce sahip olduklarını göstermiştir.

Anahtar Kelimeler: Su kullanım etkinliği, Ekonomik etkinlik, Sulama performans, Sulama birliği, Performans göstergesi.

1. Introduction

Water is a crucial resource for agricultural production. Water scarcity and overuse pose a severe and growing hazard to human life and development. Because water is a scarce resource in most parts of the world, irrigation is essential for improving yields and sustaining food production.

Poor performance in irrigation schemes; It can lead to losses in crop production and reduction in sustainable irrigation areas. The indicators of whether the expected benefit from irrigation investments aimed at transforming limited water resources into economic benefits by increasing crop production is achieved are the monitoring and evaluation parameters of the performance of irrigation schemes.

Performance assessment is an essential component of irrigation management. With performance evaluation, it is assessed whether the system's performance is satisfactory and whether there is chance for improvement. Irrigation management will determine which areas of performance need to be addressed at the conclusion of the performance evaluation. Monitoring and evaluation are two essential elements of how performance evaluations are carried out. Monitoring determines whether project operations were accomplished on time, within the set budget, and according to project specifications. Assessment, on the other hand, is done on projects that have already been completed and is used to determine whether or not the project activities were accomplished satisfactorily. Performance is measured using performance indicators derived from obtained and recorded data. Indicator analysis provides information on performance levels. Performance evaluations frequently result in recommendations for redefinition of objectives, re-identification of operation objectives, personnel training, rehabilitation measures, new infrastructure construction, maintenance work, new management plans, alternative irrigation methods, and system rehabilitation (Burton, 2010). Malano and Burton, (2001) defined comparative evaluation as periodic assessments of irrigation scheme activities using internal and external indicators. In this sense, the major goal of monitoring and assessment activities is to improve irrigation scheme performance.

According to the 2016 data of Suruç Plain, Akçakale, Şanlıurfa-Harran, Yaylak and Upper Harran irrigation networks, which are SHW XVth Region irrigation networks; water use in agriculture was evaluated with water use efficiency indicators. As a result of the research, Annual relative water supply (RWS); 0.46-1.79 and irrigation ratio (IR) values; It was calculated to be between 58 and 116% (Çolak and Çakmak, 2018). Şener (2011) examined the water use performances of 10 existing irrigation systems in SHW XIth regional directorate. The research stated that the values of RWS 0.45-6.28 and Annual Relative irrigation supply (RIS) varied between 0.0-7.07. Akçay (2016), evaluated 25 irrigation cooperatives in Aydın province between 2006 and 2014 in terms of water use efficiency and RWS was determined between 0.89-1.58, and RIS was between 0.64-1.20. Tekiner and Çakmak (2010) found Total cost per person employed on water delivery (CTp) in Çanakkale-Kepez Cooperative to be 1,100-16,680 TL/person for the years 2002-2008. According to the 2016 data of Suruç Plain, Akçakale, Şanlıurfa-Harran, Yaylak and Upper Harran irrigation schemes, which are SHW XVth Region irrigation schemes; water use in agriculture was evaluated with water use efficiency indicators. At the end of the research, RWS were calculated as 0.46-1.79 and IR as 58-116% (Çolak and Çakmak, 2018). Şener and Kurç (2012), stated that cost recovery ratio (CRR), revenue collection performance (RCP), and maintenance cost to revenue ratio (MCR) were determined as 20-205%, 16-100% and 10-223%, respectively in 22 small irrigation schemes in Thrace region.

In this study; Irrigation performances of Karataş and Karaçal irrigations, which were put into operation in Burdur in 1982, and 2015, for the years 2015-2019 were investigated. Performance evaluation of irrigations was carried out using a selected set of performance indicators for water distribution, and financial performance was evaluated by the indicators recommended by the International Technology and Research Program in Irrigation and Drainage (IPTRID).

2. Materials and Methods

2.1. Material

As the research area, Karataş and Karaçal irrigation systems in Burdur province were chosen as material. Karataş and Karaçal irrigation systems selected as the research area are located in the Burdur Lakes Basin, 51 km from Burdur to the west (*Figure 1*).

The basin is geographically between 290 38' and 300 37' east longitudes and 370 08' and 370 42' north latitudes (SHW, 2009). The climate of the research area is in the transition zone between the Mediterranean climate and the continental climate (SHW, 2019). The average temperature of the research area is 11.8 °C, the average precipitation is

310.7 mm, the month with the lowest precipitation is July with 2.6 mm, and the month with the highest precipitation is January with 78.6 mm. Average relative humidity is 49%; the lowest average value is 40% in July and the highest average value is 78% in January (SHW, 2019).

The soil type in the research area is generally alluvial soil, and most of it has a clayey and calcareous composition, the irrigation area soils are generally soils with high natural fertility. Plain soils, most of which have medium and medium-heavy texture, and heavy textured character is observed towards the west (SHW, 2019).

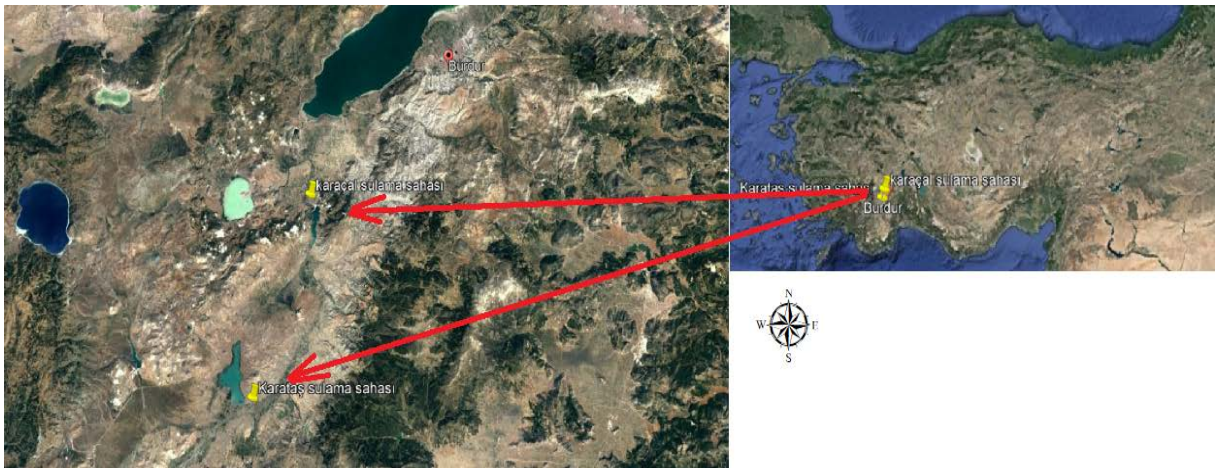

Figure 1. Location of the study

2.2. Method

In this study, the approach recommended by the International Technology and Research Program in Irrigation and Drainage (IPTRID) for the comparative evaluation of the performance of irrigation and drainage systems was used (Malano and Burton, 2001). Performance evaluation of irrigations was carried out using a selected set of performance indicators for water distribution, financial and agricultural production recommended by the IPTRID.

The performance indicators were calculated using information from the Karataş and Karaçal irrigation associations (Anonymous, 2015-2019a; Anonymous, 2015-2019b) and SHW (SHW, 2015-2019a; SHW, 2015-2019b). The US Dollar (USD) was used as the currency to compare the outcomes.

2.2.1. Water use efficiency

In the determination of water use efficiency in Karataş and Karaçal irrigation system a set of 6 indicators was used namely; Total annual volume of irrigation supply (IWS), Annual irrigation water delivery per unit command area area (IWSCA), Annual irrigation water supply per unit irrigated area (IWSIA), annual relative water supply (RWS), annual relative irrigation water supply (RIS) and irrigation ratio (IR). Formulas for indicators used to determine water use efficiency are given in equations 1, 2, 3, 4 and 5 (Malano and Burton, 2001).

Annual irrigation water supply per unit command area (IWSCA) ($m^3\,ha^{-1}$),

$$\text{IWSCA} = \frac{\text{Total annual volume of irrigation supply (IWS)}}{\text{command area}} \quad \text{(Eq.1)}$$

Annual irrigation water supply per unit irrigated area (IWSIA) ($m^3\,ha^{-1}$),

$$\text{IWSIA} = \frac{\text{Total annual volume of irrigation supply (IWS)}}{\text{irrigated area}} \quad \text{(Eq.2)}$$

Annual relative water supply (RWS),

$$\text{RWS} = \frac{\text{Total annual volume of water supply}}{\text{Total annual volume of crop water demand}} \quad \text{(Eq.3)}$$

Annual relative irrigation water supply (RIS),

$$\text{RIS} = \frac{\text{Total annual volume of irrigation supply}}{\text{Total annual volume of crop irrigation demand}} \quad \text{(Eq.4)}$$

Irrigation ratio (IR), (%)

$$IR = \frac{\text{irrigated area}}{\text{irrigable area}} \quad \text{(Eq.5)}$$

In equations; irrigated area (ha) refers to the portion of the area actually irrigated during one irrigation season. Amount of irrigation water delivery to the irrigation network (m^3) represents water delivery for irrigation, total plant water consumption (m^3), potential plant water consumption (ET_p) or actual evapotranspiration (ET_c) when the full crop water demand is met.

Evapotranspiration and irrigation requirement were calculated with the help of the CROPWAT software, taking into account the Burdur meteorological station records for each year. The reference evapotranspiration (ET_0) was calculated according to the Penman-Monteith method, and then the evapotranspiration was calculated with the help of the crop coefficients (FAO, 1992). The effective precipitation values (P_e) were determined according to the US Soil Conservation Service method and the irrigation water requirements of the crops were determined. RWS and RIS values show whether there is sufficient supply to meet the need. Values of 1 or higher RWS and RIS indicate adequate irrigation, while values less than 1 indicate insufficient irrigation supply (Şener, 2004).

2.2.2. Financial Efficiency

In determining the financial efficiency of irrigation systems 7 indicators were examined including; cost recovery ratio (CRR), maintenance costs to revenue ratio (MCR), Total MOM cost per unit area (MOMPUA), Total cost per person employed on water delivery (TCPWD), Revenue collection performance (RCP), Staffing numbers per unit area (SNPUA) and Total MOM cost per unit volume supplied (MOMPUWS) (Malano and Burton, 2001). The equations for the indicators used in the study are given in 6, 7, 8, 9, 10, 11 and 12.

Cost recovery ratio, (CRR), (%),

$$\text{Cost recovery ratio} = \frac{\text{Gross revenue collected}}{\text{Total MOM cost}} \quad \text{(Eq.6)}$$

Cost recovery ratio represents the ratio of the expenses incurred for the operation, maintenance and management of the irrigation system with the water service fee paid by the water users. Cost recovery ratio indicates when less than or equal to 30% is poor, 40-60% acceptable, 60-75% satisfactory condition, and more than 75% good condition (Vermillion, 2000).

Maintenance cost to revenue ratio, (%), (MCR),

$$MCR = \frac{\text{Maintenance cost}}{\text{Gross revenue collected}} \quad \text{(Eq.7)}$$

Total MOM cost per unit area (US$ ha^{-1}), (MOMPUA),

$$\text{MOMPUA (US\$ ha}^{-1}) = \frac{\text{Total MOM cost}}{\text{Total irrigated area serviced by the system}} \quad \text{(Eq. 8)}$$

Total cost per person employed on water delivery (TCPWD),

$$\text{TCPWD (US\$ personel}^{-1}) = \frac{\text{Total cost of personnel engaged in I\&D service}}{\text{Total number of personnel engaged in I\&D service}} \quad \text{(Eq. 9)}$$

Revenue collection performance (RCP),

$$RCP\ (\%) = \frac{Gross\ revenue\ collected}{\text{Gross revenue invoiced}} \quad \text{(Eq. 10)}$$

Revenue collection performance of less than 30% is poor, 40-60% is acceptable, 60-75 percent is satisfactory, and more than 75 percent is excellent (Vermillion, 2000)

Staffing numbers per unit area (SNPUA)

$$\text{SNPUA (personnel 1000 ha}^{-1}) = \frac{\text{Total number of personnel engaged in I\&D service} * 1000}{\text{Total annual irrigated area serviced by the system}} \quad \text{(Eq. 11)}$$

The number of personnel per 1000 hectares irrigated is referred to as staffing numbers per unit area. If the number of staffing numbers per unit area is greater than 3 persons per 1000 ha, it is considered weak; if the number is less than 3 persons per 1000 ha, it is considered good (Vermillion, 2000).

Total MOM cost per unit volume supplied (MOMPUWS)

$$\text{MOMPUWS (US\$ } m^{-3}) = \frac{\text{Total MOM cost}}{\text{Total annual volume of irrigation water delivery}} \quad \text{(Eq. 12)}$$

3. Results and Discussion

3.1. Water use efficiency

In this section, water use efficiency was calculated using 6 performance indicators. *Table 1* and *Table 2* shows Total annual volume of irrigation supply (IWS), Annual irrigation water supply per unit command area (IWSCA), Annual irrigation water supply per unit irrigated area (IWSIA) in Karataş and Karaçal irrigation systems.

Table 1. IWS, IWDCA and IWDIA in Karataş irrigation association

Years	Irrigated area (ha)	Command area (ha)	(IWS) (m^3)	(IWSCA) (m^3 ha^{-1})	(IWSIA) (m^3 ha^{-1})
2015	2343.0	5476	11223000	2049	4790
2016	3926.3	5476	23250000	4246	5922
2017	2326.4	5476	9687000	1769	4163
2018	1084.8	5476	3490000	637	3217
2019	3705	10.451	11520000	1102	3109

Table 2. IWS, IWSCA and IWSIA in Karaçal irrigation association

Years	Irrigated area(ha)	Command area (ha)	(IWD) (m^3)	(IWDCA) (m^3ha^{-1})	(IWDIA) (m^3ha^{-1})
2015	2723.0	4975	9624000	1934	3534
2016	2733.2	4975	21277000	4276	7778
2017	2323.4	4975	17140000	3445	7377
2018	1868	4975	6730000	1353	3603

As seen in *Tables 1* and *2* IWSCA was found to be the lowest 637 m^3 ha^{-1} in 2018 and the highest 4246 m^3 ha^{-1} in 2016 in Karataş irrigation system. In Karaçal irrigation system it is seen that IWSCA varies between 1353-4276 m^3 ha^{-1}. In Karataş irrigation association IWSIA calculated lowest 3217 m^3 ha^{-1} in 2018 and the highest is 5922 m^3 ha^{-1} in 2016 while in Karaçal irrigation association the lowest is 3534 m^3 ha^{-1} in 2015 and the highest is 7778 m^3ha^{-1} in 2016. IWSCA and IWSIA were 1102 and 3109 in 2019, respectively, after Karaçal irrigation association joined Karataş irrigation association. Eliçabuk and Topak (2017) determined IWSCA as 665–1301 m^3 ha^{-1} and IWSIA as 2577–5273 m^3 ha^{-1} in Gevrekli Irrigation Association. Total amount of diverted irrigation water was $6.054x10^6$-$10.747x10^6$ m^3 $year^{-1}$ IWSCA 7.23-10.54 m^3 ha^{-1} and IWSIA 7.68-16.15 m^3 ha^{-1} in Akıncılar irrigation system (Nalbantoğlu and Çakmak, 2007). The other indicators used in evaluation water use performance are RWS RIS and IR and were calculated and the result are shown *Table 3* and *Table 4*.

The result of RWS and RIS shown in *Table 3* and *4* were calculated as 0.79-0.95; and 0.47-0.96 at Karataş and Karaçal respectively it is seen that inadequate water distribution is supplied in both irrigation systems. However, it should not be forgotten that values of 0.9-1.1 are considered to be equivalent to each other in the evaluation. Also, the results of RIS shows that inadequate irrigation water is supplied both the irrigation systems. Vermillion and Vermillion and Garces-Resrepo (1996) determined RWS in Coello and Saldana to be 1.4 and 1.8 respectively in 1993. Uçar and Yardımcı (2003) determined Irrigation ratio as 15-83% and RWS as 1.66-5.72 in the irrigations of SHW in Isparta province.

Table 3. RWS RIS and IR in Karataş irrigation association

Years	IWD + Effective rainfall (m^3)	Total Irrigation water requirement (m^3)	RWS	RIS	IR (%)
2015	20735580	22926688	0.90	0.61	43
2016	36985271	40092861	0.92	0.73	72
2017	16419602	21446196	0.77	0.56	42
2018	8244678	9046585	0.91	0.53	20
2019	23742135	22242595	1.07	0.39	35

Table 4. RWS RIS and IR in Karaçal irrigation association

Years	IWD + Effective rainfall (m^3)	Total Irrigation water requirement (m^3)	RWS	RIS	IR (%)
2015	20680192	26179046	0.79	0.50	55
2016	30823197	27734119	1.11	0.96	55
2017	23865920	24998915	0.95	0.80	47
2018	14915253	18356155	0.79	0.47	37

3.2 Financial efficiency

Cost recovery ratio of Karataş and Karaçal irrigation association research area is shown in *Table 5*.

Table 5. Cost recovery ratio (%)

Years	Karataş irrigation association			Karaçal irrigation association		
	Gross revenue collected (US$)	Total MOM cost (US$)	CRR (%)	Gross revenue collected (US$)	Total MOM cost (US$)	CRR (%)
2015	186473	79252	235	11672	6573	178
2016	223624	82034	272	182378	114044	160
2017	210819	52591	401	225621	72641	311
2018	92599	77848	119	77390	53766	144
2019	311214	117503	265			

Cost recovery ratio for Karataş and Karaçal irrigation associations was found as 119-401% and 144-311% respectively. The value was calculated as the ratio of total irrigation fee collected from the users to total operation-maintenance-management costs. The Asartepe Irrigation Association stated a cost recovery ratio of 52-170% for the years 2001-2004 whereas state irrigation schemes recorded a ratio of 21-91% and the country average was 65% (Beyribey, 1997). Maintenance cost to revenue ratio is given in *Table 6*.

Table 6. Maintenance cost to revenue ratio (MCR)

Years	Karataş irrigation association			Karaçal irrigation association		
	Maintenance cost (US$)	Gross revenue collected (US$)	MCR (%)	Maintenance cost (US$)	Gross revenue collected (US$)	MCR (%)
2015	55237	186473	30	1356	11671	12
2016	48100	223624	22	71308	182378	39
2017	15774	210819	7	39323	225621	17
2018	40259	92599	43	37067	77390	48
2019	156658	311214	50			

MCR was determined as the lowest at 7% in 2017 and the highest at 43% in 2018 for the Karataş irrigation. In Karaçal irrigation association the lowest was 12% in 2015 and the highest was 48% in 2018. MCR was determined as 50% for 2019 after the merger of Karataş and Karaçal irrigation associations. When *Table 6* is examined, it is seen that more maintenance was carried out in Karaçal irrigation association than in Karataş irrigation association in 2016 and 2017 excluding the year 2015 when irrigation was opened. Although it is a relatively new irrigation scheme it was determined that relatively high maintenance costs were incurred in Karaçal irrigation before the transfer. Total MOM per unit area is given in *Table 7*.

Table 7. Total MOM cost per unit area (MOMPUA) (US$/ha)

Years	Karataş irrigation association			Karaçal irrigation association		
	Total MOM cost (US$)	Irrigated area (ha)	MOMPUA (US$ ha^{-1})	Total MOM cost (US$)	Irrigated area-(ha)	MOMPA (US$ ha^{-1})
2015	79252	2343	33.83	6573	2723	2.41
2016	82034	3926	20.90	114044	2735	41.70
2017	52590	2326	22.61	72640	2323	31.27
2018	77848	1085	71.75	53765	1868	28.78
2019	117502	3705	31.71			

Lowest MOMPUA was 20.90 US$ ha^{-1} in 2016 and the highest MOMPUA was 71.75 US$ ha^{-1} in 2018 in Karataş irrigation system (*Table 7*). Lowest MOMPUA in Karaçal irrigation system was 2.41 US$ ha^{-1} in 2015 highest was 41.70 US$ ha^{-1} in 2016. Diker (2018) stated that MOMPUA were calculated between 6.73 and 321 US$ ha^{-1} for the years 2011 and 2015 in the Lower Seyhan Plain. The total cost per person employed in water delivery is given in *Table 8*.

Table 8. Total cost per person employed on water delivery (TCPWD)

Years	Karataş irrigation association			Karaçal irrigation association		
	Total cost of personnel engaged in I&D service (US$)	Total number of personnel engaged in I&D service	(TCPWD) (US$ person^{-1})	Total cost of personnel engaged in I&D service (US$)	Total number of personnel engaged in I&D service	(TCPWD) (US$ person^{-1})
2015	51073	7	7296	56841	8	7105
2016	55061	7	7866	21950	4	5488
2017	49174	7	7025	57872	7	8267
2018	29039	7	4148	28251	9	3139
2019	82700	15	5513			

As seen in *Table 8* the lowest cost for each person employed in water delivery was 4148 US$ person^{-1}in 2018 and the highest cost was 7866 US$ person^{-1} in 2016 for Karataş irrigation. The lowest cost for Karaçal irrigation was 3139 US$ person^{-1} in 2018; the highest cost was 8267 US$ person^{-1} in 2017. After the Karataş and Karaçal irrigation were combined the total cost per person employed in water distribution was 5513 US$ person^{-1}. When TCPWD values are examined, it is seen that much more expenses were incurred in Karaçal irrigation system which is a pressurized system.

Table 9. Revenue collection performance (RCP)

Years	Karataş irrigation association			Karaçal irrigation association		
	Gross revenue collected (US$)	Gross revenue invoiced (US$)	RCP (%)	Gross revenue collected (US$)	Gross revenue invoiced (US$)	RCP (%)
2015	186473	153674	121	11671	112174	10
2016	223624	268676	83	182378	265733	69
2017	210819	271358	78	225621	240173	94
2018	92599	20944	442	77390	59621	130
2019	311214	340528	91			

Revenue collection performance (RCP) of Karataş and Karaçal irrigation systems is given in *Table 9*. Revenue collection performance for Karataş irrigation association was determined as 442% in 2018 and the lowest as 78% in 2016. It is seen that the highest is 130% in 2018 and the lowest is 10% in 2015 in Karaçal irrigation association. On the other hand, after the merger the collection rate was 91%.

RCP were calculated for the Ilgın plain pumped irrigation in the Konya region is between 83.5% and 147% (Kalender, 2017). It has been reported as 75% for the Çumra Plain irrigation association (Cihan, 2017). Vermillion and Garces-Restrepo (1996) reported that RCP in Coello and Saldana irrigation in 1993 was 102% and 109%. Regarding the research area staffing numbers per unit area is given in *Table 10*.

Accordingly, it is seen that SNPUA for Karataş irrigation association between 2015-2018 varies between 3.06-10.14 personnel 1000ha^{-1}. In Karaçal irrigation association it is seen that SNPUA varies between 1.83-5.35 personnel 1000 ha^{-1}. This indicator was realized as 6.48 personnel 1000ha^{-1} after merging of irrigation associations. According to Vermillion (2000) it was determined that staffing numbers per unit area in both irrigation areas was weak. Total MOM cost per unit volume supplied in Karataş and Karaçal irrigation areas are given in *Table 11*.

When *Table 11* is analyzed the highest total MOM cost per unit volume supplied in Karataş irrigation is 0.022 US$/m^3 in 2018 and the lowest cost is 0.004 US$/m^3 in 2016. In Karaçal irrigation association the highest total MOM cost per unit volume supplied was 0.008 US$/m^3 in 2018 and the lowest was 0.001 US$/m^3 in 2015.

Table 10. Staffing numbers per unit area (personnel 1000ha^{-1}) (SNPUA)

Years	Karataş irrigation association			Karaçal irrigation association		
	Total number of personnel engaged in I&D service	Total annual irrigated area serviced by the system	(SNPUA)	Total number of personnel engaged in I&D service	Total annual irrigated area serviced by the system	(SNPUA)
2015	13	2.343	5,55	11	2.723	4,04
2016	12	3.926	3,06	5	2.735	1,83
2017	12	2.326	5,16	8	2.323	3,44
2018	11	1.085	10,14	10	1.868	5,35
2019	24	3.705	6,48			

Table 11. Total MOM cost per unit volume supplied (MOMPUVS)

Years	Karataş irrigation association			Karaçal irrigation association		
	Total MOM cost (US$)	Total annual volume of irrigation water delivery (m3)	(MOMPUVS) (US$ m^{-3})	Total MOM cost (US$)	Total annual volume of irrigation water delivery (m^3)	(MOMPUVS) (US$ m^{-3})
2015	79252	11223000	0.007	6573	9624000	0.001
2016	82034	23255000	0.004	114044	21277000	0.005
2017	52590	9687000	0.005	72640	17142000	0.004
2018	77848	3490000	0.022	53765	6730000	0.008
2019	117502	11520000	0.010			

4. Conclusions

In this study the water use efficiency and financial efficiency performance of Karataş and Karaçal irrigation system were assessed using comparative indicators.

In Karaçal irrigation area it is seen that low irrigation ratio is realized despite the newly established completely pressurized system. The main reason inadequate irrigation in the Karaçal irrigation area is the Karaçal dam's inability to store enough water due to the low precipitation regime. When the water use efficiency is examined a very low level of insufficient distribution was observed in the water supply in the Karaçal System.

It is seen that sufficient irrigation water distribution could not be realized to meet the irrigation water requirement in Karaçal irrigation association. This situation is also stated in the planned water distribution reports of the irrigation areas. In periods when the water supply is insufficient the plants that grow under rainfed agricultural conditions in the irrigation area should be supported in the cultivation of vegetables fruits and industrial plants with high economic value in the areas where irrigation is planned.

When the financial efficiency is examined, it is seen that the water fee collection rate in the Karaçal irrigation area is higher than the Turkey average. Due to this situation, it has been determined that there is no problem in meeting MOM costs in both systems. In order to create a stronger sustainable financial structure in the irrigation association it is necessary to increase the collection rate of irrigation water fees higher.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Çukurova Koşullarında Yetiştirilen Tatlı Sorgum Genotiplerinin Selülozik Biyoetanol Veriminin Belirlenmesi

Determination of Cellulosic Bioethanol Yield of Sweet Sorghum Genotypes Grown Under Cukurova Conditions

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Öz

Tatlı sorgum bitkisi ve özsuyu alındıktan sonra geriye kalan posası birinci nesil biyoetanol, hayvan yemi, gübre, biyoyakıt ve selülozik biyoetanol üretimi gibi çeşitli amaçlar için değerlendirilmektedir ve geniş kullanım alanlarından dolayı gün geçtikçe önem kazanmaktadır. Bu çalışmada, farklı tatlı sorgum genotiplerinin özsuyu alındıktan sonra geriye kalan saplarında (posasında) teorik selülozik biyoetanol potansiyelinin belirlenmesi amaçlanmıştır. Bu amaçla yurt içi ve yurt dışındaki değişik kaynaklardan temin edilen 21 farklı tatlı sorgum (*Sorghum bicolor* var. *saccharatum* (L.) Mohlenbr.) genotipi materyal olarak kullanılmıştır. Tarla denemeleri, Çukurova (Adana) ikinci ürün koşullarında 2016 ve 2017 yıllarında yürütülmüştür. Bitkilerin hasadı, salkımdaki tanelerin süt-hamur olum dönemine denk gelen tarihlerde yapılmıştır. Hasat edilen bitkilerin yaprakları ve salkımları ayrıldıktan sonra saplar ekstrakte edilip özsuyu alınmıştır. Özsuyu alınan saplar (posalar) kurutulduktan sonra selüloz ve hemiselüloz analizleri yapılmış ve teorik selülozik biyoetanol verimleri kuru madde bazında L ton^{-1} ve L da^{-1} cinsinden hesaplanmıştır. Çalışma sonucunda iki yıllık ortalamalara göre; tatlı sorgum genotiplerinin selüloz içeriğinin %33.21-45.13, hemiselüloz içeriğinin %20.63-25.36, teorik selülozik biyoetanol veriminin ise 183.7-231.0 L ton^{-1} kuru madde (KM) ve 297.4-767.6 L da^{-1} (KM) arasında değiştiği saptanmıştır. Araştırmada özsuyu alındıktan sonra kalan posanın selülozik biyoetanol üretimi amacıyla kullanılabileceği ve Grass1, Tracy, UNL-Hyb-3 ve No91 genotiplerinin birim alanda 600 L da^{-1} üzerinde selülozik biyoetanol üretme kapasitesi ile öne çıkan genotipler oldukları görülmektedir. Tatlı sorgum bitkisinin özsuyundan biyoetanol elde edilmesi ve ayrıca geriye kalan küspesinden de selülozik biyoetanol üretilmesi ile yüksek biyokütle potansiyeline sahip bitkinin tamamından yararlanılarak daha fazla biyoetanol elde edilebileceği ve böylece yenilenebilir enerji kaynağı olarak sürdürülebilirlik, çevre ve ekonomi gibi çeşitli açılardan avantajlar sağlanabileceği sonucuna ulaşılmaktadır.

Anahtar Kelimeler: Tatlı sorgum, Genotip, Posa, Selülozik biyoetanol, Verim

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Abstract

Sweet sorghum and its bagasse of sweet sorghum plant which is left after extracting of its juice is used for various purposes such as first generation bioethanol, animal feed, fertilizer, biofuel and cellulosic bioethanol production and it has gained significance because of its broad use areas day by day. In this study, it was aimed to determine the theoretical cellulosic bioethanol potential of the remaining stalks (bagasse) of different sweet sorghum genotypes after extraction of its juice. For this reason, 21 different sweet sorghum (*Sorghum bicolor* var. *saccharatum* (L.) Mohlenbr.) genotypes obtained from different domestic and foreign sources were used as material. Field trials were carried out under second crop conditions in Cukurova (Adana) region in 2016 and 2017. The plants were harvested on dates that coincided with the milk-dough period of the grains in the cluster. After the leaves and inflorescences of the harvested plants were removed, the stalks were extracted and the juice was taken. Theoretical cellulosic bioethanol yields were calculated on the basis of dry matter (DM) in L ton^{-1} and L da^{-1} by performing cellulose and hemicellulose analyzes after the stalks (bagasse) was dried. As a result of the study, according to the two-year averages; it was determined that the cellulose content and hemicellulose content of sweet sorghum genotypes and theoretical cellulosic bioethanol yield ranged from 33.21% to 45.13%, from 20.63 to 25.36%, from 183.7 to 231.0 L ton^{-1} dry matter (DM) and from 297.4 to 767.6 L da^{-1} (DM), respectively. In the research, it is seen that the remaining bagasse after the removal of juice can be used for cellulosic bioethanol production and Grass1, Tracy, UNL-Hyb-3 and No91 genotypes are prominent genotypes having the capacity to produce cellulosic bioethanol over 600 L da^{-1} per unit area. It is concluded that if bioethanol is obtained from the juice of sweet sorghum plant and also cellulosic bioethanol is produced from its bagasse remaining after extraction of its juice more bioethanol can be supplied from the unit area by using the whole plant having a high biomass potential and thus it can be provided advantages in terms of different aspects such as sustainability, environment and economy as a renewable energy source.

Keywords: Sweet sorghum, Genotype, Bagasse, Cellulosic bioethanol, Yield

1. Giriş

Tüm dünyada olduğu gibi ülkemizde de enerjinin büyük bir bölümü petrol ve petrol türevlilerden sağlanmaktadır. Dünya nüfusunun artması ile birlikte enerji ihtiyacının da artması, fosil yakıt kullanımı da buna paralel olarak artmaktadır. Günümüzde fosil yakıtların yakılması, dünya çapında önemli CO_2 konsantrasyonlarında artışa yol açarken, iklimdeki aşırı değişikliklerle birlikte küresel ısınma ve hava durumunu olumsuz etkilediği bilinmektedir (Chauhan ve ark., 2021). Fosil yakıtların kullanımını azaltmak için çevreye daha az zararlı olan yenilenebilir enerji kaynaklarının kullanımının artırılması önemli olmaktadır. Alternatif enerji kaynakları arasında da yenilenebilir ve sürdürülebilir enerji kaynakları dikkati çekmektedir.

Yenilenebilir enerji kaynaklarının başında ise birim alanda yüksek biyokütle potansiyeline sahip tarımsal ürünler ve bu tarımsal ürünlerden etanol (biyoetanol) eldesi önem kazanmaktadır. İkinci nesil biyoetanol, daha çok biyokütle kaynaklarından elde edilmektedir. Biyokütle kaynaklarının, gıda amaçlı olarak üretimi yapılan ürünlerle rekabet etmemesi veya üretimlerini sınırlandırmaması için marjinal alanlarda üretimin yapılması da önemli bir avantaj olarak görülmektedir (Bazaluk ve ark., 2021). İkinci nesil selülozik etanol, özellikle tarım ve orman atıklarının hammadde olarak kullanıldığı ülkeler için uygun olduğu bildirilmektedir (Rivera-Burgos ve ark., 2019). Ülkemizde potansiyel ve çeşitliliği fazla olan yeterince değerlendirilemeyen biyoyakıt kaynakları; pelet haline getirilerek ülke ekonomisine katkı sağlayabilir (Develi ve ark., 2021).

Dünya genelinde kullanılmakta olan enerji kaynaklarının birçoğunu fosil enerji kaynakları oluşturmaktadır (Aybek ve ark., 2015). Etanol, hava kirliliğini azaltmak ya da petrol ürünlerinin tüketimini azaltmak amacıyla benzinle değişik oranlarda karıştırılarak kullanılabilen bir yakıttır. En yaygın uygulamalar, E10 ya da E85 diye bilinen sırasıyla %10 ve %85 etanol içeren karışımlardır (Yaşar, 2009). Tatlı sorgumdan fermente edilebilir özsu ayrıldıktan sonra geriye posa kalmakta ve bu lignoselülozik artık, önemli miktarda polimerik karbonhidratlar (selüloz ve hemiselüloz) içermektedir. Bu polisakkaritler, şekerlere hidrolize edilebilmekte ve daha sonra ikinci nesil biyoetanole fermente edilebilmektedir. Etanol kullanımı %35'e ulaşan yüksek oksijen içeriği nedeniyle yandığında çok temiz olması, atmosferde karbondioksit birikimine katkıda bulunmaması sebebiyle çevreyle dost ve yenilebilir olması gibi çeşitli avantajlara sahiptir (Arif ve ark., 2019). Alternatif enerji kaynağı olarak tatlı sorgumun, sürdürülebilir tarımsal faaliyetler açısından yenilenebilir enerji kaynakları grubunda yer alması, verimli, düşük maliyetli, uygun ve güvenli olması, ayrıca yaklaşık %37 oksijen içermesi nedenleriyle çok iyi bir biyoetanol hammadde kaynağıdır (Wyman ve ark., 1993; Raud ve ark., 2015). İkinci nesil etanol, birinci nesile göre sera gazı emisyonlarının azaltılması için çok daha yüksek bir potansiyele sahiptir (Batog ve ark., 2020).

Lignoselülozik biyokütle, dünyada en yaygın olarak bilinen biyokütledir. Bu nedenle lignoselülozik biyoetanol üretimi, son yıllarda halen sıklıkla kullanılan nişasta biyoetanolüne bir alternatiftir. Lignoselüloz, bitkilerde bulunan selüloz, hemiselüloz, lignin ve diğer ektraktlar veya mineralden oluşmaktadır. Sorgum posası %11.73-48.0 selüloz ve %10.73-26.14 hemiselüloz içermektedir (Yu ve ark., 2014; Khalil ve ark., 2015; Mahdy ve ark., 2018). Tatlı sorgum posası birçok çevreci teknoloji uygulamalarında kullanılabilmekte ve selülozik etanol üretimi de dahil öne çıkan biyoenerji teknolojilerinde kullanım için uygun olabilmektedir (Mahapatra ve ark., 2017).

Tatlı sorgum (*Sorghum bicolor* var. *saccharatum* (L.) Mohlenbr.), Poaceae familyasına bağlı bir C4 bitkisi olması nedeniyle, yüksek fotosentetik etkinliği olan, kurak ve olumsuz iklim koşullarında tarımı yapılabilen, nispeten düşük girdi gereksinmeleri olan önemli bir buğdaygil enerji bitkisidir (Steduto ve ark., 1997; Dolciotti ve ark., 1998; Mastrorilli ve ark., 1999; Ritter ve ark., 2007; Shinde ve ark., 2013). Tatlı sorgum uygun koşullarda 4-5 ay gibi yetiştirme süresinde 4.5 m' ye kadar boylanmakta, tatlı sorgumdan 4.5-11 ton da^{-1} yaş biyokütle verimi alınmakta (Dweikat, 2014) ve birim alanda yüksek biyokütle üretimi için yeterli miktarda selülozik etanol kaynağı olmasını sağlamaktadır (Han ve ark., 2013). Tatlı sorgum, ağır metal toleransına ve özellikle kadmiyumu (Cd) uzaklaştırma özelliğine sahiptir. Bu nedenle, tatlı sorgum, Cd ile kirlenmiş toprak için sürdürülebilir bir fitoremediasyon sistemi oluşturmak, iyileştirme ve eş zamanlı etanol üretimi için büyük bir potansiyele sahiptir (Xiao ve ark., 2021).

Ülkemizde tatlı sorgum biyokütlesinden ikinci nesil enerji üretimi ile ilgili çalışmalar yok denecek kadar az olup, bu konu ile ilgili yeterli bilgiye ulaşılamadığı görülmektedir. Bu çalışma; endüstride biyoetanol elde etmek için Çukurova bölgesi ikinci ürün koşullarında yetiştirilen farklı tatlı sorgum genotiplerinin özsuyu alındıktan sonra geriye kalan saplarının (posasının) teorik selülozik biyoetanol verimlerini belirlemek ve farklı genotiplerin kimyasal bileşimi ve biyoetanol verimlerindeki farklılıklar da ortaya koymak için yürütülmüştür.

2. Materyal ve Metot

2.1. Materyal

Çalışmada, çeşitli kaynaklardan temin edilen 21 adet farklı tatlı sorgum **(***Sorghum bicolor* var. *saccharatum* (L.) Mohlenbr.) genotipi materyal olarak kullanılmıştır. Temin edildiği kaynaklara göre materyallerin adları ve temin edildiği kuruluşlar, aşağıdaki gibi gruplandırılmıştır.

1) Cowley, Dale, Grass1, M81-E, Mennonita, Nebraska sugarcane, PI579753, Ramada, Roma, Rox Orange, Smith, Sugar Drip, Theis, Topper 76, Tracy, UNL-Hybrid -3 (26297xM81 E), Williams (Prof. Dr. İsmail Dweikat, Nebraska Üniversitesi, Lincoln, ABD)

2) No2 USDA orijin Çin, No91 USDA orijin Tayvan, No5 USDA orijin Güney Afrika (BATAEM, Batı Akdeniz Tarımsal Araştırma Enstitüsü, Antalya)

3) Yerel çeşit Gülşeker (Uludağ Üniversitesi, Ziraat Fak. Tarla Bitkileri Bölümü, Bursa)

2.2. Metot

Tarla denemeleri ikinci ürün şartlarında, tesadüf blokları deneme desenine göre dört tekerrürlü olarak 2016 ve 2017 yıllarında Haziran-Ekim döneminde, Çukurova/Adana koşullarında (Doğu Akdeniz Tarımsal Araştırma Enstitüsü Müdürlüğü Araştırma alanında) yürütülmüştür. Laboratuvar çalışmaları ise Karadeniz Tarımsal Araştırma Enstitüsü bünyesindeki Enerji Tarımı Araştırma Merkezi Laboratuvarı' nda gerçekleştirilmiştir.

Bitkilerin hasadı, her genotip için salkımdaki tanelerin süt-hamur olum dönemine denk gelen tarihlerde yapılmıştır. Hasat edilen tatlı sorgum genotiplerinin yaprak ve sapları alındıktan sonra kalan sapları, özel tasarlanmış aletten geçirilerek özsuyu (şırası) alınmıştır. Özsuyu alınmış saplar (posa) önce tartılmış ve daha sonra kurutulmuştur *(Şekil 1).*

Figure 1. The process of bagasse production from sweet sorghum biomass

Şekil 1. Tatlı sorgum biyokütlesinden posa elde edilmesi süreci

Tatlı sorgum genotiplerin posalarının selüloz ve hemiselüloz içeriklerini belirlemek için NDF (Nötral Deterjanda Çözünmeyen Lif), ADF (Asit Deterjanda Çözünmeyen Lif) ve ADL (Asit Deterjanda Çözünmeyen Lignin) analizleri yapılmıştır. Bu analizler için her bir genotipi temsil edecek şekilde 500 g yaş ot örneği alınmıştır ve kurutma dolabında 65-70ºC' de ağırlıkları sabitleşince selülozik hammadde analizleri için öğütülmüştür. Öğütülen örneklerden de 0.5 gram tartılarak NDF, ADF ve ADL analizleri ANKOM Fiber Analyzer Cihazı' nda gerçekleştirilmiştir (Van Soest ve ark., 1991; Kutlu, 2008). Analizler sonucunda ise aşağıdaki eşitliklerden yararlanılarak % selüloz ve hemiselüloz içerikleri hesaplanmıştır.

$$\%\, Selüloz = \%\, ADF - \%\, ADL \qquad \text{(Eş.1)}$$

$$\%\ Hemiselüloz\ =\ \%\ NDF\ -\ \%\ ADF \quad \text{(Eş.2)}$$

Teorik selülozik biyoetanol verimleri ise; hemiselüloz ve selüloz değerlerinin teorik olarak şekere dönüşümünden yola çıkarak litre/ton KM posa cinsinden hesaplanmıştır (Badger, 2002). Tatlı sorgum genotiplerinin dekara kuru madde verimleri hesaba katılarak ayrıca litre cinsinden dekara teorik selülozik biyoetanol verimleri de hesaplanmıştır. Hesaplamada; hemiselüloz dönüşüm verimi (%90), xylose fermentasyon verimi (%50), etanol stokiyometrik oranı (%51), selüloz dönüşüm verimi (%76) ve glukoz fermentasyon verimi (%75) dönüşüm katsayıları kullanılmıştır.

İncelenen tüm özellikler 4 tekrarlı olarak gerçekleştirilmiş ve sonuçlar, ortalama olarak verilmiştir. İstatistiksel analizde ise, elde edilen veriler JMP istatistik paket programı kullanılarak varyans analizine tabi tutulmuş ve ortalamalar, çoklu karşılaştırma Tukey testine göre yapılmıştır.

3. Araştırma Sonuçları ve Tartışma

3.1. Selüloz ve Hemiselüloz İçerikleri

Yapılan varyans analizi sonuçlarına göre selüloz içeriği bakımından incelendiğinde, genotiplerde ve genotip x yıl interaksiyonunda P≤0.01 seviyesinde istatistikî olarak önemli farklılık bulunmuştur (*Tablo 1*). Genotiplere göre değişmekle birlikte tatlı sorgum genotiplerinin posalarından elde edilen selüloz içeriğinin, 2016 ve 2017 yıllarında sırasıyla %32.19-41.48 ve %29.18-48.41 arasında değiştiği saptanmıştır. İki yıllık birleştirilmiş analizlere göre, selüloz içeriği %29.18-48.41 arasında değişmiş olup en yüksek selüloz içeriği, araştırmanın ikinci yılında Gülşeker genotipinde, en düşük selüloz içeriği ise yine çalışmanın ikinci yılında PI579753 genotipinde elde edilmiştir. Genotip ortalamasının %33.21-45.13 arasında değiştiği ve en düşük değerin Mennonita çeşidinde elde edildiği ve bunu sırasıyla Cowley ve PI579753 genotiplerinin izlediği belirlenmiştir.

Hemiselüloz içeriği incelendiğinde ise, genotipler arasında ve genotip x yıl interaksiyonunda P≤0.01 seviyesinde istatistikî olarak önemli farklılık bulunmuştur (*Tablo 1*). Tatlı sorgum genotiplerinin posalarındaki hemiselüloz içeriği 2016 ve 2017 yıllarında sırasıyla %22.15-27.95 ve %16.58-24.30 arasında saptanmıştır. İki yıllık birleştirilmiş analizlere göre hemiselüloz içeriğinin %16.58-27.95 arasında değiştiği ve en yüksek değer 2016 yılında Grass1 genotipinde, en düşük değer ise 2017 yılında Cowley genotipinde belirlenmiştir. Genotip ortalaması %20.63-25.36 arasında değişirken en düşük hemiselüloz içeriği Cowley genotipinde elde edilmiştir. Cowley genotipini sırasıyla Thesis ve Topper 76 çeşitleri izlemiştir. Selüloz ve hemiselüloz içeriklerinin genotiplere, çevre koşullarına göre değiştiği birçok araştırıcı tarafından da bildirilmektedir (Dolciotti ve ark., 1998; Su ve ark., 2010; Mahdy ve ark., 2018; Chauhan ve ark., 2021).

Çalışmada, selüloz içeriği yüksek olan genotiplerin hemiselüloz içeriklerinin de yüksek olduğu ve selüloz içeriği yüksek olan genotiplerin selülozik etanol verimliliğinin de yüksek olduğu görülmektedir. Selüloz içeriği ile hemiselüloz arasında olumlu ve önemli ilişkilerin olduğu görülmektedir. Han ve ark. (2013) deterjan lif, lignin ve sindirilebilirlik ölçümlerinin, etanol üretimi ile yüksek oranda ilişkili olduğunu bildirmektedir. Tatlı sorgum posasından farklı genotip ve ekolojilerde değişik analiz yöntemleri ile yapılan çalışmalarda, selüloz ve hemiselüloz içerikleri ile ilgi yapılan çalışmalar aşağıda özetlenmiştir. Marx ve ark. (2014), mikrodalga ışınlama kullanarak yaptığı çalışmada; selüloz ve hemiselüloz içeriklerini sırasıyla %36.60 ve %22.96 olarak saptamışlardır. Umagiliyage ve ark. (2015), tatlı sorgum posasının enzimatik hidrolizini geliştirme üzerine yaptıkları çalışmada; selüloz ve hemiselüloz içeriklerini sırasıyla %36.9±1.6 ve %17.8±0.6 olarak bulmuşlardır. Zhang ve ark. (2011), tatlı sorgum posasının enzimatik hidrolizi üzerine farklı ön muamelelerin etkisini inceledikleri çalışmada; tatlı sorgum posasının selüloz ve hemiselüloz içeriklerini sırasıyla %45.3 ve %26.3 olarak belirlemişlerdir. Guimaraes ve ark. (2014), NIRS cihazında 957 posa örneğinin selüloz ve hemiselüloz içeriklerinin sırasıyla %21.4-49.1 ve %18.4-34.8 arasında değiştiğini saptamışlardır.

Mahdy ve ark. (2018), Giza/Mısır'da tatlı sorgum posasının selüloz içeriğinin %19.48-24.11, hemiselüloz içeriğinin %10.73-14.39 arasında değiştiğini bildirmişlerdir. Khalil ve ark. (2015), hemiselüloz içeriğinin %11.73-17.20 ve selüloz içeriğinin %20.18-26.14 arasında değiştiğini saptamışlardır. Barcelos ve ark. (2016), selüloz ve hemiselüloz içeriklerini sırasıyla %40.4±2.6 ve %20.0±2.5 olarak belirlemişlerdir. Batog ve ark. (2020), Polonya'da ana ve ikinci ürün koşullarında çeşitlere göre değişmekle; selüloz içeriğinin %21-41.2 ve hemiselüloz içeriğinin %21.9-35.6 arasında değiştiğini, ana ürün ortalamalarının genelde ikinci ürün ortalamalarına göre daha yüksek olduğunu bildirmişlerdir.

Tablo 1. Tatlı sorgum genotiplerinden elde edilen posalarının kuru madde bazında selüloz ve hemiselüloz içerik ortamaları ve önemlilik grupları

Table 1. Avarage values and significance groups of cellulose and hemicellulose contents on dry basis of bagasses obtained from sweet sorghum genotypes

Genotipler	Selüloz İçeriği (%)			Hemiselüloz İçeriği (%)		
	2016	2017	Ortalama	2016	2017	Ortalama
Cowley	37.72 ef[+]	29.43 ı	33.57 hı*	24.68 b-f[+]	**16.58 k**	**20.63 ı***
Dale	37.69 ef	47.93 a	42.81 b	26.35 ab	22.72 abc	24.53 abc
Grass1	40.06 b	44.36 b	42.21 b	**27.95 a**	22.77 abc	**25.36 a**
M81-E	38.60 cde	37.77 f	38.18 d	23.57 c-h	20.58 e-h	22.07 e-h
Mennonita	35.17 h	31.25 h	**33.21 ı**	23.04 e-h	20.17 ghı	21.60 ghı
N. sugarcane	**32.19 ı**	39.64 de	35.91 f	25.27 bcd	**24.30 a**	24.79 ab
PI579753	39.14 bcd	**29.18 ı**	34.16 h	24.44 b-g	18.13 jk	21.29 ghı
Ramada	35.4 h1	34.66 g	35.04 g	22.92 e-h	19.33 hıj	21.12 hı
Roma	35.85 gh	37.73 f	36.79 e	**22.15 h**	20.70 d-h	21.42 ghı
Rox Orange	38.07 def	42.09 c	40.08 c	23.41 d-h	24.29 a	23.85 bcd
Smith	35.65 gh	44.24 b	39.94 c	22.99 e-h	23.71 ab	23.35 cde
Sugar Drip	34.69 h	39.52 e	37.10 e	25.50 bc	18.66 ıj	22.08 e-h
Theis	39.18 bcd	34.40 g	36.79 e	23.02 e-h	18.83 ıj	20.93 hı
Topper 76	36.82 fg	40.75 d	38.79 d	22.66 fgh	19.58 hıj	21.12 hı
Tracy	35.36 h	45.02 b	40.19 c	22.54 gh	22.40 bcd	22.47 efg
UNL-Hyb-3	37.98 def	39.33 e	38.65 d	22.89 e-h	20.02 ghı	21.45 ghı
Williams	35.70 gh	42.33 c	39.01 d	22.48 gh	21.48 c-g	21.98 fgh
No2	35.41 h	37.64 f	36.52 ef	22.62 fgh	21.40 c-g	22.01 fgh
No91	39.52 bc	37.45 f	38.48 d	24.33 b-g	22.16 b-e	23.24 c-f
No5	38.66 cde	38.16 f	38.41 d	24.86 b-e	20.35 f-ı	22.61 d-g
Gülşeker	**41.84 a**	**48.41 a**	**45.13 a**	22.41 gh	22.07 b-f	22.24 e-h
Ortalama	**37.18**	**39.11**		**23.81**	**20.96**	
DK (%)		1.22			3.25	
F (Genotip)		**			**	
F (Yıl)		Önemli Değil			Önemli Değil	
F (Genotip x Yıl İnteraksiyonu)		**			**	

+) Aynı harf ile gösterilen çeşit x yıl interaksiyonu ortalamaları arasında Tukey testine göre P≤0.05 seviyesinde istatistiksel olarak önemli farklılık yoktur.
*) Aynı sütun içerisinde benzer harf ile gösterilen çeşit ortalamaları arasında Tukey testine göre P≤0.05 seviyesinde istatistiksel olarak önemli farklılık yoktur.
**) P≤0.01 seviyesinde istatistiksel olarak önemlidir.

Han ve ark. (2013), sorgum bitkisinin sap ve posalarında hemiselüloz içeriğinin %23.90-27.80, selüloz içeriğinin %30.5-34.4 ve lignin içeriğinin %3.3-6.00 arasında değiştiği bildirmişlerdir. Su ve ark. (2010), sorgum posasının kuru madde bazında %17-18 selüloz ve %18-21 hemiselüloz arasında değiştiğini belirlemiştir. Sorgum saplarının hemiselüloz içeriğinin %34-37 ve selüloz içeriğinin 39.2-41.5 arasında değiştiğini bildirilmiştir (Chauhan ve ark., 2021).

Cotton ve ark. (2013), yemlik sorgum çeşidinin selüloz içeriğinin %27.7-35.3 arasında ve hemiselüloz içeriğinin ise %21.2-23.8 arasında değiştiğini bildirmişlerdir. Sorgum gibi buğdaygil bitkilerinden elde edilen biyokütlesinin genel olarak ortalama bileşimleri %25-40 selüloz ve %25-50 hemiselüloz olduğunu, selüloz ve lignoselülozik bakımından zengin olduğu belirlenen biyokütlenin, etanol üretimi için iyi bir substrat olarak kullanılabileceği bildirilmektedir (Sun ve Cheng, 2002; Howard ve ark., 2003; Wongwatanapaiboon ve ark., 2012; Saini ve ark., 2015).

3.2. Teorik Selülozik Biyoetanol Verimleri

Varyans analizi sonuçlarına göre teorik selülozik biyoetanol verimi (L/ton KM) bakımından incelendiğinde; genotipler ve genotip x yıl interaksiyonu bakımında P≤0.01 seviyesinde istatistikî olarak önemli farklılık bulunduğu ancak yıllara göre P≤0.01 seviyesinde istatistikî olarak önemli farklılık bulunmadığı görülmektedir (*Tablo 2*). Tatlı sorgum genotiplerinin posalarından elde edilebilecek teorik selülozik biyoetanol veriminin 2016

yılında 192.1-228.9 L ton^{-1} KM arasında, 2017 yılında ise 156.7-242.7 L ton^{-1} KM arasında değiştiği saptanmıştır. İki yıllık birleştirilmiş analiz sonucunda, teorik selülozik biyoetanol verimi 156.7-242.7 L ton^{-1} KM arasında değişmiş olup en yüksek biyoetanol verimi 2017 yılında Dale çeşidinde, en düşük verim ise yine araştırmanın ikinci yılında Cowley çeşidinde elde edilmiştir. Genotip ortalamasının 183.7-231.0 L ton^{-1} KM arasında değiştiği görülmektedir (*Tablo 2*).

Tablo 2. Tatlı sorgum genotiplerinden elde edilen posalarının kuru madde bazında teorik selülozik biyoetanol verim ortalamaları ve önemlilik grupları

Table 2. Avarage values and significance groups of theoretical cellulosic bioethanol yield on dry basis of bagasses obtained from sweet sorghum genotypes

Genotipler	Teorik Selülozik Biyoetanol Verimi (L ton^{-1} KM)			Teorik Selülozik Biyoetanol Verimi (L da^{-1} KM)		
	2016	**2017**	**Ortalama**	**2016**	**2017**	**Ortalama**
Cowley	210.8 cd^{+}	**156.7 ı**	**183.7 j***	352.7 e-h^{+}	300.2 ef	326.5 g*
Dale	215.5 bc	**242.7 a**	229.1 a	362.2 e-h	395.7 c-f	379.0 efg
Grass1	**228.9 a**	229.7 bc	229.3 a	621.0 b	603.7 abc	612.3 b
M81-E	210.8 cd	199.0 f	204.9 ef	567.5 bc	457.4 b-f	512.5 b-e
Mennonita	196.6 fgh	173.8 h	185.2 j	385.9 d-h	307.9 ef	346.9 fg
N. sugarcane	**192.1 h**	216.7 d	204.4 ef	**325.5 gh**	453.5 b-f	389.5 efg
PI579753	215.3 bc	160.3 ı	187.8 ıj	435.9 c-h	**251.1 f**	343.5 fg
Ramada	197.1 fgh	183.9 g	190.5 ı	451.4 c-g	570.6 a-d	511.0 b-e
Roma	196.5 fgh	199.2 f	197.9 gh	514.2 b-e	593.6 abc	553.9 bc
Rox Orange	208.4 d	225.7 c	217.0 b	364.0 e-h	444.2 b-f	404.1 d-g
Smith	198.2 fgh	232.0 b	215.1 b	299.9 gh	650.1 ab	475.0 b-f
Sugar Drip	202.0 ef	199.9 f	200.9 fg	304.5 gh	330.4 def	317.5 g
Theis	211.3 cd	181.5 g	196.4 h	556.9 bc	524.8 a-e	540.9 bcd
Topper 76	201.6 efg	207.1 e	204.3 ef	500.8 b-f	596.2 abc	548.5 bcd
Tracy	195.8 gh	231.0 bc	213.4 bc	341.8 fgh	404.8 b-f	373.3 efg
UNL-Hyb-3	206.5 de	203.1 ef	204.8 ef	**793.7 a**	**741.5 a**	**767.6 a**
Williams	196.9 fgh	218.4 d	207.7 de	270.9 h	323.9 def	**297.4 g**
No2	196.3 fgh	200.9 f	198.6 gh	338.2 fgh	262.1 f	300.2 g
No91	216.4 bc	202.4 ef	209.4 cd	637.6 ab	592.0 abc	614.8 b
No5	214.8 bc	199.8 f	207.3 de	533.0 bcd	338.0 def	435.5 c-g
Gülşeker	219.4 b	242.5 a	**231.0 a**	286.6 gh	375.8 c-f	331.2 fg
Ortalama	**206.2**	**205.1**		**440.2**	**453.2**	
DK (%)		1.09			18.02	
F (Genotip)		**			**	
F (Yıl)		Önemli Değil			Önemli Değil	
F (Genotip x Yıl İnteraksiyonu)		**			**	

+) Aynı harf ile gösterilen çeşit x yıl interaksiyonu ortalamaları arasında Tukey testine göre P≤0.05 seviyesinde istatistiksel olarak önemli farklılık yoktur.
*) Aynı sütun içerisinde benzer harf ile gösterilen çeşit ortalamaları arasında Tukey testine göre P≤0.05 seviyesinde istatistiksel olarak önemli farklılık yoktur.
**) P≤0.01 seviyesinde istatistiksel olarak önemlidir.

Ayrıca, tatlı sorgum genotiplerinin dekara kuru madde verimleri hesaba katılarak, litre cinsinden dekara teorik selülozik biyoetanol verimleri de hesaplanmıştır. Teorik selülozik biyoetanol verimi (L da^{-1} KM) bakımından incelendiğinde ise genotipler ve genotip x yıl interaksiyonu P≤0.01 seviyesinde istatistikî olarak önemli bulunurken, yıllara göre P≤0.01 seviyesinde istatistikî olarak önemli farklılık bulunmamıştır (*Tablo 2*). Tatlı sorgum genotiplerinin posasından elde edilebilecek teorik selülozik biyoetanol verimi, 2016 ve 2017 yılları için sırasıyla 325.5-793.7 L da^{-1} KM ve 251.1-741.5 L da^{-1} KM arasında değişmiştir. Dekara teorik selülozik biyoetanol verimi 2017 yılında daha yüksek bulunmuştur. İki yıllık birleştirilmiş analizlere göre, teorik selülozik biyoetanol verimi 251.1-793.7 L da^{-1} KM arasında değişmiştir ve en yüksek teorik selülozik biyoetanol verimi ise araştırmanın ikinci yılında PI579753 genotipinde elde edilmiştir. Genotip ortalaması 297.4-767.6 L da^{-1} KM arasında değişirken en düşük değer Williams genotipinde elde edilmiş ve bunu sırasıyla No2 genotipi ve Sugar Drip çeşidi takip etmiştir.

Zhao ve ark. (2009), tatlı sorgumda selülozik etanol verimini 2006 yılında 198.5-448.9 L da^{-1} arasında; 2007 yılında ise 179.6-659.1 L da^{-1} arasında değiştiğini bildirmişlerdir. Guimaraes ve ark. (2014), tatlı sorgum bitkisinin saplarındaki özsuyu alındıktan sonra geriye kalan posa örneklerinde teorik selülozik etanol veriminin 221-412 L ton^{-1} KM arasında değiştiğini belirlemişlerdir. Barcelos ve ark. (2016), tatlı sorgum posasından teorik selülozik etanol verimini 430 L ton^{-1} KM olarak saptamışlardır.

Batog ve ark. (2020), Polanya'da sorgum çeşitlerinin biyoetanol verimini 223-506 mg L^{-1} KM sap arasında değiştiğini bildirmektedirler. Rakhmetova ve ark. (2020), bitki özsuyundan alınan şıradan 404.1 L da^{-1} ve 639 L da^{-1} arasında etanonol elde edileceğini ve ek olarak da posanın kullanımı ile toplam biyoetanol veriminin 1.142,3 L da^{-1} ulaşabildiğini bildirmektedirler. Mahdy ve ark. (2018), etanol üretimi için yüksek selüloz ve düşük lignin içeriğine sahip çeşitlerin tercih edilmesi gerektiği bildirilmiştir. Tang ve ark. (2018), ortamın bitki büyümesi, biyokütle verimi ve bileşenleri ve ardından enerji sorgumun etanol potansiyelini önemli ölçüde ($p<0.05$) etkilediğini bildirmektedirler.

Maw ve ark. (2017), Midwest Amerika'da New Franklin lokasyonunda tatlı sorgum posalarının yıllara göre selülozik etanol verimi, 399.7-1011.9 L da^{-1} KM arasında, Mount Vernon lokasyonunda ise verimin 202.6.-844.3 L da^{-1} arasında değiştiğini saptamışlardır. Cotton ve ark. (2013), teorik etanol verimi, sınırlı su uygulaması altında yetiştirilen bitkilerde 264-338 L da^{-1} olarak belirlenirken su uygulaması yapılmadan yetiştirilen bitkilerde ise 160-252 L da^{-1} olarak tespit etmişlerdir.

4. Sonuç

Fosil yakıtların enerji kaynağı olarak kullanımı, enerji açısından ülkemizin dışa bağımlı olması, bu kaynakların kullanımı sonucunda küresel ısınma, iklim değişikliği gibi olumsuz çevresel etkileri alternatif ve yenilenebilir enerji kaynaklarına yöneltmiştir. Tarımsal kaynaklı alternatif biyoetanol kaynakları yenilenebilir, sürdürülebilir, çevre ile dost özellikleri sebebiyle büyük önem taşımaktadırlar. Bu çalışmada; diğer bitkilere kıyasla su ve gübre ihtiyacı daha az olan ve de birim alandan daha yüksek biyokütleye sahip tatlı sorgum bitkisinin biyoetanol kaynağı olarak değerlendirilebilme potansiyeli incelenmiştir. Çukurova lokasyonunda 2016 ve 2017 yıllarında genotiplerin iki yıllık ortalamalarına göre, özsuyu (şırası) alındıktan sonra geriye kalan tatlı sorgum posasından elde edilen selüloz içeriğinin %33.21-45.13, hemiselüloz içeriğinin %20.63-25.36, teorik selülozik biyoetanol veriminin 183.7-231.0 L ton^{-1} KM ve 297.4-767.6 L da^{-1} arasında değiştiği saptanmıştır. UNL-Hyb-3 genotipinin, çalışmada incelenen tüm genotipler arasında hem 2016 (793.7 L da^{-1}) ve 2017 (741.5 L da^{-1}) yıllarında ve hem de iki yıllık birleştirilmiş analiz sonucunda (767.6 L da^{-1}) birim alanda en yüksek biyoetanol verimine sahip olduğu saptanmıştır. Teorik selülozik biyoetanol verimlerinin iki yıllık ortalamalarına göre UNL-Hyb-3 genotipini sırasıyla 614.8 L da^{-1} ile No91 ve 612.3 L da^{-1} ile Grass1 genotipleri takip etmiştir. Yapılan tüm analizler göz önüne alındığında tatlı sorgum bitkisinin biyoetanol kaynağı olarak değerlendirilebileceği anlaşılmıştır. Enerji ihtiyacının büyük bir oranının ithalat ile karşılandığı ülkemizde, sürdürülebilir ve yenilenebilir enerjinin sağlanması için alternatif kaynaklardan biri olan biyoetanol, önemli ve büyük bir potansiyel oluşturmaktadır. Biyoetanol, ayrıca çevre kirliliğini azaltması ve ekonomiye katkı sağlamasından dolayı da önem taşımaktadır. Ülkemizde biyoetanol üretimi ve biyoetanol üretiminde diğer bitkilere kıyasla toprak seçiciliği, su ve gübre kullanımı daha az olan tatlı sorgum bitkisinin hammadde olarak kullanımı teşvik edilmelidir.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Geleneksel ve Analize Dayalı Kimyevi Gübre Uygulamasının Mısır Verimi ve Yaprakta Bitki Besin Elementleri İçeriğine Etkisi

The Effect of Traditional and Analysis-Based Chemical Fertilizer Application on Corn Yield and the Content of Plant Nutrient Elements in the Leaf

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Öz

Bu araştırma; 2016 yılında Muğla Dalaman Tarım İşletmesi Müdürlüğü (TİGEM) 72MAY80 tanelik ve silajlık mısır çeşidinde, deneme sahasında tesadüf blokları deneme desenine göre üç tekrarlamalı olarak yürütülmüştür. 950 kg da^{-1} mısır verimi için gerekli olan bitki besin elementleri miktarından toprak analiziyle belirlenen elementler çıkarıldıktan sonra uygulanacak gübre miktarı belirlenmiştir (41,5 kg da^{-1} üre). 950 kg da^{-1} mısır verimi için gerekli olan gübre uygulamasının %40 azaltılması (24,95 kg da $^{-1}$ üre) ve %40 arttırılması (58.1 kg da $^{-1}$ üre) ile üretici uygulaması (60 kg da $^{-1}$ üre, 32,3 kg da $^{-1}$, 15-15-15 ve 14 kg da $^{-1}$ KNO_3) olmak üzere dört farklı oranda gübre uygulamasının mısır bitkisinin verimine ve yapraktaki azot (N), fosfor (P), potasyum (K), kalsiyum (Ca), magnezyum (Mg), kükürt (S), demir (Fe), bakır (Cu), çinko (Zn), mangan (Mn), bor (B) ve molibden (Mo) elementleri içeriğine etkisini belirlemek amacıyla yapılmıştır. Toprağa tabandan uygulanan üre, 15-15-15, gübreleri ekim mibzeri ile birlikte banda verilmiştir. Deneme parsellerinde üst gübre olarak kullanılan üre ve KNO_3 gübresi damlama sulama sistemiyle üç farklı zamanda uygulanmıştır. Araştırma sonuçlarına göre toprağa 950 kg da^{-1} mısır verimine göre gübre uygulaması, gübre uygulamasının %40 azaltılması ve %40 arttırılması ile üretici uygulamasının mısır verimi ve yapraktaki azot (N), fosfor (P), potasyum (K), kalsiyum (Ca), magnezyum (Mg), kükürt (S), demir (Fe), bakır (Cu), çinko (Zn), mangan (Mn), bor (B) ve molibden (Mo) elementleri konsantrasyonuna etkisi istatistiki olarak önemli bulunmuştur ($p<0.01$). Mısır bitkisinde en yüksek verim üretici uygulamasında (1.367,0 kg da^{-1}) elde edilirken, bu uygulamayı sırayla gübre miktarının 40 arttırılması (1357,0 kg da^{-1}), 950 kg da^{-1} mısır verimine göre gübre uygulaması (1.225,3 kg da^{-1}), en düşük verim ise gübre miktarının %40 azaltılması uygulamasında (991,0 kg da^{-1}) elde edilmiştir. Ayrıca deneme parsellerine 2016 yılı gübre fiyatlarına göre uygulanan toplam gübre maliyeti (TL) belirlenmiş ve belirlenen bu miktar 2016 yılı mısırın kg fiyatına bölünerek elde edilen mısır miktarı verimden çıkarılarak gübre maliyeti hariç net verim elde edilmiştir.

Anahtar Kelimeler: Mısırda gübreleme, Verim, Gübre maliyeti, Bitki besin elementi, Yaprak analizi

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Abstract

This study is conducted in Muğla Dalaman Agricultural Management Directorate (TİGEM) in 72MAY80 grain and silage maize in the trial area according to purely random trial the randomized complete block design in 3 replications in 2016. The amount of fertilizer is obtained by substracting elements determined by soil analysis from the amount of plant nutrients required for corn yield in $^{-1}$ in 950 kg. ($^{-1}$ in 41.5 kg urea). The aim of this research is to determine whether fertilizer application at 4 different rates including the reduction of fertilizer application required for corn yield $^{-1}$ in 950 kg. by 40% ($^{-1}$ in 24.95 kg urea) and increasing it by 40% ($^{-1}$ in 58.1 kg urea) and manufacturer application ($^{-1}$ in 60 kg urea, $^{-1}$ in 32,3 kg, 15-15-15 and $^{-1}$ in 14 kg. KNO_3) has an effect on the yield of corn plant and the element content of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), copper (Cu), zinc (Zn), manganese (Mn), boron (B) and molybdenum (Mo) in the leaf. The urea applied to the soil from the base, 15-15-15, fertilizers are given to the band with the sowing seeder. The urea fertilizer used as a top fertilizer in trial plots and KNO3 fertilizer has been applied with drip irrigation system at 3 different times. According to the research results, the effect of applying fertilizer to the soil according to $^{-1}$ in 950 kg. corn yield, 40% reductions and 40% increases in fertilizer application, and manufacturer application on the yield of corn and the concentration rate of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), copper (Cu), zinc (Zn), manganese (Mn), boron (B) and molybdenum (Mo) elements in the leaf is found to be statistically significant ($p<0.01$). The highest yield in corn plant is achieved in the application of manufacturer ($^{-1}$ in 1.367,0 kg) and the application of increasing the amount of fertilizer by 40% ($^{-1}$ in 1357.0 kg), fertilizer application according to $^{-1}$ in 950 kg corn yield ($^{-1}$ in 1225.3 kg), respectively, whereas, the lowest yield is achieved in the application of reducing the amount of fertilizer by 40% ($^{-1}$ in 991.0 kg). Moreover, the total amount of fertilizer used in trial plots is calculated according to the fertilizer costs in 2016 and the price spent on fertilizer is determined in Turkish Liras (TL) and this price is divided by the 2016 corn kg price and subtracting the amount of corn obtained from the yield, and net yield is obtained excluding the fertilizer cost.

Keywords: Fertilization in corn, Yield, Fertilizer cost, Plant nutrient, Leaf analysis

1. Giriş

Gençkan (1983)'a göre mısır bitkisinin anavatanı Orta Amerika'da Meksika-Guatemala olup, binlerce yıldır bölgenin ana ürünü olarak yetiştirilmektedir. Tropik bir bitki olmasına rağmen üzerinde yapılan yoğun ıslah çalışmaları ile Dünya üzerinde Ekvator'dan Baltık Denizi'ne kadar (60° kuzey enlemi ile 42° güney enlemi arasında denizden 4000 m yüksekliğe kadar) geniş bir alana yayılmıştır (Çakmakçı ve Dallar, 2019).

Subhan (1987), mısıra 0, 10, 15, 20, 25, 30 ve 35 kg da^{-1} dozlarında azot uyguladığı çalışmada, azot uygulamayan kontrol parselinde 462 kg da^{-1} kuru madde verimi alırken, 30 kg da^{-1} azot uygulandığı parselde 631 kg da^{-1} en yüksek kuru madde verimi elde etmiştir.

Aydeniz ve Brohi (1991), mısır gibi gelişme hızı yüksek ve fazla miktarda organik madde üreten bitkilere toprak koşullarına bağlı olarak, 2-8 kg da^{-1} arasında fosfor uygulanabileceği, Lourence (1984) mısır bitkisinde en yüksek verimin 8 kg da^{-1} fosfor uygulamasıyla elde edileceğini, Özdemir (1983), olsen fosfor analiz metoduna göre toprakta 1, 2, 3, 4, 6 kg da^{-1} fosfor olması durumunda 23, 19, 16, 13 ve 7 kg da^{-1} fosforlu gübrenin uygulanması gerektiğini bildirmektedir.

Farklı beş azot dozu (0, 5, 10, 15 ve 20 kg da^{-1} N) ve 4 farklı fosfor dozunun (0, 4, 8 ve 12 kg da^{-1} P_2O_5) melez mısır çeşidinin (TTM-815) silaj verimi ve kalitesi üzerine etkilerini belirlemek amacıyla yürütülen araştırmada, azot ve fosfor dozlarının yeşil ot verimi, kuru ot verimi, bitki boyu, bitki koçan oranı, ham protein oranı ve ham protein verimi üzerine etkileri önemli bulunmuştur. Denemenin ilk yılında en yüksek yeşil ot verimi 20 kg da^{-1} azot ve 8 kg da^{-1} fosfor uygulamasında (6.552,4 kg da^{-1}), en yüksek kuru ot verimi 15 kg da^{-1} azot ve 12 kg da^{-1} fosfor (1.547,1 kg da^{-1}) uygulamasında elde edilmiştir. Denemenin ikinci yılında ise en yüksek yeşil ot verimi 20 kg da^{-1} azot ve 8 ve 12 kg da^{-1} fosfor (6.767,1 kg da^{-1}) uygulamasında, en yüksek kuru ot verimi ise 20 kg da^{-1} azot ve 8 ve 12 kg da^{-1} fosfor (1.039,0 kg da^{-1}) uygulamasından elde edilmiştir (Çelebi ve ark., 2010).

Melez atdişi mısır çeşidinin yetiştirildiği toprağa 18 kg da^{-1} N ve 9 kg da^{-1} P_2O_5 uygulanacak şekilde 15 farklı taban gübresi çeşidinin mısırda tane verimi, verim unsurları ve kalite üzerine etkilerini belirlemek amacıyla yürütülen araştırmada en yüksek tane verimi 1.328 kg da^{-1} 20.20.0 gübre çeşidinde ve 1.324 kg da^{-1} ile 10.20.20+6S+Zn gübre çeşidinden elde edilmiştir (Elmalı ve Soylu, 2008).

Yirmi kg saf azot (N), 10 kg saf fosfor (P2O5) uygulandığı farklı özelliklere sahip 6 mısır çeşidinde (PR31D24, Kalipso, 70MAY82, Suerto, P1921, DKC6724) kalite, verim ve verim unsurlarının belirlenmesi amacıyla yürütülen çalışmada, tane verimi istatistiki açıdan önemli bulunmamış ve 70MAY82 mısır çeşidinde 1.348,81 kg da^{-1} verim elde edilmiştir (Kılınç ve ark., 2018).

Vejetasyon dönemini belirlemek amacıyla 13 silajlık mısır çeşidinde yapılan araştırmada kaba yem verimi 6.736.33-9.476.72 kg da^{-1} arasında, kuru madde verimi 1.758,41-2.153,43 kg da^{-1} arasında değişmiştir (Öner ve Güneş, 2019).

Silajlık mısır yetiştiriciliğinde organik gübre kullanımının verim ve verimle ilgili özelliklere etkisini araştırmak amacıyla yapılan çalışmada katı ahır gübresi içeren organik gübre 0, 250, 500 ve 1000 kg da^{-1}, kontrol parseli için kimyasal gübre (15 kg N, 10 kg P_2O_5) uygulanmıştır. Hamur olum döneminde yapılan hasatta yeşil ot verimi, kuru madde oranı, kuru madde verimi vb özelliklere ait veriler istatistiksel olarak önemli bulunmuştur. En yüksek kuru madde verimi kimyasal gübre uygulamasında (2000 kg/da^{-1}), bu uygulamayı 1000 kg da^{-1} organik gübre uygulaması (1.962,67 kg da^{-1}) ile aynı gurupta yer alan 500 kg da^{-1} organik gübre uygulamasında (1.785,33 kg da^{-1}) elde edilmiştir (Arslan, 2016).

Doğan ve ark., (2020) yapmış olduğu çalışmada II. ürün olarak farklı iki mısır çeşidine (Dekalp-5401 ve LG 30.597); gübresiz (kontrol parseli), 8 kg da^{-1} P_2O_5, 20 kg da^{-1} N ticari gübre, 1000 kg da^{-1} tavuk gübresi, 1500 kg da^{-1} çiftlik gübresi ve 1.200 kg da^{-1} solucan gübresi olacak şekilde iki yıllık yapılan araştırma sonuçlarına göre, Dekalb 5401 çeşidinde en yüksek tane verimi 1219,2 kg da^{-1} ile ticari gübre verilen parselde, LG 30.597 mısır çeşidinde ise en yüksek tane verimi 1.124,4 kg da^{-1} ile tavuk gübresi uygulamasında elde edilmiştir.

Bu çalışmada, 950 kg da^{-1} mısır verimi için gerekli olan gübre miktarı (Barber ve Olson, 1968) baz alınarak toprak analizi yapılmıştır. 950 kg da^{-1} mısır verimi için gerekli olan element miktarından analiz sonucunda bulunan elementler çıkarıldıktan sonra hangi element uygulanması gerekiyorsa ona göre gübre programı yapılmıştır. Bu uygulamaya ilave olarak toprak analizi yaptırmadan geleneksel olarak fazla ya da çok az miktarda gübre kullanan üreticilerimiz dikkate alınarak 950 kg da^{-1} mısır verimi için önerilen gübre dozunun %40 azaltılması ve %40

arttırılması ile bu uygulamalardan bağımsız geleneksel gübre uygulaması yapan üretici uygulaması olmak üzere toprağa 4 farklı oranda gübre uygulaması yapılmıştır. Topraktan yapılan bu uygulamaların püskül oluşum döneminde koçan yaprağındaki bitki besin elementleri değişimi ile birlikte mısır verimi üzerine etkileri belirlemek amacıyla yapılmıştır.

2. Materyal ve Metot

2.1. Materyal

Deneme Muğla ilinin Dalaman ilçesinde TİGEM deneme arazisinde 2016 yılında yürütülmüştür. Çalışmada bitkisel materyal olarak 72MAY80 tanelik ve silajlık mısır çeşidi, gübre materyali olarak üre, potasyum nitrat ve 15-15-15 gübresi kullanılmıştır.

2.2. Yöntem

Araştırma, tesadüf blokları deneme desenine göre 3 tekrarlamalı olarak yürütülmüştür. Deneme parsellerinde mısır bitkisi sıra aralığı 70 cm ve sıra üzeri 15 cm olacak şekilde pnömatik mibzerle ekimi yapılmıştır. Her bir deneme parselin alanı 1100 m^2'dir.

Toprağa yapılan dört farklı gübre uygulamasında kullanılan gübrelerin adı, uygulama zamanları ve toplam uygulama miktarı (kg da^{-1}) ve uygulanan saf element miktarları (N, P_2O_5, K_2O kg da^{-1}) *Tablo 1*'de verilmiştir.

Tablo 1. Denemede kullanılan gübre çeşidi, miktarı ve uygulama zamanı

Table 1. Fertilizer type, amount and application time used in the experiment

Mısır Gübre Uygulaması	Gübre adı (kg da^{-1})	Uygulama Zamanları ve Dozları (kg da^{-1})				Toplam (kg da^{-1})	Element Miktarı (kg da^{-1})		
		Taban	Sulama				N	P_2O_5	K_2O
			1	2	3				
950 kg da^{-1} verime göre gübre uygulaması	Üre	5	4	14	18.5	41.5	19.1	-	-
Gübre oranının %40 azaltılması	Üre	3	2.4	8.7	11.1	24.9	11.45	-	-
Gübre oranının %40 arttırılması	Üre	7	5.6	19.6	25.9	58.1	26.72		
Üreticinin geleneksel gübre uygulaması	Üre	8.5	22.5	13.5	15.5	60			
	15-15-15	32.3				32.3	34.27	4.85	11.29
	KNO_3	-	3	5.5	5.5	14			

Barber ve Olson (1968)'e göre, mısır bitkisi dekardan 950 kg mısır danesi ve koçanı için 19.1 kg N, 8.9 kg P_2O_5, 23.5 kg K_2O, 7.3 kg MgO, 7.6 kg CaO, 213 g Fe, 11 g Cu, 38 g Zn ve 34 g Mn elementini kaldırmaktadır. Çalışmanın yapıldığı alanının toprak analiz sonucu ile ilgili veriler *Tablo 2*'de verilmiştir. *Tablo 2*'de görüleceği gibi 1 dekar alanda bitkiler tarafından alınabilecek bitki besin element miktarları; 18.32 kg P_2O_5, 75.68 kg K_2O, 339.33 kg MgO, 1.552,6 kg CaO, 2.620 g Fe, 1.080 g Cu, 600 g Zn ve 1.920 g Mn'dır. 950 kg mısır verimi ve gübre miktarının %40 arttırılması uygulaması için gerekli olan P_2O_5, K_2O, MgO, CaO, Fe, Cu, Zn ve Mn elementleri 950 kg verim için toprakta fazla olması nedeniyle gübre olarak kullanılmamıştır. Fosforlu ve potasyumlu gübre sadece üretici uygulamasında kullanılmış ve sadece azotlu gübre kullanılmıştır. Üretici uygulamasında ise azotlu gübre ile birlikte fosforlu ve potasyumlu gübre kullanılmıştır. Gübre uygulamaları taban gübresi mısır ekimiyle birlikte banda verilirken, üst gübre üç farklı dönemde damlama sulama ile uygulanmıştır.

Denemede her parselden püskül oluşum döneminde 50 adet koçan yaprağı alındıktan sonra çeşme suyu ve saf su ile yıkanmış, 70°C'de 48 saat süreyle kurutulduktan sonra öğütülerek analize hazır hale getirilmiştir. Örneklerde toplam N kjeldahl yöntemiyle (Bremner, 1965), toplam P, K, Ca, Mg, S, Fe, Cu, Zn, Mn ve B analizleri mikrodalgada yaş yakma yöntemine göre (0,5 g örnek +2 ml H_2O_2 + 6 ml HNO_3) yapılmış (Kacar ve İnal, 2008) plastik balonjojelerde 50 ml'ye tamamlanarak ICP-OES cihazında okunmuştur.

Araştırma verileri tesadüf blokları deneme deseni planına göre SPSS programında varyans analiz yapılmış ve önemli görülen ortalamaların karşılaştırılmasında Duncan çoklu karşılaştırma testi kullanılmıştır.

3. Araştırma Sonuçları ve Tartışma

3.1. Deneme alanının toprak özellikleri

Mısır bitkisi ekilmeden önce deneme alanını temsil edecek şekilde 0-20 cm derinlikten alınan toprak örneğinin analiz sonuçları *Tablo 2*'de verilmiştir.

Tablo 2. Araştırma alanı toprağının bazı fiziksel ve kimyasal özellikleri

Table 2. Some physical and chemical properties of the soil of the research area

Analiz adı ve Yöntemi	Sonuç	Referans
Saturasyon (%) Su ile doygunluk	57.64	(Tüzüner,1990)
EC (mmhos/cm) (Saturasyon Çamuru)	0.75	(Richards, 1954)
pH (Saturasyon Çamuru)	7.69	(Anonim, 1988)
Kireç (%) (Kalsimetrik	18.71	(Anonim, 1988)
Organik Maddde (%)(Walkley Black)	2.52	(Anonim, 1988)
N (%).(Teorik Hesaplama)	0.13	(FAO, 1990)
P_2O_5 (kg da^{-1}) (Olsen Spektrofotometre)	18.32	(FAO, 1990)
K_2O (kg da^{-1}) (A. Asetat, ICP OES)	75.68	(FAO, 1990)
CaO (kg da^{-1}) (A. Asetat, ICP OES)	1.552,6	(FAO, 1990)
MgO (kg da^{-1}) (A. Asetat, ICP OES)	339,33	(FAO, 1990)
Fe (g/da) (DTPA, ICP OES)	2.620	(Lindsay ve Norvel, 1969)
Cu (g/da) (DTPA, ICP OES)	1.080	(Follet, 1969)
Mn (g/da) (DTPA, ICP OES)	1.920	(FAO, 1990)
Zn (g/da) (DTPA, ICP OES)	600	(FAO, 1990)

Tablo 2 incelendiğinde, araştırma alanı topraklarının killi tın bünyeli, tuzsuz, hafif alkali karakterli, fazla kireçli, orta düzeyde organik madde içermektedir. Toplam azot (N), fosfor (P), potasyum (K), bakır (Cu) ve çinko (Zn) miktarları yeterli, kalsiyum (Ca) ve magnezyum (Mg) miktarı fazla, mangan (Mn) miktarı az, demir (Fe) kapsamlarının yüksek oldukları saptanmıştır.

3.2. Toprağa farklı oranda gübre uygulamanın mısır verimine ve yapraktaki bitki besin elementi içeriğine etkisi

Mısır tarımı yapılan toprağa 4 farklı gübre uygulamasının mısır verimi ve yapraktaki bitki besin elementleri içeriği üzerine etkileri ile ilgili veriler tesadüf blokları deneme deseni planına göre SPSS programından varyans analiz yapılmış ve sonuçlar *Tablo 3*'de verilmiştir. Önemli görülen ortalamaların karşılaştırılmasında Duncan çoklu karşılaştırma testi kullanılmıştır.

Tablo 3. Gübre uygulamaların mısır verimi ve yapraktaki bitki besin elementleri değişimine ait varyans analiz sonuçları

Table 3. Variance analysis results of fertilizer applications on corn yield and plant nutrient changes in leaves

Uygulama	Verim (kg da-1)	N %	P %	K %	Ca %	Mg %	S %	Zn ppm	Fe ppm	Cu ppm	Mn ppm	B ppm	Mo ppm
Gübre	**	**	**	**	**	**	**	**	**	**	**	**	**

** p< 0.01 düzeyinde önemli farklılık

Tablo 3'de görüleceği gibi toprağa farklı oranda gübre uygulamanın mısır verimi ve yapraklardaki toplam azot, fosfor, potasyum, kalsiyum, magnezyum, kükürt demir, bakır mangan, çinko, bor ve molibden miktarı üzerine etkisi istatistiki olarak önemli bulunmuştur (p<0,01). Uygulamalara bağlı olarak mısır bitkisinde elde edilen verim ve toplam bitki besin element ortalamalarına ait önemlilik grupları *Tablo 4*'da verilmiştir.

Tablo 4'de görüleceği gibi gübre uygulama miktarının artışına bağlı olarak mısırda tane verimi artmıştır. En yüksek verim gübre kullanım miktarının en yüksek olduğu üretici uygulamasında elde edilmiş (1.367 kg da^{-1}), bu parseli sırasıyla gübre oranının %40 arttırılması uygulaması (1.357 kg da^{-1}), 950 kg da^{-1} verime göre gübre

uygulaması (1.225,3 kg da^{-1}) takip etmiştir. Mısır bitkisinde en düşük verim ise gübre miktarının % 40 azaltılması uygulamasında (991 kg da^{-1}) elde edilmiştir.

Tablo 4. Toprağa farklı oranda gübre uygulamanın mısır verimi ve yapraktaki bitki besin elementleri ortalamaları ve önemlilik grupları

Table 4. Corn yield of fertilizer application to the soil at different rates, averages of plant nutrients in the leaves and their importance groups

Gübre Uygulamaları	Verim (kg da^{-1})	Azot (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)	B (ppm)	Mo (ppm)
950 kg da^{-1} verime göre gübre uygulaması	1.225,3 c	2.2 c	0.55 a	2.74 b	0.35 c	0.44 b	0.22 d	40.62 b	353.3 c	5.8 d	53.7 d	26.52 a	6.6 b
Gübrenin %40 azaltılması	991 d	2.18 c	0.01 d	2.46 c	0.36 cb	0.36 d	0.25 c	43.6 a	287.23 d	7.2 c	60.40 c	22.0 b	1.57 d
Gübrenin %40 arttırılması	1.357 b	2.60 b	0.18 c	2.21 d	0.37 b	0.42 b	0.29 b	24.81 d	479.0 b	9.07 b	94.75 b	22.28 b	8.00 a
Üretici uygulaması	1.367 a	3.18 a	0.52 b	2.89 a	0.52 a	0.47 a	0.35 a	30.79 c	601,22 a	11.63 a	111.01 a	21.26 b	3.8 c
HKO	2.333	0.006	0.000	0.004	0.000	0.000	0.000	0.963	3.407	0.057	6.916	1.191	0.263
Sınır değerleri*	950	2.7-4	0.25-0.5	1.7-3	0.21-1	0.2-1	0.21-0.5	25-100	21-250	6-20	20-200	5-25	>0.2

*Mısır bitkisinde püskül oluşturma döneminde koçan yaprağında bulunması gereken bitki besin elementleri miktarı.

Toprağa uygulanan gübrelerin yapraktaki bitki besin elementi miktarı üzerine etkisi Tablo 4'de verilmiştir. *Tablo 1*'de parseller için uygulanan toplam N, P_2O_5 ve K_2O miktarı verilmiştir. Toplam azot en fazla üretici uygulamasında (34.27 kg da^{-1}), bu uygulamayı gübre miktarının %40 arttırılması (26.4 kg da^{-1}), 950 kg da^{-1} verime göre gübre uygulaması (18.9 kg da^{-1}) ve gübre miktarının %40 düşürülmesi (11.31 kg da^{-1}) izlemiştir. Topraktan gübre uygulamasının bitkide toplam azot miktarı üzerine değişimi üretici uygulamasında en yüksek değer (%3.18) elde edilirken, bu uygulamayı gübre miktarının %40 arttırılması (%2.60) takip etmiştir. En düşük toplam N miktarı 950 kg da^{-1} verime göre gübre uygulaması (%2.2) ve gübre miktarının %40 azaltılmasında (%2.18) uygulamalarında belirlenmiştir. Üretici uygulamasında elde edilen toplam N miktarı sınır değerlerin arasında yer alırken diğer uygulamalar sınır değerinin altında belirlenmiştir.

Tablo 1'de görüleceği gibi P gübre sadece üretici uygulamasında 4.85 kg da^{-1} uygulanmış diğer parsellere toprakta alınabilir fosfor yüksek olması nedeniyle uygulanmamıştır. Yapraktaki en yüksek toplam P miktarı 950 kg da^{-1} verime göre gübre uygulamasında (%0.55) en düşük P miktarı gübrenin %40 azaltılması uygulamasında (%0.01) elde edilmiştir. Gübre oranının %40 arttırılması ve %40 azaltılmasında yapraktaki fosfor miktarı sınır değerinin altında belirlenirken diğer iki uygulamadaki sonuçlar sınır değerinin üzerinde belirlenmiştir.

Topraktaki potasyum miktarı 950 kg da^{-1} verim için gerekli olan miktardan çok fazla olması nedeniyle (75.68 kg da^{-1}) potasyumlu gübre üretici parseli hariç uygulanmamıştır. En yüksek potasyum oranı üretici uygulamasında (%2.89), en düşük ise gübre oranının % 40 arttırılmasında (%2.21) elde edilmiştir. Uygulamalardan sonra yaprakta elde edilen K miktarları sınır değerinin içinde yer almıştır.

Toprağa farklı oranda uygulanan gübrelerin yapraktaki Ca oranına etkisi üretici uygulaması ile bitkideki en yüksek Ca oranı (%0.52) elde edilirken, en düşük oran 950 kg da^{-1} verime göre gübre uygulamasında (%0.35) elde edilmiştir. Tüm uygulamalar sonucunda bitkide elde edilen Ca miktarı sınır değerinin arasında belirlenmiştir.

Gübre uygulamaları sonucunda yaprakta elde edilen Mg elementi miktarı sınır değerlerin arasında belirlenmiştir. En yüksek konsantrasyon üretici uygulamasında (%0.47) elde edilirken en düşük değer gübre miktarının %40 azaltılması uygulamasında (%0.36) elde edilmiştir.

Gübre uygulamaların S elementi konsantrasyonuna en fazla arttıran uygulama üretici uygulaması (%0,35) iken, en düşük etkiyi 950 kg da^{-1} verime göre gübre uygulamasında (%0,22) elde edilmiştir. Uygulamalardan sonra yaprakta elde edilen S miktarları sınır değerlerin arasında yer almıştır.

Toprağa uygulanan gübre miktarının %40 azaltılmasıyla yaprakta en yüksek çinko konsantrasyonu elde edilirken (43.6 ppm), en düşük konsantrasyon gübre miktarının %40 arttırılmasında (24.81 ppm) elde edilmiştir. Gübre miktarının %40 arttırılması uygulaması hariç diğer uygulamalarda elde edilen Zn değerleri sınır değerleri arasında belirlenmiştir.

Uygulamalar sonucunda yaprakta elde edilen Fe miktarı sınır değerinin üzerinde toksik olacak seviyede bulunmuştur. Üretici uygulamasında en yüksek değer elde edilirken (601.22 ppm), en düşük değer gübre miktarının %40 azaltılmasında (287.23 ppm) elde edilmiştir.

Üretici uygulamasında en yüksek Cu miktarı elde edilirken (11.63 ppm) en düşük miktar 950 kg da^{-1} verime göre gübre uygulamasında (5.8 ppm) elde edilmiş ve bu uygulama hariç diğer uygulamalarda elde edilen Cu miktarı sınır değerlerinin arasında belirlenmiştir.

Uygulamalardan sonra yaprakta elde edilen Mn elementi miktarı sınır değerlerinin arasında yer alırken en yüksek değer üretici uygulamasında (111.01 ppm) en düşük ise 950 kg da^{-1} verime göre gübre uygulamasında (53.7 ppm) elde edilmiştir.

Yaprak analizleri sonucunda elde edilen B elementi yeterli olarak belirlenmiştir. 950 kg da^{-1} verime göre gübre uygulamasında en yüksek B miktarı (26.52 ppm) elde edilirken diğer uygulamaların hepsi aynı gurupta (22.0 ppm, 22.28 ppm, 21.26 ppm) yer almış ve en düşük değer elde edilmiştir.

Tüm uygulamalardan sonra elde edilen Mo elementi miktarları sınır değerlerin üzerinde belirlenmiştir. En yüksek bor elementi miktarı gübrenin %40 arttırılmasında (8.0 ppm) en düşük ise gübrenin %40 azaltılması uygulamasında (1.57 ppm) elde edilmiştir.

Tablo 4 incelendiğinde uygulamadan sonra mısır yaprağında yapılan 12 bitki besin elementi analizinde N, K, Ca, Mg, Fe, S, Cu, Mn miktarı açısından üretici uygulamasından en yüksek konsantrasyon elde edilen uygulamadır. Bitki yaprağında toplam N elementi üretici uygulaması hariç diğer üç uygulamada elde edilen değerler sınır değerinin altında belirlenmiştir. Bitkideki P elementi miktarı gübre uygulamasının %40 arttırılması ve azaltılması uygulamaları hariç sınır değerlerinin içinde belirlenmiştir. K, Ca, Mg, Zn, Cu, Mn ve B elementleri tüm uygulamalarda sınır değerleri arasında belirlenirken, Fe ve Mo ise tüm uygulamalarda sınır değerinin üzerinde belirlenmiştir. Deneme yapılan arazinin toprak analizi sonucuna bakıldığında bitki besin elementlerince çok güçlü olması mısır verimin yüksek olmasında önemli bir faktördür.

4. Sonuç

Mısır verimi, yapraktaki bitki besin elementi oranına etkisini ve gübre maliyetini belirlemek amacıyla dekara 950 kg verime göre gübre uygulaması, bu gübre miktarının %40 azaltılması ve %40 artırılması ile üretici uygulaması olmak üzere toprağa dört farklı oranda gübre uygulaması yapılmıştır. Gübre maliyetleri çıkarılmadan elde edilen verim miktarı ve maliyetler çıkarıldıktan sonra elde edilen net verim miktarları ile ilgili bilgiler Tablo 5'de verilmiştir.

Denemenin kurulduğu 2016 yılında her deneme parsellinde kullanılan toplam gübre miktarı *Tablo 1'*de verilmiştir. 2016 yılındaki birim gübre fiyatları dikkate alınarak gübre maliyetleri belirlendikten sonra mısırın 1 kg satış fiyatı olan 0.65'e bölünerek her parselde gübre maliyetine karşılık gelen mısır miktarı belirlenmiştir. Gübre maliyeti içinde olan verim miktarından, parseller için hesaplanan mısır miktarı düşülmüş ve gübre maliyeti olmayan net mısır verimi belirlenmiştir.

Tablo 5'te görüleceği gibi gübre maliyeti içinde mısır veriminde en yüksek verim, üretici uygulamasında elde edilirken (1.367 kg da^{-1}) gübre maliyetlerinin düşürüldükten sonra 2. sıraya (1.176,54 kg da^{-1}) düşmüştür. 950 kg da^{-1} verime göre gübre uygulaması sonucunda elde edilen verim 3. sıradan (1.225,3 kg da^{-1}) 2. sıraya (1.174,23 kg da^{-1}) yükselmiştir. Gübre maliyeti düşürülmeden en yüksek verim 1.367 kg da^{-1} (üretici uygulaması) ile en düşük verim 991 kg da^{-1} (gübre miktarının %40 düşürülmesi) arasında 376 kg da^{-1} fark oluşmuştur. Gübre maliyeti düşürüldükten sonra gübre miktarının %40 arttırılması uygulamasında elde edilen en yüksek verim (1.285,5 kg da^{-1}) ile gübrenin %40 azaltılması uygulamasında elde edilen en düşük verim (960.36 kg da^{-1}) arasında 325.14 kg da^{-1} fark oluşmuştur.

***Tablo 5. Gübre maliyetli ve gübre maliyetsiz verim* (kg da^{-1})**

Table 5. Fertilizer cost and fertilizer free yield (kg da^{-1})

Gübre Uygulamaları	**Gübre maliyetli verim (kg da^{-1})**	**Gübre maliyetsiz* verim (kg da^{-1})**	**Uygulanan gübrelerin TL olarak değeri**			**Mısır karşılığı (kg)**
			Üre	**15-15-15**	**K2SO4**	
950 kg da^{-1} verime göre gübre uygulaması	1.225,3	1.174,23	41.5	-	-	51.07
Gübrenin %40 azaltılması	991	960,36	24.9	-	-	30.64
Gübrenin %40 arttırılması	1.357	1.285,5	58.1	-	-	71.50
Üretici uygulaması	1.367	1.176,54	60	32.3	14	190.46

*Denemenin kurulduğu 2016 tarihinde üre 0.8 TL/kg, 15-15-15 0.96 TL/kg, KNO_3 3.2 TL/kg, Mısır 0.65 TL/kg'dır.

Gübre bayilerinde 06.01.2022 tarihi itibariyle gübre fiyatı; üre gübresi 14.000,0 TL ton^{-1}, 15-15-15 gübresi 10.000,0 TL ton^{-1} ve KNO_3 gübresi ise 20.000,0 TL ton^{-1}'dir. 08.11.2022 tarihi itibarı ile Edirne Ticaret Borsasındaki mısırın fiyatı 2 000,0 TL ton^{-1}'dir (Anonim, 2022a). Mısır hasadının yapıldığı 2016 tarihinde 1 ABD doları 2.9846 TL (Anonim, 2016), 21.01.2022 tarihinde ise 1 ABD doları 13.4431 TL'dir (Anonim, 2022b). Bu sonuçlardan da görüleceği gibi dolar kurundaki ve dolayısıyla gübre fiyatlarının artışı da dikkate alındığında 2016 yılına göre 1 kg üre gübresi fiyatı 0.85 TL'den 14 TL'ye 16.47 kat, 1 kg 15-15-15 gübresi 0.96 TL'den 8,6 TL'ye 8.95 kat ve 1 kg KNO_3 gübresi 3.2 TL'den 20 TL'ye 6.25 kat artış olurken mısır fiyatı 0.65 TL'den 2 TL'ye 3.076 kat artış olmuştur.

Gübre çeşidindeki artışı mısır tanesindeki artışla kıyasladığımızda 2 ile 5.5 kat oranında artış olmuştur. Ekonomik karlılık bakımından tarımsal üretimde en önemli girdi olan gübrenin doğru çeşit ve miktarlarda kullanılabilmesi için üreticilerin toprak analizi ve onu destekleyen bitki analizleri yaptırarak verilen gübreleme programını uygulaması gübreden kaynaklanan girdi maliyetini azaltacaktır.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Yonca Üretiminde Enerji Tüketimi: Hasat Sistemleri Arasında Bir Karşılaştırma*

Energy Consumption in Alfalfa Production: A Comparison Between Harvesting Systems

Muttalip GÜNGÖRMEZ[1], Fulya TAN[2], Mehmet Fırat BARAN[3*]

Öz

Bu çalışmanın temel amacı, Tekirdağ ilinde balya formunda yonca kuru otu üretiminde kullanılan farklı hasat sistemlerinin girdi ve çıktı enerjilerini belirlemektir. Veriler 2019 yılında 176 yonca işletmesinden toplanmıştır. Çalışılan işletme sayısını belirlemek için tesadüf örnekleme metodu kullanılmıştır. Hasat sistemleri, yonca üretiminde kullanılan farklı alet ve makina kombinasyonlarından oluşmaktadır. Kullanılan makinaların özellikleri ve kapasitesi birbirinden oldukça farklıdır. Hasat sistemlerinde; balya makinası (dikdörtgenler prizması/silindirik), şartlandırıcı tırmıkların kullanım sıklığı ve sayıları dikkate alınmıştır. Bu nedenle, çalışma gruplarında 6 farklı hasat sistemi oluşturulmuştur (H/1-6). İlave olarak, biçim sayısına göre (1,2,3,4,5,6) hasat sistemlerinin enerji tüketimleri de incelenmiştir. İlk biçim prosesi olarak yonca üretimi dikkate alınırken, tek biçim prosesi olarak kesme işleminden sonraki uygulamalar dikkate alınmıştır. Araştırma sonuçları enerji kullanım etkinliği, enerji üretkenliği, net enerji üretiminin balya makinası çeşidine, şartlandırıcı kullanım sayısına göre değiştiğini göstermiştir. Hasat sistemlerinde toplam girdi ve çıktı enerji değerleri oldukça değişken olmuştur. En yüksek enerji girdisi oranı yakıt (38.77%) ve azotlu gübrelemede (24.89%) kaydedilmiştir. En yüksek kullanılan yakıt miktarına karşılık olarak birim alan için toplam H6 sisteminde 3244.57 MJha^{-1} yakıt enerjisi hesaplanmıştır. Şartlandırıcı ekipman kullanım sayısının artışı ve biçim sayısının artmasına bağlı olarak enerji tüketimleri de artmıştır. Altı biçim yapıldığında; dikdörtgenler prizması şeklinde balya yapan balya makinası kullanılan hasat sisteminde 1248.57 MJha^{-1} makina enerjisi tüketimi, silindirik balya makinası kullanılan hasat sisteminde ise 1751.07 MJha^{-1} makina enerjisi tüketimi hesaplanmıştır. En yüksek toplam enerji girdisi (ilk biçim) silindirik balya makinasının kullanıldığı sistemlerde (H5-H6) 8179.41 MJha^{-1}, 8377.54 MJha^{-1} olarak hesaplanmıştır. En düşük özgül enerji dikdörtgen balya makinası kullanılan sistemlerde (H3-H4) 2.94 MJkg^{-1}, 3.17 MJkg^{-1} olarak hesaplanmıştır.

Anahtar Kelimeler: Yonca, Girdi enerjisi, Çıktı enerjisi, Enerji etkinliği, Biçme, Balya makinası

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*Yüksek Lisans Çalışmasından türetilmiştir.

Abstract

The purpase of this study was to determine the amount of input-output energy used in different harvest systems in baled alfalfa hay production in Tekirdağ province, Turkey. Data were collected from 176 alfalfa farms in 2019-2020. The simple random sampling method was used to determine survey volume. Harvesting systems consisting of different tool-machine combinations are used in alfalfa production. The capacities and features of the machines used are quite different from each other. In harvesting systems; baler type (rectangular/round), number and frequency of use of the conditioner rake were taken into account. Therefore, the studied population was divided into six groups based on different harvesting systems (H/1-6). In addition, according to the number of mowing (1,2,3,4,5,6); The energy consumption of the harvesting systems used was determined. While alfalfa production was taken into consideration in the first cutting process, the applications made after the cutting process were taken into account in the single mowing process. Results showed that the energy use efficiency, energy productivity and net energy varied according to the type of bale machine used and the number of conditioners. The total energy input and output in harvesting systems was highly variable. The highest share of input energy was recorded for diesel fuels-oil (38.77%) and N fertilizer (24.89%). The fuel energy of 3244.57 $MJha^{-1}$ was calculated in the H6 system for the highest amount of fuel used per unit area. Due to the increase in the number of use of conditioner equipment and the number of mowing, energy consumption has also increased. When mowing six times; 1248.57 $MJha^{-1}$ machine energy consumption was calculated in the harvesting system using rectangular baler, and 1751.07 $MJha^{-1}$ machine energy consumption in the harvesting system using round baler. The highest total energy input (first cutting) was 8179.41 $MJha^{-1}$, 8377.54 $MJha^{-1}$ in the systems using round baler (H5-H6). The lowest specific energy was calculated 2.94 $MJkg^{-1}$, 3.17 $MJkg^{-1}$ in the systems using rectangular baler (H3-H4).

Keywords: Alfalfa, Input enegy, Output energy, Energy efficiency, Mowing, Baler machine

1. Giriş

Yonca (*Medicago sativa*), baklagiller (*Fabaceae*) familyasından uzun yıllar yaşayan gerek yeşil ot gerekse kuru ot olarak değerlendirilebilen çok yıllık bir serin mevsim yem bitkisi türüdür (Anonim 2021a). Yem bitkilerinin en önemlilerinden biri olup yem değeri de oldukça yüksektir. Dünyada en çok yetiştirilen yem bitkileri arasında yer almaktadır. Türkiye'de en fazla ekilişi yapılan yem bitkisi yoncadır. Ülkemizde yoncanın ekim alanı 2000 yılından 2020 yılına, 2.508.000 da'dan 6.628.887 da'a yükselmiştir. TÜİK 2021 yılı verilerine göre 2020 yılında yoncanın yeşil ot üretimi ekilen alanda 19.290.519 ton olarak gerçekleşmiştir. Yonca üretimi 2020 yılında toplam 22.686.644 da olarak ekilen yem bitkileri içerisinde ekim alanı oranı %29.2 ulaşmıştır (TUİK, 2021).

Yonca hasat sonrası yeşil ot/ kuru ot ve silaj olarak değerlendirilmekte ve hayvan beslemede kaba yem kaynağı olarak kullanılmaktadır (Tan, 1997; Toruk, 2003). Pelet ve un formunda tüketime sunulabildiği gibi erozyona karşı örtücü bitki ve yeşil gübre olarak da değerlendirilmektedir. Protein, kalsiyum ve diğer mineraller ile B, C, D, E ve K vitamini açısından oldukça zengin olması nedeniyle tercih edilmektedir (Anonim 2021b).

Kuru ot üretiminde genellikle balya formunda üretim yöntemleri kullanılmaktadır. Balyalama işlemlerinde dikdörtgenler prizması şeklinde balya yapan balya makinaları ve silindirik şekilde balya yapan balya makinaları kullanımı görülmekte olup, ülkemizde çoğunlukla dikdörtgen balya yapımında küçük kapasiteli (15-25 kg) balya makinaları kullanımı tercih edilirken, silindirik balya yapımında ise büyük kapasiteli (750 kg-1000 kg) balya makinaları yoğun olarak kullanılmaktadır. Bu durum şartlandırma ekipmanlarının kullanımına yönelik farklı sayılarda alet-ekipman kullanımına da neden olabilmektedir. Doğal olarak farklı makina kullanımları üretim sistemlerinin enerji tüketimleri açısından da farklar yaratabilmektedir (Toruk, 2003).

Yem bitkileri tarımında önemli bir üretim alanına sahip olan yonca genel olarak yılda, üç veya dört kez hasat edilmektedir. Sulama yapılan bölgelerde ise, yılda beş veya altı kere (Mayıs, Haziran, Temmuz, Ağustos, Eylül, Ekim) hasat edilmektedir. Artan hasat sayısı, yoncanın değerlendirilmesi amacıyla kullanılan hasat sistemlerinin ve makina kullanımının önemini daha da arttırmaktadır.

Tarımsal üretimle ilgili olarak yapılacak enerji analizleri tarımsal sistemlerin enerji tüketimi açısından tanımlanıp gruplandırılmasında önemli bir yaklaşımdır. Üretimde verimi artırmak ve girdileri azaltmak için üretimde kullanılan girdi ve çıktıların dikkatli bir şekilde analiz edilmesi gereklidir (Sabah, 2010).

Son yıllardaki sürdürülebilir tarım ilkeleri doğrultusunda bir tarımsal üretim projesinin değerlendirilmesinde ekonomi, enerji ve çevre üçlüsü birlikte incelenmektedir (Baran ve Gökdoğan, 2016a). Başka bir açılımla, herhangi bir tarımsal üretim kolunda birim alandaki ürünün enerji eşdeğeri ile üretim için harcanan enerji miktarı arasındaki oran, başarılı ve kârlı bir üretim için bir gösterge ve bir kıyas değeri olarak kullanılabileceği gibi, çevresel duyarlılığın hızla arttığı günümüzde enerjinin etkin kullanımı açısından da önemli bir değerdir. Ayrıca, alternatif üretim teknikleri arasındaki farklılığın değerlendirilmesinde birim alan başına maliyet ile birlikte göz önünde bulundurulması gereken önemli bir yaklaşımdır (Erdoğan, 2009).

Enerji etkinliği değerini artırmak için ya verimin artırılması ya da girdilerin azaltılması gerekmektedir. Özellikle toplam enerji girdisi içerisinde büyük yer tutan yakıt, kimyasal gübreler, tarımsal ilaçlar, makina ve traktör girdilerinin azaltılması gerekmektedir. Verimin artırılması belirli sınırlar içerisinde sağlanabilir. Fakat enerji kullanım etkinlik değeri girdilerin bilinçli bir şekilde yapılmasıyla (ilaçlama, mekanizasyon ve gübreleme) azaltılabilir (Çelen, 2016). Enerji kullanım etkinliğini belirlemek amacıyla yapılan bazı çalışmalarda; yonca (Mobtaker ve ark. 2012; Asgharipour ve ark. 2016), arpa (Baran ve Gökdoğan, 2014), yazlık fiğ (Baran, 2016), ikinci ürün silajlık mısır (Baran ve Gökdoğan, 2016a), şekerpancarı (Baran ve Gökdoğan, 2016b), buğday + fiğ (Baran ve ark., 2016), susam (Baran ve Gökdoğan, 2017), fiğ ve yem bezelyesi, (Kökten ve ark., 2017a), adi fiğ ve macar fiğ (Kökten ve ark., 2017b), mısır (Kökten ve ark, 2018; Abbas ve ark., 2018), pamuk (Baran ve ark., 2021) ürünlerin üretiminde enerji kullanım etkinlikleri belirlenmiştir.

Yonca bitkisinin yıl içerisinde birden fazla sayıda hasat edilmesi, farklı hasat sistemlerinin kullanılması, farklı değerlendirme yöntemlerinin uygulanması, yonca üretiminde enerji etkinliğinin önemini daha çok arttırmaktadır. Hasat işlemlerinde kuru ot ve silajlık olmak üzere farklı hasat sistemleri uygulanmaktadır. Bu çalışmada balya formunda kuru ot üretiminde uygulanan hasat sistemleri arasında enerji tüketimleri açısından bir karşılaştırma yapılması amaçlanmıştır.

2. Materyal ve Yöntem

2.1. Materyal

2.1.1. Anket uygulanacak işletme sayısının belirlenmesi

Çalışma, hayvancılık ve yonca üretiminde önemli bir bölge olan Tekirdağ bölgesinde yürütülmüştür. Çalışmanın ana materyalini oluşturan veriler, il ve ilçelerindeki yonca üreticileriyle yüz yüze anket yapılarak toplanmıştır. Örnek hacmi sonlu bir popülasyon için belli bir özelliği taşıyanların bilinen veya tahmin edilen oranına göre aşağıdaki eşitlik (1) ile hesaplanmıştır.

$$n = \frac{N*p*q}{(N-1)*\alpha^2 p+p*q} \quad \text{(Eş.1)}$$

Eşitlikte;

n : Örnek büyüklüğü,
N : Popülasyondaki işletme sayısı,
$\alpha\ ^2p$: Oranın varyansı,
r : Ortalamadan sapma (%5)
$\alpha\ 2p = r/Z\ \alpha/2$

P değeri daha, önceki araştırmalardan elde edilebileceği gibi sezgisel olarak da tahmin edilebilir. Maksimum örnek hacmine ulaşmak için P = 0.5 alınmalıdır. P'nin 0.5'ten daha az veya daha yüksek değerleri örnek hacmini düşürür. O nedenle P'nin bilinmediği durumlarda maksimum örnek hacmiyle çalışmak olası hatayı azaltacağından P = 0.5 alınmalıdır (Miran, 2002).

Örnek sayısının belirlenmesinde ortalamadan % 5 sapma ve % 95 güven derecesi ile çalışılmıştır. Yapılan hesaplamalar sonucunda, çalışılması gereken örnek işletme sayısı 175 olarak bulunmuştur. Araştırmada yonca üreticilerine uygulanan anket sayısı ise 176 adettir.

2.1.2. Yonca üretiminde enerji girdilerinin belirlenmesi

Enerji girdileri insan gücü enerjisi, makina enerjisi, yakıt-yağ enerjisi, tohum enerjisi, su enerjisi, gübre enerjisi ve ilaç enerjisinden oluşmaktadır. Enerji girdisinin belirlenmesinde Farrel ve ark. (2006)'dan uyarlanan eşitlik 2, 3' den faydalanılmıştır:

$$TEG = \sum_{i=1}^{n} R(i)\ x\ E_{eş}(i) \quad \text{(Eş.2)}$$

Burada;
TEG : Tarımsal enerji girdisi (MJ ha^{-1}),
R(i) : i girdisinin uygulama miktarı (birim$_{girdi}$ ha^{-1}),
$E_{eş}$(i) : i girdisinin enerji eşdeğeri (MJ birim$_{girdi}^{-1}$) dir.

Enerji çıktısı ise birim alandan elde edilen ürün ve yan üründen oluşmaktadır. Enerji çıktısının belirlenmesinde uyarlanan aşağıdaki eşitlikten faydalanılmıştır:

$$TEÇ = Y * LHV \quad \text{(Eş.3)}$$

Burada;
TEÇ : Tarımsal enerji çıktısı (MJ ha^{-1}),
Y : Verim (kg ha^{-1})
LHV : Alt ısıl değer (MJ kg^{-1})'dir.

Tablo 1' de enerji kullanım etkinliğinin belirlenmesinde kullanılan 4, 5, 6 ve 7 numaralı eşitlikler verilmiştir. (Yılmaz ve ark., 2010).

Tarımsal üretimde kullanılan girdi ve çıktıların enerji eşdeğerleri *Tablo 2*'de verilmiştir. Enerji çıktısı, birim alandan elde edilen ürün ve yan üründen oluşmaktadır. Enerji girdisinin ve enerji çıktısının hesaplanmasında girdi ve çıktı çeşitlerinin enerji eş değerlerinin bilinmesi gerekir. Enerji eşdeğerlerinin belirlenmesinde daha önce yapılan araştırmalardan faydalanılmıştır.

Yonca üretimindeki enerji girdileri, doğrudan ve dolaylı enerji girdileri olarak iki grupta hesaplanmıştır. Yonca üretiminde tarım alet ve makinaları tarafından tüketilen yakıt ve yağ enerji değeri doğrudan enerji girdisi olarak, kullanılan insan işgücü, tarım alet ve makinaları, gübre, ilaç ve tohumluk için tüketilen enerji değerleri

dolaylı enerji girdisi olarak dikkate alınmıştır (Koçtürk ve Engindeniz, 2009). Hasat sistemlerinde kullanılan balya makinaları (küçük dikdörtgen-büyük silindirik) için her biri ayrı ayrı hesaplanmıştır.

Tablo 1. Enerji etkinliği eşitlikleri

Table 1. Energy efficiency equations

Eşitlikler			
Toplam enerji girdisi (TEG)	$\sum_{i=1}^{n} R(i)\ x\ E_{eş}(i)$	MJ ha^{-1}	(2)
Toplam enerji çıktısı (TEÇ)	$Y * LHV$	MJ ha^{-1}	(3)
Enerji oranı	$\frac{\text{TEÇ}}{\text{TEG}}$	-	(4)
Özgül enerji	$\frac{\text{TEG}}{\text{Y}}$	MJ kg^{-1}	(5)
Enerji üretkenliği	$\frac{\text{Y}}{\text{TEG}}$	kg MJ^{-1}	(6)
Net enerji verimi	$\text{TEÇ} - \text{TEG}$	MJ ha^{-1}	(7)

Tablo 2. Tarımsal üretimde girdi ve çıktıların enerji eşdeğerleri

Table 2. Energy equivalents of inputs and outputs in agricultural production

Girdiler	Enerji eşdeğeri Katsayısı (MJbirim^{-1})	Referanslar
İnsan İşgücü (h)	1.96	Bojaca ve Schrevens (2010); Mousavi Avval ve ark., 2011
Makina Üretim Enerjisi (kg)		
Traktör	158.50	Keener ve Roller, (1975); Gözübüyük ve ark., (2012)
Toprak İşleme Aletleri	121.30	Keener ve Roller, (1975); Gözübüyük ve ark., (2012)
Tırmık		
Yakıt ve yağ (L)		
Dizel	39.60	Rathke ve Diepenbrock, (2006);
Yağ	6.51	Eren,(2011); Arıkan,(2011)
Kimyasal Gübreler (kg)		
Azot (N)	60.60	Singh, (2002)
Fosfor (P_2O_5)	11.10	Singh, (2002); Hedau ve ark. (2014)
Potasyum	6.70	Singh, (2002); Hedau ve ark. (2014)
İlaçlar (kg)		
Herbisit	269	Baran ve ark.(2019)
İnsektisit	363.60	Pimentel, (1980)
Tohum (kg)		
Yonca	6.9	Hoeppner ve ark. (2005)
Çıktı		
Yonca otu	17.17	Hoeppner ve ark. (2005)

2.1.3. Hasat sistemleri

Balya halinde kuru ot üretiminde; çayır biçme makinası (diskli tip) + Tırmıklar (şartlandırıcılar) +Balya makinası (dikdörtgen tip balya makinası-silindirik tip balya makinası) aşamaları olmak üzere bir sistemden oluşmaktadır. Bu sistem zincirinde makina kullanımları işletmelere göre farklılıklar göstermektedir. Balya makinaları kullanımında dikdörtgen tip makina kullanımında küçük kapasiteli makinalar kullanılır iken, silindirik balya makinalarında büyük kapasiteli makina kullanımı belirlendiğinden araştırmada her iki makina tipi esas alınmıştır. Makina kullanımına göre altı farklı hasat sistemi dikkate alınmıştır. Hasat sistemleri ile, yonca kuru otu üretiminde farklı balya makinası kullanımı, farklı sayıda şartlandırıcı kullanımı durumlarında enerji etkinliği farklarının etkisini ortaya koyabilmek ve her farklı durum için bir fikir edinimin sağlanması hedeflenmiştir. *Tablo 3*'de incelenen hasat sistemleri verilmiştir.

Tablo 3. Hasat sistemleri

Table 3. Harvest systems

Hasat Sistemleri	Çayır biçme makinası	Tırmık (Şartlandırıcı)			Balya makinası	
	Diskli tip	1	2	4	Dikdörtgen (küçük)	Silindirik (büyük)
H1	✓					
H2	✓	✓				
H3	✓		✓		✓	
H4	✓			✓	✓	
H5	✓		✓			✓
H6	✓			✓		✓

2.1.4. Biçim

Yonca bitkisinin bir hasat dönemi içerisinde farklı sayılarda biçim yapılması nedeni ile biçme sayısı ve işlemi dikkate alınmıştır. İlk biçim, toprak işleme, ekim ve bakım işlemlerinin dahil edilerek hesaplandığı biçimi ifade etmektedir. Tek biçim, ilk biçim harici biçimdir ve biçim sonrası uygulanan gübreleme işleminin dahil edilerek hesaplandığı biçimdir. Böylelikle işletmeler her hasat dönemi içerisinde uyguladıkları biçim sayısını dikkate alarak enerji tüketimi ve etkinliğini hakkında da fikir edinebilecektir.

3. ARAŞTIRMA SONUÇLARI VE TARTIŞMA

3.1. Doğrudan Enerji Girdileri (yakıt +yağ)

Hasat sistemlerine göre oluşturulan yakıt, yağ, toplam enerji eşdeğeri ve toplam enerji girdisine oranları *Tablo 4*' de verilmiştir.

Tablo 4. Hasat sistemlerinde hesaplanan yakıt, yağ, toplam enerji eşdeğeri ($MJha^{-1}$) ve toplam enerji girdisine oranı (%)

Table 4. The ratio of fuel, oil, total energy equivalent ($MJha^{-1}$) and total energy input calculated in harvesting systems (%)

Sistemler	Yakıt tüketimi (L/ha)	Toplam enerji eşdeğeri ($MJha^{-1}$)	Toplam enerji girdisine oranı (%)	Yağ tüketimi (L/ha)	Toplam enerji eşdeğeri ($MJha^{-1}$)	Toplam enerji girdisine oranı (%)	Yakıt+yağ tüketimi (L/ha)	Toplam enerji eşdeğeri ($MJha^{-1}$)	Toplam enerji girdisine oranı (%)
H1	55.71	1988.28	11.54	0.300	1.95	0.0113	56.01	1990.23	11.55
H2	65.71	2345.18	13.61	0.348	2.26	0.0131	66.05	2347.44	13.62
H3	77.71	2773.47	16.09	0.426	2.77	0.0161	78.13	2776.24	16.11
H4	82.91	2959.05	17.17	0.474	3.08	0.0179	83.38	2962.13	17.19
H5	85.71	3058.98	15.72	0.412	2.68	0.0138	86.12	3061.66	15.74
H6	90.91	3244.57	16.67	0.460	2.99	0.0154	91.37	3247.56	16.69

Hasat sistemlerinde makina kullanımı ve sayılarına bağlı olarak sistemlerde yakıt ve yağ tüketimlerinde artışlar belirlenmiştir. Yonca üretiminde birim alan (ha) başına toplam yakıt tüketimi H1 sisteminde hektara 55.71 litre en düşük, 90.91 litre ile H6 sisteminde en yüksek olarak hesaplanmıştır. Kullanılan yakıt miktarına karşılık olarak birim alan için toplam H1 sisteminde 1988.28 $MJha^{-1}$ yakıt enerjisi tüketilirken H6 sisteminde 3244.57 $MJha^{-1}$ yakıt enerjisi hesaplanmıştır. Yonca üretiminde birim alan (ha) başına toplam yağ tüketimi H1 sisteminde hektara 0.30 litre en düşük, 0.47 litre ile H4 sisteminde en yüksek olarak hesaplanmıştır. Kullanılan yağ miktarına karşılık olarak birim alan için toplam H1 sisteminde 1.95 $MJha^{-1}$ yağ enerjisi tüketilirken H4 sisteminde 3.08 $MJha^{-1}$ yağ enerjisi hesaplanmıştır. Toplam doğrudan enerji girdilerine bakıldığında birim alan (ha) başına en yüksek değer sırasıyla sistemlerde H6>H5>H4>H3>H2 ve H1 de şeklinde hesaplanmıştır. H1 sisteminde 1990.23 $MJha^{-1}$ yakıt+yağ enerjisi tüketilirken, H6 sisteminde 3247.56 $MJha^{-1}$ yakıt+yağ enerjisi hesaplanmıştır. En yüksek toplam enerji girdisine oranı ise % 17.19 ile H4' de, %16.69 ile H6 da olmuştur. Bunun temel nedeni tırmık sayısının kullanımının artması ile ifade edilebilir. Ayrıca, büyük kapasiteli balya makinaları kullanımında toplam enerji

eşdeğeri küçük balya makinası kullanımına göre elde edilen değerlerden fazla saptanırken, toplam enerji girdisine oranı dikkate alındığında küçük balya makinalarında daha yüksek olduğu görülmektedir.

Tablo 5' te yılda çok kez biçim yapılan yonca otu için ilk biçim, tek biçim ve altı biçim olarak hesaplanan yakıt+yağ tüketimleri ve toplam enerji eşdeğerleri verilmiştir. Bu nedenle, biçimlere ilişkin toplam enerji eşdeğerleri ayrıca hesaplanmıştır. İlk biçim, tüm uygulamaların dahil olduğu bitkisel üretim yöntemidir. Tek biçim olarak ifade edilen hesaplamalar, işletmelerin 3,4,5 veya 6 gibi çok sayıda biçim yapması durumunda hesaplama yapabilmeleri adına verilmiştir. Bölgemizde ve sulamaya bağlı olarak genellikle ortalama 6 biçim kullanımının yoğun olması nedeni ile değerlendirilmiştir. İşletmede 3 biçim yapılması durumda [ilk biçim + (tek biçim x 2)] olarak hesaplama yapılması gereklidir. Artan biçim sayısına bağlı olarak katsayı artarak hesaplanmalıdır.

Tablo 5. Yonca otu ilk biçim, tek biçim, altı biçim için yakıt tüketimleri ve toplam enerji eşdeğerleri

Table 5. Fuel consumptions and total energy equivalents for alfalfa first cut, single crop, and six crops

Sistemler	İlk biçim		Tek biçim		6 biçim	
	Yakıt+yağ tüketimi (L/ha)	Toplam enerji eşdeğeri ($MJha^{-1}$)	Yakıt + yağ tüketimi (L/ha)	Toplam enerji eşdeğeri ($MJha^{-1}$)	Yakıt+ yağ tüketimi (L/ha)	Toplam enerji eşdeğeri ($MJha^{-1}$)
H1	56.01	1990.23	10.03	357.10	106.17	2519.85
H2	66.05	2347.44	15.28	543.00	142.46	3058.62
H3	78.14	2776.24	32.60	1157.69	241.17	8564.76
H4	83.38	2962.13	43.10	1529.47	298.89	10609.49
H5	86.12	3061.66	40.59	1443.11	287.08	10277.24
H6	91.37	3247.56	51.08	1814.90	346.81	12322.06

Hasat sistemleri arasında her bir biçme işleminde yakıt+yağ tüketimleri ve toplam enerji eşdeğerleri farklılıklar hesaplanmıştır. En yüksek toplam enerji eşdeğeri ve yakıt+yağ tüketimi H6 (1814.9 $MJha^{-1}$, 51.08 L/ha) ve H4 (1529.47 $MJha^{-1}$, 43.10 L/ha) ile tırmık kullanımı sayısının fazla olduğu sistemlerde bulunmuştur. Balya makinası kullanımı dikkate alındığında ise, silindirik balya makinası kullanılan hasat sistemlerinde daha yüksek hesaplanmıştır. Bu durum balya makinası kullanımının etkinliğini göstermektedir.

3.2. Dolaylı Enerji Girdileri

Dolaylı enerji girdileri; incelenen hasat sistemleri için farklılık gösteren girdiler (insan işgücü girdisi, makina girdisi) ve hasat sistemleri için benzer olan girdiler (gübre, ilaç ve tohum girdileri) şekilde verilmiştir. *Tablo 6*' da insan işgücü ve makina girdisine ilişkin toplam enerji eşdeğeri ve toplam enerji girdisine oranları, *Tablo 7*' de ise, ilk biçim, tek biçim ve altı biçim dikkate alınarak hesaplanan insan işgücü ve makina girdileri, toplam enerji eşdeğerleri verilmiştir. *Tablo 8* de tüm hasat sistemleri için ortak olan gübre, ilaç ve tohum girdileri verilmiştir.

Tablo 6. Dolaylı enerji girdileri (insan işgücü, makina girdisi, toplam enerji eşdeğeri ve toplam enerji girdisine oranları

Table 6. Indirect energy inputs (human labor, machine input, total energy equivalent and their ratio to total energy input)

Sistemler	İnsan işgücü girdisi (h/ha)	Toplam enerji eşdeğeri ($MJha^{-1}$)	Toplam enerji girdisine oranı (%)	Makina girdisi (h/ha)	Toplam enerji eşdeğeri ($MJha^{-1}$)	Toplam enerji girdisine oranı (%)
H1	7.75	17.64	0.102	16.00	484.86	2.81
H2	8.25	18.62	0.108	16.50	496.11	2.88
H3	9.00	20.09	0.117	17.25	551.22	3.20
H4	9.50	21.07	0.122	17.75	562.47	3.26
H5	9.25	20.58	0.106	17.50	634.97	3.26
H6	9.75	21.56	0.111	18.00	646.22	3.32

Tablo 7. İlk biçim, tek biçim ve altı biçim dikkate alınarak hesaplanan insan işgücü, makina girdileri ve toplam enerji eşdeğerleri

Table 7. Human labor and machine inputs, total energy equivalents calculated considering the first form, uniform and six forms

Sistemler	İlk biçim		Tek biçim		Altı biçim	
	İnsan işgücü girdisi (h/ha)	Toplam enerji eşdeğeri ($MJha^{-1}$)	İnsan işgücü girdisi (h/ha)	Toplam enerji eşdeğeri ($MJha^{-1}$)	İnsan işgücü girdisi (h/ha)	Toplam enerji eşdeğeri ($MJha^{-1}$)
H1	7.75	17.64	1.25	1.96	14.00	27.44
H2	8.25	18.62	1.50	2.94	15.75	33.32
H3	9.00	20.09	2.75	5.39	22.75	47.04
H4	9.50	21.07	3.75	7.35	28.25	57.82
H5	9.25	20.58	3.00	5.88	24.25	49.98
H6	9.75	21.56	4.00	7.84	29.75	60.76
Sistemler	İlk biçim		Tek biçim		Altı biçim	
	Makina girdisi (h/ha)	Toplam enerji eşdeğeri ($MJha^{-1}$)	Makina girdisi (h/ha)	Toplam enerji eşdeğeri ($MJha^{-1}$)	Makina girdisi (h/ha)	Toplam enerji eşdeğeri ($MJha^{-1}$)
H1	16.00	484.86	1.00	37.11	21.00	670.41
H2	16.50	496.11	1.50	48.36	24.00	737.91
H3	17.25	551.22	2.75	114.72	31.00	1124.82
H4	17.75	562.47	3.75	137.22	36.50	1248.57
H5	17.50	634.97	3.00	198.47	32.50	1627.32
H6	18.00	646.22	4.00	220.97	38.00	1751.07

Yonca kuru ot üretiminde toplam olarak (dikdörtgenler prizması şeklinde balya yapan balya makinası kullanımında) birim alan başına toplam en yüksek 9.50 saat insan işgücü kullanımı hesaplanmıştır. Bu süre içerisinde birim alan için hektara 21.07 MJ insan işgücü enerjisi tüketimi hesaplanmıştır. Silindirik balya makinası kullanılan hasat sisteminde ise, 9.75 h/ha insan işgücü kullanımı ve 21.56 $MJha^{-1}$ insan işgücü enerjisi tüketimi hesaplanmıştır. Altı biçim yapıldığında; kuru ot üretiminde toplam olarak (dikdörtgenler prizması şeklinde balya yapan balya makinası kullanımında) 28.25 h/ha insan işgücü kullanımı ve 57.82 $MJha^{-1}$ insan işgücü enerjisi tüketimi, silindirik balya makinası kullanımında 29.75 h/ha insan işgücü kullanımı ve 60.76 $MJha^{-1}$ insan işgücü enerjisi tüketimi hesaplanmıştır (*Tablo 7*).

Makina girdisi hasat sistemlerine göre değişkenlik göstermiştir ve dikdörtgenler prizması şeklinde balya yapan balya makinası kullanımında birim alan başına toplam en yüksek H4 de 17.75 saat makina kullanımı hesaplanmıştır. Bu süre içerisinde birim alan için hektara 562.47 MJ makina enerjisi tüketimi hesaplanmıştır. Hasat sisteminde silindirik balya makinası kullanımında ise, en yüksek 18.00 h/ha makina kullanımı ile H6 da ve 646.22 $MJha^{-1}$ makina enerjisi tüketimi hesaplanmıştır (*Tablo 7*).

Tablo 8. Hasat sistemleri için ortak olan gübre, ilaç, sulama ve tohum girdileri

Table 8. Fertilizer, pesticide, irrigation and seed inputs common to harvesting systems

	Girdiler (ha)		Toplam enerji eşdeğeri ($MJha^{-1}$)	Toplam enerji girdisine oranı (%)
Gübre	(Ekim yılı)	182.5	4272.5	24.78
	(Bakım yılı)	142.0	4291.2	24.89
	İki biçim arası	40	2424.0	14.06
İlaç	Herbisit	0.5	134.5	0.78
	İnsektisit	0.5	134.5	0.78
Tohum	Yonca	8.0	55.2	0.32

Yılda altı kez biçim yapılan yonca otu için ilk biçim, sonraki biçim ve toplam biçim (6 biçim) için birim üretim alanı başına makina miktarı ve makina enerjisi tüketimi hesaplanmıştır. Altı biçim yapıldığında; kuru ot üretiminde toplam olarak (dikdörtgenler prizması şeklinde balya yapan balya makinası kullanımında) 36.50 h/ha makina

kullanımı ve 1248.57 MJha^{-1} makina enerjisi tüketimi, silindirik balya makinası kullanımında 38.00 h/ha makina kullanımı ve 1751.07 MJha^{-1} makina enerjisi tüketimi hesaplanmıştır. Toplam olarak yonca üretiminde ekim yılı için birim alan başına 182.5 kg/ha gübre kullanılmaktadır. Bu gübrelerin kullanımına bağlı olarak tüketilen üretim enerjisinden birim alan (ha) için toplam 4272.5 MJ enerji tüketilmektedir. Bu miktar yonca bitkisinin diğer bakım yılları için düşmekte ve ortalama kullanılan toplam gübre miktarı 142.0 kg/ha olmaktadır. Bu miktarda gübre kullanımı ile hesaplanan enerji tüketim değerleri ise toplam 4291.2 MJha^{-1} olarak saptanmıştır (*Tablo 8*). Yonca üretiminde etkili madde olarak, hektara 0.5 kg herbisit uygulaması yapılmakta ve toplam birim alan başına 134.5 MJha^{-1} enerji tüketimi yapılmaktadır. Yonca üretiminde etkili madde olarak, hektara 0.5 kg tohum uygulanmakta ve toplam birim alan başına 55.2 MJha^{-1} enerji tüketimi yapılmaktadır.

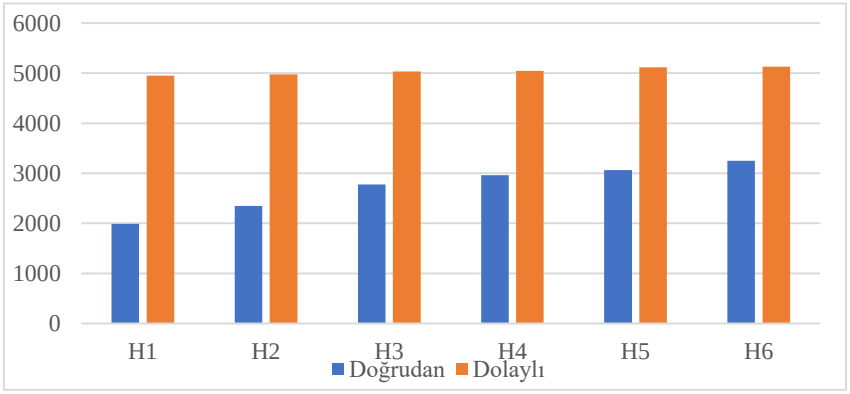
3.3. Toplam Enerji Girdisi

Toplam enerji girdisi hasat sistemlerine göre hesaplanarak *Tablo 9*' da verilmiştir. *Şekil 1*' de dolaylı ve doğrudan enerji girdilerinin değişimi gösterilmiştir.

Tablo 9. Toplam enerji girdileri

Table 9. Total energy inputs

			İlk biçim		**Altı biçim**	
Girdiler		Uygulama	Enerji girdisi (MJha^{-1})	Toplam enerji girdisine oranı (%)	Enerji girdisi (MJha^{-1})	Toplam enerji girdisine oranı (%)
Doğrudan enerji girdisi	H1		1990.23	28.69	2519.85	12.30
	H2		2347.44	32.05	3058.62	14.47
	H3		2776.24	35.55	8564.76	31.73
	H4		2962.13	37.00	10609.49	36.37
	H5		3061.66	37.43	10277.24	35.18
	H6		3247.56	38.77	12322.06	39.25
Dolaylı enerji girdisi	H1		4947.16	71.31	17897.35	87.69
	H2		4976.93	67.95	17970.73	85.52
	H3		5033.51	64.45	18371.36	68.26
	H4		5045.74	63.00	18505.89	63.62
	H5		5117.75	62.57	18876.80	64.81
	H6		5129.98	61.23	19011.33	60.74
Toplam	H1		6937.39	100	20417.2	100
	H2		7324.37	100	21029.35	100
	H3		7809.75	100	26936.12	100
	H4		8007.87	100	29115.38	100
	H5		8179.41	100	29154.04	100
	H6		8377.54	100	31333.39	100



Şekil 1. Dolaylı ve doğrudan enerji girdilerinin değişimi

Figure 1. Variation of indirect and direct energy inputs

Tablo 9 incelendiğinde yonca üretiminde kuru ot üretim sisteminde en yüksek girdi, silindirik tip balya makinası kullanımı ile doğrudan H6 sisteminde (3247.56 MJha^{-1}) ve dolaylı enerji tüketimi ise (5129.98 MJha^{-1})

toplamı 8377.54 MJha^{-1} olarak hesaplanmıştır. Toplam enerji tüketiminin; % 38.77'si doğrudan, % 61.23'ü ise dolaylı enerji tüketimleri oluşturmaktadır. İlk biçim sonrası biçim işlemlerinde doğrudan enerji tüketimleri daha yüksek olmuştur ve en yüksek enerji girdisi kuru ot üretim sistemlerinde hesaplanmıştır. Altı biçim yapan yonca işletmesinde toplamda en yüksek doğrudan enerji tüketimi % 52.83 dolaylı enerji girdisi ise %47.17 olarak hesaplanmıştır. Şekil 1' de hasat sistemleri arasında en büyük farklılıkların doğrudan enerji girdileri ile meydana geldiği görülmektedir.

3.4. Toplam Enerji Çıktısı

Yonca üretiminde birim üretim alanı için ortalama 16800 kgha^{-1} yeşil ot elde edilmiştir. Yonca için enerji eşdeğeri 17.7 enerji çıktısı ise 28845.60 MJha^{-1} olarak tespit edilmiştir (*Tablo 10*). Eren (2011) Tatlı sorgum toplam enerji çıktısını 199024.50 MJha^{-1} olarak hesaplanmıştır (Eren 2011), Baran ve ark. (2016) ikinci ürün silajlık mısırda farklı uygulamalarda toplam enerji çıktısını 221940,21 MJha^{-1}, 245594.16 MJha^{-1} 201999.28 MJha^{-1}, Kökten ve ark. (2018) dane mısır da toplam enerji çıktısını 28504.54 MJha^{-1} olarak hesaplamışlardır.

Tablo 10. Yonca üretiminde enerji çıktısı

Table 10. Energy output in alfalfa production

Çıktı	Verim(kg ha^{-1})	Enerji değeri (MJha^{-1})	Enerji çıktısı (MJha^{-1})	Toplam enerji çıktısına oranı (%)
Yonca otu	16800	17.17	28845.60	100
Tek biçim	1500	17.17	25775.0	100
Beş biçim	7500	17.17	128775.0	100

3.5. Yonca Üretiminde Enerji Etkinliği

Yonca üretimi için hesaplanan enerji etkinliği değerleri *Tablo 11'* te verilmiştir.

Tablo 11. Yonca üretiminde enerji etkinliği

Table 11. Energy efficiency in alfalfa production

Sistemler		**H1**	**H2**	**H3**	**H4**	**H5**	**H6**
Enerji oranı		7.69	7.45	5.83	5.40	5.39	5.02
Özgül Enerji	(MJ kg^{-1})	2.23	2.30	2.94	3.17	3.18	3.41
Enerji Üretkenliği	(kg MJ^{-1})	0.44	0.43	0.34	0.31	0.31	0.29
*Net Enerji Üretimi	(MJ ha^{-1})	137148.2	136486.1	130629.3	128450.0	128411.4	126232.0

*Tüm biçim dahil edilmiştir.

Tablo 11'i incelediğimizde enerji oranı, üretim sonucunda kazanılan toplam enerji miktarının, üretim işlemlerinde kullanılan toplam enerji miktarına oranıdır. Birim üretim alanı (ha) için tüketilen birim enerji (MJ) miktarına karşılık, üretim sonucunda birim üretim alanından (ha) kazanılan enerji miktarını (MJ) belirtir. Enerji oranının yüksek olması, üretimdeki enerji etkinliğinin yüksek olduğunu ifade etmektedir. Yonca üretiminde kuru ot üretimi için hesaplanan enerji oranları; en yüksek küçük balya yapımında kullanılan kuru ot üretiminde 5.83, en düşük silindirik balya makinasının kullanıldığı sistemlerde 5.39, 5.02 olarak hesaplanmıştır. Mobtaker ve ark. (2012) yonca çalışmalarında 1.88, Baran ve ark. (2016) İkinci ürün silajlık mısırı üç farklı toprak işleme uygulamasında enerji oranını 9.06-10.36, Baran, (2016) yazlık fiğ çalışmasında enerji oranını 9.51, Kökten ve ark. (2018) mısır çalışmalarında enerji oranını 4.23, Baran (2017) kışlık fiğ çalışmasında enerji oranının 8.05 olarak hesaplamışlardır.

Yonca üretiminde hesaplanan özgül enerji, sadece birim üretim alanından (ha) alınan yonca otu miktarı dikkate alındığında; dikdörtgen balya makinası kullanılarak yapılan küçük balya üretim sisteminde kuru ot üretiminde, 1 kg yonca otu üretimi için 2.94 MJ, 3.17 MJ enerji, silindirik balya makinası kullanımı ile büyük balya yapımında 1 kg yonca otu üretimi için 3.18, 3.41 MJ enerji, olarak tespit edilmiştir. Şartlandırıcı ekipman kullanımının artmasına bağlı olarak özgül enerji değeri artış gösterirken, en yüksek artış silindirik balya üretim sisteminde hesaplanmıştır.

Enerji üretkenliği ise, özgül enerji değerinin tersi olup, hasat edilen toplam ürün miktarının, üretim işlemlerinde kullanılan toplam enerji miktarına oranıdır. Enerji üretkenliği değeri, tüketilen birim miktar (MJ) enerji miktarına karşılık üretilen ürün miktarını (kg) belirtir. Enerji üretkenliği değerinin yüksek olması, üretimde enerji etkinliğinin yüksek olduğunu göstermektedir.

Yonca üretiminde hesaplanan enerji üretkenliği, sadece birim üretim alanından (ha) alınan yonca otu miktarı dikkate alındığında; dikdörtgen balya makinası kullanılan küçük balya üretim sisteminde kuru ot üretiminde, 1 MJ enerji tüketimi karşılığında 0.34 kg yonca otu balyalanmış, silindirik balya makinası kullanımı ile büyük balya yapımında 1 MJ enerji tüketimi karşılığında 0.31 kg yonca otu balya yapıldığı hesaplanmıştır. Şartlandırıcı ekipman kullanımına bağlı olarak enerji üretkenliği değerlerinde azalma olduğu da belirlenmiştir. 1MJ enerji tüketimi karşılığında; Mobtaker ve ark. (2012) 0.119, Asgharipour ve ark. (2016) 0.209, Baran (2016) yazlık fiğ 'de 0.39, Baran (2017) kışlık fiğ 'de 0.47, Kökten ve ark. (2018) dane mısırda 0.21, olarak hesaplamışlardır.

Net enerji üretimi değerinin yüksek olması, üretimdeki enerji etkinliğinin yüksek olduğunu göstermektedir. Yonca üretiminde aynı yıl içerisinde altı biçim yapılarak altı hasat işleminin uygulanması, her biçim sonrası gübreleme işleminin uygulanması yonca üretiminde enerji verimini arttırmaktadır. Yonca üretiminde net enerji üretimi, sadece birim üretim alanından (ha) alınan yonca otu miktarı dikkate alınarak hesaplanmıştır. Ekim yılı ilk biçim dahil kullanılan hasat sistemlerine göre; dikdörtgen balya makinası kullanılarak küçük balya yapılan üretim sisteminde, birim üretim alanından (ha), 128450.0 MJ net enerji, silindirik balya makinası kullanımı ile büyük balya yapımında birim üretim alanından (ha), 126232.0MJ net enerji kazanılmıştır.

4. Sonuç ve Öneriler

Tarımda enerji kullanımı, artan nüfus, sınırlı ekilebilir arazi arzı ve daha yüksek yaşam standartları arzusuna yanıt olarak artmaktadır. Artan gıda üretimindeki sürekli talep, kimyasal gübre, böcek ilacı, tarım makinaleri ve diğer doğal kaynakların yoğun kullanımına neden olmuştur. Ancak enerjinin yoğun kullanımı, halk sağlığını ve çevreyi tehdit eden sorunlar yaratmaktadır. Tarımda enerjinin verimli kullanılması çevre sorunlarını en aza indirebilir, doğal kaynakların tahribatını önleyebilir ve ekonomik bir üretim sistemi olarak sürdürülebilir tarımı teşvik edebilir. Fosil yakıtların sınırlı bir kullanım süresine sahip olması ve yenilenebilir enerji kaynaklarının çevre dostu ve sürdürülebilir enerji sistemleri olması nedeniyle enerjinin önemi her geçen gün artmaktadır (Baran, 2016a).

Çalışma kapsamında yonca üretimi yapan 176 işletmeden toplanan veriler üzerinde enerji kullanım etkinliği ve girdi/çıktı maliyetine ilişkin hesaplamalar yapılmıştır.

- Yonca kuru ot üretiminde dikdörtgen tip balya makinası kullanımı ile doğrudan (8564.76 $MJha^{-1}$) ve dolaylı (18371.36 $MJha^{-1}$) enerji tüketimlerin toplamı 26936.12 $MJha^{-1}$ olarak hesaplanmıştır. Silindirik balya makinası kullanımında ise enerji tüketimi ortalama %7.61 oranında daha yüksek hesaplanmıştır.
- Toplam enerji tüketiminin; yaklaşık %40'ı doğrudan, %60'sı ise dolaylı enerji tüketimleri oluşturmaktadır.
- Dikdörtgen tip balya makinası kullanımı ile 1 kg yonca otu üretimi için 2.94 MJ-3.17 MJ enerji, silindirik balya makinası kullanımı ile büyük balya yapımında 1 kg yonca otu üretimi için 3.18, 3.41 MJ enerji, olarak tespit edilmiştir.
- İlk biçim sonrası biçim işlemlerinde doğrudan enerji tüketimleri daha yüksek bulunmuştur.
- Birim üretim alanı (ha) için tüketilen birim enerji (MJ) miktarına karşılık, üretim sonucunda birim üretim alanından (ha) kazanılan enerji miktarını (MJ) en yüksek silindirik balya makinası kullanılan sistemlerde hesaplanmıştır.
- Dikdörtgen balya makinası kullanılan hasat sistemlerinde enerji etkinliği silindirik balya makinası kullanılan sistemlere oranla %1.73'lük bir fark sağlayabilmiştir.
- Şartlandırıcı kullanımının sayısındaki artış ise; dikdörtgen balya makinası kullanılan hasat sistemlerinde %1.67'lik bir fark sağlarken, bu fark silindirik balya makinası kullanılan sistemlerde %1.7 olarak hesaplanmıştır.

Ülke tarımının geleceği açısından birim üretim alanı başına harcanan bütün girdilerden en yüksek değerde verim alınarak üretimin sürdürülmesi son derece önemlidir. Ülkemiz koşullarını yansıtır şekilde; gübre, ilaç ve mekanizasyon unsurlarına ilişkin birim üretim enerjisi gereksinim değerlerinin öncelikle belirlenmesi bir zorunluluktur. Bu sayede gerçek koşulları yansıtır daha doğru sonuçların üretilmesi mümkün olacaktır. Ayrıca, anket çalışmalarıyla toplanan verilerle ilgili büyük sorunlar yaşanmakta, daha doğru sonuçların elde edilmesine

katkısı olacak fazla sayıda anket verilerinin değerlendirilmesi, çelişkili yanıtlar ve anket iptali nedeniyle mümkün olmamaktadır. Bu amaçla, bilişim teknolojilerinin kullanılmasıyla uygun sayısal hesap ve depolama ortamlarının oluşturulması oldukça önemlidir. Bu gibi ortamlardan süzülecek verilerin optimum işletmecilik ilkeleriyle harmanlanmasıyla, kârlılığı ve enerji etkinliğini düşüren etmenlerle ilgili doğru değerlendirmeler yapılabilmesi mümkün olacaktır.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Effect of Cutting Treatment on Seed Yield and Seed Quality of Dill

Biçimin Dereotu Tohum Verimi ve Kalite Özellikleri Üzerine Etkisi

Ozlem ALAN[1]*, Hulya ILBI[2]

Abstract

Dill, *Anethum graveolens* L., is grown in various regions of the world. It has been used as vegetable and medicinal plant since ancient times. Seed quality is important in dill cultivation and there is limited information on the effects of cutting treatment in this species. This research was carried out to find out the effect of cutting treatment on phenological traits, seed yield and quality of dill at Ege University, Izmir, during 2016-2018. The experiments were carried out in the randomized complete block design with three replications, comprising of cutting treatment for both spring and autumn seeding period. Significant differences were noted in the flowering period, seed yield and quality attributes with cutting treatment for both seeding period. The obtained results showed that the days from sowing to bolting initiation were increased with cutting treatment from 51 days to 65 days in spring seeding period and from 153 days to 184 days in autumn seeding period. The plant height, number of umbels per plant, seed weight per plant were lower in the cut plants in comparison to that of uncut plants for both seeding period. The uncut plants has produced significantly higher plant height (113 cm-spring seeding period; 133 cm-autumn seeding period), number of umbels/plant (8.4-spring seeding period; 10.1-autumn seeding period) and seed weight/plant (6.4 g-spring seeding period; 10.9 g-autumn seeding period). The cutting treatment decreased germination percentage by 9.27% in the spring seeding period and by 12.13% in the autumn seeding period compared to the control plant seeds. Lower mean germination time at 20/30°C (3.77 days-spring seeding period; 4.54 days-autumn seeding period) were also observed in uncut plants. Thus, it was concluded that cutting is not recommended in the vegetative stage in dill seed production as it provided lower seed yield and seed quality for both autumn and spring seed planting periods.

Keywords: *Anethum graveolens* L., Cutting, Phenological observations, Seed weight, Germination

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Öz

Dereotu, *Anethum graveolens* L., dünyanın çeşitli bölgelerinde yetiştirilmektedir. Antik çağlardan beri sebze ve tıbbi bitki olarak kullanılmaktadır. Dereotu yetiştiriciliğinde tohum kalitesi önemlidir ve bu türde biçimin etkileri konusunda sınırlı bilgi bulunmaktadır. Bu araştırma, dereotunun fenolojik özellikleri, tohum verimi ve kalite parametreleri üzerine biçimin etkisini belirlemek amacıyla, 2016-2018 yıllarında Ege Üniversitesi, İzmir'de yapılmıştır. Denemeler, ilkbahar ve sonbahar tohum ekim döneminde, tesadüf blokları deneme deseninde, üç tekerrürlü olarak kurulmuştur. Her iki ekim döneminde de biçim ile çiçeklenme dönemi, tohum verimi ve kalite özelliklerinde önemli farklılıklar kaydedilmiştir. Elde edilen sonuçlar, tohum ekim tarihinden generatif dönem başlangıcına kadar geçen sürenin biçim uygulaması ile ilkbahar tohum ekim döneminde 51 günden 65 güne; sonbahar tohum ekim döneminde 153 günden 184 güne çıktığını göstermiştir. Biçim yapılan bitkilerde bitki boyu, bitki başına şemsiye sayısı ve bitki başına tohum ağırlığı, her iki ekim döneminde de biçim yapılmamış bitkilere göre daha düşük bulunmuştur. Biçim yapılmayan bitkiler, daha yüksek bitki boyu (113 cm-ilkbahar ekim dönemi; 133 cm sonbahar ekim dönemi), bitki başına şemsiye sayısı (8.4-ilkbahar ekim dönemi; 10.1-sonbahar ekim dönemi) ve bitki başına tohum ağırlığı (6.4 g-ilkbahar ekim dönemi; 10.9 g-sonbahar ekim dönemi) meydana getirmiştir. Biçim uygulaması kontrol bitki tohumlarına göre çimlenme yüzdesini ilkbahar ekim döneminde %9.27, sonbahar ekim döneminde ise %12.13 oranında düşürmüştür. Biçim yapılmayan bitkilerde daha düşük ortalama çimlenme zamanı (3.77 gün-ilkbahar ekim dönemi; 4.54 gün sonbahar ekim dönemi) gözlenmiştir. Bu nedenle, dereotu tohumluk üretiminde, hem sonbahar hem de ilkbahar ekim döneminde daha düşük tohum verimi ve tohum kalitesini sağladığı için, vejetatif aşamada biçimin tavsiye edilmediği sonucuna varılmıştır.

Anahtar Kelimeler: *Anethum graveolens* L., Biçim, Fenolojik özellikler, Tohum ağırlığı, Çimlenme

1. Introduction

Dill which has been cultivated since ancient times is native to South West Asia or South East Europe and belongs to the *Apiaceae* (*Umbelliferae*) family. There are two cultivated species of dill in the world: European dill (*Anethum graveolens*) which grows in most parts of the World and Indian dill (*Anethum sowa*) which grows in and around India (Gupta et al., 2012). In addition to its leaves being used as vegetable, both its leaves and seeds are consumed as medicinal and aromatic plants due to the essential oils it contains by 2.5-4% (Carvon, Apiol, Dihydrocarvon, Limonen) and it is also used as a sedative, antispasmodic, diuretic and carminative in babies (Öztürk et al., 2004).

According to the recent statistics, the amount of dill production has increased in Turkey. The amount of production, which was 2.978 tons in 2010, reached to 8.267 tons with an increase of 194% in 2020. While 1.6% of this production is provided by greenhouse production, open field growing accounted for the remaining part of it (Anonymous 2019a). And organic production is carried out for approximately 50 tons of the specified production amount while conventional production is performed for the remaining amount (Anonymous, 2019b). Based on production area, it is observed that 56% of dill production in Turkey is provided by the Mediterranean region, followed by Marmara region by 23%, Aegean region by 9%, and Central Anatolia region by 7% (Yaldız et al., 2018).

Seeds for dill production is provided by various public and private sector institutions. Mostly open pollination varieties are used. Seeds are also provided by farmers who produce their own seeds.

Dill is marketed continuously throughout the year as a green vegetable and is grown both in open field conditions and under plastic tunnels (Yaldız et al., 2018). Single cut is performed when grown as a green vegetable but two cuts are recommended under good care conditions (Vural et al., 2000). For seed production, dill requires cool weather conditions in vegetative development periods and warm and dry weather conditions during seed formation and seed maturity. Thus, seeds can be planted in regions having temperate climatic conditions with relatively warm winters in early spring (February-March) or in autumn (September-October) seasons (Alan et al., 2022). In both seasons, high and low soil temperatures cause failure of field emergence or irregular emergence in this species that is grown by direct seeding and that has a long field emergence period, resulting in product loss (Zehtab-Salmasi et al., 2006; Ghassemi-Golezani et al., 2018). In addition, there have been reports about problems with the quality of the produced dill seeds, such as poor germination and slow and heterogeneous field emergence (Bukharov et al., 2021; Alan et al., 2022).

It was stated that, various production factors such as soil, cultural practices, harvest time, and climate conditions affect seed quality (Delouche, 1980; Balkan, 2019; Kadıoğlu, 2021). Especially climate conditions (maximum and minimum temperature, precipitation, humidity) in the period that starts with flower formation and continues with pollination, fertilization, and seed maturation affect seed quality and yield (Singh et al., 2013). It has also been shown that dill seed yield and quality was affected by some factors such as weather conditions, irrigation, seed harvest time (Zehtab-Salmasi et al., 2006; Ghassemi-Golezani et al., 2018; Alan et al., 2022), seed stalk architecture, disease and pests (Bralewski et al., 2005; Dorota and Bralewski, 2006; Holubowicz and Morozowska, 2011), umbel position (Bukharov et al., 2021). To the best of our knowledge there have been no studies to date investigating the effects of cutting on seed quality in dill, although it was reported that cutting decreased seed yield (Moustafa et al.,1990; Osman and El-Wahab, 2009).

In general, private companies and medicinal and aromatic plant breeders produce dill seed in both autumn and spring seeding seasons depending on years and regions. At the same time, it is noted that farmers who produce their own seeds get their supply of seeds from cut plants. Therefore, in this study we aimed to compare the effects of cutting on phenological traits, seed yield, and quality of dill seeds under temperate climate conditions for spring and autumn seeding period.

2. Materials and Methods

2.1. Plant material and cultural practices

The study was conducted at Ege University Odemiş Vocational Training School field (latitude 38°12'N, longitude 27°52'E, altitude 111 m a.s.l.) and laboratory, and Ege University Seed Technology Application and Research Center laboratory in 2016-2018 period.

Physical and chemical properties of soil of the trial field were given in *Table 1*, climate data were given in *Figure 1*. The soil of the field was clay-loam, neutral, without salt problems and had a low organic matter content.

Table 1. Some physical and chemical characteristics of experimental soil

	Soil Depth, cm	
Characteristics	**0-30**	**30-60**
Organic Matter, (%)	1.34	0.78
Total Nitrogen, (%)	0.081	0.047
Phosphorus, (ppm)	24	28.8
Potassium, (ppm)	210	300
pH	7.9	7.7
Saturation (%)	60.9 (clay-loam)	62.9 (clay-loam)
Electrical Conductivity (MOhms/cm)	0.08	0.17

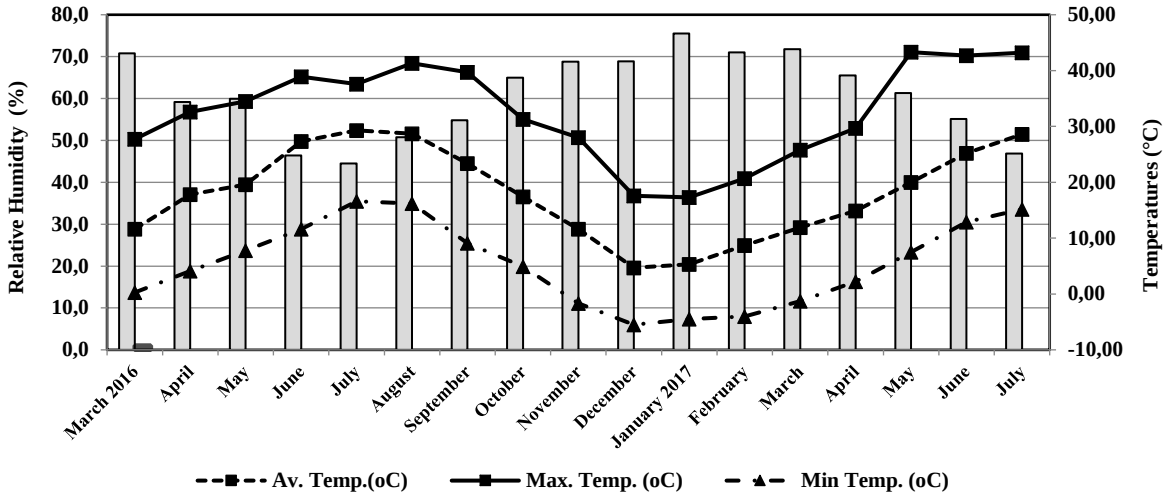

Figure 1. Mean monthly meteorological data of dill growing seasons from March 2016 to July 2017(Anonymous 2017)

For field tests a randomized block design was used with three replications in which 10 m x 1.50 m=15 m^2 plots contained two cutting treatment in both season. And experimental set up was randomized plot design for the seed quality parameters.

Dill seeds of cv. "Gönen" (from Kücükçiftlik Seed Company, Turkey) were sown with a spacing of 30 cm between plants within a row and 35 cm between the row on 20 March 2016 for the spring growing cycle and on 29 September 2016 for the autumn growing cycle. Same fertilization practices were performed in both season. Plants were fertilized with equivalent to 40 kg ha^{-1} nitrogen, 40 kg ha^{-1} P_2O_5 and 20 kg ha^{-1} K_2O (Zehtab-Salmasi et al., 2006) based on the soil test results. Before sowing the soil was fertilized using about 13.3 kg 15:15:15 composite fertilizer per 0.24 acres. Thus potassium was completely added to the base. After removing the nitrogen and phosphorus provided from base dressing, all the remaining nitrogen and phosphorus were applied 30 days after sowing through fertigation as urea (3.5 kg / per acre) and MAP (monoammoniumphosphate; 3.3 kg / per acre). Weed control was conducted mechanically between plots and by hand in rows and drip irrigation method was applied as needed.

Cuttings were performed on May 11, 2016 for spring seeding period, on November 12, 2016 for autumn seeding period when plants reached 15-20 cm in height by cutting back to 3-5 cm above the soil level. In order to investigate the effects of cutting treatment, the following observations and seed yield and quality parameters were studied.

2.2. Phenological observations

When plants enter into generative stage, daily field observations were conducted to determine days to bolting initiation (the emergence of the elongated stalk on which flower buds develop), days to 50% bolting, days to the end of the bolting, days to flower initiation (5% open primary flowers) and days to 50% flower formation from date of sowing on the whole plot basis for both seeding period.

2.3. Seed yield parameters

Seed harvests were performed when seeds matured on main plant but not shed. This period was coincided with mid-July at cut and uncut plants in spring period (55 days after anthesis) and with the end of June at cut and uncut plants in autumn period (65 days after anthesis). During harvest period, 10 plants from the centre of each replicate were harvested randomly in the morning and plant height (cm) and number of umbels per plant were determined. Then the seeds were dried to 8% moisture content in room temperature and seed weight per plant (g) was determined. Subsequently, harvested seeds from each replicate were mixed then stored in sealed glass jars at 5 ± 1°C for three months.

2.4. Seed quality parameters

The seed quality tests were carried out in the laboratory of Ege University, Research and Technology Center for Seed Science. The germination tests were carried out using 8 × 50 seeds. Seeds were sown between moistened paper and kept at a temperature of 5 °C for seven days and then placed into an incubator at 20/30 °C- 16 hours in the dark and 8 hours in the light conditions for the standard germination (SG) test. A low temperature germination (LG) test was performed at 13 °C (ISTA, 2020). Normal seedling percentage were evaluated according to ISTA, (2020) after 21 days for SG test and 30 days for LG test. In addition, during both germination tests, the number of germinated seeds with a 2 mm radicle were counted every 24 h, to calculate mean germination time (MGT). MGT was calculated as Eq 1. (Ellis and Roberts, 1980);

$$\sum (nt) / \sum n \qquad \text{(Eq.1).}$$

where n = number of seeds newly germinated (2 mm radicle) at time t;

t = days from when set to germinate

2.5. Statistical analysis

Analysis were conducted using TARİST statistical software (Açıkgöz et al., 1994) and least significant differences between means were calculated at $P=0.05$

3. Results and Discussion

3.1. Phenological observations

The effects of cutting on phenological characteristics of dills in both growing seasons are presented in *Table 2*. During spring seeding, significant differences were noted in the times from sowing to bolting initiation, 50% bolting, end of bolting and flower initiation ($P \leq 0.05$). Cutting treatment had no effect on the times from sowing to 50% flower formation. Bolting was initiated 51 days (May 12th) after seeds were sown in the uncut plants, while 65 days (May 25 th) after for the cut plants. Similar results were obtained for days to 50% bolting, end of bolting and days to flowering initiation where the span of reproductive phase was decreased. Although cutting had not statistically significant effect on the days to 50% flower formation, this period in cut plants was more extended compared to the uncut plants. It can also be seen that bolting was initiated on May 12th for uncut plants and on May 25th for cut plants while 50% flower formation took place at the end of May for both cut and uncut plants.

In autumn seeding period, cutting treatment had significant effect on bolting initiation ($P \leq 0.01$), 50% bolting, end of the bolting and flower initiation ($P \leq 0.05$), while it had no effect on the times from sowing to 50% flower formation (*Table 2*). Bolting was initiated 153 days (March 1st) after seeds were sown in the uncut plants, while 184 days (April 2nd) after for the cut plants. Also, cutting treatment increased the times from sowing to 50% bolting (from 166 days to 199 days), end of bolting (from 190 days to 206 days), flower initiation (from 173 days to 186 days) in this seeding period. It was also noted that the 50% flower formation took place by mid-April for both cut and uncut plants. This study showed that while the bolting and flowering were initiated in May for spring

seeding cycle, they were initiated earlier (uncut plants-March, cutting plants-April) and were extended for a longer period in autumn seeding cycle (*Table 2*). While phenological properties varied according to genotypes, they can also change depending on cultural applications and climate characteristics. Because a certain vegetative growth is required ahead of bolting initiation, this period caused extension of bolting initiation and flower initiation in cut plants. Similarly, in *Trifolium alexandrinum* L. (Yadav et al., 2015) and *Medicago sativa* (Kowithayakorn and Hill, 1982) late bolting and flower initiation were reported in cut plants.

Table 2. The effect of cutting on bolting and flowering for spring and autumn seeding period in dill.

	Spring			Autumn		
	Uncut plants	**Cut plants**	***Significance***	**Uncut plants**	**Cut plants**	***Significance***
Days to bolting initiation (date)	51 (10 May)	65 (24 May)	*	153 (1 March)	184 (01 April)	**
Days to 50% bolting (date)	65 (24 May)	74 (02 June)	*	166 (14 March)	199 (16 April)	*
Days to the end of bolting (date)	72 (31 May)	81 (09 June)	*	190 (07 April)	206 (23 April)	*
Days to flowering initiation (date)	63 (22 May)	71 (30 May)	*	173 (21 March)	186 (03 April)	*
Days to 50% flower formation (date)	69 (28 May)	73 (01 June)	*ns*	195 (12 April)	200 (17 April)	*ns*

ns = not significant, * = significant at $P \leq 0.05$; ** = significant at $P \leq 0.01$

3.2. Seed yield parameters

In spring seeding period, cutting had significant effect on plant height (*P≤0.01*), number of umbels per plant (*P≤0.05*), and seed yield per plant (*P≤0.05*) (*Table 3*). Cutting treatment decreased the plant height from 113 cm to 89 cm, the number of umbels per plant from 8.4 to 5.8 and the seed yield per plant from 6.4 g to 4.5 g.

In autumn seeding period, the cutting treatment had significant effect on plant height and seed yield per plant (*P≤0.01*) whereas it had no significant effect on the number of umbels per plant (*Table 3*). Plant height of cutting plants was taller by 9% (133 cm-uncut plant; 122 cm-cut plant). The seed yield was decreased by cutting treatments from 10.9 g seed/plant to 9.1 g seed/plant. Although there was no statistically significant difference in the number of umbels per plant in both treatments, the number of umbel per plant decreased by 0.4 with cutting.

Table 3. The effect of cutting on dill seed yield and yield parameters for spring and autumn seeding period

Seeding period		**Plant height (cm)**	**Number of umbels/plant**	**Seed yield/plant (g)**
Spring	Uncut plants	113±1.45	8.4±0.32	6.4±0.38
	Cut plants	89±1.45	5.8±0.32	4.5±0.38
Significance		**	*	*
Autumn	Uncut plants	133±0.73	10.1±0.32	10.9±0.15
	Cut plants	122±0.73	9.7±0.32	9.1±0.15
Significance		**	*ns*	**

ns = not significant, * = significant at $P \leq 0.05$; ** = significant at $P \leq 0.01$
Data are expressed as mean ± standard error

In this study cutting back plants to 3-5 cm above the soil level when plants reached 15-20 cm in height lead to the decrease in plant height, in the number of umbels per plant and in seed yield per plant in both seeding period. Literature in relation to the effect of cutting treatment on the seed yield was varied. Moustafa et al., (1990) mentioned that first cutting of dill 75 days after seeding and second cutting 45 days after that increased seed yield compared to uncut plants. The increases in temperature along with the differences in total temperature values between the two cutting applications may have led to this result. On the other hand, Osman and El-Wahab (2009) argued that one or two cuts in dill and parsley resulted in decrease in seed yield and in components compared to uncut plants. Similar results of cutting treatment had been reported in *Setaria sphacelate* (Dwivedi et al., 1999),

fenugreek (Gill et al., 2001), coriander (Datta et al., 2008), some grass plants (Bhatt et al., 2009), and sorghum (*Sorghum bicolor* (L.) Moench.) (Patil and Merwade, 2016). It was also noted in this study that the cutting treatment decreased the plant height by 21%, the number of umbel per plant by 31% and the seed yield per plant by 30% in spring seeding period but the treatment decreased all yield parameters by 8%, 4% and 16%, respectively in autumn seeding period. Thus, it can be stated that higher decrease on the yield and yield components in spring seeding period was due to the increase in maximum and minimum temperature (*Figure 1*) combined with day length causing bolting initiation in plants with insufficient vegetative growth in this growing period.

3.3. Seed quality parameters

As can be seen in *Table 4*, in spring seeding period the SG (*P≤0.01*), the LG (*P≤0.05*) and the MGT at 20/30 °C (*P≤0.05*) were affected significantly by cutting treatment, but treatment had no effect on the MGT at 13 °C. The SG was 86.3% in uncut plants and 78.3% with cutting treatment. The MGT was increased from 3.77 days to 4.38 days by cutting treatment. While LG were 83.5% in uncut plants, and it was decreased to 80.0% by cutting.

Table 4. The effect of cutting on seed quality of dill for spring and autumn seeding period

Seeding period		SG (%)	MGT at 20/30 °C (days)	LG (%)	MGT at 13 °C (days)
Spring	Uncut plants	86.3±1.40	3.77±0.19	83.5±1.12	8.85±0.13
	Cut plants	78.3±1.40	4.38±0.19	80.0±1.12	8.60±0.13
Significance		**	*	*	*ns*
Autumn	Uncut plants	80.8±1.8	4.54±0.19	75.3±0.95	8.16±0.19
	Cut plants	71.0±1.8	5.15±0.19	59.0±0.95	10.69±0.19
Significance		**	*	**	**

ns = not significant, * = significant at *P*≤0.05; ** = significant at *P*≤0.01
SG: standard germination; MGT: mean germination time; LG: low temperature germination.
Data are expressed as mean ± standard error

The effect of cutting on SG (*P≤0.01*), MGT (at 20/30 °C; *P≤0.05*), LG (*P≤0.01*), and MGT (at 13 °C; *P≤0.01*) in autumn seeding period was also found to be significant (*Table 4*). The cutting decreased SG from 80.8% to 71.0% and LG from 75.3% to 59%. The cutting treatment delayed germination from 4.54 days to 5.15 days at 20/30 °C; from 8.16 days to 10.69 days at 13 °C.

This study showed that higher SG and LG and lower MGT at both temperatures were found in cut plants. There are no data available on the effect of cutting on seed quality in dill. However, cutting treatment had adverse effect on seed quality compared to uncut grass plants in *Setaria sphacelat* (Dwivedi et al., 1999) and in sorghum (*Sorghum bicolor* (L.) Moench.) (Patil and Merwade, 2016). In this research, it was also determined that the cutting treatment decreased the SG by 9% and the LG by 4% in spring seeding period but the treatment decreased the SG and the LG by 12% and 22%, respectively in autumn seeding period. Particularly, the decrease in LG in autumn seeding might be due to the decrease in seed vigor by cutting.

In autumn seeding period, 50% flower initiation occurred in April and the seeds harvested in June. As shown in *Figure 1* minimum and maximum temperatures during seed development stages including pollination, fertilization, and seed maturation were recorded as 2 °C - 29.7 °C in April, as 7.5 °C - 43 °C in May, and as 12.9 °C - 42.7 °C in June, respectively. In spring seeding period, 50% flower initiation occurred in May and the seeds harvested in July. And minimum and maximum temperatures varied between 7.8 °C – 34.5 °C in May, 11.6 °C – 38.9 °C in June, and 16.6 °C – 37.6 °C in July, respectively. Therefore, it may be hypothesized that significant decrease in seed quality parameters in autumn period, particularly in cut plants, may result from extreme temperatures during pollination, fertilization, and seed maturation periods. Decreasing effect of high temperature conditions after flower initiation and thorough the fertilization and seed maturation periods in seed quality has also been reported in *Phaseolus vulgaris, Oriza sativa, Hordeum vulgare* L. and wheat (Siddique and Goodwin, 1980; Ellis et al., 1993¸ Ellis and Pieta Filho, 1992).

According to Bukharov et al. (2021) who studied the short-term (1-5 days) effect of high temperature (40°C) on the growth of the embryo and germination of dill seeds, the degree of development of the embryo determines

seed germination. The reported results showed that the less developed embryos in seeds from secondary umbels are more sensitive to high temperatures during dill seed germination. It can be stated that the extreme temperatures during seed production can lead to less developed embryos in dill seeds.

4. Conclusions

We found that the days to bolting and to flower initiation in cut plants was shorter than in uncut plants but cutting had no effect on the days from sowing to 50% flower formation. Also, while the bolting and flowering initiated in May for spring seeding period, both phenological stages took place earlier (in March for uncut plants- and in April in cut plants-) and times for each stages were longer in autumn seeding period. Plant height, number of umbels per plant and seed weight per plant decreased with cutting treatment. The uncut plants had the highest seed yield and seed quality due to better attributing components. In addition cutting treatment decreased germination percentage at 20/30°C (SG) and at 13°C (LG), and increased mean germination time at 20/30°C. Thus it can be concluded that cutting treatment of dill at vegetative stage to market green leaves is not advisable for commercial seed production of dill.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Evaluation of NASA POWER Climatic Data against Ground-Based Observations in The Mediterranean and Continental Regions of Turkey

Türkiye'nin Akdeniz ve Karasal İklim Bölgelerinde NASA POWER İklim Verilerinin Yerden Yapılan Gözlemlere Karşı Değerlendirilmesi

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Abstract

The weather reanalysis datasets are very advantageous data types worldwide that fill the gaps of missed measuring data and are alternatives that compensate for the scarcity of observed climate data. The main purpose of this study was to evaluate the effect of horizontal distance, altitude, and climatic regions compared to sea level on NASA POWER reanalysis data for daily temperature variables, relative humidity, and wind speed observed in meteorology stations in the Mediterranean and Continental regions of Turkey. For this purpose, three different meteorology stations (Antalya airport, Elmalı, Teffenni) from the Mediterranean region with different distances and elevations compared to sea level and one station (Ankara) far from the Mediterranean region with continental climate were selected. The statistical approach used to compare observed and estimated values in this study was determination coefficient (R^2), Nash-Sutcliffe Efficiency (NSE), Root Mean Square Error (RMSE), Normalized Root Mean Square Error (NRMSE), and Mean Bias Error (MBE). The results showed a high relation between the POWER reanalysis dataset and observed data for all parameters except wind speed. For daily maximum, minimum and mean temperature, the R^2 and NSE achieved higher than 0.91 and 0.88 respectively, while the mean bias error MBE ranged between -3 °C up to +2 °C and the RMSE was less than 4 °C in all stations. Additionally, POWER estimated data correlation accuracy for temperature variables increased toward higher altitudes in the study area. Similarly, this performance was followed by relative humidity, increasing relation accuracy toward higher elevated regions. The R^2 was higher than 0.69 in higher altitudes and less than 0.4 in lower elevations. The MBE for relative humidity ranges -2% in Antalya to +9% in Ankara, and the RMSE attained less than 13.81% in all regions. The POWER daily wind speed did not show relation with observed data without adjusting for elevation and seasonal bias correction. Overall, it was concluded that the NASA POWER dataset could predict temperature and relative humidity over study area and give a promising result if used in research, water, and agricultural decision-making where observation data are not available.

Keywords: Decision-making, Estimation, Global atmospheric models, Meteorological data, Reanalysis data

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Öz

İklimsel parametreler için yeniden analiz veri kümeleri, dünya çapında ölçülemeyen ya da eksik verilere alternatifler olan çok avantajlı veri türleridir. Bu çalışmanın temel amacı, ülkemizin Akdeniz ve karasal iklime sahip bölgelerindeki meteoroloji istasyonlarında ölçülen ve NASA POWER yeniden analiz yöntemiyle tahmin edilen günlük sıcaklık, bağıl nem ve rüzgâr hızı parametrelerine ait verilerin deniz seviyesine göre yatay mesafe, yükseklik ve iklim bölgelerinin etkisine bağlı olarak değerlendirmektir. Bu amaçla, Akdeniz bölgesinden deniz seviyesine göre farklı yatay uzaklıkta ve kotlarda üç farklı meteoroloji istasyonu (Antalya havalimanı, Elmalı, Teffenni) ile Akdeniz bölgesine uzak karasal iklime sahip bir istasyon (Ankara) seçilmiştir. Bu çalışmada ölçülen ve tahmin edilen değerleri karşılaştırmak için, determinasyon katsayısı (R^2), Nash-Sutcliffe Verimliliği (NSE), Ortalama Kareler Hatasının Karekökü (RMSE), Normalleştirilmiş Ortalama Kareler Hatasının Karekökü (NRMSE) ve Ortalama Yanlı Hatası (MBE) performans kriterleri kullanılmıştır. Sonuçlar, rüzgâr hızı dışındaki tüm parametreler için POWER yeniden analiz veri seti ile gözlemlenen veriler arasında yüksek bir ilişki göstermiştir. Günlük maksimum, minimum ve ortalama sıcaklık için, R^2 ve NSE sırasıyla 0.91 ve 0.88'den daha yüksek bir değere ulaşırken, MBE -3 °C ile +2 °C arasında değişkenlik gösterdi. İstasyonların tamamında RMSE'nin 4 °C az olduğu belirlenmiştir. Ayrıca, sıcaklık değişkenleri için POWER tahmininin veri doğruluğu, yükselen irtifaya bağlı olarak artış göstermiştir. Ortalama bağıl nem için de benzer sonuçlar elde edilmiştir. R^2, yüksek irtifalarda 0,69'dan fazla ve alçak irtifalarda 0,4'ten düşük olarak elde edilmiştir. Tüm bölgelerde RMSE değerinin %13.81'den daha az olduğu saptanmıştır. POWER günlük rüzgâr hızı, farklı yükseklik ve iklim tiplerinde gözlemlenen verilerle iyi bir ilişki göstermemiştir. Sonuç olarak, NASA POWER veri setinin çalışma alanı üzerindeki sıcaklık ve bağıl nemi tahmin edebileceği ve gözlem verilerinin bulunmadığı araştırma, su ve tarımsal karar verme süreçlerinde kullanılması durumunda umut verici sonuçlar verebileceği sonucuna ulaşılmıştır.

Anahtar Kelimeler: Karar verme, Tahmin, Küresel atmosferik modeller, Meteorolojik veriler, Yeniden analiz verileri

1. Introduction

Climate information is considered vital in the decision-making of the environmental, agricultural, and industrial services. Empirical models are widely applied for decision making of crop water requirement and irrigation scheduling which is highly dependent to weather information data (Konukcu et al., 2020; Sener et al., 2007). Spatially surveying and figuring out promising areas for particular cultivars and tracking of local water use are the maximum sizable targets withinside the agricultural sector (White et al., 2008). Spatially monitoring of specific traits of a crop in a region with different characteristics, requires long-term daily weather records well covering the targeted area (Daly, 2006). Although satellite and measuring station-based meteorological has advanced in many nations, however, in many growing countries either measuring stations are missed, measuring meteorological station records are low in quality, or observing weather information is not available for free (Rodrigues and Braga, 2021). Therefore, the NASA POWER reanalysis meteorological data from a mix of observation, satellites, and global atmospheric models is considered as one of the most crucial climate data sources, which can be used to fill the gaps and compensate for the shortage of measured weather data (Aboelkhair et al., 2019). There are many reanalysis datasets available around the world (CFSR, ERA, JRA-55, MERRA, NCEP/NCAR, and POWER) and these datasets has given acceptable results in many regions around the globe (Chen et al., 2019; Chen et al., 2014; Bao and Zhang 2013). However, these reanalysis datasets are either not globally, lack some of weather parameters, or need specific data processing skills. Therefore, the NASA POWER reanalysis meteorological data from a mix of observation, satellites, and global atmospheric models is considered as one of the most crucial climate data sources, which is a single point and global coverage with hourly, daily, annually temporal average, and its user-friendly interface that helps any user to access near-real-time climatic data for any part of the world. These can be used to fill the gaps and compensate for the shortage of measured weather records (Aboelkhair et al., 2019). Furthermore, many studies (Schneider et al., 2013; Dee et al., 2011; Kobayashi et al., 2015; Kanamitsu et al., 2002; Rienecker et al., 2011; Chandler et al., 2013) evaluated most of the parameters from various mentioned reanalysis datasets against different sources of observation around the globe, and the majority of these investigations showed a close agreement of reanalysis data with the ground-based observation datasets. On the other hand, there are a small number of studies that investigated the performance of POWER datasets.

Rodrigues and Braga (2021) investigated the applicability of POWER maximum and minimum air temperature, wind speed, relative humidity, and solar radiation in Portugal. The result of this study recommended the accuracy of POWER variables with observation data for all parameters except wind speed. Similarly, Aboelkhair et al. (2019) assessed POWER satellite and model datasets for minimum, average, maximum temperature, dew point, and relative humidity in Egypt. This study concluded that a good relationship existed between POWER and observed data for all temperature variables demonstrating an RMSE of 5 °C but the estimated relative humidity was not predicted correctly with the RMSE of 11.6%. Bai et al. (2010) evaluated the POWER model-derived and observation weather dataset for daily maximum and minimum temperatures and total solar radiation, resulting agreement of POWER and the monitored data with acceptable accuracy in China. POWER daily temperature variables tested by White et al. (2008) in the continental climate of the USA showed a good fit with observed data demonstrating 4.1 °C and 3.7 °C differences for maximum and minimum temperatures, respectively. Moreover, this investigation suggested the possibility of data improvement by correcting seasonal bias and ground elevation effect. Likewise, an assessment was conducted in Italy by Negm et al. (2017) to validate the suitability of POWER data in the prediction of reference evapotranspiration through daily total solar radiation, wind speed, relative humidity, minimum, average, and maximum air temperatures. This investigation proved the accuracy of the NASA POWER dataset. However relative humidity was not accurately estimated in comparison to coastal weather stations. Another study has been carried out by Monteiro et al. (2018) in Brazil, concluding similar results for the coastal relative air humidity. There are some studies using satellite and model-derived datasets evaluating watershed runoff, land and sea surface temperature, and climate change projections in Turkey. These studies have claimed satisfaction and the accuracy of satellite and model-based meteorological parameters in modeling of hydrology and agro-climatology (Alramlawi and Fistikoglu, 2022; Kuzay et al., 2022; Tuzcu Kokal and Musaoğlu, 2021; Bicer, 2020; Irvem and Ozbuldu 2019; Tan, 2019; Demircan et al., 2017). However, the NASA POWER reanalysis dataset for different weather variables over Turkey has not been assessed yet. So, The main aim of the study was to evaluate the accuracy of daily measured meteorological variables with daily POWER Dataset (daily maximum, minimum, and mean air temperature, relative humidity, and wind speed) in the lower elevation of the coastal area to the higher elevation of the inland area in Turkey.

2. Materials and Methods

2.1. Study Area

This study took place in two different climatic zones of the study area located in specific geographical coordination datum shown in *Table 1*. Due to the geographical location of Antalya, the meteorology stations vary in terms of their distance from the sea and their altitudes Since this condition is directly related to the purpose of the study, meteorological stations located in Antalya in the Mediterranean region were selected. The altitude ranges are between zero meters in the Mediterranean Sea to 1142 meters in the Elmalı district *(Figure 1).* The Mediterranean zone, specifically Antalya province has cool, rainy winters and hot, moderately dry summers. Higher altitudes across the Mediterranean zone block the Mediterranean effects to increases inland, giving the Central Anatolia (Ankara) area a continental climate. The Ankara region is high exposure to extremes than are the coastal areas. Despite intense extreme winters at the plateau, the summers are warm and dry (MGM, 2022).

Table 1. Geographic information of the study area

Station	Longitude	Latitude	Climate type	Altitude (m)	Distance from sea (km)	Ranges of data
Antalya-(Airport)	30.7990	36.9076	Mediterranean	64	8	Jan/2016-Dec/2020
Elmalı	29.9121	36.7372	Mediterranean	1142	55	Jan/2016-Dec/2020
Teffenni	29.7794	37.3161	Mediterranean	1095	90	Jan/2016-Dec/2020
Ankara	32.8637	39.9727	Continental	891	185	Jan/2016-Dec/2020

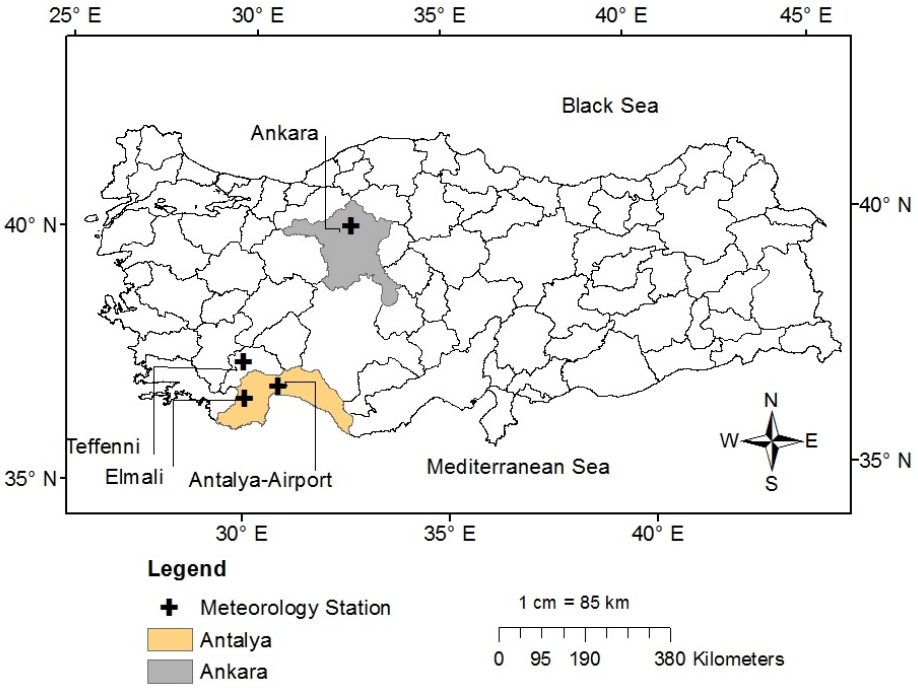

Figure 1. Climatic stations in the study area

2.2. Data

The observed daily meteorological data for the period of five years (from the start of January 2016 up to the end of December 2020) were obtained from the Turkish General Department of Meteorology which had recorded by automated meteorological ground stations located in the Antalya airport, Elmalı, Teffenni, and Ankara. The height of the wind speed sensor in these measuring stations is 10 meters from the ground surface while the temperature and relative humidity, and sunshine duration sensors are installed two meters high from the surface, respectively (MGM, 2022). The daily weather data for the same period and sensor were downloaded from the NASA POWER website (NASA POWER, 2022) for each station based on their geographic coordination points (*Table 1*).

2.3 Method

We selected Antalya airport, Elmalı, and Teffenni stations in the Mediterranean, and the Ankara station in the continental climate region of Turkey. Since the elevation of these measuring stations varies from each other, therefore, we expected to test NASA POWER weather variables in different elevation and climatic regions. All observed daily weather parameters (average temperature (°C), maximum temperature (°C), minimum temperature (°C), relative humidity (%), and wind speed (m s^{-1}) have been processed for quality check by R-Instat software. One-day missed measuring data were interpolated from one day before and after the missing day based on the linear regression method. The continued missed values for more than a day were deleted from the database. Furthermore, we used a total number of (1827) clear values for all variables in the measuring stations of Antalya airport, Ankara, and Elmalı while the total number of clear daily values used for temperature variables, relative humidity, and wind speed in Teffenni station was 1823, 1793, and 1823, respectively. The measured and estimated datasets were evaluated based on determination coefficient (R^2), Nash-Sutcliffe Efficiency (NSE), Root Mean Square Error (RMSE), Normalized Root Mean Square Error (NRMSE), and Mean Bias Error (MBE) that were listed in equations (1-5) given below:

$$R^2 = \frac{[\sum_{i=1}^{n}(X_i-\overline{X_i})(Y_i-\overline{Y_i})]}{\sum_{i=1}^{n}(X_i-\overline{X_i})^2 \sum_{i=1}^{n}(Y_i-\overline{Y_i})^2} \quad \text{(Eq.1)}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_i-Y_i)^2}{n}} \quad \text{(Eq.2)}$$

$$NRMSE = \frac{RMSE}{X_i}100 \quad \text{(Eq.3)}$$

$$MBE = \frac{\sum_{i=1}^{n}(X_i-Y_i)}{n} \quad \text{(Eq.4)}$$

$$NSE = 1 - \frac{\sum_{i=1}^{n}(X_i-Y_i)^2}{\sum_{i=1}^{n}(X_i-\overline{X_i})^2} \quad \text{(Eq.5)}$$

where Xi, Yi, $\bar{X}$i, and $\bar{Y}$i represents observed, estimated values, mean observed, and mean estimated values, respectively. Each sample is demonstrated by (i) and the number of samples pinpointed as (n) in the equations. The best and worst determination coefficient values for R^2 and NSE presented more than 0.75 up to 1 and less than 0.25 respectively (Henseler et al., 2009). The smaller value, the better accuracy defines RMSE, and the goodness of fit is below than 15% shown by NRMSE. The MBE measures the over or underestimation of predicted data through its positive and negative values (Willmott and Matsuura, 2006).

3. Results and Discussion

3.1. Evaluation of NASA POWER daily mean, maximum and minimum temperature

The NASA POWER successfully proved the estimation of daily mean, minimum and maximum temperature in all stations indicating a relation coefficient value of higher than 0.9, showing an excellent accuracy when compared with five years of daily observed data in different altitudes of the study area *(Figure 2-4).* These results were obtained by adopting the determination coefficient and other statistical calculations performed in *Table 2*.

The POWER mean temperature indicators demonstrated a maximum RMSE of 3.05 °C day^{-1} and MBE of -2.74 °C day^{-1} for Ankara station followed by Antalya and Teffenni stations recording MBE and RMSE of -1.62°C day^{-1}, 2.45°C day^{-1} and -0.09, 1.37, respectively, while Elmalı station kept its positive MBE of 1.13°C day^{-1}. The POWER mean temperature's underestimation slightly increased in Antalya and Ankara regions. According to mentioned statistical criteria illustrated in *Table 2*, the POWER mean temperature estimation was successful in Elmalı and Teffenni regions but there was a slight underestimation in Ankara and Antalya stations (*Figure 2*). Similarly, the relation of simulated maximum temperature was sufficiently high in the Teffenni region (*Figure 3*) having the RMSE, MBE, and NSE of 1.69 °C day^{-1}, -0.84°C day^{-1}, and 0.96 respectively. Additionally, maximum RMSE was calculated in Antalya 2.78°C day^{-1} followed by Ankara 2.46 °C day^{-1} and Elmalı 2.39 °C day^{-1} (*Table 2*). The maximum MBE -1.95 °C day^{-1} determined in Ankara; describing an underestimation of about 2°C in the region. Despite, representing a high determination coefficient of NASA POWER minimum temperature

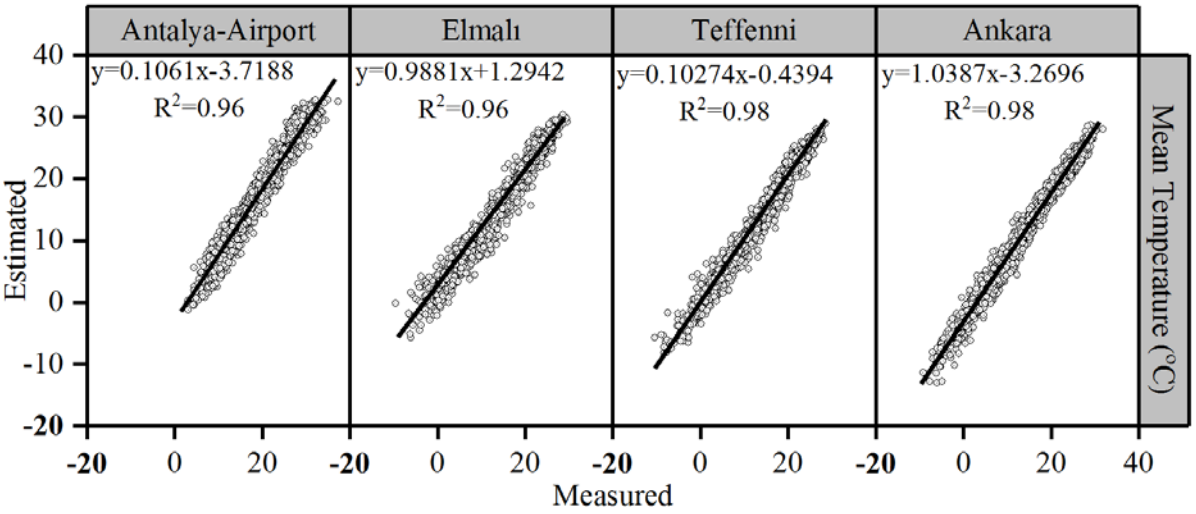

Figure 2. The relation of NASA POWER daily estimated and measured mean temperature

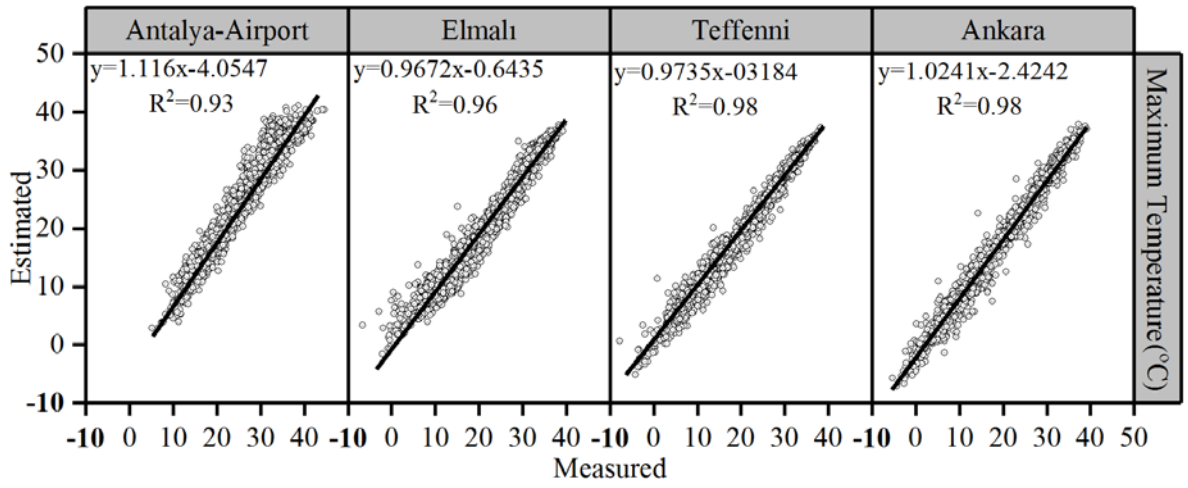

Figure 3. The relation of NASA POWER daily estimated and measured maximum temperature

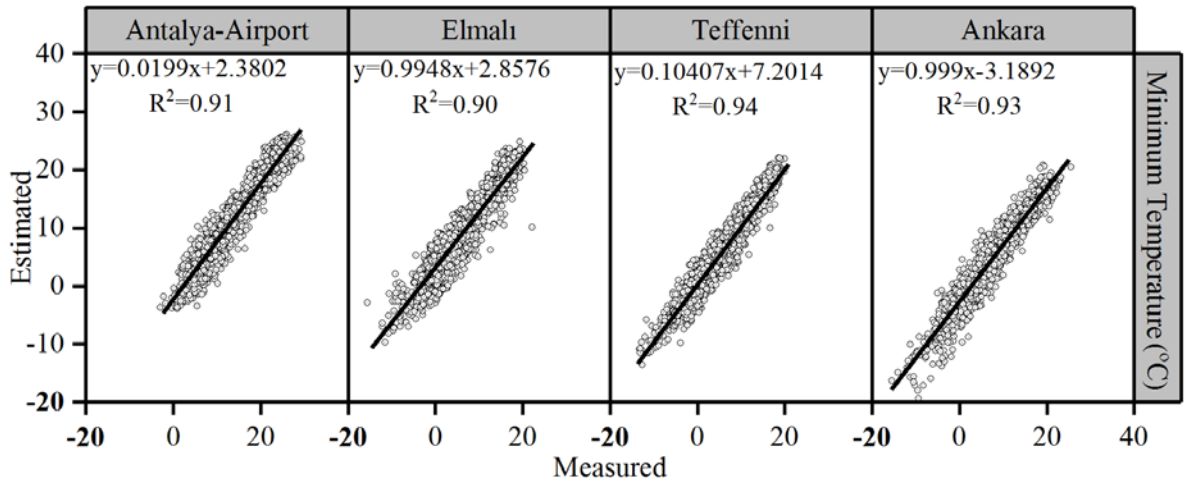

Figure 4. The relation of NASA POWER daily estimated and measured minimum temperature

Table 2. Statistical evaluation of observed and NASA POWER predicted daily temperature parameters

Parameter	Station	R^2	RMSE	NRMSE	MBE	NSE
Mean Temperature (°C)	Antalya airport	0.96	2.45	0.12	-1.62	0.88
	Elmalı	0.96	1.95	0.14	1.13	0.94
	Teffenni	0.98	1.37	0.10	-0.09	0.97
	Ankara	0.98	3.05	0.22	-2.74	0.87
Maximum Temperature (°C)	Antalya airport	0.93	2.78	0.11	-1.13	0.87
	Elmalı	0.96	2.39	0.11	-1.35	0.93
	Teffenni	0.98	1.69	0.08	-0.84	0.96
	Ankara	0.98	2.46	0.12	-1.95	0.93
Minimum Temperature (°C)	Antalya airport	0.91	3.02	0.20	-2.08	0.8
	Elmalı	0.90	3.62	0.49	2.82	0.73
	Teffenni	0.94	1.93	0.28	0.47	0.92
	Ankara	0.93	3.8	0.46	-3.19	0.74

with the ground-based measured minimum temperature in the study area, The POWER data had underestimated minimum temperature by 3°C in Ankara regions, showing the effect of continental climate in this region (*Figure 4*). Ankara station has shown a negative MBE -3.19°C day^{-1} followed by Antalya station having a daily -2°C of underestimation, while Elmalı showed a positive MBE 2.82°C day^{-1} value pinpointing a slight overestimation. This variable was normally estimated in the Teffenni station showing a daily MBE of 0.47°C day^{-1} (*Table 2*).

The comparison of temperature data showed good agreement with POWER temperature variables in the Mediterranean region of Turkey. There was a high relation ($R^2 \geq 0.9$) of NASA POWER temperature variables in the study area with different elevations while White et al. (2008) reported a relationship of less than ($R^2 \leq 0.88$) in major parts of the USA. They concluded that temperature has highly affected by elevation in the mountainous and coastal area while our results showed that elevation and coastal regions do not affect temperature variables. We assume that this variability might be due to other sources of errors such as industrialization, land-use intensity, and land cover variability, which can affect temperature variables, specifically the maximum temperature. Furthermore, temperature variables might be affected by point-based and regional-based correlations since regional-based temperature might be higher in residential areas, industrialized regions, and rock lands in comparison to the dense vegetation and well-covered grasslands. On the contrary, the minimum temperature might fall much more down during the night throughout the winter season. These factors could be sensed in regional-based POWER temperature variables pixel by pixel while point-based POWER temperature variables are not exposed to mentioned factors. Additionally, a good correlation of point-based POWER temperature variables was proved in various regions including the Mediterranean, desert lands, and the mountainous area when they reported a good correlation of point-based POWER temperature variables in Egypt and Oman (Aboelkhair et al.,2019, and Marzouk, 2021). The NASA POWER temperature data at the two-meter above surface is implying the reliability and accuracy of these datasets around the globe. Hence, we can strongly suggest the applicability of NASA POWER temperature variables as the complement of missing data or applying instead of measured low-quality temperature parameters in the study area.

3.2. Evaluation of NASA POWER daily relative humidity

Based on the data shown in *Table 3* and *Figure 5*, the estimated daily relative humidity from the POWER reanalysis dataset was shown a good relationship with the observation data except for the Antalya airport station, showing the R^2 of 0.4 and MBE of -2.33%. The maximum R^2 value (0.77) and MBE (9.13%) were recorded in the Ankara-based station followed by the Teffenni (R^2=0.72) and Elmalı (R^2=0.70) stations with the MBE of 2.27% and 5.32% respectively.

Table 3. Statistical evaluation of observed and NASA POWER predicted daily relative humidity (%) parameter

Station	R^2	RMSE	NRMSE	MBE	NSE
Antalya airport	0.41	13.81	0.22	-2.33	0.26
Elmalı	0.69	12.24	0.21	5.32	0.59
Teffenni	0.72	9.72	0.16	2.27	0.64
Ankara	0.77	12.48	0.22	9.13	0.48

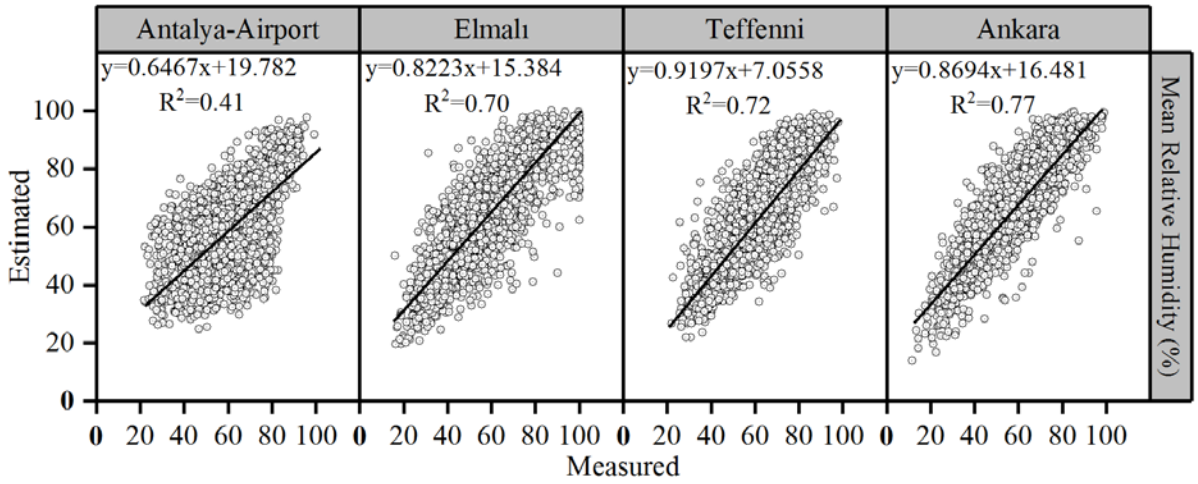

Figure 5. The relation of NASA POWER daily estimated and measured mean relative humidity

Based on the literature review, NASA POWER has estimated a slightly lower percentage of relative humidity in lower altitudes. However, a higher relation between POWER estimated relative humidity was recorded in higher elevation (*Table 3).* This little uncertainty could be obvious for estimating RMSE 13.81% and 12.48% for Antalya and Ankara stations respectively. The RMSE and R^2 for Elmalı and Teffenni Stations were 12.24%, 0.69 and 9.72%, 0.72 respectively. Generally, the estimated relative humidity showed an acceptable relationship in different part of the Mediterranean region and a good correlation to regions with a stable climate and higher elevation. The previous study carried out in Brazil by Monteiro et al. (2018) also reached the same conclusion regarding the effect of elevation and Mediterranean on the estimation of relative humidity by NASA POWER. However, Aboelkhair et al. (2019) stated disagreement of NASA POWER-based estimation of monthly relative humidity with a relationship of ($R^2 \leq 0.1$) in coastal weather stations but our result for daily relative humidity shows a relationship range of ($R^2 = 0.7$ or ≥ 0.5) in the Mediterranean and continental regions. Therefore, we can conclude that distance from the sea might affect the correlation of POWER relative humidity.

3.3. Evaluation of NASA POWER daily wind speed

NASA POWER estimated wind speed showed the lowest relation with the observation variable among all parameters *(Table 4).* The maximum R^2 (0.45) of estimated wind speed was shown in the Antalya station describing disagreement of estimated wind speed values with the observed data *(Figure 6).*

These values gradually decreased for Teffenni, Elmalı, and Ankara stations with a much lower determination coefficient of (0.45), (0.35), and (0.18), respectively. Furthermore, the lowest RMSE and MBE were recorded 0.33 m s^{-1} and -0.47 m s^{-1} for Antalya airport followed by Elmalı station with an RMSE and MBE of 1.23 m s^{-1} and 1.01 m s^{-1} respectively. The higher RMSE (2.07 m s^{-1}) and MBE (1.74 m s^{-1}) was found in Teffenni station followed by Ankara which represented 1.68 m s^{-1} of RMSE and 1.13 m $s^{-1}$of MBE in the study area (*Table 4*).

Table 4. Statistical evaluation of observed and NASA POWER predicted daily relative humidity parameter

Station	R^2	RMSE	NRMSE	MBE	NSE
Antalya airport	0.45	0.33	0.33	-0.47	0.32
Elmalı	0.35	1.23	0.94	1.01	-6.93
Teffenni	0.45	2.07	2.05	1.74	-36.46
Ankara	0.18	1.68	0.82	1.13	-1.81

Wind circulations prevalence remained challengeable in the territory of Turkey due to its being surrounded on three sides by the sea and varied topography. Rapid changes of pressure and availability of high-altitude mountains across the study area interrupt wind speed and its direction to the region (Malanotte-Rizzoli and Bergamasco, 1989). This could be very apparent withinside the Ankara area with its surrounding high mountains that decrease the influence of the Mediterranean weather and create a different microclimate in central Anatolia. The rugged topography and surrounding oceans are the main reasons that affect wind speed and its direction and are tough to be estimated by weather global models before adjusting for elevation and seasonal bias correction.

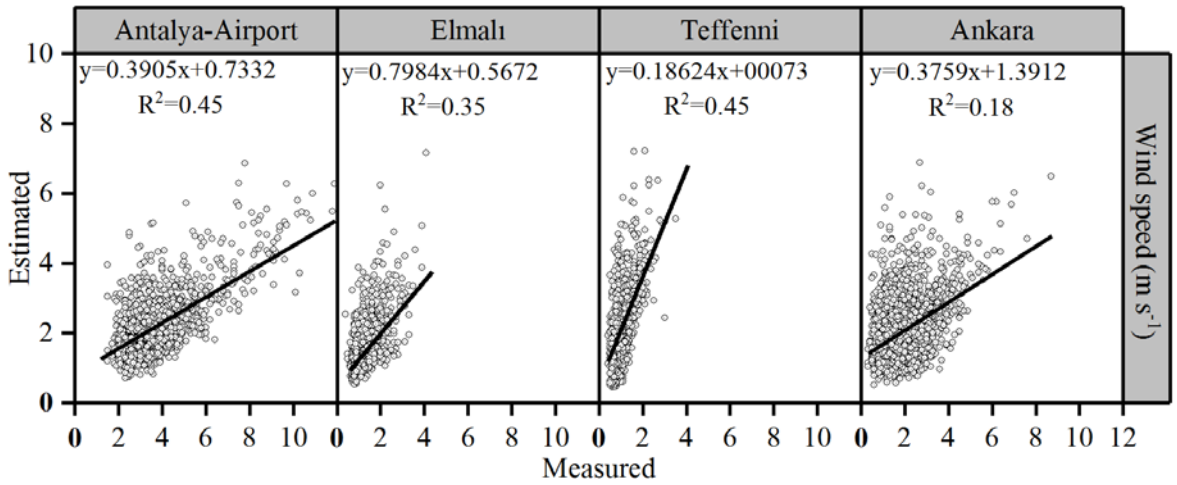

Figure 6. The relation of NASA POWER daily estimated and measured mean wind speed

4. Conclusions

Weather data is a notable factor for water resource management. However, data availability with good quality is still a significant challenge in the majority of the regions around the world. Therefore, assessing the usefulness of applying daily reanalysis data like NASA POWER as an alternative to ground observations is highly required. The results showed a high relation between the POWER reanalysis dataset and observed data for all parameters except wind speed. For maximum, minimum, and mean temperature, the coefficient of determination (R^2) and Nash Sutcliff model efficiency (NSE) achieved higher than 0.91 and 0.88, respectively. The mean bias error (MBE) ranged between -3 °C to +2 °C, and the root mean square error (RMSE) reached less than 4°C in all stations. Additionally, POWER estimated data correlation accuracy for temperature variables increase toward higher altitudes in the study area. Similarly, this performance was followed by relative humidity, increasing correlation accuracy toward higher elevated regions. The R^2 was higher than 0.69 in higher altitudes and less than 0.4 in lower elevations. The MBE for relative humidity ranged from -2 % in Antalya to +9% in Ankara, and RMSE attained less than 13.81% in all regions. Our assessment's findings demonstrated that POWER-based data can estimate most of the climatic data such as maximum, minimum, and mean temperature, and relative humidity with high accuracy. However, wind speed and precipitation of NASA POWER simulated data estimations still need improvements. To sum up, NASA POWER model-simulated data could be frightful to obtain weather data sets where ground weather station data is not available. Nevertheless, additional studies suggested validating the use of NASA POWER in estimation of water requirement through calculation of evapotranspiration, and crop yield response to various weather parameters in the study area.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Traditional Machine Learning-Based Classification of Cashew Kernels Using Colour Features

Kaju Çekirdeklerinin Renk Özellikleri Kullanılarak Geleneksel Makine Öğrenmesine Dayalı Sınıflandırılması

Geofrey Prudence BAITU[1*], Omsalma Alsadig Adam GADALLA[2], Yeşim Benal ÖZTEKİN[3]

Abstract

Cashew is one of the major commercial commodities contributing to the national economy of Tanzania as foreign revenue. And yet still the processing of cashew is run locally using manual labour for a big part. If processed well under ideal conditions, cashews kernels are expected to be white in colour. But due to various factors like prolonged roasting in the steam chambers or over-drying, some cashew kernels tend to have a slight brown colour, and these are referred to as scorched cashews. Despite sharing the same characteristics with white cashew kernels, including nutritional quality, these cashew kernels are supposed to be graded differently. In many places around the world, particularly in Tanzania, the sorting and grading process of cashew kernels is performed by hand. In international trade, cashew grading is very important and this means more effective and consistent methods need to be applied in this stage of production in order to increase the quality of the products. The objective of this study was to evaluate the use of traditional Machine Learning techniques in the classification of cashew kernels as white or scorched by using colour features. In this experiment, various colour features were extracted from the images. The extracted features include the means (μ), standard deviations (σ), and skewness (γ) of the channels in RGB and HSV colour spaces. The relevant features for this classification problem were selected by applying the wrapper approach using the Boruta Library in Python, and the irrelevant ones were removed. 5 models are studied and their efficiencies analysed. The studied models are Logistic Regression, Decision Tree, Random Forest, Support Vector Machine and K-Nearest Neighbour. The Decision Tree model recorded the least accuracy of 98.4%. The maximum accuracy of 99.8% was obtained in the Random Forest model with 100 trees. Due to simplicity in application and high accuracy, the Random Forest is recommended as the best model from this study.

Keywords: Logistic Regression, Decision Tree, Random Forest, Support Vector Machine K-Nearest Neighbour, Cashews

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* This study is summarized from the MSc. thesis.

Öz

Kaju, Tanzanya'nın ülke ekonomisine dış gelir olarak katkı sağlayan başlıca ticari ürünlerden biridir. Kaju çekirdeklerinin işlenmesi, halen büyük ölçüde el emeği kullanılarak yerel olanaklarla yapılmaktadır. İdeal koşullarda iyi işlenirse kajuların beyaz renkte olması beklenir. Ancak, buhar odalarında uzun süre kavurma veya aşırı kurutma gibi çeşitli faktörler nedeniyle, bazı kaju çekirdekleri hafif kahverengi bir renge dönüşebilmektedir. Renk değiştirmiş bu kajulara kavrulmuş kaju denir. Besin kalitesi de dahil olmak üzere beyaz kaju çekirdekleri ile aynı özelliklere sahip olmasına rağmen, renk ve görünüm tüketicilerin kalite algısını etkilediği için bu kaju çekirdeklerinin ayrılması gerekmektedir. Tanzanya başta olmak üzere dünyanın pek çok yerinde kaju çekirdeklerinin ayırma ve sınıflandırma işlemi elle yapılmaktadır. Uluslararası ticarette, kaju sınıflandırması çok önemli olup ürün kalitesini artırmak için üretimin bu aşamasında daha etkili ve tutarlı yöntemlerin uygulanması gerektiği anlamına gelir. Bu çalışmanın amacı, kaju çekirdeklerinin beyaz veya kavrulmuş olarak sınıflandırılmasında renk özellikleri kullanılarak geleneksel Makine Öğrenmesi tekniklerinin kullanımının değerlendirilmesidir. Bu çalışmada, görüntülerden farklı renk özellikleri çıkarılmıştır. Çıkarılan özellikler, RGB ve HSV renk uzaylarında kanalların ortalamaları (μ), standart sapmaları (σ) ve çarpıklığını (γ) içerir. Python'da Boruta Kütüphanesi kullanılarak sarmal (*wrapper*) yöntemi uygulanarak bu sınıflandırma problemi için ilgili özellikler seçilmiş ve ilgili olmayanlar çıkarılmıştır. Bu çalışmada 5 model çalışılmış ve verimlilikleri analiz edilmiştir. Değerlendirme teknikleri Lojistik Regresyon, Karar Ağacı, Rastgele Orman, Destek Vektör Makinesi ve K-En Yakın Komşu (KNN) yöntemleridir. Karar Ağacı modeli, %98,4 ile en düşük doğruluğu vermiştir. 100 ağaçlı Rastgele Orman modelinde maksimum %99,8 doğruluk elde edilmiştir. Uygulamadaki basitliği ve yüksek doğruluğu nedeniyle Rastgele Orman bu çalışma için en iyi model olarak önerilmektedir.

Anahtar Kelimeler: Lojistik Regresyon, Karar Ağacı, Rastgele Orman, Destek Vektör Makinesi ve K-En Yakın Komşu (KNN), Kaju fıstığı

1. Introduction

The cashew tree (*Anacardium occidentale*) is an evergreen tropical tree of the *Anacardiaceae* family that produces cashew nuts and cashew apples. This tree can grow to a height of 8-20 m depending on different factors like climate and soil characteristics, also there are dwarf cultivars that can be as short as 6 m (Catarino et al., 2015). In general, all types of nuts have numerous health benefits to humans (Karcık and Taşan, 2018). With different kinds of nuts in the market like, pistachios, macadamias, peanuts, almonds and hazels, the low sugar, rich fibre, heart-healthy fats and plant protein content of cashew nuts make them one of the most edible nuts in the world (Kilanko et al., 2020). Tanzania is one of the cashew producers in the world and due to its good soil condition and favourable weather, Tanzania is famous for producing premium quality cashew nuts. Cashew nut plays a major role in Tanzania's economy as one of the main cash crops, in the season 2019/20 about 232.7 tons of cashew were produced showing an increase in production from the previous crop season where 225.1 tons were produced as indicated in (*Figure 1*), (Faria, 2021). Cashew nut processing can be summarized into six steps which are roasting, cutting, drying, humidifying, peeling and grading (Muniz et al., 2006). In order to meet international standards, the grading process becomes a crucial part so, it has to be done carefully (Kumar et al., 2013). Based on their size, shape and colour cashew kernels are visually inspected and graded into grades. Currently, in many places the sorting and grading process is done manually by using human labour, this makes the process tedious, subject to human errors, inconsistent as well as time-consuming and this raises a concern to apply automated ways to perform this task (Mehak and Veena, 2018). The use of mechanization for agriculture production has a crucial significance in the quality of the product (Özpınar and Çay, 2018). And as mechanization is for human physical labour, so is artificial intelligence for human mind labour.

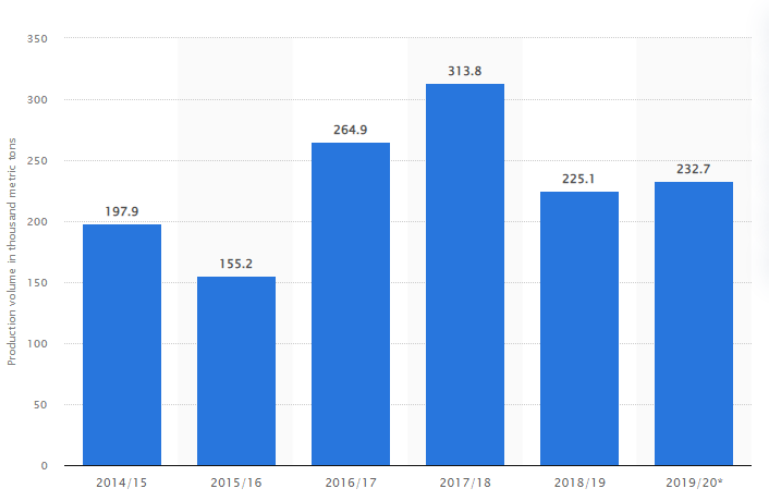

Figure 1. Cashew production in Tanzania between 2014 and 2020 (Faria, 2021).

Computer-based vision and machine vision technologies are relatively economical, consistent, flexible and reliable and have over and over proven to have superior accuracy (Du et al., 2016). Ahmadabadi et al., (2017) used Support Vector Machine to design and develop an online grading system for peeled pistachio nuts equipped with machine vision technology. Various models with different kernel functions were developed and tested, and the highest accuracy of 99.17% was obtained from a model using the cubic polynomial kernel function. Nagpure and Joshi (2016) also did a study to grade cashew nuts on the bases of colour, texture and size by applying the K-Nearest Neighbours classifier. A Feed-Forward Neural Network model using colour features extracted from Red Green Blue (RGB) images was used to classify cashew kernels into six grades with a classification rate of 80% (Ganganagowdar and Siddaramappa, 2011a). Also, another study was done to classify white whole cashew kernel using texture features. In this study, a Multilayer Feed-Forward Neural Network was used, and the accuracy of this algorithm was 90% (Ganganagowdar and Siddaramappa, 2011b). A novel intelligent model extracted 24 colour and 16 morphological features of the cashew kernel and used a Multilayer Perceptron ANN to recognize and classify white wholes into different grades using a Backpropagation learning algorithm and attained a classification of 88.93% (Ganganagowdar and Siddaramappa, 2016). Vidyarthi et al. (2020) applied four different deep Convolutional Neural Network models, which are VGG-16, ResNet50, Inception-V3 and a custom model to classify cashew kernels into five categories. The overall minimum accuracy of all the models was 95.1%. A study

was done by Aran et al., (2016) to find out the effect of different features in the grading of the cashew kernel. In this study, colour, texture, shape and size features were extracted and tested on five different classification algorithms (i.e., Random Forest, Multilayer Perception, Multi-class classifier, Regression and Backpropagation Neural Network (BPNN)). The results revealed that BPNN had the best accuracy of about 96.8%. Sunoj et al., (2018) used the morphological features and shadows from cashew kernel images to classify whole and split cashew kernels. In this study, a single point light source inclined at 56° was used to generate cashew shadows, which were then processed in the ImageJ plugin. The classification algorithm developed in this study used object shadows and surface grayscale-intensity-profile for the whole and split-up cashews, respectively, and it had a 100% accuracy. Babu et al. (2012) developed an intelligent classifier model by extracting colour features of the cashew kernel and passing them as inputs into the Neural Network system. The system had an accuracy of 86% in classifying the cashew kernels into different grades. Mehak and Veena (2018) implemented two classification techniques to develop an accurate and efficient classification model for industrial cashew kernel grading. Eight cashew grades were used in this study. Support Vector Machine had an accuracy of 85% when running with the One-vs-All algorithm. When the One-vs-One algorithm was used, the accuracy increased to 90.6%. The highest accuracy observed in this study was in the Random Forest classifier, where the maximum recorded accuracy was 94.28%. Nadar and Kundargi (2018) used the Bayes algorithm to build a classification model in MATLAB 7.8 to classify the cashew kernels by analysing the shape parameters of the cashew kernel (i.e., length (L), width (W) and thickness (T)). Another study was performed by Thakkar et al. (2011) to evaluate the performance of different classification algorithms in cashew nuts grading systems. In this study, the physical properties of the cashew kernels were extracted and used as attributes for the classification model. Various classification algorithms were tested, including; ML-Perceptron KNN, Naive Bayes SVM and Decision Tree. The results of the study were as follows; ML-Perceptron had a classification accuracy of 86%, Decision Tree-79%, K-Nearest Neighbour- 76%, Naïve Bayes-81% and SVM had an accuracy of 77%.

Computer vision has been widely applied in agricultural product inspection, and more studies are still being carried out to improve this technology. In the experiments listed above, we can see how various textural, morphological, colour features have been used to classify the cashew kernels in different ways. Most of the studies performed used representational machine learning approaches to classify the cashew kernels. There has not been an experiment done to study the effect of colour features in the classification of cashew kernels using traditional machine learning. In this study, the main objective was to study the usefulness of the colour features in the classification of cashew kernels into white and scorched categories. The emphasis was put on using traditional machine learning-based algorithms to classify the cashew kernels instead of using the representational machine learning algorithms. The algorithms were written using the Python programming language and run in Spyder integrated development environment.

2. Materials and Methods

2.1. Experiment samples

The cashew kernel samples were obtained from the Tanzania Agricultural Research Institution Centre in Naliendele (TARI Naliendele), located at **10° 22′ 20“S, 40° 10′ 34“E** along the coastal belt of the Indian Ocean. The samples were raw and included the scorched and white whole classes of cashew kernel. The samples were inspected and stored at room temperature. A total of 1000 cashew kernels (both white and scorched) were collected for the experiment.

2.2. Image acquisition

Like other computer vision studies, the first step was the acquisition of samples' images. In this experiment, a high-resolution Guppy Pro F-032 camera was utilized to capture the images and store them in Portable Network Graphics file format (PNG). The size of the image used was 120x120. By using a tripod stand, the camera was fixed at a constant distance from the base, where the samples were placed. A black surface was used as a background in this experiment. Proper lighting is very essential in acquiring images with the best quality. In this experiment, two 8-watt fluorescent lamps were used as the source of light in the image acquisition chamber.

2.3. Image pre-processing and segmentation

After the image acquisition process, the images may need to be pre-processed to make the following steps free of error and easier. Noise is one of the most unavoidable problems in image acquisition. So, after the images were

captured, they were pre-processed to remove noise. Later, image segmentation was performed to remove the background of the image retaining only the object of interest while keeping the colour information of the original cashew kernel after segmentation. To achieve the image segmentation process, the system should first detect the object from the background. Threshold segmentation technique was applied in this study, as explained by (Dong et al., 2013). Various threshold values were tested until an optimal threshold value with maximum spread between the foreground and the background was found.

2.4. Feature extraction and feature selection

The features used in this study to classify the cashew kernels were the colour features of the cashew kernels. A wide range of colour features can be extracted from an image, but the colour moments are the most prominent features that can define the characteristics of the image. Among the colour moments, the most important ones used in image retrieval applications are the low order moments. Different colour features were extracted from the captured images and the features that were extracted in this experiment include the means (μ), standard deviations (σ), and skewness (γ) of the red (R), green (G) and blue (B) channels from the RGB colour space, the hue (H), saturated (S) and value (V) channels from the HSV colour space, the excess blue (2B-G-R), excess green (2G-R-B) and excess red (2R-G-B). The mean (μ), standard deviation (σ), and skewness (γ) of the pixels in the image were calculated using the following equations, respectively (Aran et al., 2016).

$$Mean(\mu) = \sum_{j=1}^{N} \frac{1}{N} P_{ij} \quad \text{(Eq.1).}$$

$$Standard\ deviations\ (\sigma) = \sqrt{(\frac{1}{N}\sum_{j=1}^{N}(P_{ij} - E_i)^2)} \quad \text{(Eq.2).}$$

$$Skewness\ (\gamma) = \sqrt[3]{(\frac{1}{N}\sum_{j=1}^{N}(P_{ij} - E_i)^3)} \quad \text{(Eq.3).}$$

A total of 21 features were extracted from the images. To improve the efficiency of a classification model and decrease the running time, it is highly recommended to use only the important features and get rid of irrelevant features. This process is called feature selection. In this experiment, feature selection was done in Python using the Boruta Library, which uses the wrapper approach to select the relevant features by building a random forest classifier.

2.5. Classification models

With the development in technology, the invention of machine learning has proven to be very useful in different areas. Machine learning generally means the computer can learn to perform a particular task without being detailed programmed to do so. Firstly, the computer learns from specific data then it can work on new data on its own. Generally, we can group machine learning models into two groups depending on the kind of data fed into the system. The first type is traditional machine learning. These are algorithms that usually use numerical features as input. In traditional machine learning, the choice of the algorithm and the input data (features) to be used is determined by the expert. On the other hand, we have representational machine learning which can take unstructured data like videos and photos as input and learn from these data the significant features to focus on without the expert having to extract and specify the features. In this experiment, five traditional machine learning models were tested and studied for classifying the cashew kernel into white and scorched classes using the selected colour features. These models are Logistic Regression, Decision Tree, Random Forest, Support Vector Machine and K-Nearest Neighbour model.

3. Results and Discussion

3.1. Data collection

Out of the 1000 collected cashew kernels samples, 812 were selected and captured for the experiment. 402 of the captured images were scorched and 410 were white. (*Figure 2*) shows an example of the images captured in this experiment. 67% of these samples were used for training the model, the rest 33% were spared for testing the model.

Figure 2. Sample of the captured cashew kernels scorched nut on the left, white nut on the right.

3.2. Image segmentation

Different threshold values were tested to segment the foreground from the background in Python and the threshold of 60 was found to have the best performance. This threshold value was used to segment the images in a sense that the pixels with intensity value less than 60 were not processed and those with intensity value greater than 60 were assigned a constant value to create a mask that can be applied to the original image to segment the foreground from the background. (*Figure 3*) show the stage an image went through from an original image to the segmented image both for white and segmented.

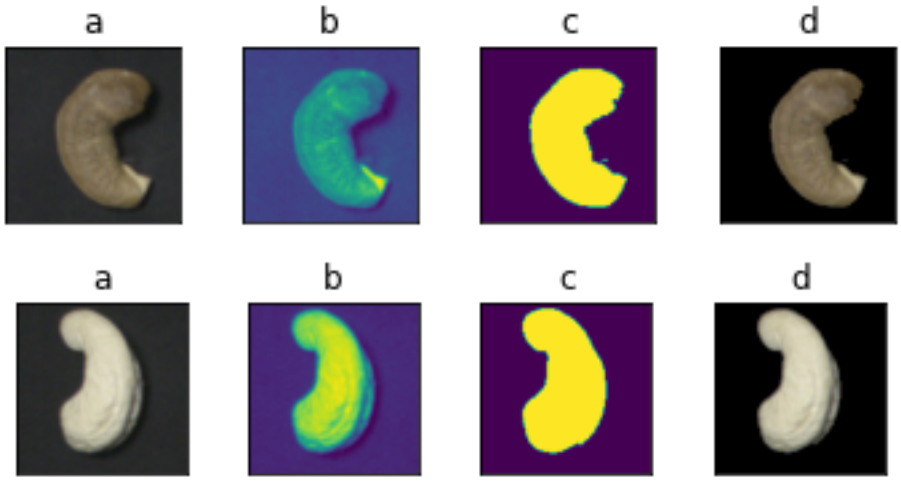

Figure 3. Raw image segmentation stages

3.3. Feature selection and extraction

This experiment used the colour features of the cashew kernels to classify them into white or scorched categories. 21 colour features were extracted and after evaluating the effectiveness of all features in predicting the category of the cashew kernels only 14 features were found to have a significant effect and the other irrelevant 7 features were left out. (*Table 1*) below shows the list of features used and those left out.

Table 1.List of accepted and rejected features

No.	Feature	Status	No.	Feature	Status
1.	Red Mean	Rejected	12.	Excess Blue	Rejected
2.	Green Mean	Rejected	13.	Hue Mean	Accepted
3.	Blue Mean	Accepted	14.	Saturated Mean	Rejected
4.	Red Std	Accepted	15.	Value Mean	Rejected
5.	Green Std	Accepted	16.	Hue Std	Accepted
6.	Blue Std	Accepted	17.	Saturated Std	Accepted
7.	Red Skewness	Accepted	18.	Value Std	Accepted
8.	Green Skewness	Accepted	19.	Hue Skewness	Accepted
9.	Blue Skewness	Accepted	20.	Saturated Skewness	Accepted
10.	Excess Red	Rejected	21.	Value Skewness	Accepted
11.	Excess Green	Rejected			

3.4. *Classifiers*

Five traditional Machine Learning models were evaluated in this study, the classification accuracy, recall, precision and F1_score were used for comparison of the models. (*Table 2*) below shows a summary of classification report for all the models tested. The first model was Logistic Regression, the accuracy of this model from the validation was found to be 99.6%. (*Figure 4*) below shows the confusion matrix of the Logistic Regression model for this classification problem.

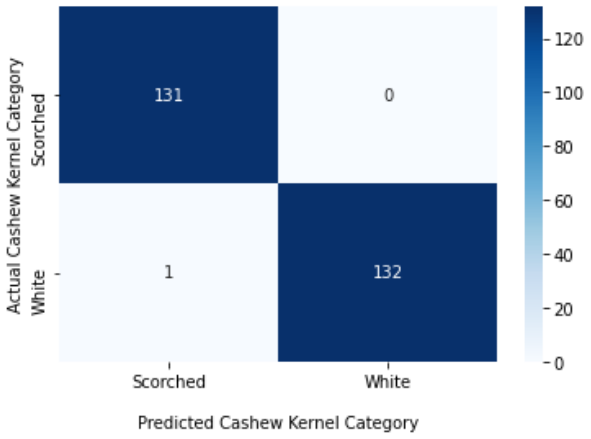

Figure 4. Logistic Regression model confusion matrix

The second model to be tested was the Decision Tree model. The classification Decision Tree implicated in this experiment used the Gini impurity as a deciding factor at the split nodes. The accuracy of the Decision Tree in this experiment was found to be 98.1%. (*Figure 5*) below shows the confusion matrix of the Decision Tree model for this classification problem.

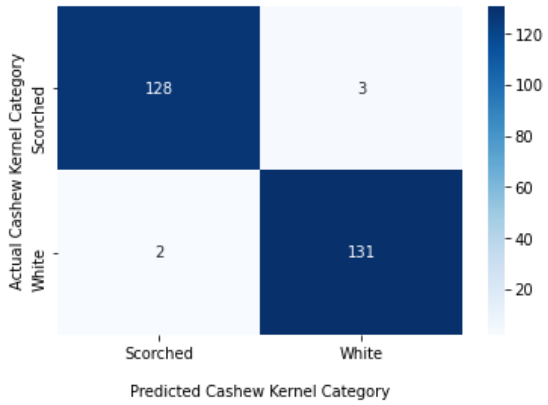

Figure 5. Decision Tree model confusion matrix

A Random Forest is a correction of many decision trees so, it is an improvement of the Decision Tree method. First, a Random Forest with 10 trees was used and the accuracy was 98.5%. Later the number of trees was increased to 100 trees, and the accuracy elevated to 99.8%. (*Figure 6*) below shows the confusion matrix for the two Random Forest models tested for this classification problem.

A Support Vector Machine was also used in this classification. The accuracy of the Support Vector Machine algorithm was 99.6%. (*Figure 7*) below shows the confusion matrix of the Decision Tree model tested for this classification problem.

Last but not least, the samples were tested in the K-Nearest Neighbour algorithm. First, the value of K was set to 7 and the accuracy of the system was found to be 98.8%. Upon decreasing the value of K to 5 the accuracy increased to 99.5%. The maximum accuracy was obtained after lowering the value of K down to 3 where we got 99.7% accuracy. (*Figure 8*) below shows the confusion matrix for the three KNN models tested for this classification problem.

(*Table 2*) show the summary of the test algorithms with their performance accuracies, recall, precision and F1

scores.

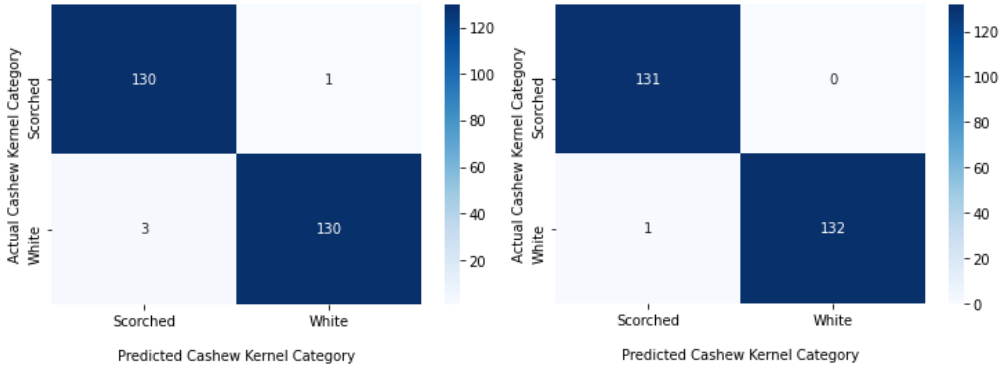

Figure 6. Random Forest model confusion matrix (10 trees on the left, 100 trees on the right)

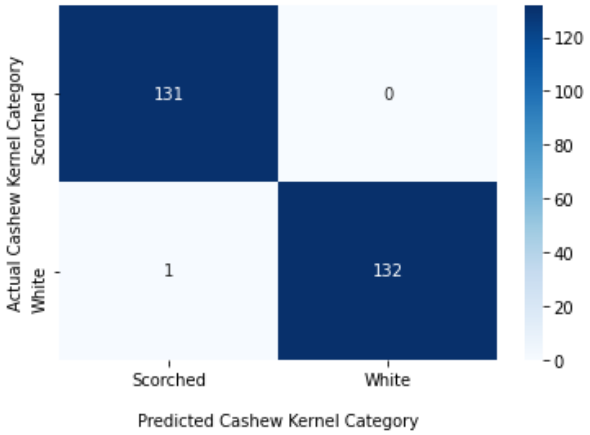

Figure 7. Support Vector Machine model confusion matrix

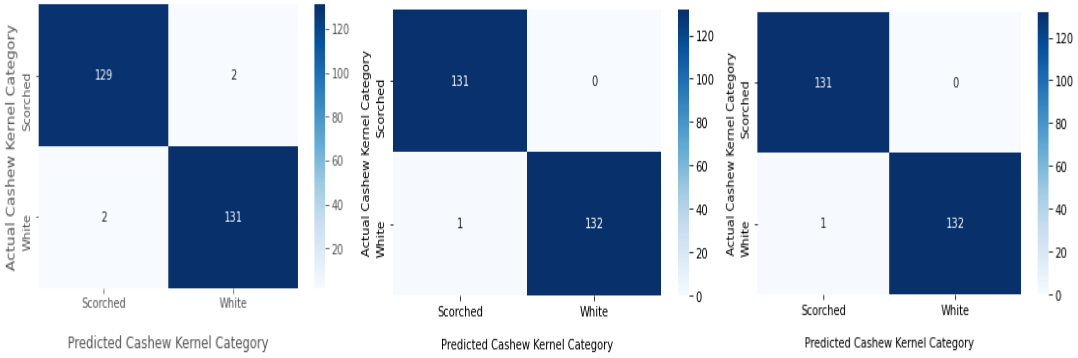

Figure 8. KNN model confusion matrix (K=7 on the left, K=5 on the centre, K=3 on the right)

Table 2. Classification performance of the tested model

No.	Classification Method		Classification Accuracy	Recall	Precision	F1_score
1.	Logistic Regression		99.6%	0.9925	0.9987	0.9962
2.	Decision tree		98.1%	0.9849	0.9776	0.9812
3.	Random Forest	10 Trees	98.5%	0.9774	0.9923	0.9848
		100 Trees	99.8%	0.9924	0.9991	0.9982
4.	Support Vector Machine		99.6%	0.9925	0.9987	0.9962
5.	K- Nearest Neighbour	K= 7	98.8%	0.9874	0.9922	0.9898
		K= 5	99.5%	0.9901	0.9989	0.9951
		K= 3	99.7%	0.9913	0.9990	0.9975

4. Conclusion

Cashew kernel classification is still a very big problem in many places where manual labour is used extensively. This means that still there is a need to apply computer vision-based classification techniques to help improve the efficiency of the classification process as well as lower the overall operation costs. This study aims to evaluate the effectiveness of colour features in the classification of cashew kernel into white and scorched categories. From the results obtained, the colour features have proved to be effective in the classification of the cashew kernels into these two categories. All the tested traditional Machine Learning techniques have given promising results in this classification. Random Forests are usually easy to construct and with the accuracy obtained in this study, it would be more practical to prefer Random Forest for this classification.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Seasonal Changes of FSH, LH, Total and Free Testosterone Hormones in Saanen Bucks*

Saanen Tekelerde FSH, LH, Total ve Serbest Testosteron Hormonlarının Mevsimsel Değişimleri

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Abstract

In the study, seasonal changes in follicle-stimulating hormone (FSH), lutein hormone (LH), total testosterone (TTH), and Free Testosterone Hormone (FTH) of Saanen goats were investigated. In order to determine the hormone levels between February 2019 and December 2019, blood samples were taken from bucks (n=6) twice a week during the entire trial. FSH level started to decrease relatively after August and the lowest value was determined as 173.01 mlU/ml in January. The difference between the months in the mean FSH level was found to be significant ($p < 0.05$). The highest LH level was obtained in July (13.12 mIU/mL) and the lowest level (8.02 mIU/mL) was obtained in May. However, during the mating season, the increase in LH level was found to be similar to the FSH level. The difference in LH levels by months was found to be statistically significant ($p<0.05$). Total testosterone level was similar to FSH and LH levels. The highest and lowest total testosterone hormone (TTH) levels in March and January, respectively; 3.03 ng-/mL and 0.62 ng-/-mL. The highest free testosterone hormone (FTH) level was 119.69 pg/ml in August and the lowest was 29.09 pg/ml in December. The difference between FTH by months was significant ($p<0.05$). The effect of day length on seasonal variation of reproductive hormones in Saanen bucks is statistically significant ($p<0.05$). As a result, it was determined that reproductive hormone levels in Saanen bucks depend on the season and the release levels are significantly affected by climatic factors such as day length. To summarize, there is a need for more different studies including sampling frequency, sampling time as well as sample size, and other environmental factors in order to examine the effects of male reproductive characteristics and other important hormones in bucks in more detail to interpret the results more accurately.

Keywords: Saanen buck, Reproductive hormone, Seasonal change, Free testosterone hormone, Annual cycle

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Öz

Araştırmada, Saanen tekelerine ait folikül uyarıcı hormon (FSH), lutein hormon (LH), toplam testosteron (TTH) ve Serbest Testosteron Hormonunun (FTH) mevsimsel değişiklikleri incelenmiştir. Şubat 2019 ile Aralık 2019 arasındaki aylarda hormon düzeylerinin belirlenmesi için tekelerden (n=6) haftada iki kez olmak üzere tüm deneme süresince kan örnekleri alındı. FSH düzeyi, ağustos ayından sonra göreli olarak düşmeye başlamış ve en düşük değer ocak ayında 173.01 mlU/ml olarak belirlenmiştir. FSH düzeyi ortalamalarında aylar arasındaki fark anlamlı bulunmuştur ($p < 0.05$). En yüksek LH düzeyi Temmuz (13.12 mIU/mL) ve en düşük düzey ise (8.02 mIU/mL) mayıs ayında elde edilmiştir. Ancak çiftleşme mevsiminde, LH düzeyindeki artışın FSH düzeyiyle benzer olduğu saptanmıştır. Aylara göre LH düzeylerindeki fark istatistiksel olarak önemli bulunmuştur ($p<0.05$). Toplam testosteron düzeyi, FSH ve LH düzeyi ile benzerlik göstermiştir. Mart ve ocak aylarında en yüksek ve en düşük toplam testosteron hormonu (TTH) düzeyi sırasıyla; 3.03 ng-/mL ve 0.62 ng-/-mL dir. En yüksek Serbest testosteron hormonu (FTH) düzeyi ağustos ayında 119.69 pg/ml, en düşük ise aralık ayında 29.09 pg/ml olarak belirlenmiştir. Aylara göre FTH arasındaki fark anlamlıdır ($p<0.05$). Saanen tekelerinde üreme hormonlarının mevsimsel değişimi üzerine gün uzunluğunun etkisi istatistiki olarak önemlidir ($p<0.05$). Sonuç olarak, Saanen tekelerinde üreme hormonu düzeylerinin mevsime bağlı olduğu ve salım düzeylerinin gün uzunluğu gibi iklimsel faktörlerden önemli ölçüde etkilendiği belirlenmiştir. Özetlemek gerekirse, tekelerde erkek üreme özellikleri ve diğer önemli hormonların etkilerini daha ayrıntılı incelemek ve sonuçların daha sağlıklı yorumlanabilmesi için örnek alma sıklığı, örnek alma zamanının yanı sıra örnek büyüklüğü ve diğer çevresel faktörlerin de içinde yer aldığı daha farklı çalışmalara da ihtiyaç vardır.

Anahtar Kelimeler: Saanen teke, Üreme hormonu, Mevsimsel değişim, Serbest testosteron hormonu, Yıllık döngü

1. Introduction

The seasonality of reproduction is influenced mainly by annual variations in the photoperiod. It means that increase the proportionally to latitude such that reproductive and non-reproductive seasons for some farm animals (Sharpe, 2003; Abecia et al., 2012; Vasantha, 2016). However, in animals raised in tropical regions, other environmental factors other than day length also influence the mating season (Rosa and Bryant, 2003; Nakao et al., 2008). The most obvious effects of seasonal variation in reproduction are seen in female mammalian farm animals, cattle may be excluded (Koluman Darcan et al., 2013). These animals have a mating and anestrus period, unlike poultry (Goodman and Inskeep, 2006; Cattanach et al., 1977). Males have a mating season similar to females. (Chemineau et al., 1988; Cheng et al., 1981). Characteristics in male animals that change depending on the season are respectively; sexual activity, semen production, testicular characteristics, and accordingly changes in the level of reproductive hormones (Kafi et al., 2004; Zamiri and Khodaei, 2005; Todini et al., 2007; Zarazaga et al., 2009).

FSH and LH hormones play an important role in spermatogenesis in male farm animals (Kumar et al., 1997; Araki et al., 2000). However, studies in male mice suggest that a mutation occurring during FSH production adversely affects both testicular and semen characteristics. In addition, growth retardation in reproductive organs negatively affected Gn - RH production of spermatozoa capable of fertilization in mice (Cattanach et al.,1977; Abdelrahman et al., 2019). FSH and LH hormones regulate the function of reproductive organs by a feedback mechanism. The issue of how the inhibin hormone regulates FSH secretion in domestic mammal female animals is still a research topic. Immunoneutralization of inhibin hormone in females has been studied in many animal species such as the rat (Culler and Negro-Vilar, 1988), cattle (Kaneko et al., 1995), sheep (Mann et al., 1990), and hamster (Kishi et al., 1997) and was observed to cause a certain increase in FSH secretion in most of the animals.

FSH and LH are important hormones in the reproductive physiology of both male and female organisms (Şenok et al., 2020). However, in male animals, testosterone is the most important gonadal hormone regulating both FSH and LH secretion. As known, the role of the inhibin hormone, which acts as a regulator of FSH secretion, is largely dependent on the species and age of the animal. However, the importance of inhibin hormone in the regulation of FSH secretion in adult male animals varies between species (Martin et al., 1991; McKeown et al., 1997; Dias et al., 2012). In this study, it was aimed to investigate the seasonal variations of some reproductive hormones in Saanen bucks. For this purpose, the experiment was carried out to determine the annual cycles of FSH, LH, total testosterone and free testosterone hormones of bucks.

2. Material and Method

This research was conducted under the supervision of the Ege University Animal Experiments Local Animal Ethics Committee (*number: 2017-0/90*). This study was carried out on province, Turkey. The average annual precipitation is 742 mm. Bornova district coordinates are latitude 38.4710 and longitude 27.2177. The highest and lowest ambient temperature the in Bornova district in June and January months is 31°C and 5.3°C, respectively. Relative humidity in the study area changes between 48 % and 79 %. The experiment animals consist of 2-year-old 6 head Saanen bucks.

The barn where the goats were stabled has a total floor area of 72 m2 (12 individual pens × 6 m2). In addition, there was a open-top area of 10 m2 in front of each pen. The energy content was 1.2 times the energy requirement in flushing rations for bucks (NRC, 2007). Alfalfa hay (89.44% DM, 18.59% CP), and corn silage (87.21% DM, 9.88% CP) were fed concentrated feed (90.44% DM, 17.99% CP) 700 g was given to the animals individually in the male units. There is at least one double and 8-liter capacity floated waterer in each pen in the facility. The staff veterinarian of Ege University routinely performed health protection practices for all animals.

In this study, five-milliliter blood samples were taken (*AYSET TUBE 8,5 mL Serum Sep Clot Activator*) twice a week from bucks (96 times/1 buck) to determine hormones level (Yarney and Sanford, 1983). Blood samples were centrifuged at 5000 rpm for 10 minutes and then stored at -20 degrees Celsius. The blood serum was performed by radioimmunoassay method. Levels of the free testosterone were measured by RIA kit (Immunotech Beckman Coulter Company, RIA Testosterone: REF DSL4900), the sensitivity of this assay was 0.13 pg/mL of serum. Levels of the testosterone were measured by RIA kit (Immunotech Beckman Coulter Company, RIA Testosterone: REF IM1087), the sensitivity of this assay was 0.05 ng/mL of serum. Levels of the FSH were measured by RIA kit (Immunotech Beckman Coulter Company, RIA Testosterone: REF IM3301), the sensitivity of this assay was 0.17 IU/L of serum. Levels of the LH were measured by RIA kit (Immunotech Beckman Coulter

Company, RIA Testosterone: REF IM1381), the sensitivity of this assay was 0.16 IU/L of serum. Analyzes on hormones took place in the pharmaceutical laboratory of the nuclear center research at Ege University. Serum FSH, LH, total and free testosterone hormone levels were analyzed using the SAS. Analysis was done on the monthly individual average of the samples taken. The experiment (differences between months investigated for each hormone parameter) were analyzed repeated measures analysis of variance (ANOVA). The difference between the months was observed with Duncan Test (Gürbüz et al., 2003).

3. Results

FSH hormone level has higher values in between August and November in bucks compared to other months due to the mating season. In all bucks, the highest value was obtained in August during the mating season. In August, the mean value of FSH is 411.65 mlU/ml. FSH hormone level started to decrease relatively after August and the lowest value was determined as 173.01 mlU/ml in January.

As expected, bucks first increased during the breeding season (between August and November), peaked in August, and then decreased with the autumn season. The difference in FSH level among months was found to be statistically significant. When the male goats were examined individually, the difference in FSH levels was significant in August ($p < 0.05$). Follicle Stimulating Hormone means were given in *Table 1*. Before the mating season (January – July), the LH analysis revealed that the individual data of LH were very close to each other. The figures are similar to FSH values. The highest LH levels were in July (13.12 mIU/mL) and the lowest in May (8.02 mIU/mL). However, by entering the mating season, it was found that LH values also increased as much as FSH values. When the means were examined for a mating period, the highest and lowest LH values were 34.24 mIU/mL, 12.00 mIU/mL, respectively. LH values of the Saanen bucks were given in *Table 1*. The difference in LH levels by months was statistically significant ($p<0.05$).

The TTH values (January - July) were found to be very close before the breeding season. The total testosterone values showed a resemblance to the FSH and LH values. The highest and lowest TTH levels were 3.03 ng/mL and 0.62 ng/mL in March and January, respectively. However, the TTH value, at the start of the breeding season, increased very rapidly similar to those of FSH and LH values. The highest TTH level was 14.85 ng/mL in August and the lowest value was 3.99 ng/mL in December. The difference between the TTH values in terms of months was significant ($p<0.05$). The total testosterone hormone (TTH) were given in *Table 1*.

Before the breeding season (January – July), the free testosterone hormone (FTH) level showed that the individual values of FTH were very close to each other. The values of free testosterone (FTH) show a similarity to FSH, LH, and TTH values. The highest FTH level in March was 10.76 pg/mL and the lowest was 0.82 pg/mL in January. However, with the emergence of the breeding season, similar to that of FSH, LH, TTH, and FTH values were also found to increase very rapidly. The highest FTH level in August was found to be 119.69 pg/mL and the lowest was 29.09 pg/mL in December. The difference between the FTH by months was significant ($p<0.05$). FTH values of Saanen bucks were given in *Table 1*.

Table 1. Hormones level changes by months (mIU/ml)

	Jan	***Feb***	***Mar***	***Apr***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***
FSH	173.01	176.58	176.47	173.37	180.50	182.74	193.73	411.65	282.41	278.77	274.34	239.98
(mIU/ml)	±0.71 [a]	±1.34 [a]	±1.40 [a]	±1.58 [a]	±0.71 [b]	±0.74 [b]	±1.08 [b]	±7.12 [d]	±5.45 [c]	±7.99 [c]	±4.23 [c]	±1.99 [c]
LH	9.06	8.51	9.74	8.80	8.02	8.82	13.12	34.24	25.78	20.70	18.33	12.00
(mIU/ml)	±0.47 [b]	±0.61 [a]	±0.36 [b]	±0.54 [a]	±0.40 [a]	±0.53 [a]	±0.34 [c]	±0.20 [e]	±0.38 [d]	±0.81 [d]	±0.40 [d]	±0.36 [c]
TTH	0.62	0.93	3.03	1.73	1.55	0.98	1.23	14.85	10.71	11.89	7.08	3.99
(mIU/ml)	±0.11 [a]	±0.34 [a]	±0.72 [c]	±0.46 [b]	±0.46 [b]	±0.21 [a]	±0.26 [b]	±0.91 [f]	±2.03 [e]	±0.90 [e]	±0.70 [d]	±1.31 [c]
FTH	0.82	1.50	10.76	4.30	5.03	1.83	3.41	119.69	63.48	69.62	57.39	29.09
(mIU/ml)	±0.29 [a]	±0.58 [a]	±3.15 [c]	±2.16 [b]	±2.14 [b]	±0.44 [a]	±1.12 [b]	±15.11 [f]	±15.0 [c]	±8.08 [e]	±6.20 [e]	±8.92 [d]

a,b,c,d :different lower cases in the same line represent statistically significant differences

Reproduction hormones analysis revealed in examined that the individual data of all hormones were very close to each other (*Figure 1*). The highest hormones levels were in August. However, this peak continued to decline after a month.

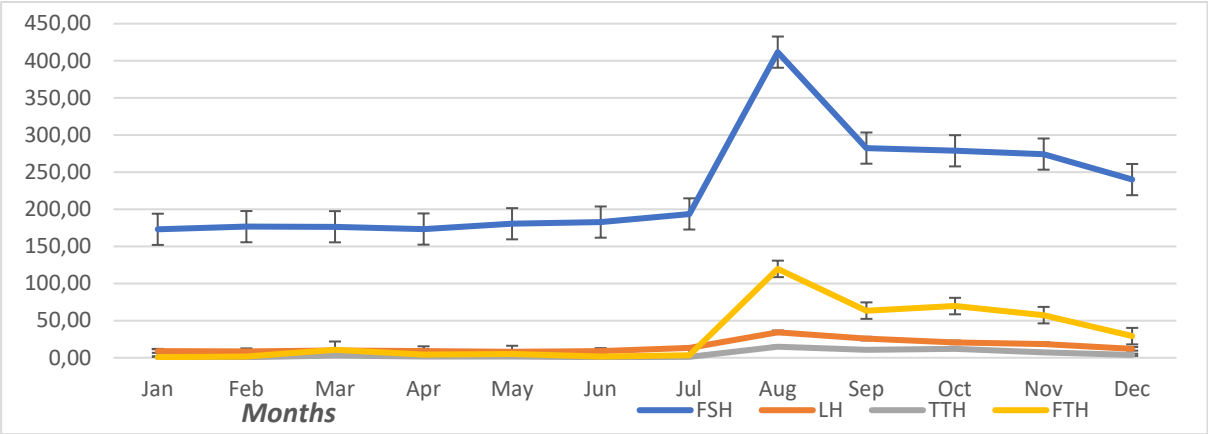

Figure 1. Change of hormones throughout the year

4. Discussion and Conclusion

This study was conducted in order to determine the year-round variability of some reproductive hormones levels in Saanen bucks vary during the whole year. In addition to the determining factor of day length, incommercial goat farms, the length of the breeding season is varying among different genotypes also depending on different environmental factors and especially day length (Yılmaz, 1999; Karadağ and Soysal, 2018; Nikbin et al., 2018). The effect of day length on bucks is proportionally less than on does. However, this effect can sometimes be negative on testicular development and sperm production (Chemineau et al., 1988; Marai et al., 2007; Coloma et al., 2011; Fatet et al., 2011). Reproductive activity on bucks raised in temperate climates is not wholly dependent on the season such as goats, but they generally show a reproductive cycle stimulated by reduced day length (Todini et al., 2007; Muduuli et al., 1979; Dellal and Cedden, 2012). In small ruminants, ovulation/mating generally occurs in autumn. The breeding season length of Saanen bucks in İzmir province where the study was conducted continues from September until the end of November (Kandemir et al., 2018). As it is known, the control of reproduction depending on the length of the day is controlled by increasing regular secretions of melatonin hormone produced from the pineal gland in the period when the days begin to decrease (Eldon, 1993; Gomez-Brunet et al., 2009).

The results of this study on FSH concentrations in Saanen bucks during the breeding season were examined, the difference in FSH between months was statistically significant ($p<0.05$). These findings of FSH concentrations are similar to those obtained in other goat and sheep breeds (Araki et al., 2000; Gomez-Brunet et al., 2009, Findlay and Clarke, 1987). Increased levels of Gn-RH cause the expression and secretion of FSH and LH hormones for goats (Mori and Kano, 1984; Malpaux et al., 1994; Medan et al., 2003).

The differences between months in FSH and LH concentrations for Saanen bucks are similar to studies in Angora goats (Loubser et al., 1983), dwarf goats (Howland et al., 1985), Australian Kashmiri goats (Walkden-Brown et al., 1994), Zaraibi goats (Barkawi et al., 2006), and Angora goats (Pehlivan et al., 2017). Similar to our study, Todini et al. (2007) found that plasma testosterone concentrations for bucks were higher in summer than autumn. The study of Chentouf et al. (2011) confirms these results. The authors stated that plasma testosterone levels in Northern Moroccan bucks increased during the spring and summer. This indicates the photoperiod-related reproductive seasonality of Northern Moroccan bucks. On the other hand, seasonal changes in plasma testosterone levels for Akkeçi bucks in Turkey were determined in autumn with the highest values and the lowest values in spring (Polat et al., 2011). Todini et al. (2007) found that plasma testosterone concentrations for bucks were higher in summer than autumn. Similar results were found in this study. Plasma testosterone levels increased during the spring and summer (Chentouf et al., 2011). This indicates the photoperiod-related reproductive seasonality of northern Moroccan bucks. Barkawi et al. (2006) concluded that seasonal sexual activity has a different period in Zaraibi goats. In the northern hemisphere, especially in autumn and summer, gonadal hormones are working effectively above the standard level. Perez and Mateos (1995) reported that Maguena and Vareta bucks were at high levels in autumn and summer. Zarazaga et al. (2009) determined the effects of the season on the reproductive performance with intense sexual activity between August and November for Payoya bucks. Circumference of the

scrotum is positively related to sexual activity. Al-Ghalban et al. (2004), detected that circumference of the scrotum had high figures in August for Damascus bucks. In the same study, they reported that it started to increase for the spring months. Circumference of the scrotum is positively related to sexual activity

The plasma testosterone increase begins before or around the summer in subtropical regions in Mexico's local breeds (Delgadillo et al., 2002; Delgadillo et al., 2004). Similar effects were seen on testosterone hormone levels in Creole bucks from Mexico (Delgadillo et al., 2001). The testosterone hormone plays an important role breeding, regulation of secondary sexual characteristics and spermatogenesis in male goats (Perez and Mateos, 1995; Polat et al., 2011). The seasonal variation of testosterone hormone level is controlled by LH concentrations synthesized in the pituitary gland (Delgadillo et al., 1999; Delgadillo et al., 2001). According to the results, the levels of LH and testosterone hormones in Saanen bucks during the breeding season (September-October) show similar results. Mean testosterone hormone levels for Saanen male goats' mean in August were 119.69 ng/ml (*Table 1*). Similar results have been reported in other studies performed for Angora male goats, the testosterone values in breeding season were observed to be 15.86 ng/ml by Loubser et al. (1983), 9.21 ng/ml by Ritar (1991) and 13.80 ng/ml by Pehlivan et al. (2017). The results of the testosterone concentrations in the Saanen bucks were also consistent with those reported in the other goat breeds (Zarazaga et al., 2009; Muduuli et al., 1979; Howland et al., 1985; Polat et al., 2011). The effects of the seasons affect the sexual activity of females more than male goats. Throughout the year, sexual activity in male goats does not completely stop, and when the level decreases, it is not observed. Male reproductive cells production continues. Male reproductive cell production continues. It is not affected by the seasons. It is observed that the expression of sexual activity increases as the mating season approaches (Delgadillo et al., 2001, Quin et al., 2000; Zhang and Yang, 2006; Mayer, 2016).

In this study, it was determined that the reproduction hormone secretions in Saanen bucks were season dependent and their release levels were significantly affected by environmental factors such as day length. Additionally, the Saanen bucks studied were found to exhibit intense sexual activity in July and August.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Taze Kesilmiş Pırasada Askorbik Asit Uygulamasının Soğukta Depolama Boyunca Kalite Değişimine Etkisi*

The Effect of Ascorbic Acid Treatment on The Quality Changes of Fresh-Cut Leek During Cold Storage

Bekir GÜLAL[1], Mehmet Ali KOYUNCU[2*]

Öz

Çalışmada askorbik asit (AA) uygulamasının taze kesilmiş 'Lincoln' pırasa çeşidinin soğukta depolama boyunca kalitesi üzerine etkileri incelenmiştir. Optimum dönemde derimi yapılan pırasalar hızlı bir şekilde laboratuvara nakledilmiştir. Pırasalar zorlanmış hava ile (2 °C) 6 saat süreyle ön soğutma işlemine tabi tutulduktan sonra uygulamalar (kontrol, %1 ve %2 AA) için üç gruba ayrılmıştır. Ön soğutma işleminden sonra pırasalar serin ve steril koşullar altında 5-6 °C sıcaklıktaki çeşme suyuna birkaç kez daldırarak bahçe kaynaklı toz ve kalıntılar uzaklaştırılmıştır. Taze kesim işleminden sonra %1 ve %2 AA uygulanmış pırasa örnekleriyle kontrol grubu köpük kâselere yerleştirilerek üzeri streç filmle (16 µ) kaplanmıştır. Ambalajlanmış pırasalar 0±1 °C ve %90±5 oransal nemde 30 gün boyunca depolanmıştır. Depolama boyunca altı gün aralıklarla pırasalarda ağırlık kaybı (%), yalancı gövde sertliği (N), suda çözünebilir kuru madde (%), titre edilebilir asitlik (g 100 ml^{-1}), solunum hızı (ml CO_2/kg^{-1} h^{-1}), yalancı gövde rengi ve duyusal özellikler belirlenmiştir. AA uygulamaları kontrole kıyasla taze kesilmiş pırasalarda ağırlık kayıplarını azaltmıştır. Depolama boyunca %2'lik doz daha etkili olmak üzere, AA uygulamaları yalancı gövde sertliğini kontrole göre daha iyi korumuştur. Soğukta depolama boyunca AA uygulamaları taze kesilmiş pırasaların TEA miktarını korumuş ve solunum hızını net bir şekilde baskılamıştır. AA uygulamaları kontrol örneklerine kıyasla depolama süresince pırasaların görsel kalitelerini daha iyi korumuştur. Sonuç olarak, AA uygulanmayan kontrol grubundaki pırasalar 0±1 °C ve % 90±5 oransal nemde 24 gün depolanabilirken, her iki AA (%1ve %2) uygulaması bu süreyi 30 güne kadar uzatmıştır. Ancak farklı doz ve uygulama şekilleri kullanılarak bu konuda daha detaylı çalışmalara ihtiyaç vardır.

Anahtar Kelimeler: *Allium porrum*, Taze kesme, Askorbik asit, Kalite, Depolama

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Abstract

In the present research, the effects of ascorbic acid (AA) treatments on the quality of fresh-cut leek cv. 'Lincoln' during cold storage were investigated. Leek samples, harvested at optimum stage, were immediately transferred to the laboratory. Leek samples were pre-cooled with forced air (2 °C) for 6 hours and divided into three groups for treatments (control, 1% and 2% AA). After pre-cooling, dust and residues on leeks originating from the orchard were removed by dipping into cold tap water (5-6 °C) under cool and sterile conditions. After fresh-cut processes, the AA treated (1% and 2%) and control samples were packaged in polystyrene foam tray covered with stretch film (16 µ). Packaged leeks were stored at 0 ± 1 °C and 90 ± 5% relative humidity (RH) for 30 days. The weight loss (%), pseudo stem firmness (N) total soluble solids (%), titratable acidity (g 100 ml^{-1}), respiration rate (ml CO_2 kg^{-1} h^{-1}), pseudo stem colour and sensory evaluation of leeks were performed at six day intervals during storage. The AA treatments decreased weight loss of fresh-cut leeks compared to control. The AA treatments, especially the 2% dose, preserved the pseudo stem firmness better than the control during storage. The AA treatments clearly suppressed respiration rate and maintained the TA of fresh-cut leek during cold storage. The AA treatments preserved the visual quality of the leeks better than the control samples during storage. As a result, it was determined that control group leeks could be stored for 24 days at 0 ± 1 ° C and 90 ± 5% (RH) but this period could be extended up to 30 days by AA (%1-2%) treatments. However, further detailed research on this topic considering different treatment type and dozes is required.

Keywords: *Allium porrum*, Fresh-cut, Ascorbic acid, Quality, Storage

1. Giriş

Pırasa ülkemizde ve Batı Avrupa'da en yaygın yetiştirilen kışlık sebze türlerinden biridir. Günümüzde Türkiye başta olmak üzere Fransa, Belçika ve Polonya'da büyük ölçekli olarak yetiştiriciliği yapılmaktadır (Bernaert ve ark., 2013). Türkiye son zamanlarda yıllık 200.000 tonun üzerinde pırasa üretimiyle dünyada önemli bir yere sahiptir (TÜİK, 2021). Pırasa ülkemizde bütün bölgelerimizde üretilip tüketilen bir sebze türüdür. Özellikle kara ikliminin hüküm sürdüğü bölgelerimizde kışlık sebze tüketiminin çok önemli bir bölümünü oluşturur (Vural ve ark., 2000). Lif açısından zengin olan pırasanın insan beslenmesinde önemli bir yeri vardır. Pırasalarda derimden sonra pazara ulaşıncaya kadar doğal olarak belirli bir süre geçmektedir. Bu aşamalarda diğer bazı bahçe ürünlerinde olduğu gibi pırasada ciddi iç ve dış kalite kayıpları oluşmaktadır. Pırasaların bütün olarak ya da değişik şekillerde kesim işleminden sonra paketlenerek pazarlanması bu kayıpların boyutlarında büyük değişiklikler oluşturmaktadır.

Son yıllarda dünyada doğal, taze ve besleyici hazır gıdalar için tüketiciler tarafından artan talepler doğrultusunda taze kesilmiş meyve ve sebze pazarında gelişmeler oldukça hızlanmıştır (Shah ve Nath, 2006; Oms-Oliu ve ark., 2010). Bu gelişmeler beraberinde gıda güvenliğine olan ilgiyi de arttırmıştır. Gıda güvenliği tüketicilerin gıdaya olan algılarını ve gıda tercihleriyle ilgili kararlarını da etkilemektedir (Niyaz ve Demirbaş, 2018). Ülkemizde de gelişmiş ülkeler kadar hızlı olmasa da taze kesilmiş bahçe ürünlerine ve gıda güvenliğine karşı ilgi her geçen gün artmaktadır. Uluslararası Taze Kesilmiş Ürün Birliği (The International Fresh-cut Produce Association) taze kesilmiş ürünleri %100 kullanılabilir özelliğe sahip soyulmuş, kesilmiş veya parçalara ayrılarak paketlenmiş, tazeliğini koruyan ve besin değeri yüksek meyve ve sebzeler olarak tanımlamaktadır.

Taze kesme işlemleri sırasında oluşan mekanik yaralanmalar nedeniyle meyveler ve sebzelerde derim sonrası dönemde kalite kayıpları hızlanmaktadır (Dilmaçünal ve ark., 2014). Pırasalarda derim sonrası kesim işlemleri kükürtlü bileşikler, polifenol ve vitamin içeriğinde değişikliğe sebep olmaktadır. Örneğin bu işlemler yüzeyde oksidasyonu artırmakta ve polifenol içeriğinde azalmalara neden olmaktadır (Bernaert ve ark., 2013). Mikrobiyolojik bozulmaları da hızlandıran tüm bu süreçler ürünlerin soğukta depolama ve raf ömrünü kısaltmaktadır. İstenmeyen bu gelişmeleri ortadan kaldırmak ya da sınırlandırmak için alternatif uygulamalara ihtiyaç duyulmaktadır. Bunların başında değişik maddelerden hazırlanan yenilebilir kaplama maddeleri gelmektedir (Bal, 2019). Ayrıca ortamda bulunan oksijenin uzaklaştırılması, ürüne göre ambalaj içi gaz bileşiminin oluşturulması, çeşitli kimyasal inhibitörlerin kullanılması ve soğukta depolama gibi farklı yöntemler de uygulanabilmektedir. Derim sonrası ömrün uzatılması ve kalite kayıplarının yavaşlatılması için yaygın olarak kullanılan maddelerden birisi de bir antioksidan olan askorbik asittir (Saba ve Sogvar, 2016). Antioksidanlar oksijenle reaksiyona girerek esmerleşmenin başlamasını baskılayabilir. Bu tip maddeler renksiz o-kinonları kimyasal olarak indirgeyerek o-difenollere dönüştürürler Bu reaksiyon süresince indirgen maddeler geri dönüşümsüz olarak okside olurlar. Dolayısıyla esmerleşme önlenmiş olur. AA ayrıca taze kesilmiş sebzelerde kesim yüzeyinde kuruma veya ligninleşme sonucu oluşan beyazlaşmayı da azaltmaktadır (Kasım, 2021). Özellikle AA'nın meyve ve sebzelerde oksidatif esmerleşmeyi sınırlandırmada ve meyve eti sertliğini korumada etkili olduğu rapor edilmiştir (Bauernfeind, 1982; Liu ve ark., 2016). Askorbik asit, meyve etindeki oksidatif esmerleşmeyi azaltmasının yanında genellikle pH kontrolü amacıyla asit dengeleyici olarak da kullanılmaktadır (Shiri ve ark. 2011; Yan ve ark., 2017).

Taze kesilmiş bahçe ürünlerinin soğuk zincirinde depolama aşaması önemli bir yer kaplamakta olup, bu aşamadaki kayıpları azaltmak son derece önemlidir. Bunun için soğukta depolama sırasında taze kesilmiş ürünlerde metabolik faaliyetleri yavaşlatmaya ve mikrobiyolojik yükünü düşürmeye yönelik uygulamalar seçilmelidir. Depo ortam faktörleri yanında ürüne özel ambalaj malzemesi ve kaplama maddesi seçimine özen gösterilmelidir. Bütün bu bilgiler doğrultusunda mevcut çalışmada, AA uygulamasının soğukta depolama boyunca taze kesilmiş Lincoln pırasa çeşidinin kalite değişimine etkisi incelenmiştir.

2. Materyal ve Metot

2.1. Deneme Materyali, Uygulamalar ve Soğukta Depolama

Denemede materyal olarak Lincoln pırasa çeşidi kullanılmıştır. Pırasalar Burdur ilinin Bucak ilçesinden, ticari olarak yetiştiricilik yapan bir üreticinin bahçesinden temin edilmiştir.

Pırasalar yalancı gövde uzunluğu, kalınlığı ve gevrekliği ile renk özellikleri dikkate alınarak (Şalk ve ark., 2008) 15 Ekim 2018 tarihinde derilmiştir. Derim sabahın erken saatlerinde gövde kalınlığı en az 3 cm'ye ulaşmış,

yalancı gövdeleri gevrek ve düzgün olanlar seçilerek elle yapılmıştır. Derimi yapılan pırasalar bir saat içinde Isparta Uygulamalı Bilimler Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü Derim Sonrası Fizyolojisi laboratuvarına nakledilmiştir. Pırasalar hemen zorlanmış hava ile (2 °C) ön soğutma işlemine (Türk ve ark., 2017) (gövde iç sıcaklığı 5 °C'ye düşene kadar, 6 saat süreyle) tabi tutulmuştur. Pratikte daha rahat uygulanabildiği (özel ön soğutma ünitesi olmadığında normal soğuk odalar da kullanılabildiği için) ve pırasada suyla ön soğutmanın olası yan etkileri bilinmediği için hava ile ön soğutma yöntemi tercih edilmiştir. Ön soğutma işleminden sonra pırasalar 5-6 °C sıcaklıktaki çeşme suyuna birkaç kez hızlıca (1-2 saniyelik sürelerle) daldırılarak bahçe kaynaklı toz vb. kalıntılar uzaklaştırılmıştır. Yıkama işlemi tamamlanan pırasaların üzerindeki su damlaları kuruduktan sonra üç gruba ayrılarak taze kesim işlemine tabi tutulmuştur. Taze kesim işlemleri steril (işlemin yapıldığı tezgah yüzeyi %96'lık etil alkolle dezenfekte edilmiş) ve serin (18 ± 2 °C) koşullarda yapılmıştır. Taze kesim işlemi keskin bıçak kullanılarak her bir pırasa örneği 15-20 cm uzunluğunda olacak şekilde elle yapılmıştır.

Taze kesim işleminden sonra ilk iki grup pırasa örneği %1 ve %2AA içeren 5-6 °C sıcaklığa sahip çözeltiye 20 saniye boyunca daldırılmıştır. Doz ve daldırma sürelerine önceki yıllarda yürüttüğümüz çalışmalara (basılmamış) dayanılarak karar verilmiştir. Üçüncü grup örnekler sadece 5-6 °C sıcaklığa sahip saf suya aynı süreyle daldırılarak kontrol olarak denemeye dâhil edilmiştir. Uygulamalardan sonra pırasalar aynı sıcaklığa sahip soğuk odada (5±1 °C) üzerindeki su damlacıkları uzaklaştırılıncaya kadar fan altında bekletilmiştir. Pırasalar yukarıda tanımlanmış serin ve steril koşullarda hızlı bir şekilde köpük kaselere yerleştirilerek (450-500 gr) üzeri streç filmle (16 µ) kaplanmıştır. Ambalajlanan pırasalar 0±1 °C ve %90±5 oransal nemde 30 gün boyunca depolanmıştır. Altı gün aralıklarla depodan çıkarılan pırasa örneklerine aşağıda belirtilen fiziksel ve kimyasal analizler yapılmıştır.

2.2. Fiziksel ve Kimyasal Analizler

***Ağırlık kaybı*:**

Deneme başlangıcında her uygulama için üç tekerrür olacak şekilde köpük kâselere yerleştirilen pırasa dilimlerinin (450-500 gr) üzeri streç filmle (16 µ) kaplanmıştır. Ambalajlanmış pırasa örneklerinin başlangıç ağırlığı alındıktan sonra depoya yerleştirilmiş ve her analiz döneminde aynı örneklerde tartım yapılmıştır. Bu örnekler sadece ağırlık kaybı analizlerinde kullanılmıştır. Her analiz döneminde 0.01 g duyarlılıktaki dijital terazi (Scaltec SBA51) ile ağırlıkları belirlenmiş paketli pırasalarda başlangıç değerine göre ağırlık kayıpları yüzde (%) olarak hesaplanmıştır.

***Yalancı gövde sertliği*:**

Ölçümler deneme başlangıcında ve her analiz döneminde depodan çıkartılan dilimlenmiş pırasaların gövdesi üzerinde, tamamen beyaz ve yeşilimsi kısımlarda olacak şekilde iki ayrı yerinden yapılmıştır. Her tekerrürde paket içerisinden rastgele seçilmiş 8 adet pırasa dilimi (kesilmiş pırasa örneği) kullanılmıştır. Sertlik ölçümleri tekstür cihazı (Lloyd LF Plus) ile bağlı olduğu bilgisayara yüklenen paket program kullanılarak ölçülmüştür. Denemede 100 mm dk^{-1} değişmez hızda 5 mm çapındaki silindirik uç batırılmış (6 mm) ve elde edilen maksimum kuvvet Newton (N) cinsinden sertlik değeri olarak değerlendirilmiştir.

***Yalancı gövde rengi*:**

Depolama süresince deneme örneklerinde (her tekerrürde 8 adet pırasa diliminde) renk değişimi Minolta CR-300 marka renk ölçme cihazı ile belirlenmiştir. Renk ölçümünde homojenlik sağlayabilmek için her bir pırasa diliminde üç ölçüm (baş, orta ve son kısım olacak şekilde) yapılmış ve ortalamaları alınarak o dilimin renk değeri belirlenmiştir. Sonuçlar L^*, a^*, b^*, değerleri cinsinden belirlenmiş ve buna göre kroma (C^*) ve hue ($h°$) değerleri hesaplanmıştır (Koyuncu ve ark., 2019).

***Suda çözünür kuru madde (SÇKM) ve titre edilebilir asitlik (TEA) miktarı*:**

Her analiz döneminde her tekerrürden alınan 5 adet pırasa diliminin katı meyve sıkacağı yardımıyla suyu çıkartılarak SÇKM miktarı dijital refraktometre (Atago Pocket PAL-1) ile belirlenmiştir (%). Aynı örnekten 10 ml pırasa suyu alınarak pH değeri 8.1'e gelinceye kadar 0.1 N NaOH ile titre edilmiş ve harcanan NaOH miktarı üzerinden TEA miktarı (g 100 ml^{-1}) belirlenmiştir.

***Solunum hızı*:**

Her analiz döneminde her tekerrürdeki o dönme ait paket içerisinden rastgele alınan 100-150 g dilimlenmiş pırasa örneği 0.5 L hacmindeki tamamen gaz sızdırmaz plastik kavanozlara tartılarak oda sıcaklığında 2-3 saat

bekletilmiştir. Bir enjektör yardımıyla gaz örnekleri alınarak hemen gaz kramotografisine enjekte edilerek ortamdaki CO_2 miktarı belirlenmiştir. Elde edilen CO_2 miktarı üzerinden solunum hızı (ml CO_2 $kg^{-1}s^{-1}$) hesaplanmıştır (Erbaş ve Koyuncu, 2016).

Duyusal analizler:

Pırasa dilimlerinin dış görünüş değerlendirmesi için 1-9 skalası (pazarlanamaz: 1-4; pazarlanabilir: ≥ 5; iyi: 7-8; çok iyi: 9) kullanılmıştır. Panelistler pırasa dilimlerinin bütününde ve kesim yüzeylerindeki renk değişimi, solma-sararma, büzüşme ve gözle görülebilir mikroorganizma oluşumlarını dikkate alarak değerlendirme yapmışlardır. Değerlendirmeler 5 kişilik panelist grubu tarafından, 3 tekerrürlü ve her tekerrürde 5 dilim pırasa kullanılarak yapılmıştır (Erbaş ve Koyuncu, 2016).

2.3. İstatistiksel Analiz

Deneme tesadüf parsellerinde faktöriyel deneme desenine göre üç tekerrürlü olarak yürütülmüş ve verilerin istatistik analizleri JMP 7 paket programı kullanılarak yapılmıştır. Grup ortalamaları arasındaki farkların belirlenmesinde Tukey Testi kullanılmıştır.

3. Araştırma Sonuçları ve Tartışma

3.1. Ağırlık kaybı

Taze kesilmiş meyve ve sebzelerde ağırlık kaybı doğrudan ürünün ağırlığında azalmaya neden olurken aynı zamanda görsel kalitenin de azalmasına yol açtığı için oldukça önemlidir. Denemede, AA uygulamaları taze kesilmiş pırasalarda depolamanın ilk haftasından itibaren ağırlık kaybını sınırlandırmıştır. Pırasalarda ağırlık kayıpları depolama süresince beklendiği gibi artmış ve 30. günde % 2.62 (kontrol) ile % 1.75 (%1 AA) arasında değişmiş olup, kontrol grubunda dahi depolamayı sonlandıracak seviyelere ulaşmamıştır. Ayrıca AA'nın her iki dozu da ağırlık kaybını kontrole kıyasla istatistik ($P<0.05$) olarak önemli oranda azaltırken, %1 ve %2'lik dozlar aynı grupta yer almıştır. AA uygulamalarının ürünün solunum hızını da baskılayarak ilave bir etki yarattığı ve ağırlık kaybının %1'ler seviyesinde kalmasına neden olduğu düşünülmektedir *(Tablo 1)*. Kasım ve Kasım (2017) bulgularımıza paralel olarak taze kesilmiş pırasalarda 28 günlük soğukta depolama boyunca ağırlık kayıplarının %1'ler seviyesinde kaldığını bildirmişlerdir. Benzer şekilde Papandreopoulou ve ark. (2015) yenilebilir kaplama maddesi uygulanmış taze kesilmiş pırasalarda soğukta depolama boyunca ağırlık kaybının kontrol örneklerine göre önemli derecede az olduğunu bulmuşlardır. Diğer taraftan değişik bahçe ürünleriyle yürütülen çalışmalarda AA uygulamalarının ağırlık kaybını dikkate değer ölçüde azalttığı da bildirilmiştir (Zhou ve ark., 2021; Liu ve ark., 2016).

3.2. Yalancı gövde sertliği

Taze kesilmiş Lincoln pırasa çeşidinde soğukta depolama boyunca gövde sertliği (N) üzerine hem depolama süresi hem de AA uygulamalarının etkisi önemli ($P<0.05$) olmuştur *(Tablo 1)*. Bütün uygulamalarda muhafaza süresinin artmasına bağlı olarak pırasa dilimlerinde gövde sertliği azalmıştır. Başlangıçta 49.34 N olan gövde sertliği, 30 günlük depolama sonunda ortalama 37.50 N'ye kadar düşmüştür. Depolama boyunca en sert pırasalar ortalama 47.22 N'lik değerle %2 AA uygulanan grupta bulunurken, bunu %1'lik AA uygulaması (44.16 N) ve kontrol örnekleri (42.27 N) izlemiştir. Papandreopoulou ve ark. (2015) salep bazlı kaplama çözeltisine daldırdıktan sonra soğukta depolanmış pırasa dilimlerinde kontrole kıyasla yalancı gövde sertliğinin daha yüksek olduğunu belirlemişlerdir. Benzer şekilde Barzegar ve ark. (2018) AA uygulanmış biberlerin depolama sonunda daha sert kaldıklarını rapor etmişlerdir. Diğer taraftan Zhou ve ark. (2021) taze kesilmiş patateslerde AA uygulamasının meyve sertliğini istendiği gibi korumadığını, Kasım ve Kasım (2016) AA'nın farklı dozlarına göre taze kesilmiş havuçlarda sertliğin değiştiğini ve kontrol örneklerinin daha sert bulunduğunu bildirmişlerdir. Remorini ve ark. (2015) ise AA uygulanmış minimal işlenmiş elmalarda sertlik değerlerinin çeşitler bazında değiştiğini rapor etmişlerdir. Görüldüğü gibi taze kesilmiş farklı tür ve çeşitlerin sertlik değerleri üzerine depolama boyunca AA uygulamasının etkisinin farklı olabileceği ortaya konmuştur. Mevcut çalışmada AA'nın taze kesilmiş pırasaların solunum hızını yavaşlatmak suretiyle yaşlanmayı geciktirmesi ve ayrıca su kaybını da azaltması suretiyle sertliğin korunmasında etkili olduğu kanaatine varılmıştır. Nitekim Lin ve ark. (2007) AA uygulamasının ürünlerde membran lipitlerinin peroksidasyonunu ve solunumu yavaşlatarak yumuşamayı geciktirdiğini bildirmiştir.

Tablo1. Taze kesilmiş Lincoln pırasa çeşidinde AA uygulamasının depolama boyunca ağırlık kaybı (%), yalancı gövde sertliği (N), SÇKM (%) ve TEA (g 100 ml^{-1}) miktarı üzerine etkisi

Table 1. Effects of ascorbic acid treatment on weight loss(%), pseudo stem firmness (N), total soluble solids (%) and titratable acidity (g 100 ml^{-1}) of fresh-cut leek cv. 'Lincoln' during storage

	Depolama Süresi						
Uygulamalar	Başlangıç	6. gün	12. gün	18. gün	24. gün	30. gün	Ort.
			Ağırlık Kaybı				
Kontrol	-	0.57ıj	1.00gh	1.44ef	2.18b	2.62a	**1.56A**
%1 AA	-	0.45j	0.81hı	1.16g	1.49de	1.75cd	**1.13B**
%2 AA	-	0.46j	0.76hı	1.18fg	1.51de	1.85c	**1.15B**
Ortalama		**0.49e**	**0.86d**	**1.26c**	**1.73b**	**2.07a**	
			Gövde Sertliği				
Kontrol	49.34	43.81	42.25	41.52	40.63	36.07	**42.27B**
%1 AA	49.34	48.53	46.88	45.24	40.59	34.39	**44.16AB**
%2 AA	49.34	50.61	49.93	46.71	44.68	42.05	**47.22A**
Ortalama	**49.34a**	**47.65ab**	**46.35ab**	**44.49ab**	**41.97bc**	**37.50c**	
			SÇKM				
Kontrol	6.50de	9.80a	7.05c-e	8.30a-d	6.45de	7.25b-e	**7.56A**
%1 AA	6.50de	9.03ab	6.83c-e	7.23b-e	5.80e	5.48e	**6.81B**
%2 AA	6.50de	8.50a-c	9.13ab	8.37a-d	5.80e	5.53e	**7.31AB**
Ortalama	**6.50c**	**9.11a**	**7.67b**	**7.97b**	**6.02c**	**6.09c**	
			TEA				
Kontrol	0.096a-d	0.092a-e	0.072e	0.080b-e	0.097a-d	0.075de	**0.085B**
%1 AA	0.096a-d	0.096a-d	0.076c-e	0.086b-e	0.111a	0.098a-d	**0.094A**
%2 AA	0.096a-d	0.103ab	0.094a-e	0.099a-c	0.071e	0.090a-e	**0.092A**
Ortalama	**0.096a**	**0.097a**	**0.081b**	**0.088ab**	**0.093a**	**0.088ab**	
			Önemlilik dereceleri				
	Depolama Süresi (DS)		*Uygulama (U)*		*DS × U*		
Ağırlık kaybı	**		**		*		
Gövde Sertliği	**		*		ÖD		
SÇKM	**		**		**		
TEA	**		**		**		

ÖD: Önemli değil, *: P<0.05, **: P<0.01, Satır ve sütunlarda değişik harflerle gösterilen ortalamalar arasındaki farklılıklar istatistik olarak önemli bulunmuştur (P<0.05).

3.3. Suda çözünür kuru madde miktarı

Taze kesilmiş pırasalarda SÇKM miktarı üzerine depolama süresi, uygulama ve depolama süresi × uygulama interaksiyonunun etkisi istatistik olarak önemli (*P*<0.05) olmuştur *(Tablo 1).* Depolama başında %6.50 olan SÇKM değeri 30. günün sonunda %6.81 (%1 AA) ile %7.56 (kontrol) arasında değişmiştir. Depolama boyunca inişli çıkışlı değişkenlik gösteren SÇKM değerleri kontrol uygulaması hariç başlangıç değerine kıyasla azalmıştır. Benzer şekilde Tsouvaltzis ve ark. (2007) ve Kasım ve Kasım (2017) taze kesilmiş pırasalarda SÇKM içeriğinin depolama sonunda başlangıca göre azaldığını saptamışlardır. Çalışmada elde edilen ortalama değerler incelendiğinde ise kontrol örneklerinde daha bariz olmak üzere tüm uygulamalarda SÇKM değerleri artmıştır. Li ve ark. (2012) bulgularımızın aksine, AA uygulanarak aktif MAP içerisinde depolanan taze kesilmiş patlıcanlarda SÇKM değerlerinin kontrole göre daha yüksek seviyelerde kaldığını bildirmişlerdir. Bu durumu kombine uygulamaların metabolik aktiviteyi daha iyi baskılamasıyla ilişkilendirmişlerdir. Mevcut çalışmada kontrol uygulamalarında SÇKM miktarının daha yüksek bulunması, su kaybının bu örneklerde daha yüksek olmasıyla açıklanabilir. Diğer bir ifade ile bu farklılığın solunum hızından çok su kaybıyla ilişkili olabileceği düşünülmüştür. Farklı çalışmalardan farklı sonuç alınması, denemelerde kullanılan tür ve çeşitlerin AA ve benzeri maddeleri içeren uygulamalara karşı değişik düzeyde tepki vermesiyle açıklanabilir.

3.4. Titre edilebilir asit miktarı

Hem depolama süresi hem de AA uygulamalarının pırasa örneklerinin TEA miktarı üzerine etkisi istatistik olarak önemli (P< 0.05) bulunmuştur *(Tablo 1).*

Başlangıçta ortalama 0.096 g 100 ml^{-1} olan TEA miktarı, %2 AA ve kontrol örneklerinde kısmen azalarak depolama sonunda sırasıyla ortalama 0.090 ve 0.075 g 100 ml^{-1} olmuştur. %1 AA uygulamasında depolama sonunda TEA miktarının hemen hemen aynı seviyede olması dikkat çekici olmuştur. Bulgularımıza paralel olarak, Barzegar ve ark. (2018) AA uygulanmış biberlerde soğukta depolama boyunca TEA miktarının kontrol örneklerine göre daha yüksek kaldığını saptamışlardır. Bezer şekilde Oms-Oliu ve ark. (2007) taze kesilmiş kavunlarda ve Guerreiro ve ark. (2017) minimal işlenmiş elmalarda AA uygulamasının depolama boyunca TEA kaybını sınırlandırdığını rapor etmişlerdir. Organik asit bakımından oldukça zengin olan taze bahçe ürünlerinde yaşamsal faaliyetlerin devam edebilmesi için organik asitlerin parçalandığı, solunumda kullanıldığı ve olgunlaşma ile birlikte azaldığı bilinmektedir (Kader, 2002). Bu çalışmada da AA uygulanan taze kesilmiş pırasaların solunum hızının kontrol grubuna göre önemli oranda düşük olması (*Tablo 3*) ve bu örneklerde TEA değerlerinin depolama sonunda yüksek olması bu görüşle uyumlu bulunmuştur.

Tablo 2. Taze kesilmiş Lincoln pırasa çeşidinde AA uygulamasının depolama boyunca yalancı gövde rengi (L*, C*, h°) üzerine etkisi

Table 2. Effects of ascorbic acid treatment on pseudo stem colour (L, C*, h°) of fresh-cut leek cv. 'Lincoln' during storage*

Uygulamalar	Depolama Süresi						
	Başlangıç	6. gün	12. gün	18. gün	24. gün	30. gün	Ort.
				*L**			
Kontrol	76.53	72.65	73.36	75.69	73.49	69.01	**73.45**^{ÖD}
%1 AA	76.53	71.91	77.78	74.34	74.46	69.66	**74.11**
%2 AA	76.53	73.53	79.03	73.84	76.10	69.67	**74.78**
Ortalama	**76.53a**	**72.69b**	**76.72a**	**74.62ab**	**74.68ab**	**69.45c**	
				*C**			
Kontrol	26.56	31.97	30.93	23.93	32.82	27.19	**28.90A**
%1 AA	26.56	28.86	24.36	24.01	29.57	25.45	**26.47AB**
%2 AA	26.56	24.55	22.27	25.63	28.87	25.81	**25.61B**
Ortalama	**26.56ab**	**28.46ab**	**25.85ab**	**24.52b**	**30.42a**	**26.15ab**	
				h°			
Kontrol	62.16	61.46	61.98	65.25	60.49	63.91	**62.54**^{ÖD}
%1 AA	62.16	62.59	64.40	66.43	60.42	64.38	**63.40**
%2 AA	62.16	63.94	65.88	63.74	60.35	64.04	**63.35**
Ortalama	**62.16bc**	**62.66a-c**	**64.08ab**	**65.14a**	**60.42c**	**64.11ab**	

Önemlilik dereceleri			
	Depolama Süresi (DS)	*Uygulama (U)*	*DS × U*
L*	**	ÖD	ÖD
C*	*	*	ÖD
h°	**	ÖD	ÖD

ÖD: Önemli değil, *: P<0.05, **: P<0.01, Satır ve sütunlarda değişik harflerle gösterilen ortalamalar arasındaki farklılıklar istatistik olarak önemli bulunmuştur (P<0.05).

3.5. *Yalancı gövde rengi*

Taze kesilmiş pırasalarda gövde rengi *L** ve hue (*h*°) değerleri üzerine sadece depolama süresinin etkisi önemli (P<0.05) olurken, *C** değeri hem depolama süresi hem de uygulamalara göre değişmiştir. Çalışmada depolama sonunda en yüksek ortalama *L** değeri %2'lik AA (74.78) uygulamasında saptanırken, bunu sırasıyla %1'lik AA (74.11) ve kontrol (73.45) uygulamaları takip etmiş, ancak uygulamalar arasındaki farklılık istatistik olarak önemli bulunmamıştır (p>0.05). Başlangıç değerleriyle (76.53) kıyaslandığında depolama sonunda, tüm uygulamalarda

*L** değerleri (69.01-69.67) azalırken, *h°* değerlerinde kısmen artışlar olmuş, *C** değerleri ise sadece kontrol uygulamasında artış göstermiştir *(Tablo 2).*

Benzer şekilde Tsouvaltzis ve ark. (2007) taze kesilmiş pırasalarda depolama boyunca *L** ve *C** değerlerinin azaldığını bildirmişlerdir. Kasım ve Kasım (2017) taze kesilmiş pırasalarda *L** değerinin tüm uygulamalarda depolama boyunca azaldığını ancak yenilebilir kaplama maddesi uygulamasında azalmanın sınırlı kaldığını rapor etmişlerdir. Taze kesilmiş yeşil renkli ürünlerde kesme işlemi klorofil kaybına yol açarak sararmaya neden olurken, havuç gibi ürünlerde ise beyazlaşma ve renk değişimi olabilmektedir. Dolayısıyla kullanılan meyve ve sebzelere göre taze kesilmiş ürünlerde renk değişimi farklılaşabilmektedir. AA uygulamalarının genel olarak taze kesilmiş meyvelerde başta kararma olmak üzere renk değişimine neden olan enzimlerin aktivitelerini azaltarak, depolama süresince meyvelerin renginin korunmasında olumlu sonuçlar verdiği bildirilmektedir (Li ve ark., 2012; Liu ve ark., 2016; Zhou ve ark., 2021). Ancak dışsal AA uygulamasının taze kesilmiş ürünlerde renk değişimini engellemedeki mekanizması bütün yönleriyle açıklığa kavuşmuş değildir (Remorini ve ark., 2015).

3.6. Solunum hızı

Taze kesilmiş pırasaların solunum hızı (ml CO_2 $kg^{-1}s^{-1}$) üzerine depolama süresi, uygulamalar ve bunların interaksiyonunun etkisi istatistik olarak önemli ($P<0.05$) bulunmuştur *(Tablo 3).* Solunum hızı ilk hafta tüm uygulamalarda başlangıç değerlerinden düşük seyretmiş ve depolamanın 12. gününden itibaren başta kontrol örnekleri olmak üzere dikkate değer bir artış göstermiştir. Son iki dönemde kademeli olarak azalsa da başlangıç değerlerinden yüksek kalmıştır. AA uygulamaları solunum hızını bariz bir şekilde baskılamış ve yüksek dozda (% 2 AA) etki daha güçlü olmuştur. Kontrol örneklerinde ortalama solunum hızı 101.15 ml CO_2 $kg^{-1}s^{-1}$ olurken, bu değer % 1 ve % 2 AA uygulamalarında sırasıyla 81.75 ve 68.70 ml CO_2 $kg^{-1}s^{-1}$olarak saptanmıştır. Benzer şekilde AA uygulamaları taze kesilmiş patateslerde (Zhou ve ark., 2021) ve mantarlarda (Ojeda ve ark., 2019) depolama boyunca kontrole örneklerine göre solunum hızını azaltmıştır. Bahçe ürünlerinde taze kesim işleminden sonra solunumun hızlandığı ve ürünün karakteristik özelliğini veren lezzet ve aroma bileşiklerinde farklılaşmanın ve kayıpların arttığı bilinmektedir (Beaulieu ve Baldwin, 2002; Liu ve ark., 2007; Zhang ve ark., 2020). Bu nedenle asit karakteristikli koruyucu maddeler ve ürünü ortamdan belirli oranda izole ederek solunumu baskılayan yenilebilir kaplamalar kullanılmaktadır (Koyuncu ve Savran, 2002; Olivas ve Barbosa-Canovas, 2005). Derim sonrası metabolik aktivitedeki yavaşlamanın bir göstergesi olan baskılanmış solunum hızı, taze ürünlerdeki yaşlanma ve kalite kayıplarını geciktirmektedir. Dolayısıyla solunum hızını düşüren uygulamalar derim sonrası kalite kayıplarını yavaşlatarak ürünlerin depolanma süresini uzatmaktadır (Bal ve Çelik, 2005). Mevcut çalışmada AA uygulamasının bir stres faktörü olarak hücrede solunumla ilgili enzimlerin faaliyetlerini yavaşlatarak ve membran bütünlüğünü koruyarak (Lin ve ark., 2007) solunumu baskıladığı düşünülmektedir.

3.7. Duyusal değerlendirmeler

Denemede AA uygulamaları ve depolama süresi taze kesilmiş pırasaların dış görünüşlerini önemli düzeyde ($P<0.05$) etkilemiştir *(Tablo 3).* Kontrol ve %2 AA uygulamasında denemenin 12., %1 AA uygulamasında ise 18. gününde başlayarak depolama boyunca pırasalarda dış görünüş puanları azalmış, ancak AA uygulanmış örneklerde bu azalma daha sınırlı olmuştur. *Tablo 3*'de görüldüğü gibi kontrol grubundaki pırasalar dış görünüş puanları bakımından AA uygulaması yapılan örneklerden depolamanın 12. gününden itibaren farklılaşmaya başlamıştır. Bu fark depolama sonunda daha belirgin olmuş ve 30. günde AA uygulanmış pırasalar pazarlanabilir seviyeye ($P\geq 5.00$) çok yakın puanlar (4.72-4.83) almıştır. Kontrol örnekleri depolamanın 24. gününden sonra dış görünüş bakımından pazarlanabilir özelliklerini kaybetmiş ve depolama sonunda 3.25. puan almıştır. AA uygulamalarının depolama boyunca pırasalarda kalite kaybını sınırlandırması hem doku bütünlüğünü koruması hem de metabolik aktiviteyi yavaşlatmış olması ile açıklanabilir. Nitekim çalışmada AA uygulamasının ağırlık kaybı ve solunum hızını yavaşlattığı görülmektedir *(Tablo 1* ve *3)*. Deneme bulgularımıza uyumlu olarak taze kesilmiş patateslerde (Zhou ve ark., 2021), elmalarda (Liu ve ark., 2016), patlıcanlarda (Li ve ark., 2012) ve ananaslarda (Liu ve ark., 2007) AA tek başına ya da çeşitli kaplama maddeleriyle beraber kullanıldığında, depolama boyunca ürünlerin görsel kalitesinin daha iyi korunduğu rapor edilmiştir. Ayrıca Kasım ve Kasım (2017) yenilebilir kaplama maddelerinin soğukta depolama boyunca taze kesilmiş pırasaların dış görünüşünün korunmasında etkili olduğunu belirlemişlerdir.

Tablo 3. Taze kesilmiş Lincoln pırasa çeşidinde AA uygulamasının depolama boyunca solunum hızı (ml CO_2 $kg^{-1}s^{-1}$) ve dış görünüş (puan) üzerine etkisi

Table 3. Effects of ascorbic acid treatment on respiration rate (ml CO_2 $kg^{-1}h^{-1}$) and external appearance (score) of fresh-cut leek cv. 'Lincoln' during storage

Uygulamalar	Depolama Süresi						
	Başlangıç	6. gün	12. gün	18. gün	24. gün	30. gün	Ort.
	Solunum hızı						
Kontrol	34.97de	18.76e	107.66bc	194.39a	140.34ab	110.79bc	**101.15A**
%1 AA	34.97de	17.86e	43.51c-e	151.85ab	143.29ab	99.02b-d	**81.75B**
%2 AA	34.97de	18.77e	12.84e	132.56ab	119.84b	93.21b-d	**68.70B**
Ortalama	**34.97cd**	**18.46d**	**54.67c**	**159.60a**	**134.49a**	**101.01b**	
	Dış görünüş puanları						
Kontrol	9.00	9.00	8.59	7.58	5.92	3.25	**7.22B**
%1 AA	9.00	9.00	9.00	8.50	7.56	4.72	**7.96A**
%2 AA	9.00	9.00	8.94	8.22	7.72	4.83	**7.95A**
Ortalama	**9.00a**	**9.00a**	**8.84ab**	**8.10b**	**7.07c**	**4.27d**	
	Önemlilik dereceleri						
	Depolama Süresi (DS)		*Uygulama (U)*			*DS × U*	
Solunum hızı	**		**			*	
Dış görünüş	**		**			ÖD	

ÖD: Önemli değil, *: P<0.05, **: P<0.01, Satır ve sütunlarda değişik harflerle gösterilen ortalamalar arasındaki farklılıklar istatistik olarak önemli bulunmuştur (P<0.05).

4. Sonuç

Çalışmada beklendiği gibi depolama süresince tüm taze kesilmiş pırasa örneklerinde sertlik değeri azalırken, ağırlık kaybı artmıştır. Ancak AA uygulanmış pırasalarda bu kayıplar daha sınırlı kalmıştır. AA uygulanmış pırasa dilimleri daha az ağırlık kaybı ve daha sert yalancı gövde ile kontrol örneklerinden ayrışmış ve istatistiksel olarak farklı grupta yer almıştır. Özellikle %2'lik doz olmak üzere her iki AA uygulaması kontrole göre dilimlenmiş pırasaların solunum hızını bariz şekilde yavaşlatmıştır. AA uygulaması kontrol örneklerine göre depolama boyunca pırasaların görsel kalitelerini daha iyi korumuştur. Çalışmada taze-kesilmiş Lincoln pırasa çeşidinin streç filmle kaplı köpük kaseler içinde, 0±1 °C ve %90±5 oransal nemde 24 gün depolanabileceği belirlenmiştir. Ancak %1ve 2'lik AA uygulaması ile bu sürenin 30 güne kadar uzatılabileceği görülmüştür.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Effects of Combination of Copper Fungicide and Plant Activator on Late Blight and Quality Criteria of Potato

Bakırlı Fungusit ve Bitki Aktivatörü Kombinasyonunun Patates Mildiyösü Hastalığı ve Patates Kalite Kriterleri Üzerine Etkisi

Nilay ÖZDEMİR[1*]

Abstract

Late blight caused by *Phytophthora infestans* is one of the most important fungal diseases that cause damage to both the green parts and tuber of the potato plant and limits potato cultivation. Systemic fungicides are mostly preferred by farmers in the control of potato late blight. The fact that systemic fungicides cause health problems in terms of human and environmental health has revealed the need for research on control methods that do not threaten environmental health. In recent years, successful results have been obtained in the control of many diseases with plant activators known as Induced Systemic Resistance (ISR) promoters. This study was carried out in the spring season of 2016-2017 to observe the effect of copper fungicide and plant activator (*Lactobacillus acidophilus* fermentation product) combination on the control of potato late blight disease and some quality criteria of potato tubers in the experimental plots of Ege University Ödemiş Vocational School in Ödemiş district of İzmir province. The experiment was planned as two separate experiments with Marabel and Melody potato cultivars. The experiment was established according to a split-plot experimental design with four replications. In this study, the effect of the treatments on potato quality and yield criteria such as tuber number, tuber width, tuber length, single tuber weight, yield per decare, and the effects of the pesticides on potato late blight disease and disease severity parameters were evaluated. When the data obtained as a result of the study were evaluated, it was determined that the combination application had a positive effect on the control of potato late blight disease in both potato cultivars compared to the control plots. When the quality criteria of potato tubers were evaluated, the highest number of tubers was obtained from the plots where copper fungicide and plant activator (Isr-2000) combination was applied. Significant increase was obtained in potato quality and yield criteria such as tuber width, tuber length, average tuber weight and yield per decare when the combination plots were compared with the control plots. In conclusion, the use of contact fungicides and plant activator combinations in the control of late blight in the spring period within the scope of sustainable agriculture is promising as an application alternative in the control of plant diseases in organic agriculture.

Keywords: Potato, *Phytophthora infestans*, Organic agriculture, Plant activator, Copper fungicide

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Öz

Phytophthora infestans'ın neden olduğu mildiyö hastalığı patates bitkisinde hem yeşil aksamda hem de yumruda zarara sebep olan, patates yetiştiriciliğini sınırlandıran en önemli fungal hastalıklardan birisidir. Patates mildiyösü ile mücadelede çiftçiler tarafından en çok sistemik fungusitler tercih edilmektedir. Sistemik fungusitlerin insan ve çevre sağlığı açısından sağlık sorunlarına sebep olması, çevre sağlığını tehdit etmeyen mücadele yöntemleri araştırma ihtiyacını ortaya çıkarmıştır. Son yıllarda yapılan araştırmalarda uyarılmış sistemik dayanıklılık (Induced Systemic Resistance) (ISR) teşvik edici olarak bilinen bitki aktivatörleri ile birçok hastalığın kontrolünde başarılı sonuçlar elde edilmiştir. Çalışma İzmir iline bağlı Ödemiş ilçesinde yer alan Ege Üniversitesi Ödemiş Meslek Yüksekokulu deneme parsellerinde bakırlı fungusit ile bitki aktivatörü (*Lactobacillus acidophilus* fermentasyon ürünü) kombinasyonunun, patates mildiyösü hastalığının kontrolündeki ve patates yumrularının bazı kalite kriterleri üzerindeki etkisini gözlemlemek amacıyla 2016-2017 yıllarında ilkbahar sezonunda yürütülmüştür. Deneme Marabel ve Melody patates çeşitleri ile iki ayrı deneme şeklinde planlanmıştır. Deneme, dört tekerrürlü bölünen bölünmüş parseller deneme desenine göre kurulmuştur. Bu çalışmada, uygulamaların yumru adedi, yumru eni, yumru boyu, tek yumru ağırlığı, dekara verim gibi patateste kalite ve verim kriterleri ve patates mildiyösü hastalığına ilaçların etkisi ve hastalık şiddeti parametreleri değerlendirmeye alınmıştır. Çalışma sonucunda elde edilen veriler değerlendirildiğinde, kombinasyon uygulamasının kontrol parsellerine kıyasla her iki patates çeşidinde de patates geç yanıklık hastalığının kontrolü üzerinde olumlu bir etkiye sahip olduğu tespit edilmiştir. Patates yumrularının kalite kriterleri değerlendirildiğinde, bakırlı fungusit ve bitki aktivatörü (Isr-2000) kombinasyonu uyguladığımız parsellerden en yüksek yumru adedi elde edilmiştir. Yumru eni, yumru boyu, ortalama yumru ağırlığı ve dekara verim gibi patatesin kalite ve verim kriterlerinde kombinasyon uygulanan parseller kontrol parselleri ile kıyaslandığında önemli artış elde edilmiştir. Sonuç olarak, sürdürülebilir tarım kapsamında ilkbahar döneminde patates mildiyösü hastalığının kontrolünde kontakt etkili fungusitler ve bitki aktivatörü kombinasyonlarının kullanımı organik tarımda bitki hastalıkları ile mücadelede bir uygulama alternatifi olarak umut vadetmektedir.

Anahtar Kelimeler: Patates, *Phytophthora infestans*, Organik tarım, Bitki aktivatörü, Bakırlı fungusit

1. Introduction

Potato (*Solanum tuberosum* L.), which is a member of the Solanaceae family and has spread throughout the world from the Andes of South America, is one of the most important plants that can respond to the growing hunger problem in the world (Yıldırım et al., 2005). Today, it can be grown in almost every part of Turkey. It is one of the best plants that can be involved in crop rotation, especially in light, sandy-loam soils. Considering the increasing world population and limited agricultural areas, potato is a product that the world cares about both in terms of the product amount obtained per unit area and the quality of the product to meet the needs of more people. In the countries where it is grown, potato is a plant that contributes quite a lot to the national economy due to the high amount of product taken from the unit area (Bostan, 1996).

According to 2021 data from Turkey, the cultivation area of potatoes is 1.389.175 decares, the production amount is 5.100.000 tons, and the yield per unit area is 3671 kg da^{-1} (Anonymous, 2022a). The Ödemiş province has a significant share in terms of potato production in Turkey. According to 2021 data in Ödemiş, potato production takes place in three periods on approximately 92.000 decares of land Ödemiş plain in spring, Gölcük plateau and Bozdağ in summer, and Ödemiş plain again in autumn (Anonymous, 2022b).

Potato late blight (*Phytophthora infestans*) is one of the diseases seen in potato cultivation areas in the Ödemiş district and causes the most yield loss. The pathogen of the disease subsists in crop residues, infected tubers and other plants in the *Solanaceae* family. The spores of the disease's pathogen are airborne and can be carried to healthy plants by air flows. As a result of the increase in humidity in the spring, the pathogen causes sporulation on infected plants and these spores hold on to the plant from the lower leaves of cultivated plants close to the soil with the wind or raindrops. They enter the plant through natural surface openings or injured tissues in cultivated plants and penetrate the plant. They can cause secondary infections during the year (Stevenson, et al., 2001). Fungal spores must first germinate for the development of late blight disease. Appropriate temperature and high proportional humidity, such as water film, dew, and rain on the plant surface are required for this. The presence of free water on the leaf increases the activity of *P. infestans,* the pathogen of the late blight disease as well as many other leaf pathogens (Harrison, 1995; Agrios, 2005; Fry, 2008, Tian et al., 2016).

The most effective method in the fight against the disease is chemical control. Pesticides should be applied with appropriate systemic fungicides when the disease is seen in the field or when the climate conditions are suitable for the disease for chemical control to be successful. Due to the negative effects of systemic pesticides on the environment and human health, the fact that they create resistance on the target organism over time, and the high risk of residues, new solutions should be found in the fight against the disease. As a result of these problems, it has become obligatory to develop more effective, environmentally friendly fungicides against *P. infestans* and to use them with the best application techniques (Cook and Deahl, 1998). Plant activators are substances that activate the natural defence system of plants, allow them to make better use of nutrients, help protect them from stress conditions and similar external agents and factors, affect yield and product quality positively, and have natural strengthening, resistance increasing, soil structure regulating features. Plant activators have recently been preferred as an alternative to traditional plant disease control methods. Very successful results have been obtained from the combination of plant activator and copper hydroxide in blight diseases (Aysan et al., 2019; Tosun and Ergün, 2002).

In this study, copper fungicide with a contact-effective mechanism and a plant activator (ISR-2000), which is thought to increase the resistance by affecting the natural resistance mechanisms of the plant against diseases, were selected. ISR-2000 is a preparation consisting of biological, organic, and natural extracts formulation developed for use in herbal production and presented to agriculture. It contains *Lactobacillus acidophilus,* yeast extract, plant extract, and benzoic acid. It is a natural compound that exists in the plant but does not always appear under normal conditions, activates the natural defence mechanism, and is obtained biologically. The use of ISR-2000 is an environmentally friendly organic product that provides a high defence system and resistance against diseases and stress, an increase in crop yield and quality, an excellent economic return, and an increase in earnings (Yaman, 2006).

The aim of this study was to determine the effects of copper fungicide alone or in combination with a plant activator on plant growth characteristics, tuber quality and yield in the control of late blight disease, which causes significant yield loss in potato plants intensively produced in the spring season in Ödemiş region. It is thought that the results obtained at the end of the study will be useful for potato producers.

2. Materials and Methods

In order to determine the effects of copper fungicide and plant activator (ISR-2000) combination on disease control and plant growth characteristics of two potato cultivars against late blight (Phytophthora infestans) disease in Ödemiş, a study was carried out in the field and laboratories of Ege University Ödemiş Vocational School in the spring potato growing season of 2016-2017. Two different potato cultivars, Melody and Marabel, were used in the study (*Table 1*). Copper fungicide alone, combination of copper fungicide and plant activator (ISR-2000) and Aviso fungicide, which is a licensed commercial preparation with 57% metiram + 4% cymoxanil active ingredient, were used against potato late blight disease (*Table 2*). The study was conducted as two separate experiments on potato cultivars. The soil of the experiment area was determined as loamy sandy texture and poor in organic matter. Climatic data for the spring potato production season in the experimental area are given in *Table 3*.

2.1. Determining the Efficiency of Applications in Field Conditions

This experiment was conducted to determine the efficacy of a combination of copper fungicide and plant activator (ISR-2000) against potato late blight disease by spraying green parts under natural inoculation conditions in an area where the disease was observed in previous years. The experiment was planned according to a split-plot design with 4 treatments (3 fungicides + control) and 4 replications for two different potato cultivars. The experiment was established with 20 plants in each plot after edge effects. In order to prevent the chemical treatments from affecting each other, isolation rows of at least one metre were left between each treatment. All maintenance operations were carried out in the same way in all plots so that there was no difference between the plots. Potato seeds were sown between 15 February and 20 February. Potato harvesting was carried out between 20 June and 1 July. Spraying was started when the first potato late blight disease symptoms were seen in the environment and at least three sprayings were made at 10-12 days intervals at the doses recommended by the companies. The trial was planned in accordance with the Plant Disease Standard Pesticide Trial Methods of the General Directorate of Agricultural Research and Policies of the Ministry of Agriculture and Forestry of the Republic of Turkey. The counts were evaluated according to the 0-5 scale of TAGEM Plant Diseases Standard Pesticide Trial Methods, taking into account the duration of the drug effect and the disease severity in the control (*Table 4*). The values obtained as a result of the treatments were converted into disease severity using the Towsend-Heuberger formula (Towsend and Heuberger,1943). The effects of treatments on late blight of potato disease were calculated by comparing with control plots according to Abbott formula (Anonymous, 2015). The results obtained in the experiment were analysed using the statistical package SPSS v. 28.0 (SPSS, 2021). Significant differences between the averages obtained were determined using Tukey test. Treatments in the same statistical group were grouped with the same letter and the results were interpreted.

2.2. Characteristics Related to Plant Yield and Quality

In the experiment, yield and quality characteristics of tubers obtained at the end of harvest were examined to see the effect of copper fungicide alone and in combination with plant activator (ISR-2000) on plant yield and quality characteristics.

Table 1. Characteristics of potato cultivars

CHARACTERISTICS	MARABEL	MELODY
Plant height	Middle	Middle
Flower Color	White	White
Maturity	Early	Mid Early
Tuber Shape	Oval	Oval-Flat
Tuber Color	Dark yellow	Light yellow
Average Yield	2228 kg da^{-1}	3475 kg da^{-1}
Late Blight Disease Resistance	Resistant	Middle

Table 2. Characterization of experimental units of fungicides applied against potato late blight in feld trials.

Commercial Name	Active Substance	Provider	Formulation	Application dose
Champion	%77 Copper hydroxide	Hektaş	WG	250 g da^{-1}
Aviso	Cymoxanil+Metiram (%4,8+57)	Basf	WG	200 g da^{-1}
ISR 2000	855,81 g/l Lactobacillus acidophilus	Alltech Crop Science	Liquid	100 g da^{-1}

Table 3. Some climate data during the potato growing seasons of Ödemiş, İzmir between 2016-2017 *

Months	Rainfall (mm)		Average temperature (°C)		Relative Humidity (%)	
	2016	**2017**	**2016**	**2017**	**2016**	**2017**
JANUARY	252.5	51.0	9.4	11.7	70.9	74.3
FEBRUARY	187.0	18.5	11.2	11.7	70.2	68.2
MARCH	56.8	50.2	14.0	13.2	58.5	60.7
APRIL	30.2	73.8	17.3	17.0	54.0	78.5
MAY	43.7	18.4	22.7	20.8	54.7	15.3
JUNE	27.1	45.2	25.7	25.0	50.7	53.0

* based on the Ödemiş-İzmir Meteorological Station records

Table 4. The disease rating scale for late blight.

Rating	Reaction Description
0	No infection
1	At least one leaf is infected on one of the 10 branches in the plant.
2	Usually, at least one leaf on each branch is infected, but the plant appears green.
3	50% of the leaf area in the plant is destroyed and necrosis.
4	75% of the leaf area in the plant is destroyed and necrosis.
5	All the leaves are dead, the stems are drying up,

2.3. Sampling and Isolation Studies

Since *Phytophthora infestans* is an obligate parasite, its isolation and development in culture medium is quite difficult. During the experiment, diseased plant samples were collected during the spring potato growing period and isolation studies were carried out using Rye A Agar medium, one of the selective media. The experimental field was carried out under natural inoculation conditions where the disease was observed in previous years and no artificial inoculation was applied to the plants (Caten and Jinks, 1968; Tosun et al., 2003).

3. Results and Discussion

In order to investigate the effect of copper fungicide alone and in combination with plant activator (ISR-2000) in the control of potato late blight disease (*Phytophthora infestans*), which is one of the biggest problems of potato cultivation, trials were carried out on Melody and Marabel potato cultivars during spring potato planting periods for two years in 2016 and 2017. As a result of the statistical analyses performed according to the data obtained, the statistical significance of the effects of variance sources on potato late blight disease and potato yield and quality characteristics are given in *Tables 5* and *6*. The effects of copper fungicide alone (Champion) and copper fungicide and plant activator (Champion + ISR-2000) combination on late blight disease and potato yield and quality traits in two potato cultivars are given in *Tables 7* and *8*. According to F values (*Tables 5* and *6*), the effects of year, variety and fungicide treatments on tuber number were found to be statistically significant at $p \leq 0.01$ level. The effect of the interactions of the factors on the number of tubers was found to be statistically insignificant. The highest number of tubers was obtained with the combination of copper fungicide (Champion) and plant activator (ISR-2000) in both potato cultivars under Ödemiş conditions (11.16 number/plant; 9.99 number/plant). According to the results obtained in this study, the combination of copper fungicide (Champion) and plant activator (ISR-2000) increased the number of tubers, which is similar to the statements of many researchers that plant activators have a positive effect on fruit number. In 2013, some researchers investigated the effect of plant activators alone

on potato tuber size and yield. They found that both activators used in the study increased the number of tubers compared to the control (Öztürk and Yıldırım, 2013). In another study conducted in 2003, researchers reported an increase in the number of tubers in potato plants treated with Crop-set and ISR-2000 compared to the control (Koca and Yıldırım, 2003). The development of the tuber depends on a good vegetative development and the transport of photosynthesis products synthesized in the leaves from the leaves to the tubers. It has been stated by various researchers that late blight disease not only prevents the tuber from reaching the desired size but also causes a decrease in the number of tubers of sufficient size (Glass et al., 2001; Güler et al., 2011).

The effects of cultivar, fungicide treatments and cultivar x fungicide interactions on tuber width were found statistically significant at p≤0.01 level. In both potato cultivars used in the experiment, the highest tuber width values were obtained in plots treated with Aviso fungicide followed by copper fungicide (Champion) and plant activator combination (ISR-2000). Some researchers have reported that tuber width values differ according to potato variety (Çalışkan et al., 1997; Yıldırım et al., 2005). The difference in tuber width measurements between cultivars is similar to the literature. According to the findings obtained in this study, copper fungicide and plant activator (ISR-2000) combination treatment resulted in an increase in tuber width compared to the control. The results obtained are similar to the findings of some researchers who have worked with the plant activator in potato (Öztürk and Yıldırım, 2013; Çalışkan et al., 2021).

Table 5. The F values of tuber number, tuber width(mm) and tuber length(mm)

Source of Variation	df	Tuber Number	Tuber Width (mm)	Tuber Length(mm)
Year	1	25.97^{**}	10.99^{*}	9.64^{*}
Cultivar	1	14.84^{**}	390.75^{**}	199.43^{**}
Treatment	3	55.72^{**}	976.83^{**}	1252.10^{**}
Year x Cultivar	2	0.08^{ns}	15.02^{**}	1.23^{ns}
Year x Treatment	3	1.50^{ns}	5.68^{*}	0.76^{ns}
Cultivar x Treatment	3	1.22^{ns}	25.57^{**}	2.92^{*}
Year x Cultivar x Treatment	3	0.10^{ns}	3.51^{*}	1.10^{ns}

*Significant at the p≤0.05 level
** Significant at the p≤0.01 level
ns non significant

Table 6. The F values of the single tuber weight (g), yield(kg/da) and disease severity (%)

Source of Variation	df	Single Tuber Weight (g)	Yield (kg da^{-1})	Disease Severity (%)
Year	1	11.44^{**}	1.90^{ns}	10.74^{*}
Cultivar	1	312.12^{**}	0.19^{ns}	12.95^{**}
Treatment	3	4223.86^{**}	1967.93^{**}	3881.28^{**}
Year x Cultivar	2	7.56^{*}	28.27^{**}	0.23^{ns}
Year x Treatment	3	4.55^{*}	8.26^{**}	2.41^{ns}
Cultivar x Treatment	3	16.5^{**}	6.67^{**}	0.99^{ns}
Year x Cultivar x Treatment	3	35.78^{**}	6.02^{*}	0.37^{ns}

* Significant at the p≤0.05 level
** Significant at the p≤0.01 level
ns non significant

The effect of cultivar and fungicide treatments on tuber length was found statistically significant at p≤0.01 level, while the effect of cultivar x fungicide interaction was found significant at p≤0.05 level. Among the fungicide treatments, the combination of copper fungicide (Champion) and plant activator (ISR-2000) was observed as the plots with the highest tuber length after the fungicide plots used as comparison in both potato cultivars. It was also reported by different researchers that tuber length values differed according to the cultivars used (Çalışkan et al., 1997; Yıldırım et al., 2005). In this study, the difference in tuber length among the cultivars is in parallel with the literature. In the experiment, an increase in tuber length was observed in the plots where copper fungicide (Champion) and plant activator (ISR -2000) combination was applied compared to the control.

In 2013, researchers reported that plant activators provided an increase in tuber length compared to control plots (Öztürk and Yıldırım, 2013). The results we obtained in terms of tuber length are in parallel with the literature.

Table 7. Means of treatments on late blight, tuber number, tuber width(mm) and tuber length(mm) in the field trial

Treatment	Tuber Number	Tuber Width (mm)	Tuber Length(mm)
Cultivar (Marabel)			
Champion	10.03±0.96a	60.73± 1.81b	83.13±2.14c
Champion+ISR2000	11.16±1.23a	68.15±1.39a	106.86±4.02b
Aviso	10.24± 0.72a	69.43±1.59a	113.11± 2.79a
Control	7.62±0.76b c	46.43±1.28c	57.46±2.32d
$LSD_{(0.05)}$	0.67	1.75	8.95
Cultivar (Melody)			
Champion	9.74±1.05a	65.23±1.60b	96.08±3.11b
Champion+ISR2000	9.99±0.99a	72.85±2.61a	118.84±2.65a
Aviso	9.28±0.48a	74.13±2.51a	121.65± 4.61a
Control	7.16±0.59b	52.42±1.70c	65.22±2.58c
$LSD_{(0.05)}$	0.43	2.30	8.19

* Means with the same letter in the same column are in the same group.

Table 8. Means of treatments on late blight, single tuber weight(g.), yield(kg/da), disease severity(%) and effect (%) in the field trial

Treatment	Single Tuber Weight (g)	Yield (kg da^{-1})	Disease Severity (%)	Effect (%)
Cultivar (Marabel)				
Champion	101.97±2.68c	3200.64±120.47c	40.38±3.20b	56.87
Champion+ISR2000	163.65±5.51b	4734.35±297.02b	25.38±3.50c	72.87
Aviso	180.62±3.64a	5103.13±257.59a	10.50±0.92d	88.67
Control	73.95±4.05d	1810.54±123.04d	93.75±1.48a	0.00
$LSD_{(0.05)}$	15.24	15511.78	6.22	
Cultivar (Melody)				
Champion	114.70±4.62c	3532.88±227.73b	37.63±3.02b	59.26
Champion+ISR2000	188.04±7.29b	4810.10±190.29a	22.13±2.29c	75.87
Aviso	198.70±6.02a	5064.34±306.95a	9.88±1.64d	87.29
Control	83.80±3.09d	1786.45±154.69c	92.00±2.92a	0.00
$LSD_{(0.05)}$	23.98	36840.82	4.36	

* Means with the same letter in the same column are in the same group.

Considering the potato single tuber weight, cultivar and fungicide treatments were found to be statistically significant at the p≤0.01 level. When the effect of the combination of copper fungicide and plant activator (ISR-2000) on potato single tuber weight was examined, it was observed that the highest tuber weight was obtained after the comparative fungicide treatment in both potato cultivars. It was reported by many researchers that the tuber weight values obtained in the studies differed according to the cultivars used. (Arslan and Kevseroğlu, 1991; Yıldırım et al., 2005). The difference in tuber weight parameters of potato cultivars is similar to the literature. In this study, cultivar x fungicide interaction was found to be statistically significant at the level of 1% in terms of average tuber weight. When examined in terms of the effect of the treatment, an increase in tuber weight was detected in both potato cultivars in the parcels where the combination of copper fungicide and plant activator (ISR-2000) was applied. In a study conducted by researchers working with plant activators in potato plant in 2013, it was reported that plant activator application increased single tuber weight compared to control (Öztürk and Yıldırım, 2013). The findings related to single tuber weight are like the literature.

When the effect of copper fungicide and plant activator (ISR-2000) combination on potato yield was analysed, it was 4734.35 kg/da. in Marabel potato variety and 4810.10 kg/da. in Melody potato variety. It was the plot with the highest yield value after the comparative fungicide treated plots. In this study, when the effect of variance

sources on yield per decare of potato was examined, the effect of fungicide treatments and cultivar x fungicide interaction was found to be statistically significant at the $p \leq 0.01$ level. This study, when the effect of the application on yield per decare was examined, in parcels where copper fungicide and plant activator (ISR-2000) combination is applied, a significant increase in tuber yield per decare was observed in both potato cultivars compared to the control. It is also stated by many researchers that potato late blight disease is a devastating disease and adversely affects yield and product quality. The findings obtained in this study on the effect of the treatments on the yield values per decare in potato are in parallel with the literature. (Doke, 1983; Grenville- Briggs et al., 2005; Whisson et al.,2007; Morgan and Kamoun, 2007; Haverkort et al., 2008).

The effect of fungicide applications on disease severity against potato late blight, which was the main objective of this study, was found to be statistically significant at $p \leq 0.01$ level. The lowest disease severity in both potato cultivars was observed in the plots where Aviso comparison fungicide was applied (10.50%; 9.88%). This was followed by the combination of copper fungicide and plant activator (ISR 2000) (25.38%; 22.13%). On the other hand, in the plots where copper fungicide was applied alone, 40.38% disease severity was observed in Marabel potato variety and 37.63% disease severity was observed in Melody potato variety. In the plots where the combination of copper fungicide and plant activator (ISR-2000) was applied, it was found to be an effective application in the control of potato late blight disease with 72.87% efficiency in Marabel potato variety and 75.87% efficiency in Melody potato variety. In the plots where copper fungicide was applied alone, 56.87% effect was observed in Marabel potato variety and 59.26% effect was observed in Melody variety against potato late blight disease compared to the control plot. Supporting the findings of this study, it was reported that the combination of plant activator and copper preparations against tomato bacterial spot disease increased the success in suppressing the disease and prolonged the effect of spraying in a trial conducted in 2003 (Karabay et.al., 2003). Similarly, in a study conducted in tomato in 2005, it was found that the combination of copper hydroxide and plant activator was more effective against bacterial plant diseases when applied together than when applied alone (Türküsay and Tosun, 2005). Some researchers have also stated that the use of plant activators together with fungicides is more effective in the control of plant diseases. It was emphasised that plant activators are more preferable than classical chemical control methods due to the low risk of developing resistance against pathogens and providing long-term protection. In addition, in a study conducted in tomato, some researchers reported that the combination of copper hydroxide and plant activator was effective on tomato late blight disease (Tosun and Ergün, 2002). In a study published in 1997, it was reported that the application of a combination of plant activator and fungicide against grain powdery mildew (Erysiphe graminis) provided 82% protection, while the combination of plant activator with metalaxyl-M fungicide against tobacco downy mildew largely prevented the disease (Novartis, 1997). The results of this study are in parallel with the results of many researchers that plant activators increase plant resistance against plant diseases (Werner et al., 2002; Karavaş, 2002; Karabay et al., 2003; Çetinkaya and Aysan, 2005; Üstün et al., 2005; Boyraz et al., 2006; Delisoy and Altınok, 2019; Karabüyük and Aysan, 2019; Aktepe, 2021).

4. Conclusions

As a result, the combination of copper fungicide and plant activator (ISR-2000), one of the contact-acting fungicides, was found to be significantly effective against potato late blight disease compared to control plots. In the study, it was determined that late blight disease had a significant effect on plant growth characteristics and yield of potato. When potato late blight disease was controlled, it was observed that more and high quality products could be obtained from unit area. There was no difference between the cultivars in terms of resistance to potato late blight disease in the spring potato growing period. The data obtained in this study support the inclusion of copper fungicide and plant activator (ISR-2000) combination in integrated control programmes against fungal diseases in potato production areas. When the results obtained in this study are evaluated in general, it is concluded that the use of plant activators and contact fungicides together in the treatment of fungal diseases in potato production areas will be guiding for potato producers due to its benefits such as increased effectiveness of contact fungicides against the disease, no residue risk, increase in yield and quality.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Isolation, Identification and Determination of *Saccharomyces cerevisiae* Yeast Species from The Wines Made by Spontaneous Fermentation Using Papazkarası Grapes from Thrace Region

Trakya Yöresine Ait Papazkarası Üzümleri Kullanılarak, Spontan Fermantasyon ile Elde Edilen Şaraplardan *Saccharomyces cerevisiae* Türü Mayaların İzolasyonu, Tanımlanması ve Teknolojik Özelliklerinin Belirlenmesi

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Abstract

Especially in large-scale commercial wine production, fermentation is usually carried out by using the species of *Saccharomyces cerevisiae* yeast cultures. Standard wine yeast starter cultures are brought from abroad and used in industrial winemaking in our country. Thus, in course of time, the wines of all producers began to show similar properties. Today, studies focus on terroir wines production with local characteristics by using the countries' own local wine yeasts as a starter. Within the scope of this study Papazkarası grapes were collected from 4 vineyards with different characteristics, such as viticulture practices, microclimatic conditions and locations in the borders of Edirne and Kırklareli. In addition, the grapes were also collected from the vineyard in Tekirdağ Viticulture Research Institute. Spontaneous fermentation was done by crushing the collected grapes in the laboratory. At the end of the fermentation, yeast isolations were made from the musts to YPD medium and a total of 66 isolates were obtained as a result of purification. Fermentation rate, H_2S production amount, growth at high temperature, growth at high sugar concentration, resistance to high ethanol, ability to grow at low pH values, resistance to SO_2, and volatile acid analysis were done to determine whether they meet the technological requirements for basic winemaking, together with two commercial wine yeasts. DNA sequencing analyzes were made by selecting 15 of the isolates that were found to have the necessary characteristics and it was determined that they belonged to the *Saccharomyces cerevisiae* species. DNA fingerprinting analysis was performed using delta 12-21 primers to determine the strain differences of the isolates determined to belong to the same species. By DNA fingerprint analysis, it was determined that 9 out of 15 isolates were different strains.

Keywords: Papazkarası, *S. cerevisiae*, Wine, DNA, Yeast

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*This study is summarized from the Msc. thesis.

Öz

Günümüzde, özellikle büyük çaplı ticari şarap üretiminde, fermantasyon genellikle *Saccharomyces cerevisiae* türü maya kültürleri kullanılarak gerçekleştirilmektedir. Standart şarap mayası starter kültürleri Uluslararası büyük maya üreticisi firmalardan alınarak ülkemizde, şarap yapımında kullanılmaktadır. Bu da, üreticilerin şaraplarının zamanla birbirine benzemesine yol açmaktadır. Günümüzde yapılan çalışmalar, ülkelerin kendi yerel şarap mayalarını starter olarak kullanarak yerel özellikler taşıyan teruar şaraplarının üretimine yoğunlaşmaktadır. Bu çalışma kapsamında, Edirne ve Kırklareli sınırlarında bulunan, yapılan bağcılık uygulamaları, mikroklimatik şartları, konumları gibi özellikleri farklılık taşıyan 4 bağdan ve Tekirdağ Bağcılık Araştırma Enstitüsündeki bir bağ parselinden olmak üzere toplam 5 farklı lokasyondan Papazkarası çeşidine ait üzümler önolojik olgunluk aşamasında toplanmıştır. Toplanan üzümler laboratuvara getirilerek ezilmiş ve sonrasında spontan fermantasyona bırakılmıştır. Fermantasyon sonunda fermante olmuş şıralardan, YPD besiyerlerine, ekim yapılmıştır. Besiyerlerinde gelişen kolonilerin saflaştırması işlemi sonucunda toplam 66 adet izolat elde edilmiştir. İzolatların, 2 adet ticari şarap mayası ile birlikte, temel şarap yapımı için gereken teknolojik özellikleri karşılayıp karşılamadıklarını belirlemek için fermantasyon hızı, H_2S üretim miktarı, yüksek sıcaklıkta gelişebilme, yüksek şeker konsantrasyonunda gelişebilme, yüksek etanole dayanıklılık, düşük pH değerlerinde gelişebilme, SO_2'ye dayanıklılık, uçar asit miktarı analizleri uygulanmıştır. Gerekli özelliklere sahip olanlardan 15 tanesi seçilerek DNA dizileme analizleri yapılmış ve *Saccharomyces cerevisiae* türüne ait oldukları tespit edilmiştir. Aynı türe ait oldukları belirlenen izolatların alt tür bazında birbirinden farklı olup olmadıklarını belirlemek üzere delta 12-21 primerleri kullanılarak DNA parmak izi analizi yapılmıştır. Bu izolatlara yapılan DNA parmak izi analizlerinde 9 adet farklı suş tespit edilmiştir.

Anahtar Kelimeler: Papazkarası, *S. cerevisiae*, Şarap, DNA, Maya, Karakterizasyon

1. Introduction

Wine is one of humanity's oldest beverages. The wine was originally formed by fermentation of damaged grapes in barrels (Chambers and Pretorius, 2010). Today, wine fermentation is carried out using yeasts such as *Saccharomyces cerevisiae* (Jolly et al., 2006). *S. cerevisiae*, which is also used in fields such as enzymes and bread production today (Özdinç and Velioğlu, 2022), is accepted as the main yeast species responsible for alcoholic fermentation due to its ability to grow in grape juice, which is characterized by high sugar and low nitrogen content. *S. cerevisiae* species produce high amounts of ethyl alcohol, inhibit the growth of other yeasts and become dominant during must fermentation (Cocolin et al., 2004).

The factors that determine the quality and character of the wine are the grapes used and the cultivation style, as well as the fermentation outputs of the yeast used. Standard yeast cultures produced worldwide are widely used in industrial winemaking. Thus, over time, the wines of all producers began to show similar characters. Today, studies focus on wine production with local characteristics by using the countries' own local wine yeast as a starter culture (Varela and Borneman, 2016). In addition, autochthonous yeasts show better adaptability to specific musts determined by terroir and grape variety (Bokulich et al., 2013).

Wine yeasts selected for use in wine production need to have certain technological properties (fermentation rate, H_2S production amount, growth at high temperature, growth at high sugar concentration, resistance to high ethanol, ability to grow at low pH values, resistance to SO_2, volatile acid etc.) that will make them suitable for industrial wine production, and the determination of these technological properties is very important for the efficiency of the fermentation process. Many of the technological features differ greatly within yeast strains. Therefore, the technological properties of all isolates must be determined. In addition, during the selection of yeasts, their genomic structures should be determined and defined as well as morphological differences (Lopes et al., 2006)

Turkey terroir is very suitable for the cultivation of different grape varieties (Tahmaz et al., 2022). Thrace region is one of the important wine grape growing regions in Turkey. Papazkarası grape variety is the indigenous and ancient grape variety of the Thrace region. Within the borders of Thrace, there are many Papazkarası vineyards with different characteristics. There is no study in the international literature on the isolation and identification of *Saccharomyces cerevisiae* yeasts suitable for winemaking from Papazkarası grapes in this region. Grapes harvested from Papazkarası vineyards with different characteristics in the Thrace region were used in this study since factors such as geography, altitude, climate, the presence of other grape varieties grown in the same vineyard, soil structure, and age of the vineyard are the most important factors on the yeast population and variety on the grape.

The aim of the study was to isolate, identify and determine the technological properties of Saccharomyces cerevisiae yeast strains from microvinification experiments with Papazkarası varieties collected from vineyards in the Thrace region. Thus, it will be contributed to the process of collecting local yeasts from our country's own genetic resources, identifying suitable and resistant species, and selecting yeasts strains suitable for winemaking, in order to produce wines with unique flavors with high international competitiveness. In addition, since the isolated and identified wine yeast candidates will be stocked, a contribution will be made to the gene bank of our country and a resource will be created for future studies.

2. Materials and Methods

2.1. Region

Grapes to be used in the study were harvested at maturity stages from 5 vineyards located within the borders of Edirne, Kırklareli and Tekirdağ (*Figure 1*).

- Kirklareli, Üsküp : 41°45’10”N 27°23’30”E, Altitude: 351m
- Kirklareli, Hamitabat : 41°32’00”N 27°17’41”E, Altitude: 140m
- Edirne, Kircasalih : 41°22’52”N 26°48’6”E, Altitude: 87m
- Edirne, Yeniköy : 41°20’18”N 26°45’17”E, Altitude: 78m
- Tekirdağ Viticulture Research Institute : 40°58’30”N 27°28’03”E, Altitude: 50m

While determining the technological properties of isolated yeasts, 2 commercial wine yeasts (RC212, ICV Opale)

were used. *Candida krusei* strain, which is known to be a strong producer, was used to determine the level of H_2S production.

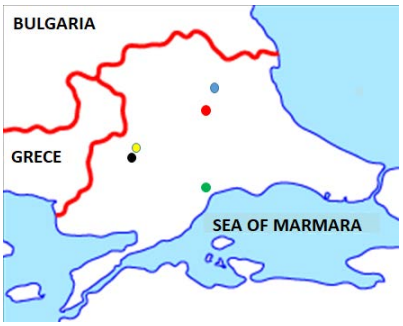

Figure 1. Regions where Papazkarası grapes are harvested

2.2. Spontaneous fermentation process

25 mg l^{-1} sulfur dioxide (SO_2) has been added to avoid any biological risk but to ensure the greatest possible yeast population in the must (Parish and Carroll, 1987). Musts were left to ferment at a constant temperature of 17°C. Until the end of the fermentation, the weight loss in the bottles was measured every day and it was predicted that the fermentations were finished when the weight loss stopped. In all prepared trials, fermentations were completed between 15-25 days.

2.3. Isolation

At the end of the fermentation, samples were taken from the musts and inoculated on YPD agar (1% yeast extract, 2% peptone, 2% dextrose, 1.5% agar) containing 0.015 mg l^{-1} amoxicillin at concentrations of 10^{-2} to 10^{-6} and Incubated at 28°C for 4 days (Çavdaroğlu, 2017). At the end of the incubation, the colonies were randomly selected according to their morphological characteristics and purified by cultivating on another YPD agar with the streaking method. The purification process was repeated 6 times (Valero et al., 2007).

2.4. Identifying technological features

H_2S Production: The rotten egg smell created by hydrogen sulfide in wines is an undesirable situation. Therefore, yeasts to be used as wine starter cultures are required to produce low levels of H_2S. Isolated yeast strains were cultivated on BIGGY (bismuth sulphite glucose glycine yeast) agar and incubated at 30°C for 5 days, and hydrogen sulfide production was estimated by looking at the colour formation on the medium. The degree of browning of yeast lines; 1: white, 2: cream, 3: light brown, 4: brown, 5: dark brown and 6: black (Cordente et al., 2009).

Fermentation Rate: It is desired that wine yeasts become dominant in the must and suppress other microorganisms in the first stages of fermentation. In this study, the growth rate of the isolates was determined by measuring the weight loss that occurred in the media between the 24^{th} and 72^{nd} hours of fermentation. Inoculations were made by putting 20 mL of YPD medium with a pH of 3.5, containing 20% glucose in 50 mL sterile tubes, and the tubes were left to incubate at 25°C. The weight loss due to CO_2 gas output between the 24^{th} and 72^{nd} hours of fermentation was calculated in "g CO_2 $(L\ h)^{-1}$" (Pérez-Coello et al., 1999)

High Temperature Tolerance: Yeast strains were inoculated in YPD broth (10 mL), incubated at 37 and 42°C for 5 days, and their growth was examined (Nikolaou et al., 2006).

High Sugar Tolerance: Yeast cultures were inoculated into 10 mL YPD Broth medium adjusted to 30°Bx, and incubated at 30°C for 3 days. At the end of the period, the growth of gas-forming isolates in two-thirds of the Durham tube was considered positive (Iranzo et al., 1998).

High Ethanol Tolerance: After counting with a Thoma slide (~3 µL 10^6 cfu mL-1), yeast isolates are inoculated into a 10 mL YPD medium, containing 100-130-150-170 mL L^{-1} ethanol and incubated at 30°C for 72 hours. Their growth at the end of this period was examined (Guimarães et al., 2006).

Low pH Tolerance: YPD media with pH values adjusted to 3.0 and 4.0 with HCL and NaOH were put in 15 mL tubes as 10 mL. Isolates are inoculated (10 µL) and incubated at 28°C for 7 days. At the end of this period, the gas accumulation in the tubes was examined. Unadjusted YPD medium with a pH of 6.67 was used as a control in the

experiment. (Charoenchai et al., 1998).

Sulfur Tolerance: The growth characteristics of the isolates on YPD media supplemented with SO_2 at concentrations of 0, 50, 100, 150, and 200 mg L^{-1} were investigated. Activated yeast cultures were inoculated into the medium at a level of approximately 10^6 cells mL^{-1} and incubated at 28°C for 72 hours. (Guimãraes et al., 2006).

Volatile Acid Production: YPD medium containing 20% glucose was used to detect for volatile acid production. The steam distillation method was used to determine the amount of volatile acid formed by yeast in the medium. Sixty mL of liquid distilled by steam distillation system was heated to boiling point. Then, it was titrated with 0.1 N NaOH solution under phenolphthalein indicator until colour change was observed. (Ough and Amerine, 1988).

2.5. Molecular characterization

DNA sequencing analyses: Among 66 isolated yeast strains, sequencing and DNA fingerprinting analyzes were performed for 15 yeast strains that showed proficiency in technological tests.

After using the lyticase enzyme to break down the yeast cell walls, the steps specified in the "Wizard Genomic DNA purification Kit" product of Promega company were followed. The purity of the isolated DNA was determined by nanodrop.

In the studies, ITS1 (5´TCC GTA GGT GAA CCT TGC GG 3´) was used as the forward primer and ITS4 (5´TCC TCC GCT TAT TGA TAT GC 3´) was used as the reverse primer. In the study, 17.5 µL nuclease-free sterile water, 2.5 µL buffer (does not contain $MgCl_2$), 0.5 µL (deoxynucleotide triphosphate) dNTPmix, 0.5 µL ITS1 forward and 0.5 µL ITS4 reverse primers, 2 µL $MgCl_2$, 0.5 µL Taq DNA polymerase enzyme and 50 ng DNA were added in a total volume of 50 µL in 500 µL PCR tubes. PCR reaction parameters were programmed as 15 min initial denaturation at 95°C, 60 s denaturation at 94°C, 2 min annealing at 55°C, and 2 min extension at 72°C, and this process was repeated 35 times. PCR was completed with a 10 min final extension at 72°C (Blaiotta et al., 2002). Sequence analysis of DNA samples visualized on agarose gel was performed at Namık Kemal University Scientific and Technological Research Application and Research Center. The nucleotide sequences of yeast samples were compared with known sequences in NCBI GenBank using the BLAST program.

DNA fingerprinting analysis: To see the differences in yeast samples based on strain, DNA fingerprinting analyzes were performed using delta12 (5´TCAACAATGGAATCCCAAC´3) and delta21 (5´CATCTTAACACCGTATATGA´3) primers. The PCR reaction contains 25 µL volume of 2.5 mM $MgCl_2$, 0.2 mM dNTP mix, 1 µM forward primer (delta 12), 1 µM, reverse primer (delta 21), 1.25 Units of Go-taq flexi DNA polymerase (Promega), 50 ng DNA. PCR conditions were pre-denaturation at 95°C for 4 min, then 30 cycles of 30 s at 95°C, annealing at 46°C for 30 s, polymerization at 72°C for 90 s, and finally a final extension at 72°C for 7 min. Post-PCR samples were run on a 1.4% agarose gel in 1xTBE buffer at 100 V for 2 hours. In the presence of ethidium bromide, they were viewed under UV light and their photographs were recorded (Bilgin, 2015).

3. Results and Discussion

With the weightings made during the spontaneous fermentation process, data such as the start times of fermentations, their speeds in certain periods, and the finishing stages were obtained (*Figure 2*).

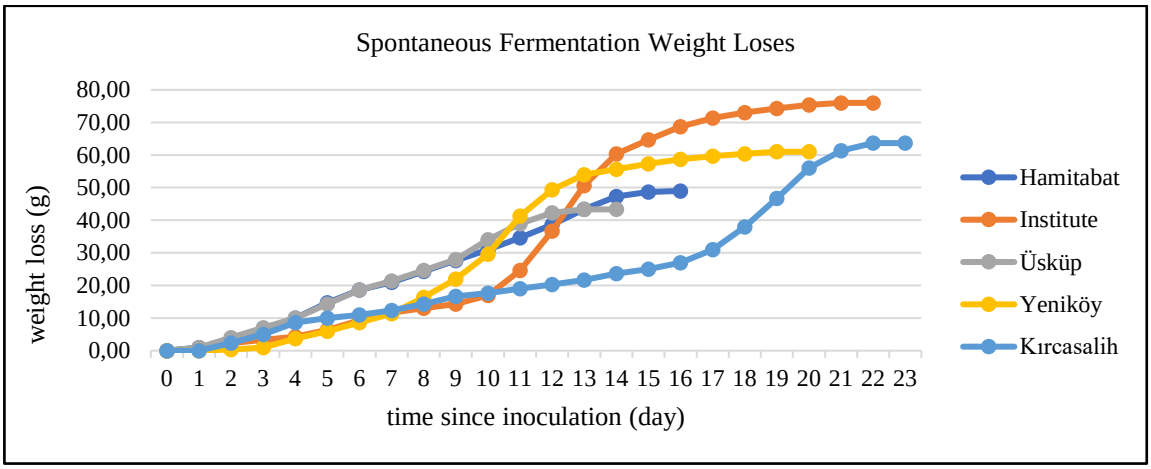

Figure 2. Weight reductions of grape must collected from different vineyards during spontaneous fermentation

It was observed that fermentations in all samples except Yeniköy started in 2-3 days, and in Yeniköy samples, fermentations started on the 4th day. This time may vary depending on the density of the microorganism flora in the samples and/or the capabilities of the microorganisms initiating fermentation. In addition, the completion times and rates of fermentations differed from each other, which is due to the differences in the initial sugar, water-soluble dry matter and microbial flora on the peel (Lu et al., 2020).

3.1. Isolation and sampling

When the weight reductions were fixed, samples were taken from each of the fermented musts (Guimarães et al. 2006). A total of 66 isolates were purified. The isolates were named as the initial letter of the region they were taken from and the isolate number (H9: 9. Isolate obtained from the vineyard in Hamitabat region).

3.2. Analyzes to Determine the Technological Characteristics of Yeasts

H_2S Production: Since the rotten egg odor created by hydrogen sulfide in wines is undesirable, yeasts to be used as wine starters are required to produce low levels of H_2S (*Figure 3*).

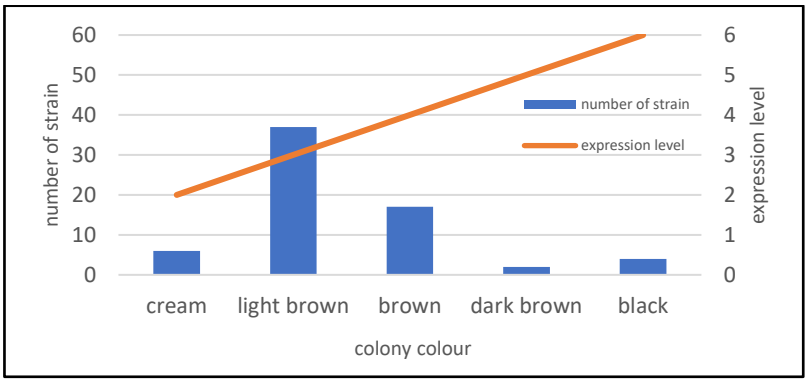

Figure 3. H_2S production levels according to colony colours formed by isolates on BIGGY agar

In the hydrogen sulfide production analysis, 6 strains formed cream-coloured (2) colonies on BIGGY agar, while 37 light brown (3), 17 brown (4), 2 dark brown (5) and 4 black (6) colours were formed. Commercial yeast strains taken as references formed a brown colour, indicating that they are intermediate hydrogen sulfide producers. 60 of the isolates that formed brown and lighter coloured colonies were accepted as potential wine starters. 6 isolates (Ü1, Ü6, Ü8, Ü9, Ü16 and Ü19) forming dark brown and darker colonies were evaluated in the category of yeast that does not have wine-making properties due to their high hydrogen sulfide production. It has been observed that 5 out of 6 isolates (Y7, Y8, Y9, H6, E1), which give cream colour, have been successful in other technological analyzes as well, so they have a high potential to be used in the production of wines that are required to have very low H_2S levels from yeast or to be made from damaged grapes.

In similar studies, it is seen that the majority of the isolated *S. cerevisiae* strains give light brown and brown colony colour (Budroni et al., 2006; Lopes et al., 2007; Bağder, 2008; Çelik et al., 2017).

Fermentation Rate: In the experiments, all yeasts, except for 6 isolates (Ü1, Ü6, Ü8, Ü9, Ü16, Ü19), which were found to have no ability to ferment the must, caused a weight reduction greater than 0.25 g CO_2 $(L\ h)^{-1}$ between 24-72. hours. (Iranzo et al., 1998).

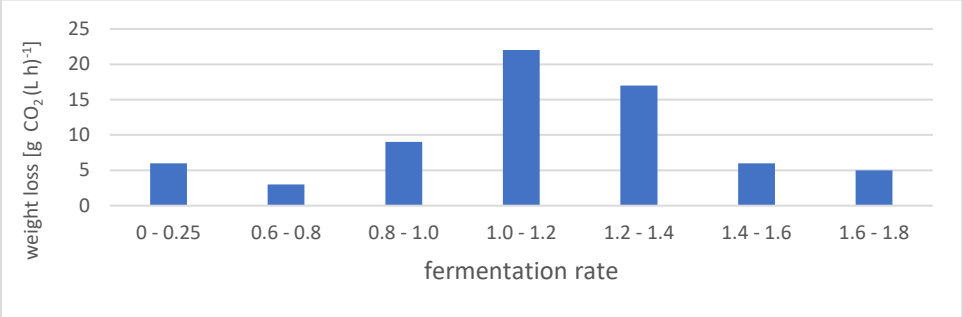

Figure 4. Weight reductions in the media between the 24th and 72nd hours of inoculation

The weight reductions of the other yeasts in the study were found to be in the range of 0.739 - 1.698 g CO_2 $(l\ h)^{-1}$. From this point of view, in terms of fermentation rate, it is seen that all other isolates can be used as starter cultures in wine. It was observed that 36 of the isolates had higher fermentation rates than the control group, commercial red wine yeast (RC212), and 30 of them had higher fermentation rates than the control group, commercial white wine yeast (ICV Opale). It was determined that the isolates leading in weight reductions at the end of fermentation were also prominent in weight reductions between 24-72 hours (*Figure 4*). Yeasts with a high fermentation rate are those isolated from grapes collected in Yeniköy and Hamitabat, proportionally. According to other studies on this subject, it has been observed that more than half of the isolates are dominant yeasts with a high fermentation rate that can ferment the must very strongly (Pérez-Coello et al., 1999; Orlić et al., 2005; Budroni et al., 2006; Bagder, 2008).

Table 1. Technological tests of isolates

Other technological tests of isolates	Number of tolerant isolates	Number of intolerant isolates
High temperature tolerance (37°C)	66	-
High temperature tolerance (42°C)	56	10
Growth at 30°Bx	66	-
Ethanol tolerance (10%)	64	2
Ethanol tolerance (13%)	57	9
Ethanol tolerance (15%)	53	13
Ethanol tolerance (17%)	10	56
pH tolerance (3.0)	66	-
pH tolerance (4.0)	66	-
SO_2 tolerance (50 ppm)	66	-
SO_2 tolerance (100 ppm)	65	1
SO_2 tolerance (150 ppm)	64	2
SO_2 tolerance (200 ppm)	64	2

High temperature tolerance: It has been observed that all isolated strains can grow at 37°C. Only 10 of 66 isolates (K6, K8, Ü1, Ü2, Ü6, Ü9, Ü17, H8, H10 and H15) failed to grow at 42°C (*Table 1*). This rate is seen as a high rate compared to the development of isolates in similar studies at these temperatures (Bağder, 2008; Çavdaroğlu, 2017; Antia et al., 2018). With this analysis, the temperature resistance of the majority of isolated yeasts was found to be suitable for winemaking. Yeasts that grow well at high temperatures have the potential to be used to prevent stuck fermentation in situations where there is no cooling system and extreme temperature rises can be observed during fermentation. 5 of the 10 isolates that could not grow at 42°C were yeasts isolated from grapes in the Üsküp region. Since the sugar content of the grapes in this vineyard was relatively low (14°Bx) at the harvest stage, the alcohol content at the end of the fermentation was also relatively low. Therefore, it was considered that some of the yeasts isolated from the grapes collected from the Üsküp region may be *non-Saccharomyces* yeasts, and it is estimated that the isolates that did not grow at 42°C are *non-Saccharomyces* yeasts (Ali and Khan, 2014). Control yeasts showed growth at both temperatures.

High Sugar Concentration Tolerance: It was observed that all isolates in the study were able to grow at 30°Bx (*Table 1*). From this point of view, it's seen that the isolates can be used as starters resistant to osmotic pressure in the production of wines to be obtained from musts with high sugar concentrations obtained from grapes harvested late, grown in hot climates or obtained from grapes with botrytis. In other studies, it is seen that *S. cerevisiae* is generally resistant to this sugar concentration (Kuchen et al., 2019).

Ethanol Tolerance: Ü16 and Ü19 isolates were not evaluated as wine starters since they could not grow in 10% alcohol and K6, Ü9, H8, H9, H11, H12 and H13 isolates could not grow in 13% alcohol. On the other hand, K9, Ü2, Ü6 and Ü17 isolates were able to grow at 10% and 13% concentrations, but not at 15% concentration (*Table 1*). The use of these yeast strains in the production of high-alcohol wines can lead to potential problems. However, it is thought to have the potential to be used in the production of white wine or lower alcohol wines. The possibilities of using them in such areas have the quality to be researched in further studies. 53 isolates were able to grow at 15% ethanol concentration. The fact that they can develop at this concentration is a sufficient property for wine making and shows that they can be used as starters (Gerőcs et al., 2020). In addition, K3, K5, K7, K8, K10, K11, K12, K13, Ü3 and Ü18 isolates grew even at 17% ethanol concentrations. Tests for resistance to ethanol concentrations of 15% and above are

mostly used for selecting starter cultures to be used in bioethanol or biomass production. However, considering that ethanol is a stress factor on yeast, it can be predicted that the increase in the resistance of yeast to be used as a starter culture to ethanol will reduce the possibility of producing secondary metabolites that are produced under stress and can negatively affect the quality. For this reason, it was decided to select the isolates, which are thought to be starter cultures, from among the strains that can grow at 17% ethanol concentration. In percentage terms, the results are very similar to the other studies (Antia et al., 2018; Gerőcs et al., 2020).

pH Tolerance: In the analysis, it was revealed that all isolates and control strains were resistant to pH 3.0 and 4.0 stress factors and could grow at these pHs (*Table 1*). No difference was observed between the isolates and it was observed that all durham tubes were completely filled with gas. With this result, it was observed that the isolates were capable of initiating fermentation at low must pH's due to factors such as grape variety, grape maturity, and peel - grain ratio.

According to the study by Lu et al. (2016), it is seen that the growth of the isolated yeast species in our study is good in terms of resistance to must pH, which is one of the strong stress factors.

Sulfur Dioxide Tolerance: All isolates except E9 and E10 showed growth at SO_2 concentrations of 0-200 ppm (*Table 1*). While 200 ppm SO_2 concentration is determined as the upper limit for white wines with a residual sugar content of less than 4 g L^{-1} according to the International Organization of Vine and Wine (OIV) standards, this rate is 150 ppm for red wines with the same characteristic (OIV, 2021). It is thought that the isolates in the study can be used in cases where the high sulfur application may be required (low acid must, white grape must, processing of bruised grapes into wine etc.). The results are compatible with similar studies (Nurgel, 2000; Nikolaou et al., 2006; Bağder, 2008; Çavdaroğlu, 2017; Çelik et al., 2017)

Volatile Acid production: The volatile acid production potentials of 15 yeasts selected from among the isolates whose technological properties were determined, suitable for winemaking were investigated. According to OIV standards, it was observed that they formed less than 1.2 g L^{-1} of acetic acid (*Table 2*), which is the highest volatile acid concentration that wines can have. The results are similar to the other studies (Tristezza et al., 2014; Çelik et al., 2017; Furdíková et al., 2017). The obtained values were found to be average when compared with the other studies. In the Tukey multiple comparison test, it was observed that the volatile acid production degrees of the isolates were not statistically different from each other.

Table 2. Amount of volatile acid produced by isolates

Isolate no	Volatile acid (g L^{-1})	Isolate no	Volatile acid (g L^{-1})
K1	0.336 ± 0.021	Ü18	0.348 ± 0.094
K10	0.420 ± 0.098	H4	0.408 ± 0.138
K11	0.332 ± 0.132	H5	0.268 ± 0.045
Y4	0.328 ± 0.028	H6	0.276 ± 0.012
Y7	0.304 ± 0.037	E2	0.328 ± 0.037
Y9	0.352 ± 0.091	E4	0.292 ± 0.048
Ü3	0.348 ± 0.072	E7	0.256 ± 0.007
Ü14	0.328 ± 0.014	RC212	0.280 ± 0.018

3.3. Characterization

ITS gene regions were read in both directions and nucleotide sequences were compared with each other. The regions showing differences were evaluated manually on DNA sequencing chromatograms and prepared for BLAST analysis. Sequence analysis results were compared with the existing sequences in GenBank with the BLAST program and molecular diagnoses of yeast samples were made. As a result of the sequencing analysis, it was determined that all of the 15 selected isolates belong to the species *Saccharomyces cerevisiae*.

In the results obtained by sequencing analysis, after it was determined that all 15 isolates belonged to the *S. cerevisiae* species, it was decided to apply DNA fingerprinting analysis to all selected isolates in order to evaluate the differences on the basis of strains.

DNA samples amplified in PCR with Delta 12-21 primers were run in 1xTBE gel containing 1.4 agarose at 100V

for 2 hours and their images were recorded (*Figure 5*). The gel image was found to be similar to the images taken in studies in this area (Legras and Karst, 2003; Bilgin, 2015; Garofalo et al., 2016).

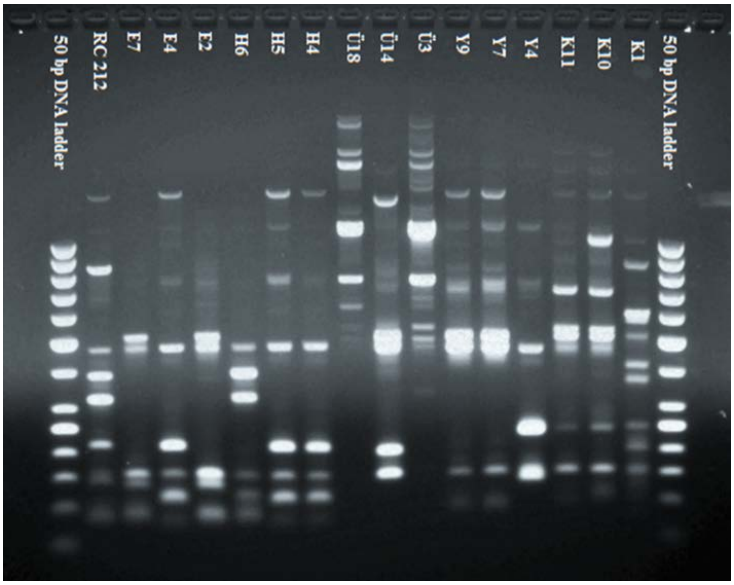

Figure 5. Gel electrophoresis image of DNA amplified with delta 12 - delta 21 primers

When the image recorded after electrophoresis was examined, it was seen that K10 - K11, Y7 - Y9, Ü3 - Ü18, H4 - H5 and E2 - E7 isolates were identical to each other. Interestingly, it was observed that the E4 isolate from a different vineyard was the same strain as the H4 and H5 isolates. It was observed that none of the yeasts identified in this study were the same strain as the commercial yeast (RC212). As a result of DNA fingerprinting using Delta 12-21 primers, it was seen that 9 of the selected strains were different *S. cerevisiae* strains.

4. Conclusions

Obtained isolates are stored in glycerol stocks at -80°C in Tekirdağ Viticulture Research Institute. Storage of isolates is important in terms of providing resources for future studies or applications. Future studies may be needed to determine whether these yeasts, whose basic winemaking competencies have been demonstrated, can produce quality wine.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

A Comparison of Acrylamide Contents of Some Nuts Produced Organically and Conventionally

Organik ve Konvansiyonel Yöntemlerle Üretilen Çeşitli Kuruyemişlerin Akrilamid İçeriklerinin Karşılaştırılması

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Abstract

Acrylamide is a carcinogenic and neurotoxic compound defined as a heat treatment process contaminant. Due to its health concern, acrylamide formation needed to be minimized. The objective of this study is to examine how much acrylamide is contained in dried almonds *(Prunus dulcis*), hazelnuts (*Corylus avellana*), pistachios (*Pistacia vera*), peanuts (*Arachishypogaea*), sunflower seeds (*Helianthus annuus*) as well as pumpkin seeds (*Cucurbita pepo*) that have been cultivated via organically-certified and conventional processes. Frequently and regularly-consumed nuts - comprising 180 samples that have been cultivated via organically-certified and conventional processes - were studied with UHPLC-MS/MS approach in Turkey. Substantial disparities were statistically found ($P<0.05$) between the almond, pistachio, peanut and sunflower seed variations that have been cultivated via organically-certified and conventional processes. Conversely, no considerable difference could be found among the variations of hazelnut and pumpkin seeds. It could be observed that the average concentrations of acrylamide in the nuts cultivated via organically-certified and conventional processes were 1.68 ng ml^{-1} and 266.14 ng ml^{-1} in almonds, 7.90 ng ml^{-1} and 6.68 ng ml^{-1} in hazelnuts, 4.86 ng ml^{-1} and 9.95 ng ml^{-1} in pistachios, 14.09 ng ml^{-1} and 36.27 ng ml^{-1} in peanuts, 5.96 ng ml^{-1} and 4.54 ng ml^{-1} in pumpkin seeds correspondingly. The amount of acrylamide was not ascertained in organically-certified sunflower seeds, while in conventional sunflower seeds, the amount was 16.92 ng ml^{-1}. According to the generally-accepted theory, the production of acrylamide is attributed to the Maillard reaction that takes place during the processing and preparation of high-temperature foods. The data obtained show that consumers should be informed more accurately about the food safety of organic nuts. The effects of organically produced nuts on acrylamide intake from food in daily consumption should also be taken into account. In order to prevent or reduce the formation of acrylamide compounds in organic nuts and to monitor them more effectively, extensive studies should be carried out and food heat treatment methods should be optimized.

Keywords: Acrylamide, Food safety, Organic certified nuts, Heat process contaminant, UHPLC-MS/MS

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* This study is summarized from the MSc. thesis.

Öz

Akrilamid, ısıl işlem proses kirleticisi olarak tanımlanan kanserojen ve nörotoksik bir bileşiktir. Sağlık endişesi nedeniyle akrilamid oluşumunun en aza indirilmesi gerekmektedir. Bu çalışmanın amacı, organik sertifikalı ve konvansiyonel yöntemlerle üretilen badem (*Prunus dulcis*), fındık (*Corylus avellana*), antepfıstığı (*Pistacia vera*), yerfıstığı (*Arachishypogaea*), ayçiçeği çekirdeği (*Helianthus annuus*) ve kabak çekirdeğinde (*Cucurbita pepo*) akrilamid miktarlarını araştırmak ve bulunan değerleri karşılaştırmaktadır. Türkiye'de organik sertifikalı ve konvansiyonel yöntemlerle yetiştirilen ve ülke genelinde yaygın ve düzenli olarak tüketilen kuruyemiş çeşitlerinden 180 adet örnek UHPLC-MS/MS cihazı kullanılarak incelenmiştir. Organik sertifikalı ve konvansiyonel yöntemlerle yetiştirilen badem, antep fıstığı, yerfıstığı ve ayçiçeği tohumu çeşitleri arasında istatistiksel olarak önemli farklılıklar bulunmuştur ($P<0,05$). Buna karşılık, fındık ve kabak çekirdeği çeşitlerinde önemli bir fark bulunmamıştır. Organik sertifikalı ve konvansiyonel yöntemlerle üretilmiş kuruyemişlerde ortalama akrilamid konsantrasyonlarının sırasıyla bademde 1,68 ng ml^{-1} ve 266,14 ng ml^{-1}, fındıkta 7,90 ng ml^{-1} ve 6,68 ng ml^{-1} olduğu, sırasıyla antep fıstığında 4,86 ng ml^{-1} ve 9,95 ng ml^{-1}, yerfıstığında 14,09 ng ml^{-1} ve 36,27 ng ml^{-1}, kabak çekirdeğinde 5,96 ng ml^{-1} ve 4,54 ng ml^{-1} olarak belirlenmiştir. Organik sertifikalı ayçiçeklerinde akrilamid miktarı tespit edilmezken, konvansiyonel yöntemlerle üretilmiş ayçiçeklerinde ise 16,92 ng ml^{-1} olarak belirlenmiştir. Genel kabul gören teoriye göre akrilamid oluşumu, yüksek sıcaklıktaki gıdaların işlenmesi ve hazırlanması sırasında meydana gelen Maillard reaksiyonuna bağlanmaktadır. Elde edilen veriler, tüketicilerin organik kuruyemişlerin gıda güvenliği konusunda daha doğru bilgilendirilmesi gerektiğini göstermektedir. Organik olarak üretilen kuruyemişlerin günlük tüketimde gıdalardan akrilamid alımına etkileri de dikkate alınmalıdır. Organik kuruyemişlerde akrilamid bileşiği oluşumunu önlemek veya azaltmak ve daha etkin bir şekilde izlemek için kapsamlı çalışmalar yapılmalı ve gıda ısıl işleme yöntemleri optimize edilmelidir.

Anahtar Kelimeler: Akrilamid, Gıda güvenliği, Organik sertifikalı kuruyemişler, Isıl proses kontaminat, UHPLC-MS/MS

1. Introduction

The interest in food products that are believed to be environmentally and health friendly such as natural and organic foods is increasing day by day. Organic farming is a sustainable farming technique that avoids the use of unnatural inputs such as pesticides and synthetic fertilizers and supplies quality, health and environmental standards. Organic food production, on the other hand, is the production in which inappropriate practical application and process are not used, without agricultural residues and chemical food additives, the least processed product and the most appropriate packaging. With the global orientation, an organic market with a rapidly growing trade volume has emerged today (Gok, 2008). Fruits, field crops and vegetables constitute a significant portion of organic herbal products produced in Turkey. Since most of the organic products grown in our country are exported, production is shaped according to the demand from abroad (Demiryurek, 2011).

Nuts and fresh/dry fruit products are organic products exported in Turkey. Production is gathered in nine main categories. These are dried fruits, nuts, fresh and processed fruits and vegetables, legumes, cereals, oil seeds, industrial plants, spices and medicinal plants, and other raw or processed products. Walnut, pistachios, almond, peanut, chestnut are included in the category of hard-shelled fruits. Sunflower and sesame are in the category of oily seeds. Peanuts, poppy seeds, hazelnut flour, apricot kernels etc. are in the other category.

According to studies conducted for consumers, organic foods are perceived as safer, more nutritious and without chemicals that harm health in their content (Karcik and Tasan, 2018). However, the results of studies showing that organic foods are safer than conventional foods are quite contradictory and interesting. The Institute of Food Technologies states that there is a qualitative difference between organic and traditional foods, and more data is needed to state that both production systems are superior to each other in terms of safety or nutritional composition (Turkozu and Karabudak, 2013). It is stated in some studies (Buttriss and Hughes 2000; Magkos et al., 2003; Tosun and Kaya, 2010; Berker, 2012) that various contaminations can be seen in organic foods depending on environmental factors and may involve various risks.

In our country and in the world, heat treatment is applied to nuts at certain temperatures before being offered for consumption. With the application of heat treatments, toxic chemical compounds that may adversely affect the nutritive properties of the food may occur, as well as the formation of the desired properties such as color, taste and structure (Claeys et al., 2005). Compounds such as acrylamide, hydroxymethylfurfural, chloropropanol and its esters, polycyclic aromatic hydrocarbons, N-alkyl N-nitrosamines, *trans* fatty acids, furan and its derivatives are process contaminants formed as a result of heat treatment. These chemical compounds produce carcinogenic and/or mutagenic effects (Yavuz and Ozcelik, 2013; Mogol, 2014; Tasan and Demir, 2019). Among the mentioned thermal process contaminants, the detection of acrylamide and 5-hydroxymethylfurfural (HMF), its metabolism, its effects on health, and the development of strategies to reduce its levels have been the subject of many studies (Masatcioglu, 2013; Mogol, 2014). Acrylamide is a carcinogenic (Mestdagh et al., 2008) and neurotoxic compound originating from food ingredients and defined as a process contaminant. Although acrylamide is not found in raw foodstuffs, its amounts in heat-treated foods are of concern. Acrylamide formation is associated with the Maillard reaction that occurs as a result of high heat during the preparation and processing of foods. This reaction occurs at temperatures above 100°C. When the required humidity level is provided, acrylamide formation can be observed at temperatures below 120°C (Pedreschi et al., 2007). Although there is a linear relationship between the degree of processing temperature and time and the formation of acrylamide, there are differences in acrylamide level even between different products of the same food varieties or the same products produced on different dates (Can, 2007). The composition, variety, storage conditions and seasonal changes of foodstuffs, especially in terms of asparagine and reducing sugars (especially fructose and glucose), cause differences in acrylamide content (Gokmen et al., 2006). Acrylamide contents have been determined in the vast majority of foodstuffs widely consumed in the world. There are limited studies on the acrylamide content of our traditional products in our country.

In the evaluation of the quality of organic foods, foods not only should be questioned in terms of harmful compounds that are transmitted as a result of environmental effects such as heavy metals, pesticides or incorrect applications but also, antinutrient compounds that can be formed by food processing should be considered (Finotti et al., 2006). Some varieties of organic nuts can also be heat treated. In Turkey, dried nuts are produced mostly by traditional methods and by applying minimum processing technologies (Tezer et al., 2015). In industrial

applications, for example, hazelnuts are processed between 100-180°C for 5-10 minutes. Nuts variety, air circulation and similar factors are decisive in these processes (Suvari et al., 2017).

When the studies on acrylamide are examined in the literature, it is seen that the studies focus on the effects of different heat treatment methods (Zhang and Zhang, 2008), parameters (Nizamlioglu, 2015; Unver, 2016; Asadi et al., 2020), storage time (Amrein et al., 2005), food categories (Sayaslan et al., 2008; Karasek et al., 2009). In this study, the acrylamide content that can be formed by heat treatment in organic nuts was determined and compared with nuts produced by conventional methods, it contributed significantly to the literature with the results of specific food quality in the field of organic food safety.

2. Materials and Methods

2.1. Materials

Organic certified nut varieties were determined as almond (*Prunus dulcis*), hazelnut (*Corylus avellana*), pistachio (*Pistacia vera*), peanut (*Arachishypogaea*), sunflower seeds (*Helianthus annuus*) and pumpkin seeds (*Cucurbita pepo*). In the study, samples of each organic certified nut variety were obtained from five different brands in the market. In order to make comparisons and evaluations, samples from five different brands were obtained from the same dried nut varieties produced by conventional methods. In the sample procurement, attention was paid to ensure that there were samples from all brands with three different batch numbers, and logo and certificate numbered ones were selected on the label. Acrylamide analyzes were applied to the dried nuts samples, which were obtained in shell, after the shells were removed.

2.2. Chemicals and reagents

Magnesium sulfate anhydrus ($MgSO_4$) (purity>99.5%), acrylamide analytical standard (purity> 99.8%) and formic acid Sigma-Aldrich (UK) company, sodium chloride, aluminum oxide (Al_2O_3) and n-hexane were obtained from Merck (Darmstadt, Germany), acetonitrile (ACN) was obtained from PanReac (Barcelona, Spain). Ultrapure water (MilliQ system, Millipore, Bedford, MA, USA) was used in analysis.

2.3. Samples preparation

1 g of dried nut samples (grinded in a grinder (Siemens MC 23 200) and homogenized) were weighed and placed in a 50 ml centrifuge tube. 5 ml of n-hexane was added and shaken with vortex (Heidolph Reax Top) for 1 minute. Then, a mixture of 10 ml of ultrapure water, 10 ml of acetonitrile (ACN), 5 g of anhydrous magnesium sulfate ($MgSO_4$) and 1 g of sodium chloride (NaCl) was added into the tube. After the salts were added, the tubes were vortexed again for 1 minute to prevent crystallization. The tubes were centrifuged at 4500 rpm for 6 minutes and separated into layers. 3 ml of liquid from the middle chamber containing acrylamide was transferred to 15 ml small centrifuge tubes containing 150 mg of aluminum oxide. The mixture was vortexed for 30 seconds and then centrifuged at 4500 rpm for 3 minutes. After centrifugation, 2 ml of the upper liquid was drawn with a syringe, passed through 0.45 µm Macherey-Nagel (Chromafil AO 1745/25) filters, transferred to glass tubes and evaporated under nitrogen gas to ensure dryness with a light stream. The residue was diluted by adding 200 µl of ultrapure water to the dried glass tubes and mixed with vortex for 1 minute. The samples taken from here into mini centrifuge vials were centrifuged at 14800 rpm for 10 minutes and transferred from these vials to vials with glass inserts. The amount of acrylamide was measured by injecting the samples twice into the UHPLC-MS/MS (Ultra High-Pressure Liquid Chromotography Mass Specthrometry, AB Sciex, 3200 QTrap) and the mean values were reported as ng ml-1 with their standard deviations (Ali Omar et al., 2015).

2.4. Preparation of the calibration curve

In order to detect acrylamide quantitatively, calibration standards at different concentrations were injected into the UHPLC-MS/MS device and a linear calibration curve (R^2=0.9997) was drawn. 100 ppm main stock solution was obtained and stored at -18˚C. By diluting the main stock with ultrapure water, 2 ppm intermediate stock acrylamide was obtained. Then, by making dilutions to the amounts taken from the intermediate stock solution, calibration standards were obtained at concentrations of 0-1-5-10-25-50-75-100 ppb. The prepared intermediate stock solutions were stored at +4°C.

2.5. Chromatographic conditions

Studies were carried out on the UPLC-MS/MS device according to the following conditions;

Injection volume: 20 µl, Column: Venusil AQ C18 3 µm 100 Å (2.1 mm x 50 mm), Detector: MS/MS detector

Mobil Phase A: Ultrapure water containing 0.1% formic acid (90%), Mobile Phase B: Acetonitrile with 0.1% formic acid (10%), Flow rate: 0.25 ml mobile phase/minute, Pump: Turbo pump, Column temperature: 40˚C

Source parameters; Gas temperature: 550°C, Ionization type: Turbo ion spray positive polarity, Capillary voltage: 5500 V, Curtain Gas (CUR): 20 psi, Nebulizer pressure 1 (GS 1): 40 psi, Nebulizer pressure 2 (GS 2): 60 psi, Infer face heater (Ihe): On

2.6. Recovery, limit of detection (LOD) and limit of quantitation (LOQ)

Almonds, sunflower seeds, peanuts, hazelnuts, pistachios and pumpkin seeds without acrylamide were studied in raw samples. After separating the oil by adding n-hexane on 1 gr sample. 500 µl of 100 ppm stock acrylamide standard solution was added. Extraction continued. The necessary standards for the calibration curve were prepared by diluting the extract obtained as a result of this process with the mobile phase. According to these standards the detection (LOD, Limit of Detection) limit of the samples was 0.33 ng ml^{-1} (ppb), the detection (LOQ, Limit of Quantitation) limit was 1 ng ml^{-1} (ppb). The % recovery values of sunflower seeds, almonds, peanuts, pistachios, hazelnuts and pumpkin seeds were determined as 143%, 136%, 137%, 135%, 118% and 128%, respectively.

2.7. Statistical analysis

Analyzes were performed in triplicate for each sample. The results were calculated as the arithmetic mean and standard errors (±) of the replications. Statistical analyzes of the obtained data were performed with ANOVA and Duncan test using STATISTICA Software. The significance of the difference between the mean data in the tables is shown with the lettering system.

3. Results and Discussion

Acrylamide content of almond, hazelnut and pistachios produced via organically certified and conventional process are shown in the *Table 1*. Acrylamide contents of peanuts, sunflower seeds and pumpkin seeds produced via organically certified and conventional process are shown in the *Table 2*.

Table 1. Acrylamide contents of almonds, hazelnuts and pistachios produced by conventional methods and certified organic (ng ml^{-1})

Samples (Company number)	Almond		Hazelnut		Pistachios	
	Organic[1]	Conventional[2]	Organic	Conventional	Organic	Conventional
1	2.47±0.07b	76.81±3.16e	17.54±0.77a	9.49±0.17a	4.51±0.11c	4.44±0.20d
2	0.33±0.04e	241.08±15.27c	8.86±0.06b	3.34±0.09d	5.22±0.12b	25.38±0.63a
3	3.22±0.11a	231.16±4.50d	6.40±0.12c	8.94±0.09b	6.33±0.42a	5.22±0.20c
4	1.35±0.10c	318.62±21.43b	3.50±0.12d	3.22±0.10d	3.09±0.14d	5.07±0.16c
5	1.02±0.04d	463.05±36.03a	3.18±0.15d	8.43±0.10c	5.14±0.04b	9.66±0.14b
Overall average	1.68±1.16B	266.14±140.74A	7.90±5.87	6.68±3.13	4.86±1.19B	9.95±8.87A

[1]: They are the results of organic certified company samples and are the average of three replications
[2]: They are the results of the company samples produced by the conventional method and are the average of three replications.
The differences between the averages shown with different letters for the company samples were found to be statistically significant, and the lettering was done in vertical alignment, a, b, c, d (↓), ($P<0.05$). The differences between the averages of the same type of nuts shown with different letters for the general average were found to be statistically significant, and the lettering was made in horizontal alignment, A, B (→), ($P<0.05$).

Table 2. Acrylamide contents of peanuts, sunflower seeds and pumpkin seeds produced by conventional methods and certified organic (ng ml^{-1})

Samples (Company number)	Peanut		Sunflower		Pumpkin seeds	
	Organic[1]	Conventional[2]	Organic	Conventional	Organic	Conventional
1	26.64±3.42a	33.64±4.92b	ND	37.75±4.99a	12.61±2.21a	2.41±0.50c
2	19.17±1.40b	26.17±1.11b	ND	29.25±3.47b	1.18±0.08b	4.65±0.49b
3	7.33±0.42c	65.61±7.98a	ND	NDd	0.95±0.12b	4.76±0.36b
4	9.40±0.92c	15.09±0.10c	ND	NDd	0.99±0.12b	3.89±0.73b
5	7.89±0.73c	40.82±0.62b	ND	17.58±1.75c	14.06±1.78a	6.98±0.93a
Overall average	14.09±8.51B	36.27±18.97A	NDB	16.92±17.02A	5.96±6.75	4.54±1.66

[1]: The results of the organic certified company samples and the average of three replications.
[2]: It is the results of the company samples produced by the conventional method and is the average of three replications. ND: Not at detectable level.
The differences between the averages shown with different letters for the company samples were found to be statistically significant, and the lettering was done in vertical alignment, a, b, c, d (↓), (P<0.05). The differences between the averages of the same type of nuts shown with different letters for the general average were found to be statistically significant, and the lettering was made in horizontal alignment, A, B (→), (P<0.05).

The acrylamide values of almonds produced by organic certified and conventional methods were 1.68±1.16 ng ml^{-1} (range 0.33-3.22 ng ml^{-1}) and 266.14±140.74 ng ml^{-1} (range 76.81-463.05 ng ml^{-1}), were determined, respectively. Since it is known that almond contains acrylamide precursors, free asparagine and reducing sugar, at significant levels, the roasting temperature and time parameters should be adjusted appropriately. On the other hand, although acrylamide values determined in organic certified almonds in the study remained at a very low level, there is a possibility that short-term heat treatment was carried out. The data showed that it is important to evaluate almonds and almond products that may contain almonds in terms of acrylamide content.

The acrylamide values of hazelnuts produced by organic certified and conventional methods were 7.90 ng ml^{-1} (range 3.18-17.54 ng ml^{-1}) and 6.68 ng ml^{-1} (range 3.22-9.49 ng ml^{-1}), were determined, respectively. Although the average acrylamide values of organic certified hazelnuts were found to be higher, this difference is not statistically significant. In the study, acrylamide values determined in hazelnuts produced by organic certified and conventional methods remain at a very low level compared to the data in the literature. Olmez et al. (2008) found 10-421 µg kg^{-1} in roasted hazelnut samples and 128 µg kg^{-1} on average, Jagerstad and Skog (2005) determined it in the range of 64-457 µg kg^{-1} in hazelnut and hazelnut paste samples. Amrein et al. (2005) determined low levels of acrylamide (16-56 ng g^{-1}) in roasted hazelnuts and this was due to the low levels of asparagine amino acids in hazelnuts. (Xu et al., 2013) determined acrylamides at the level of 150 ng g^{-1} in roasted hazelnuts.

Our data showed, it is possible that these products were subjected to short-term heat treatments at very low temperatures and under similar conditions.

The acrylamide values of the organic certified and conventionally produced pistachios were determined 4.86 ng ml^{-1} (range 3.09-6.33 ng ml^{-1}) and 9.95 ng ml^{-1} (range 4.44-25.38 ng ml^{-1}), respectively. The average of acrylamide values in organic certified pistachios was lower and the effect of the production methods that created this difference is statistically significant. Acrylamide values were quite low compared to the data in the literature. Schlörmann et al. (2015) found that acrylamide contents changed depending on the roasting conditions and acrylamide compounds were found in the range of 14-88 µg kg^{-1} in pistachio samples, which were heated at 140.8-185.1ºC for 21-25 minutes. Ozer (2012) determined 318-462 ng g^{-1} acrylamide compound in pistachio, while Otles and Otles (2004) determined it as <30 ng g^{-1} in pistachio powder product. In our study, it is considered that pistachios were applied at short-term and relatively low temperatures for drying and/or roasting purposes.

The acrylamide values of organic certified and conventionally produced peanuts were determined 14.09 ng ml^{-1} (range 7.33-26.64 ng ml^{-1}) and 36.27 ng ml^{-1} (range 15.09-65.61 ng ml^{-1}), respectively. Olmez et al. (2008) determined acrylamide compounds in the range of 10-120 µg kg^{-1} (average 66 µg kg^{-1}) in roasted peanuts and between 45-63 µg kg^{-1} (average 54 µg kg^{-1}) in peanut butter. Suvari et al. (2017) found 21.4-60.5 ng ml^{-1} (mean 34.69 ng ml^{-1}). Yates (2012) reported the acrylamide content in roasted unsalted peanuts as 28 µg kg^{-1}. Acrylamide content of 15 roasted peanuts analyzed according to FDA data (Anonymous, 2005) varies between less than detectable value and 36 ppb. Cressey et al. (2012) determined 9-84 µg kg^{-1} (average 42 µg kg^{-1}). These results are close or very similar to the values contained in the samples produced by conventional methods in our study. In our study the effect of organic and conventional methods can be seen. The acrylamide values of peanuts were higher than the content of hazelnuts and pistachios, but considerably lower than the content of almonds produced by conventional methods.

The acrylamide values of pumpkin seeds produced by organic certified and conventional methods were determined 5.96 ng ml^{-1} (range 0.95-14.06 ng ml^{-1}) and 4.54 ng ml-1 (range 2.41-6.98 ng ml^{-1}), respectively. Although organic certified pumpkin seeds had higher acrylamide content, this difference is not statistically significant. On the other hand, although organic certified pumpkin seeds, hazelnuts, pistachios and peanuts contained higher levels of acrylamide precursors compared to their acrylamide contents, it is remarkable that organic certified almonds had a low acrylamide content.

Acrylamide compound was not detectable in organic certified sunflower seeds. On the other hand, it was 16.92 ng ml^{-1} on average in sunflower seeds produced by conventional methods. This result, determined in organic certified sunflower seeds, differs from other examined organic certified pumpkin seeds, hazelnuts, pistachios, peanuts and almonds.

4. Conclusion

It is important to investigate the acrylamide compound, which has negative effects on human health, in organic nut varieties and to evaluate the results in the context of organic food safety. The data obtained in this study stated that similar processing conditions were applied to pumpkin seeds and hazelnut varieties, which were dried nut varieties produced by organic and conventional methods, while relatively higher temperature and/or time were used in the conventional method in peanut and pistachio varieties. It is remarkable that the organic certified almond variety had the lowest acrylamide content and the organic certified sunflower seeds were free of acrylamides. On the other hand, it is considerable that there were higher rates of acrylamides in organic certified pumpkin seeds and hazelnuts than those produced by conventional methods. Eventually this study provides significant data that enables comparison of suspected acrylamide compounds in both organic and conventional production systems which fulfils the gap of research in organic product area.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Biyogaz Tesislerinde Üretilen Gübrenin Değerlendirilme Metotları ve Fizibiliteye Etkisi*

Evaluation Methods of Fertilizer Produced in Biogas Plants and Its Effect on Feasibility

Volkan ÇOBAN[1*]

Öz

Globalleşen dünyanın en büyük ihtiyaçlarından biri de enerjidir. Bu sebeple Dünyada ve ülkemizde yenilenebilir enerji kaynağı olan biyogaz tesislerinden enerji üretimi gün geçtikçe artmaktadır. Hayvansal kaynaklı hammaddeden biyogaz üretimi sonrasında katı ve sıvı gübre olmak üzere çeşitli çıktılar elde edilmektedir. Bu tesislerde üretilen gübrenin tarımda değerlendirilmesi gerek yatırım fizibilitesine gerekse çevreye verebileceği olası negatif etkisinden dolayı önem arz etmektedir. Bu çalışmada mezofilik şartlarda çalışan 3 MW elektrik üretim kapasiteli bir yaş fermantasyon tesisinde biyogaz üretimi boyutlandırılmıştır. Biyogaz tesisinin hidrolik bekletme süresi olarak 34 gün seçilmiştir. Fermantasyon tankları ise sürekli karıştırmalı tank reaktörlerdir. Enerji eldesi için biyogaz motoru kullanılmıştır. Biyogaz tesisinde enerji eldesinin yanında ürün olarak katı ve sıvı gübre üretilmektedir. Biyogaz tesisinde üretilen katı gübrenin satılabilir forma dönüştürülebilmesi ve toprakta uygulandığında daha verimli olabilmesi için zenginleştirme işlemleri sıralanmıştır. Üretilen gübrenin 3 farklı şekilde değerlendirilebileceği göz önünde bulundurularak yapılabilirlik analizleri incelenmiştir. İlk opsiyonda üretilen gübre satılmadan direkt tarımda kullanıldığı, ikinci opsiyonda katı organik gübre olarak satıldığı, diğer opsiyonda ise içerisine gerekli ilaveler yapılarak organomineral gübre formuna dönüştürülüp satıldığı düşünülmüştür. Elde edilen sonuçlar kapsamında enerji üretiminin yanı sıra gübre satışının tesis fizibilitesine olan etkileri ortaya konulmuştur. Yapılan hesaplamalar ışığında; tesislerin birim kW başına maliyetleri sırasıyla; 2.090 $/kWe, 3.726 $/kWe, 6.225 kWe olmaktadır. Yalnızca elektrik üretiminden gelir elde bir biyogaz tesisinin 6,01 yıl olan basit geri ödeme süresi, elektrik satışına ek organomineral gübre satışı ile 1,69 yıla indirgendiği tespit edilmiştir. Gübrenin organik gübre olarak satılması durumunda ise basit geri ödeme süresi 4,24 yıl olmuştur. Ancak, geri ödemesi süresinin azalmasına karşılık ilave olarak sisteme eklenecek diamonyumfosfat maliyeti biyogaz tesis maliyetlerini yaklaşık olarak %92,5 oranında artırdığı gözlenmiştir.

Anahtar Kelimeler: Biyogaz, Organomineral gübre, Fermente gübre, Organik gübre, Yaş fermantasyon.

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Abstract

Energy is a major demand of the globalization world. For this reason, energy production from biogas plants as a renewable energy source, is increasing day by day in the world and in our country. After the production of biogas from raw material of animal origin, various outputs can be obtained. These outputs are solid and liquid fertilizers. The use of the fertilizer produced in these plants in agriculture is important because of its possible negative impact on both the investment feasibility and the environment. In this study, biogas production was dimensioned in a wet fermentation plant with 3 MW electricity production capacity operating under mesophilic conditions. 30 days was chosen as the hydraulic retention time of the biogas plant. Fermentation tanks are continuous stirred tank reactors. The biogas engine was used for energy generation. In the biogas plant, solid and liquid fertilizers are produced as a product in addition to energy production. Enrichment processes are listed in order to convert the solid fertilizer produced in the biogas plant into salable form and to be more efficient when applied to the soil. Considering that the produced fertilizer can be evaluated in 3 different ways, feasibility analysis was examined. It is thought that the fertilizer produced in the first option is used directly in agriculture without being sold, in the second option, it is sold as solid organic fertilizer, and in the other option, it is converted into an organomineral fertilizer form by making the necessary additions. Within the scope of the results obtained, the effects of energy production as well as fertilizer sales on the feasibility of the facility were revealed. Considering the calculations made, the costs per unit kW of the facilities are respectively: 2,090 $/kWe, 3,726 $/kWe, 6,225 kWe. It has been determined that the simple payback period of 6.01 years for a biogas plant that generates income only from electricity production is reduced to 1.69 years with the sale of additional organomineral fertilizers. If the fertilizer was sold as organic fertilizer, the simple payback period was 4.24 years. However, it was observed that the cost of diammonium phosphate to be added to the system, in addition to the decrease in the payback period, increased the biogas plant costs by approximately 92.5%.

Keywords: Biogas, Organomineral fertilizer, Fermented fertilizer, Organic fertilizer, Wet fermentation.

1. Giriş

Globalleşen dünyanın en büyük ihtiyaçlarından biri de enerjidir. Enerji üretimi birçok çeşitli kaynak ve yöntemler ile yapılırken yaygın olarak yenilenebilir enerji ve yenilenemez enerji olarak 2'ye ayrılmaktadır. Yenilenebilir enerji; doğayı korumak ve sürdürülebilirliği sağlamak amacıyla önem arz etmektedir. Rüzgâr, güneş, jeotermal, hidroelektrik ve biyokütle başlıca yenilenebilir enerji kaynaklarındandır.

Fosilleşmemiş karbon, hidrojen, oksijen bağı içeren organik bileşiklere biyokütle denir. Biyogaz prosesinde; hayvansal, tarımsal ve evsel biyokütle atıklarından anaerobik şartlarda; %55-%70 metan içeriğine sahip yanıcı bir gaz türü olan biyogaz elde edilmektedir (Eryilmaz ve ark., 2015). Biyogaz üretimi çevre dostu olması nedeniyle; ülkemizde ve dünyada gün geçtikçe artmaktadır.

Türkiye'nin biyogaz üretim potansiyeli incelendiğinde; hayvansal atık miktarı 163.297.308 (ton/yıl), bitkisel atık miktarı 176.313.301 (ton/yıl), kentsel katı atık miktarı 31.331.836 (ton/yıl) 'dır. Atıkların toplam enerji eş değeri ise; 44.228.795 (TEP/yıl)'dır (YEGM, 2019). Türkiye'nin biyogaz amaçlı, hayvansal gübrelerden elde edilebilir uçucu kuru madde miktarı 33.210,844 milyar ton/yıl (Aybek ve ark., 2015), toplam metan üretim potansiyeli 22.466 Nm3gün-1 (Kayişoğlu ve Göncü, 2020), sadece tavuk gübresine dayalı biyogaz potansiyeli 390 milyon m3'tür (Avcıoğlu ve ark., 2013). Bu potansiyele rağmen 2019'da lisanslı hayvansal ve bitkisel atık kaynaklı biyogaz tesisi sayısı 41 olup, deponi gazından elektrik üretimi yapan tesis sayısı da 59'dur. Hayvansal atık kaynaklı lisanslı biyogaz tesisi kurulu gücü 203,4 MW, deponi gaz (evsel atıkların depolanmasıyla, anaerobik koşullarda elde edilen biyogaz) kaynaklı lisanslı tesislerin kurulu gücü ise 299,6 MW'tır (EPDK, 2019). Avrupada ise 2000'li yılların başında 6 milyon ton petrol eşdeğeri (Mtoe) değerinde biyogaz üretimi varken günümüzde bu rakam 20 milyon tonun üzerine çıkmaktadır (Akinyele ve Rayudu, 2016; Cherubini, 2010).

Enerji Piyasası Düzenleme Kurulu (EPDK)'nın ve Enerji İşleri Genel Müdürlüğü (BEPA)'nın yayımladığı veriler ışığında Türkiye'nin biyogaz üretim potansiyeline göre kurulu güç, potansiyelin sadece küçük bir kısmı olarak değerlendirilmektedir. Biyogaz tesislerinin çevresel etkisinin artırılabilmesi için tesis sayısı da artırılmalıdır. Tesis sayısını tetikleyen unsur ise yatırımcılara cazip hale gelecek olan karlı yatırım olma durumudur. Bir biyogaz tesisinin gelir kalemleri incelendiğinde en önemli ve stabil gelir sağlayan parametre ise elektrik üretimidir. Elektrik gelirinin yanı sıra tesis çıktısı olan; katı ve sıvı gübre satışı yapılması gelir miktarının artırılmasında önemli bir rol oynayabilmektedir.

Biyogaz üretim süreci sonrasında üretilen katı gübre toprak iyileştirici niteliğinde, içerisinde toprak için faydalı N, P ve K olarak bilinen azot, fosfor ve potasyum elementlerini ihtiva eden ve organik madde açısından zengin kompost gübredir (Abebe, 2017). Gübrenin tarıma yöneltilmesi ve sürdürülebilir şekilde yararlanılabilmesi gerek tarım gerekse çevre değerleri açısından önemlidir. Toprak iyileştirici kompost gübre toprağın organik içeriğini artırmaktadır. Türkiye tarım topraklarının yalnız %1'i organik madde içeriği bakımından tarım yapılabilir değerlerin üzerindedir (Güçdemir, 2006). Bu durum organik gübreye olan ihtiyacı arttırmaktadır. Son yıllardaki mineral gübredeki fiyat artışı ve toprak iyileştirici gübre kullanımının mineral gübreye olan ihtiyacı azaltması; bu tarz tesislerden üretilen gübreye çiftçilerin rağbet göstermesini sağlamıştır. Ancak, üretilen katı gübrenin daha değerli forma geçmesi ve tarımda kullanılabilmesi için ilave bir dizi operasyona ihtiyaç duyulmaktadır. Bu operasyonlar sonucunda elde edilen organomineral gübre formuna geçebilmek için ise kompost gübreye mineral ilavesi şarttır. Çalışma ile; bir biyogaz tesisi fizibilitesi ve biyogaz tesisine ek organomineral gübre tesisinin fizibilitesi, yatırım maliyetleri, gelir-gider tabloları karşılaştırılmıştır. Böylelikle literatüre biyogaz tesislerinde elde edilen gübrelerin özellikleri, ilave edilmesi gereken mineral miktarları ve bunların maliyetleri konusunda veri tabanı oluşturmak istenmiştir.

2. Materyal ve Metot

2.1. Numune toplama, hazırlama ve karakterizasyon

Bu çalışmada; büyükbaş atığı ve yumurtacı tavuk atığından elektrik üretimi yapan bir biyogaz tesisi baz alınarak hesaplamalar yapılmıştır. Hesaplamalarda kullanılacak numuneler (Marcato ve ark., 2008)'de tarif edildiği şekilde toplanmıştır. Bir biyogaz tesisinin biyogaz üretim potansiyeli açısından yaygın olarak kullanılan hesaplama yöntemi şu şekildedir (Akbulut, 2012);

$$KM\ (g) = MM\ (g) \times (KMO(\%)/100) \quad \text{(Eş.1)}$$

$$UKM(g) = KM(g) \times \big(UKMO(\%)\big)/100 \quad \text{(Eş.2)}$$

$$B\ddot{U}M\ (m^3/saat) = (UKM\ ((ton.UKM)/g\ddot{u}n) \times BMP(m^3/(ton.UKM)))/24(saat\ /\ g\ddot{u}n) \quad \text{(Eş.3)}$$

$$BTK(kW) = B\ddot{U}M(m^3/t) \times MO(\%) \times Hmetan(kW/m^3) \times \epsilon\ (\%) \quad \text{(Eş.4)}$$

Çalışma yapılırken biyokütle üzerinden kuru madde (KM), uçucu kuru madde ve N, P, K analizleri yapılmıştır. Uçucu kuru madde (UKM) analizi SM- 2540 B, KM analizi SM 2540 D standardına göre yapılmıştır (Ubi ve ark., 2016). Eşitlik 1'de taze materyal (MM) ile kuru madde oranı (KMO) çarpılarak günlük yüklenen KM miktarı bulunmaktadır. Eşitlik 2'de ise uçucu kuru madde oranı (UKMO) ile KM miktarı çarpılarak günlük yüklenen UKM miktarı bulunmaktadır. Bu değer Eşitlik 3'te malzemenin biyolojik metan potansiyeli (BMP) ile çarpılmakta ve çıkan sonuç saatlik olarak üretilen biyogaz miktarını (BÜM) vermektedir. Eşitlik 4 'te BÜM ile metan oranı (MO), metanın birim enerji içeriği (H_{metan}) ve gaz motoru elektriksel verimi (ϵ) çarpılarak biyogaz tesis kapasitesi hesaplanmaktadır. Hayvansal atıkların kuru madde oranı reaktör içinde karıştırılmaya uygun olamadığı için simülasyonda ilave su ekleneceği kabul edilmiştir. N, P, K analizleri ise; Toplam N, mikro Kjeldhal'in metoduna göre; Fosfor, amonyum molibdat mavisi yöntemi ile; Potasyum EDTA titrasyonu alev fotometresinde Kalsiyum (Ca) ve Magnezyum (Mg) ile belirlenmiştir (Wendland, 2012). Karbon, hidrojen, oksijen, kükürt oranları ASTM D 5373 standardına uygun olarak analiz edilerek bulunmuştur.

2.2. Biyometan potansiyel testi hesapları

Hammaddelere yönelik analizler pratik olarak bire bir yapılırken, hammaddelerden biyogaz üretimi ve çıkacak gübrenin nitelikleri ampirik olarak hesaplanmıştır. BMP değeri, Buswell yöntemi kullanılarak hesaplanmıştır (Symons ve Buswell, 1933). Biyokütlenin biyogaza dönüşümünü teorik olarak ortaya koyan eşitlik, denklik 5'te verilen şekilde bulunur. Elementer analiz sonucunda elde edilen değerler denklik 6 da yerine konulduğunda metan (CH_4) ve denklik 7'de yerine konulduğunda karbondioksit (CO_2) oranı hesaplanabilmektedir.

$$C_cH_hO_oN_nS_s + 1/4(4c-h-2o+3n+2s)\ H_2O \rightarrow 1/8\ (4c-h+2o+3n+2s)\ CO_2 + 1/8(4c+h-2o-3n-2s)\ CH_4 + nNH_3 + sH_2S \quad \text{(Eş.5)}$$

$$\text{Biyokütleden elde edilecek } CH_4 \text{ oranı} = \frac{1}{8}(4c+h-2o-3n-2s) \quad \text{(Eş.6)}$$

$$\text{Biyokütleden elde edilecek } CO_2 \text{ oranı} = \frac{1}{8}(4c-h+2o+3n+2s) \quad \text{(Eş.7)}$$

2.3. Kapasite tayini

Kurguya göre çiftliklerden gelen hayvansal atık ön depoya alınır. Ön depoya alınan atık istenilen kuru madde oranına göre düzenlemeleri yapılır. Kuru maddesi ayarlanmış ürün üreteçlere (reaktörlere) yüklenilir. Uygun bekleme sürelerinde (HRT; Hydrolic retantion time) bakterilerin çoğalması sağlanılır. Metagenosiz bakterileri ile %50-%60 metan içeren biyogaz üretilir (Bogner, 1992). Biyogaz gaz şartlandırma ünitelerinden geçirilerek saflaştırılır ve kojenerasyon ünitesine gönderilir. Gaz motoru vasıtasıyla da elektrik üretimi gerçekleştirilir. Reaktör sonrasındaki hammadde ise; separatöre gönderilerek, katı ve sıvı faz olarak ikiye ayrıştırılır (Sreekrishnan ve ark., 2004). Üretilen gübre toprak açısından faydalı N, P, K ve organik madde miktarı olarak zengin bir üründür (Brown ve ark., 2007). Biyogaz tesisine ait proses akış diyagramı Şekil 1'de verilmiştir.

Organomineral tesisinde, sıvı gübre dekarbonizasyon ve strippping proseslerinden işlenmesiyle azot elementince zengin amonyaklı su elde edilir. Separatör sonrasında üretilen yaklaşık %25 kuru madde içeriğine sahip katı gübre ise kompost ünitesinde %55 kuru maddeye ulaşıncaya dek bekletilir. Komposttan çıkan katı gübre ile stripping sonrası amonyaklı su, homojanizatöre DAP (Di amonyum fosfat) eklenerek karıştırılır. Granülatör ve kurutma vasıtası ile de %85 kuru madde içeriğine sahip organomineral gübre üretimi gerçekleştirilir. Organik gübre ve organomineral gübre üretim tesislerine ait kütle akış şemaları *Şekil 2* ve *3*'te verilmiştir.

Bu çalışma tesis çıktısı olan gübre, 3 şekilde değerlendirilebileceği göz önünde bulundurularak kurgulanmıştır. İlk opsiyonda üretilen gübre satılmadan direkt tarımda kullanılır, ikinci opsiyonda katı organik gübre olarak satılır, diğer opsiyonda içerisine gerekli ilaveler yapılarak organomineral gübre formuna dönüştürülüp satılır. Bu kapsamda gübrenin organomineral gübre değerlerine gelmesi için gerekli ilaveler ve miktarları hesaplanmış, bu ilavelerin operasyonel giderlere etkisi incelenmiştir.

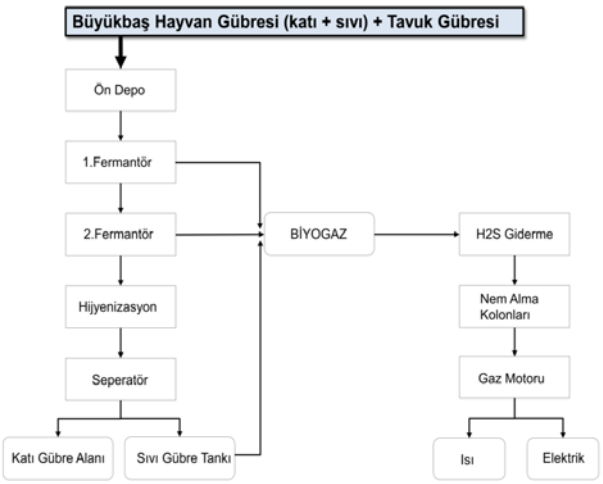

Figure 1. Biogas plant process flow chart

Şekil 1. Biyogaz tesisi proses akış şeması

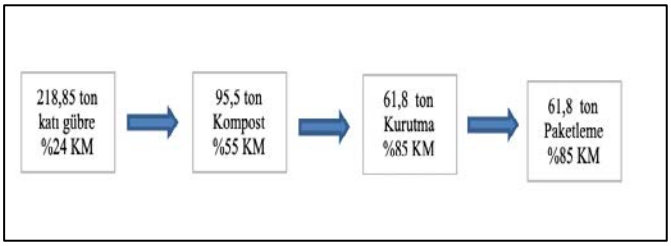

Figure 2. Organic fertilizer production plant mass flow chart

Şekil 2. Organik gübre üretim tesisi kütle akış şeması

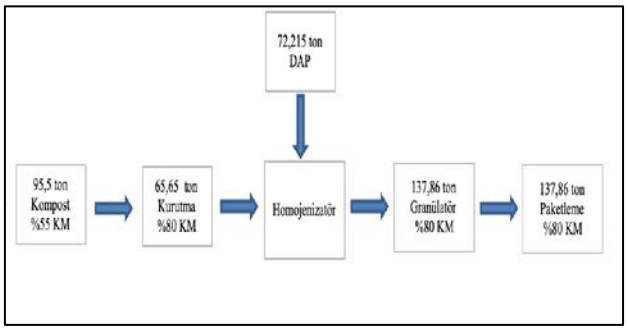

Figure 3. Organomineral fertilizer production plant mass flow chart

Şekil 3. Organomineral gübre üretim tesisi kütle akış şeması

2.4. Fizibilite hesaplama metodolojisi

Bir yatırımın geri ödeme süresinin (amortisman) hesaplanması için, aşağıdaki 3 unsura ihtiyaç bulunmaktadır (Marcato ve ark., 2008). Bunlar; Yatırım bedeli (CAPEX), Gelirler ve Giderlerdir (OPEX).

Amortisman süresi(yıl)=(CAPEX)\/(FAVÖK) (Eş.8)

Favök=Gelirler-Giderler (Eş.9)

Faliyetten doğan nakit akım=Favök-Vergi (Eş.10)

Yıllık elektrik geliri aşağıdaki formül ile hesaplanmıştır.

EÜM=Kojenerasyon kapasitesi × ω x γ (Eş.11)

γ = (Tam kapasite oranı-İç tüketim oranı) (Eş.12)

3. Araştırma Sonuçları ve Tartışma

3.1. Numune toplama, hazırlama ve karakterizasyon sonuçları

Yumurtacı tavuk çiftliği gübresi ile büyükbaş hayvan gübresine ait numunelere ait karakterizasyon sonuçları *Tablo 1 ve 2*'de verilmiştir. Seperatör sonrasındaki katı ve sıvı gübrenin beklenen analiz sonuçları ise *Tablo 3*'te yer verilmiştir (Gedik ve ark, 2005).

Analiz sonuçları incelendiğinde sonuçların literatür değerlerinin paralelinde değerler olduğu görülmüştür. Tang ve ark. (2005)'nın yılında yaptıkları çalışmada büyükbaş hayvan gübresinin karbon değeri %38-40, azot değeri ise %2,30-2,50 aralığında değişmiştir. Bavariani ve ark. (2019)'nın tavuk gübresi üzerinde yapmış oldukları analizlerde ise karbon değerini %40-42, azot değerini ise %3,80-4,70 aralığında bulmuşlardır.

Tablo 1. Yumurtacı tavuk gübresi elementer analizi

Table 1. Elemental analysis of laying chicken manure

	Elementer Analiz (%)	**Atom ağırlığı ($gr.mol^{-1}$)**	**Molekül Bileşenleri**
C	42,3	12	3,53
N	4,55	14	0,33
H	3,97	1	3,97
S	0,3	32	0,01
O	27,97	16	1,75

Tablo 2. Büyükbaş hayvan gübresi elementer analizi

Table 2. Elemental analysis of cow manure

	Elementer Analiz (%)	**Atom ağırlığı ($gr.mol^{-1}$)**	**Molekül Bileşenleri**
C	41,07	12	3,42
N	2,63	14	0,19
H	4,79	1	4,79
S	0,4	32	0,01
O	26,87	16	1,68

Tablo 3. Separatör sonrası üretilen katı ve sıvı gübrenin nütrient analizi

Table 3. Nutrient analysis of solid and liquid fertilizer produced after separator

	TS (%)	**N ($kg.m^{-3}$)**	**NH_4 ($kg.m^{-3}$)**	**P_2O_5 ($kg.m^{-3}$)**	**K_2O ($kg.m^{-3}$)**
Sıvı faz	5,7	4,9	3,1	2	5,4
Katı Faz	24,3	5,8	2,7	5	5,8

3.2. Kapasite tayini sonuçları

Güç ünitesi kapsamında 2 adet %40 elektriksel verimle çalışan 1.500 kWe kapasiteli gaz motoru kullanılacaktır. Mezofilik şartlarda gaz üretimi yapılacak olup, sürekli karıştırmalı (CSTR) tip 4 adet reaktör kullanılacaktır. Hidrolik bozunma süresi olarak (HRT) 34 gün seçilmiştir. Tesise günlük olarak 345 ton büyükbaş hayvan gübresi, 260 ton tavuk gübresi ve 200 ton taze su ilavesi yapıldığı düşünülmüştür. *Tablo 1, 2 ve 3*'teki verilerin Buswell eşitliğinde yerine konularak yapılan hesaplama sonuçları *Tablo 4*'te verilmiştir. *Tablo 4*'teki elektrik üretimi kapasitesine yaklaşık olarak %8 oranında üretim verim kaybı kabulü yapılarak biyogaz tesisinin kapasitesi olarak 3 MW belirlenmiştir.

Günlük olarak 805 ton taze materyal sisteme beslenirken, kütle denklikleri yoluyla yapılan hesaplamalar sonucunda seperatör sonrasında 218,85 ton katı gübre elde edilebileceği hesaplanmıştır. Sıvı gübre dekarbonizasyon ve strippping proseslerinden işlenmesiyle ise 4,4 ton/gün %35 oranında azot elementine sahip amonyaklı su elde edilir. Kompostlaştırma işlemi sonrasında %25 KM değerinden %55 KM değerine çıkarılmış

95,5 ton kompost gübre elde edilir. Kompost gübrenin katı gübre olarak paketlenip satılabilmesi için kurutma işlemi ile %85 KM değerine çıkarılması gerekir. Kurutma sonucunda 61,8 ton organik katı gübre elde edilmiş olur.

Organomineral tesisi, organik katı gübre tesisinden kompostlaştırma işlemi sonrasında farklılaşır. Gübrenin zenginleştirilmesi amacıyla sıvı gübrenin içerisinden elde edilen amonyaklı su ile satın alınan DAP kimyasalı karıştırılarak gübreye eklenir. Bu işlemin yapılabilmesi için gübrenin %80 katı oranına kadar kurutulması gerekir. Kurutulan gübre ile ilave edilen DAP ve amonyaklı su bir homojenizatörde homojenize edilir. Homojenizasyon sonrasında sıradaki işlemler; granül haline getirme ve paketleme işlemleridir. Bu prosesler sonucunda 137,86 ton organomineral gübre satılabilecek forma gelmiş olur.

3.3. Fizibilite hesaplama sonuçları

3 MW elektrik üretim kapasiteli bir biyogaz tesisinin ilk yatırım maliyeti 6.270.000 USD'dir. Yatırıma ait detaylar *Tablo 5*'te verilmiştir. Direkt tesis maliyeti, toplam maliyetin %51'lik kısmına tekabül etmektedir. Geri kalan kısım ise indirekt maliyetler, yüklenici karı ve beklenmedik durumların oluşturabileceği maliyetlerdir. Bu hesaplar yapılırken enerji nakil hattının tesise 1 km uzakta olduğu kabulü yapılmıştır. Enerji nakil hattının tesise daha uzak olması durumunda bu maliyet yaklaşık olarak 50.000 USD/km artış gösterebilmektedir. Ancak, yapılan enerji nakil hattı harcaması 2 yıl içerisinde devletten geri alınabilmektedir. Bu sebeple, enerji nakil hattının uzamasının 10 yıllık bazda geri ödeme süresine etkisi sınırlı kalacaktır. Biyogaz tesisine organik gübre tesisi ilave edildiğinde ilk yatırım maliyeti 11.178.000 USD, organomineral gübre tesisi ilave edildiğinde ilk yatırım maliyeti 18.677.400 USD'ye çıkmaktadır. Bu durumda birim kW başına maliyetler sırasıyla; 2.090 $/kWe, 3.726 $/kWe, 6.225 kWe olmaktadır. Diğer yenilenebilir enerji tesislerinin birim maliyetleri ile kıyaslandığında özellikle organomineral gübre ilaveli tesisin maliyetinin diğer yenilenebilir enerji tesislerine göre nerdeyse 10 kat fazla olduğu göze çarpmaktadır. Örnek verilecek olursa; güneşe dayalı bir tesisin ilk yatırım bedeli yaklaşık olarak 600.000 USD mertebesindedir (Vekil ve Özyiğit, 2020). Bu durum bize tesisin artık bir enerji üretim odaklı bir tesis olmaktan çok gübre üretimi odaklı bir tesis olduğunu açıkça ortaya koymaktadır.

Biyogaz tesisi yenilenebilir enerji kaynağı olarak düşünüldüğünde en önemli gelir kaynağı elektrik üretimi olmaktadır. Çalışmada elektrikten elde edilecek kazanç hesabı için 2021 yılı ortalama elektrik birim (MWh) fiyatı ortalama USD/TL kuru üzerinden çevrilerek hesaplanmış ve yaklaşık olarak 55,6 USD olarak alınmıştır (EPİAŞ, 2022). Yıllık gübre geliri incelendiğinde ise günlük 61,8 ton katı organik gübre ya da 137,86 ton organomineral gübre üretimi beklenmektedir. Organik gübrenin birim fiyatı olarak 75 $/ton ve organomineral gübrenin birim fiyatı olarak 500 $/ton olarak belirlenmiştir. 3 MWh kapasiteli bir biyogaz tesisinin yıllık çalışma süresi 7.000 saat olarak alınabilir (Walla ve Schneeberger, 2008). Tesis iç tüketimi üretilen elektrikten karşılanmak zorundadır. Bu sebeple elektrik üretiminin biyogaz tesisinde %10'u, biyogaz ve organomineral gübre tesisinde ise; %40'ı enerji tüketim gideri olarak hesaplara katılmıştır.

Tesis giderleri *Tablo 6*'da verilen değerler üzerinden hesaplanmıştır. Tesis işletme giderlerinde hammadde maliyeti olarak gübrelerin yaklaşık olarak ortalama 50 km uzaklıktan taşındığı düşünülmüştür. Taşıma maliyeti olarak 1 $/ton ve ham su maliyeti 0,2 $/ton kabul edilmiştir. Kendi gübresini kendi üreten bir tesis olduğunda bu giderin olmayacağı veya daha uzak mesafelerden atık taşındığında ise giderin artacağı unutulmamalıdır. Çevre mevzuatı gereği atık bertaraf tesisi konumundaki bu tesislerin atık bertaraf gelirleri de olmalıdır. Ancak, ülkemizde henüz böyle bir gelir alabilen bir tesis olmadığı için atık bertaraf ücreti geliri yok olarak kabul edilmiştir. Çoğu ülkede biyokütleye dayalı biyogaz tesislerinin sadece elektrik satışı ile ve herhangi bir ilave destek olmadan kar ettirilebilmesi zor olduğu bilinmektedir. Bunun sebebi ise atığın taşıma maliyetleridir (Yabe, 2013). Yapılan hesaplarda da dünya geneline paralel değerler elde edilmiştir ve benzer sonuca varılmıştır. Tesiste 16 kişi çalışacağı düşünülmüştür. Bu kişilerin dağılımı şu şekildedir; 1 genel müdür, 1 muhasebeci, 1 lojistik müdürü, 3 adet mühendis, 3 adet teknisyen, 4 adet güvenlik personeli ile 3 adet şoför çalışan. Genel müdür birim maliyeti 1500 $/ay iken diğer işçilerim ortalama maliyeti 600 $/ay olarak alınmıştır. Bakım maliyeti olarak gaz motorunun ve diğer ekipmanların ayrı ayrı maliyetleri alınıp toplanmıştır. Gaz motoru bakım maliyeti olarak 0,020 $/kWh, diğer bakım maliyeti olarak ise 0,006 $/kWh değeri alınmıştır (Caresana ve ark., 2011). Tesisin ilk devreye alınmasında gübrenin fermantasyon sıcaklığına getirilmesi gerekmektedir. Bu kapasitede bir tesisin ilk ısıtma maliyetinin 20.000 $ olacağı tahmin edilmiştir. Dağıtım bedeli ve yıllık lisans bedelleri EPDK'nın belirlemiş olduğu fiyatlar üzerinden hesaplanmıştır.

Tablo 4. Buswell yöntemi ile elektrik üretim kapasitesi hesaplama sonuçları

Table 4. Electricity production capacity calculation results with buswell method

Atık Tipi	Miktar (ton.gün^{-1})	CH_4 Miktarı (ton.gün^{-1})	CO_2 Miktarı (ton.gün^{-1})	CH_4 Oranı (%)	CO_2 Oranı (%)	Elektrik Üretim Kapasitesi (kWh)
Büyükbaş hayvan gübresi	345,00	1,82	1,61	53,08	46,92	1.320,75
Yumurtacı tavuk gübresi	260,00	1,70	1,83	48,16	51,84	1.927,82
					TOPLAM	**3.248,57**

Tablo 5. Biyogaz tesisi maliyeti

Table 5. Biogas plant cost

Biyogaz tesisi maliyeti	Birim Tutar ($)	Yüzde (%)
A. Tesis direkt toplam maliyeti (TDM)	3.200.000	51,0
1. Ekipman maliyetleri		
2. Montaj maliyeti		
3. Borulama maliyeti		
4. Enstrümantasyon maliyeti		
5. İzolasyon maliyeti		
6. Elektriksel maliyetler		
7. Enerji nakil hattı maliyeti		
8. Destek ünite maliyetleri		
B. Tesis indirekt toplam maliyeti (TİM)	1.900.000	30,3
1. Mühendislik maliyeti		
2. İnşaat maliyeti		
C. Yüklenici ücreti ve beklenmedik durum maliyeti (YM)	1.170.000	18,7
1. Yüklenici ücreti		
2. Beklenmedik durum maliyeti		
D. Toplam yatırım maliyeti (TYM=TDM+TİM+YM)	**6.270.000**	**100**

Tablo 6. Biyogaz ve organomineral gübre tesisi işletme giderleri tablosu

Table 6. Biogas and organomineral fertilizer plant operating costs

İşletme Giderleri	Miktar ($/yıl)	Oran (%)
A. Biyogaz tesisi işletme giderleri	1.001.270	%7,5
1. Hammadde maliyeti		
2. Ham su maliyeti		
3. Personel maliyeti		
4. Bakım maliyeti		
5. Devreye alma maliyeti		
6. Dağıtım bedeli		
7. Yıllık lisans bedeli		
8. Sigorta bedelleri		
9. Ofis giderleri		
B. Gübre tesisi işletme giderleri		
1. DAP maliyeti	12.392.094	%92,5

Tesis gelirleri hesaplandığında biyogaz tesisinin sadece elektrik geliri 2.513.700 $/yıl'dır. Organik gübre gelirinin de ilavesiyle bu değer 4.205.475 $/yıl'a, organomineral gübre geliri ilavesiyle ise 26.835.250 $/yıl'a çıkmaktadır. Organomineral gübrenin getirdiği gelir artışı çok dramatiktir. Böylece tesisin yenilenebilir enerji tesisi olmaktan gübre üretim tesisi olmaya geçişi net olarak göze çarpmaktadır. *Tablo 7*'de sadece biyogaz tesisi ile çeşitli gübre tesisi opsiyonlarının fizibilite değerleri karşılaştırılmıştır. 3 MW hayvansal atıklı bir biyogaz tesisinin basit geri ödeme süresi 6,01 yıl, biyogaz tesisine ek organik gübre ve organomineral gübre tesisinin basit geri ödeme süresi 4,24 ve 1,69 yıl olarak saptanmıştır. Biyogaz tesisinin geri ödeme süresi 6 yıl çıkmış olmasına

rağmen dünya üzerinde benzerlerinin 8 yıl gibi daha uzun süreli değerlere sahip olduğu düşünüldüğünde nispeten uygundur sonucuna varılabilir (Mel ve ark, 2015). Tesisin geri ödeme süresi veya fizibilitesinin yanında sürdürülebilirliği de önemlidir. Baulomanti ve ark.'nın da araştırmalarında belirttiği gibi bir biyogaz tesisinin sürdürülebilirliğini etkileyen en önemli faktör gübre yönetimi olmaktadır (Baulomanti ve ark., 2013).

Tablo 7. Fizibilite Karşılaştırmaları

Table 7. Feasibility comparisons

	Biyogaz Tesisi Fizibilitesi (Sadece elektrik satış geliri)	**Biyogaz Tesisi + Organik Katı Gübre Üretim Tesisi Fizibilitesi**	**Biyogaz Tesisi + Organomineral Gübre Üretim Tesisi Fizibilitesi**
Yatırım Maliyeti ($/yıl)	6.270.000	11.178.000	18.677.400
Giderler ($/yıl)	1.001.270	1.001.270	13.204.200
Gelirler ($/yıl)	2.513.700	4.205.475	26.835.250
Vergi ($/yıl)	469.698	566.333	2.601.694
Faaliyetten Doğan Nakit Akım ($/yıl)	1.042.732	2.637.872	11.029.356
GERİ ÖDEME SÜRESİ (yıl)	**6,01**	**4,24**	**1,69**

4. Sonuç

Çalışma ile Türkiye'deki organik atıkların değerlendirilmesi, toprağa geri kazandırılması ve enerji tüketiminde dışa bağımlılığının azaltılması maksadıyla biyogaz tesis sayısının artırılmasının önemi vurgulanmıştır. Biyogaz tesislerinin çıktısı olan organik gübrenin tarımsal arazilerde değerlendirilmesi gerekmektedir. Hayvancılık ve tarımın arasında biyogaz tesisinin bir köprü görevi oluşturması beklenmektedir. Organomineral ve organik gübre pazarının yaygınlaşması ve sıfır atık politikalarıyla birlikte; kimyasal gübrelerin kullanımının git gide azalması, toprağın ve tarımın faydasına olacaktır.

Biyogaz tesislerinde elektrik satışına ek gübre satışının da yapılması geri ödeme sürelerini kısaltıp yatırımcıyı bu alanlara teşvik edecektir. Çalışmada; her ne kadar yatırım miktarı büyümüş olsa da tesis geri ödeme süresinin 6,01 yıldan 1,69 yıla indirgenebildiği ortaya konulmuştur. Ancak, geri ödemesi süresinin azalmasına karşılık ilave olarak sisteme eklenecek DAP maliyeti biyogaz tesis maliyetlerini yaklaşık olarak %92,5 oranında artırmıştır. Organomineral tesisinin işletme giderlerini yüksek oranda artırması ile gübrenin satılamaması durumunda nakit akışında büyük bir risk doğurabileceği gözden kaçırılmamalıdır.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Factors Influencing Participation in Self-Managed Livestock Markets in Rural Communities in the Republic of Benin*

Benin Cumhuriyeti'ndeki Kırsal Topluluklarda Kendi Kendini Yöneten Hayvan Pazarlarına Katılımı Etkileyen Faktörler

Oscar AKOUEGNONHOU[1]*, Nevin DEMİRBAŞ[2]

Abstract

Livestock in West Africa is an example of regional value chain development. It is essentially based on the trade in livestock between production areas and consumption centers. The livestock trade is an important economic activity in pastoral and agro-pastoral communities as it is their source of income. The livestock trade in these regions takes place at several sites, the best known of which are the livestock markets. Two different types of livestock market are investigated in this study. Self-managed livestock markets (Marché à Bétail Autogéré: MBA), are new models for marketing livestock in the Republic of Benin. Unlike traditional livestock markets (Marché à Bétail traditionnel: MT), MBAs offer several advantages to its participants by creating a platform where sellers and buyers can meet to trade without intermediaries. The absence of the intermediary system in the operation of MBA markets makes them different from MT markets. Because of their important role in rural development, MBAs have become the focus of policy makers and international development organizations. The purpose of this study was to analyse the factors that affect farmers' participation in MBA markets. The study used primary data collected from face-to-face surveys of a random sample of 300 livestock farmers consisting of 150 respondents from the MBA and 150 respondents from the MT. Descriptive statistics and Binary Logistic Regression were used to analyze the data. The results of the Logistic Regression Analysis revealed that access to market information, payment type, cooperative partnership, beef cattle herd size, sheep herd size, goat herd size and farmland ownership have significant positive effects on MBA market participation, while distance to market has significant negative effects on MBA market participation. Improving these factors could increase the participation of livestock farmers in the MBAs in the Republic of Benin. This would increase their income and improve their living conditions. Knowledge of the factors influencing participation in MBA markets would also help stakeholders and policy makers in their decision making.

Keywords: Binary logistic regression, Republic of Benin, Self-managed livestock markets, Traditional livestock markets, Rural development

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*This study is summarized from the first author's Ph.D. thesis.

Öz

Batı Afrika'da hayvancılık faaliyeti, bölgesel bir değer zinciri gelişimine karşılık gelmektedir. Bu zincir, temel olarak üretim alanları ile tüketim merkezleri arasındaki hayvan ticaretinden oluşmaktadır. Batı Afrika'da hayvan ticareti, pastoral ve agro-pastoral toplulukların gelir kaynağı olması nedeniyle önemli bir ekonomik faaliyettir. Bu bölgelerde hayvan ticareti, en yoğun olarak hayvan pazarlarında olmak üzere farklı yerlerde gerçekleştirilmektedir. Bu çalışmada bir Afrika ülkesi olan Benin Cumhuriyeti'nde iki farklı hayvan pazarı modeli kapsama alınmıştır. Bunlardan biri olan "Kendi Kendini Yöneten Hayvan Pazarları (*Marché à Bétail Autogéré*: MBA)", Benin Cumhuriyeti'nde hayvanların pazarlanması için yeni bir modeldir. Diğer hayvan pazarı modeli olan "Geleneksel Hayvan Pazarlarından (*Marché à Bétail traditionnel*: MT)" farklı olarak MBA'lar, satıcı ve alıcıların aracılar olmadan ticaret yapmak için bir araya gelebilecekleri bir platform oluşturarak paydaşlarına çeşitli avantajlar sunmaktadır. MBA'ların işleyiş mekanizmasında aracılık sisteminin bulunmaması, bu pazarları MT'lerden farklı kılmaktadır. Kırsal kalkınmadaki önemli rolleri nedeniyle, MBA'lar Benin Cumhuriyeti'nde politikacıların ve uluslararası kalkınma kuruluşlarının odak noktası haline gelmiştir. Bu nedenle, bu araştırmada çiftçilerin Kendi Kendini Yöneten Hayvan Pazarlarına katılımını etkileyen faktörlerin analiz edilmesi amaçlanmıştır. Araştırmanın birincil verileri, 150'si MBA'lardan ve 150'si MT'lerden olmak üzere 300 çiftçiden oluşan rastgele bir örneklemle yüz yüze yapılan anketler aracılığıyla toplanmıştır. Verileri analiz etmek için tanımlayıcı istatistikler ve Binary Lojistik Regresyon analizi kullanılmıştır. Sonuçlara göre, pazar bilgilerine erişim, ödeme şekli, kooperatif ortaklığı, sığır sürüsünün büyüklüğü, koyun sürüsünün büyüklüğü, keçi sürüsünün büyüklüğü ve tarım arazisi büyüklüğü çiftçilerin MBA seçimini anlamlı ve olumlu yönde etkilerken, pazara uzaklık MBA seçimini anlamlı ve olumsuz yönde etkilemektedir. Belirlenen bu faktörlerle ilgili iyileştirmelere gidilmesi, Benin Cumhuriyeti'ndeki hayvan yetiştiricilerinin bu yeni pazar modeline katılımını artırabilecektir. Bu ise yetiştiricilerin gelirlerini artırırken, yaşam koşullarını da iyileştirebilecektir. Bu araştırmanın sonuçları, gelir ve yaşam koşullarının iyileştirilmesi hedefleri yönünden, pazar paydaşlarına ve politikacılara karar alma süreçlerinde yardımcı olacaktır.

Anahtar Kelimeler: Binary lojistik regresyon, Benin Cumhuriyeti, Kendi kendini yöneten hayvan pazarları, Geleneksel hayvan pazarları, Kırsal kalkınma

1. Introduction

The Republic of Benin is a country with an agricultural economy where livestock farming occupies a predominant place in the national economy. Its contribution to the Gross Domestic Product is 5.82% and represents 15.55% of the Gross Agricultural Production value (FAO and ECOWAS, 2016). The populations involved in livestock activities in Benin are mainly pastoralists and agro-pastoralists. Their economic viability depends on animal husbandry. Most pastoralists are from the Peulh ethnic group and own large herds of beef cattle, sheep or goat (Chabi, 2016). As for the agro-pastoralists, they are a mixture of several ethnic groups (Peulh, Gando, Bariba, etc.) and combine livestock with agriculture. The number of animals is an important capital element for farmers. In the past, farmers did not usually sell their animals, but today most of them are involved in commercial production and trade of live animals. This is due to many reasons such as: the increasing demand for meat and other animal products due to the growing population (Onibon, 2004); the creation of the MBA, which give farmers the opportunity to deal directly with buyers; the improvement of animal prices; the sedentarization of some nomadic farmers in order to avoid the effects of climate change, etc.

Most live animal transactions take place in livestock markets. There are mainly two types of livestock markets in the Republic of Benin. These are traditional livestock markets (MT), which are the oldest market model in Benin and self-managed livestock markets (MBA), which are a new model (UDOPER, 2007). This study will focus on the MBA markets. Because of their economic and financial weight, the MBA markets are a real pillar of local development. They are a new model of livestock marketing developed and managed by the farmers themselves. These markets are the focus of livestock farmers, livestock traders, local authorities, national and international organizations.

The participation of livestock farmers in the market has been widely considered essential for the livelihoods of rural people and economic growth in developing countries (Barret, 2008). The rise in income is expected to be achieved principally through the involvement and participation of small-holder farmers and rural communities in economic activities along the market value chain and concomitant employment generation (Kyeyamwa et al., 2008; Ayele et al., 2019).

Analysis of market participation is fundamental to transforming livestock farming to market orientation then, expected increase market participation. Markets are a reflection of the territorial dynamics in which livestock farming and product marketing activities take place (Duteurtre, 2010). Analysis of market participation indicates the factors that affect farmers' choice. For example, when transaction costs are high, it discourages market participation by small-scale farmers (Key et al., 2000). According to Zaibet et al. (2009), the non-participation in the market by farmers negatively affects the continuity and therefore the sustainability of the livestock activity.

The analysis of factors affecting livestock farmers' participation in livestock markets has been conducted in many scientific studies (Alene et al., 2008; Ayele et al., 2019; Abate and Addis, 2021; Lutta et al., 2021). This is very important in the case of Benin because of the great interest that MBA markets represent nowadays in the rural economy. However, very few research has been conducted in the livestock sub-sector to specifically study MBA in Benin. Onibon, (2004) revealed the existence of the MBA markets in a report and described their functioning. But, there is no studies have been conducted on the determinants of farmers' decisions to participate in the MBA in the Republic of Benin.

This study aimed to analyze the factors that influence participation in the MBAs in pastoral and agro-pastoral communities in the municipalities of Gogounou, Nikki, Bassila, Matéri, Savè and Iwoyé (Kétou) in Benin. This will increase the participation of livestock farmers in the MBAs in Benin.

This information is crucial for understanding the socio-economic and market factors of the MBA markets' participation in Benin. Because lack of knowledge about factors that determine livestock market participation among the pastoral communities can lead to misguided interventions that can impact on improving household welfare of pastoralists (Ehui et al., 2009; Alkemade et al., 2013).

2. Materials and Methods

This research was carried out in the Republic of Benin. It was conducted in both traditional (MT) and modern (MBA) livestock markets. In the MT markets, the trading system is traditional and intermediaries-driven. They are common in the local areas of many African countries. The MBA markets are the modern livestock markets where the transactions take place without intermediaries. The trading system is much more

organized and modernized than that in the MT markets. The research aimed to analyze the factors influencing participation in MBAs in rural communities in the Republic of Benin.

A two-stage sampling procedure was used to draw the sample respondents. In the first stage, with the help of the head of the Ministry of Agriculture Department, the potential MBA and MT markets were identified in the municipalities of Gogounou, Nikki, Bassila, Matéri, Savè and Iwoyé (Kétou). In the second stage, from the identified MBA and MT, 300 livestock farmers (150 from MBAs and 150 from MTs) were randomly selected and surveyed. Face-to-face surveys were conducted using a structured questionnaire.

The values of the descriptive statistics were used for the purpose of summarizing and presenting the data. To compare the frequency distribution of one variable to another, cross-tabulations were also used. The relationship between market participation and continuous independent variables (beef cattle herd size, sheep herd size, goat herd size, household size, farmland ownership, distance to market, age, education level) was determined by using Pearson Correlation Coefficients (Chhetri et al., 2013; Shrestha, 2019). Chi-square tests were used to examine the degree of association between market participation and categorical independent variables (gender, access to market information, payment type, pasture use, cooperative partnership, access to credit) (Chhetri et al., 2013; Shrestha, 2019). The variance inflation factor (VIF) was used to check multicollinearity. Variable with a high VIF value (VIF ≥ 10) was removed from the model (Girma and Abebaw, 2012; Shrestha, 2019; Marwati et al., 2020). The Binary Logistic Regression Model was used to determine the factors that influence the farmers' participation in MBA markets. Only the independent variables of the regression model with a statistically significant coefficient were interpreted.

The Binary Logistic Regression Model belongs to the general class of binary choice model, where the dependent variable is dichotomous (Greene, 2003). It is an extension of the linear probability model and takes the form:

$$\gamma_i = X_i\beta + \varepsilon_i \quad \text{(Eq.1).}$$

γ_i = 1, if γ_i * > 0, otherwise γ_i = 0

Where X_i, is the vector of independent variables related to ith livestock farmers. The dependent variable γi, is equal to 1 if the farmer decides to participate in the MBA market and 0 otherwise. Equation (1) above describes the probability of a farmer deciding to participate in the MBA market. Gender, access to market information, payment type, pasture use, cooperative partnership, access to credit, beef cattle herd size, sheep herd size, goat herd size, household size, farmland ownership, distance to market, age and education level are the independent variables in the model. Their coefficients were used to interpret the variation they bring to the model (*Table 1*).

The above linear model can be transformed into a cumulative probability function as follows:

$$P_i = F(X_i\beta) \quad \text{(Eq.2) (Greene, 2003)}$$

If the cumulative probability function is logistic, then we have the logit model of the form:

$$P_i = \frac{1}{1+e^{-xi\beta}} \quad \text{(Eq.3).}$$

The marginal effect of a particular variable on the probability that a particular household decides to sell is given by:

$$\frac{\partial Pi}{\partial Xi} = f(X'\beta)\beta k \quad \text{(Eq.4)}$$

It takes the form:

$$f(X'\beta) = \frac{e^{-x\prime\beta}}{(1+e^{-x'\beta})^2} \quad \text{(Eq.5) (Greene, 2003)}$$

Table 1. Variables used in the model

Variables	Variable Description	Variable Type	Expected sign
Dependent Variable	MBA market participation Y = 1 (participation) Y = 0 (otherwise)		
Independent Variables			
Access to market information	Farmer's access to market information (1 = Yes, 0 = No)	Dummy	+
Payment type	Payment type (1 = Cash, 2 = Credit)	Dummy	+
Pasture Use	Use of pasture (1 = Yes, 0 = No)	Dummy	+
Cooperative partnership	Partnership to a livestock organization (1 = Yes, 0 = No)	Dummy	+
Access to credit	Farmer's access to credit (1 = Yes, 0 = No)	Dummy	+
Beef cattle herd size	Number of cattle owned (number)	Continuous	+
Sheep herd size	Number of sheep owned (number)	Continuous	+
Goat herd size	Number of goat owned (number)	Continuous	+
Household size	Number of family members (number)		±
Farmland ownership	Farmland owned (ha)	Continuous	+
Distance to market	The distance to market (km)	Continuous	-
Education level	Farmer's education level (year)	Continuous	+

3. Results and Discussion

3.1. Descriptive information of sample

Among the sample respondents, 97.67% were men and 2.33% were women. Men are generally head of the households and owners of the herd; their sons are shepherds; their wife has the right to milk the herd and sell it. Men are more likely to be involved in decision making (Nightingale, 2002; Chhetri et al., 2013). 45.33% were between 41-60 years old. 76% had a primary education level. The family size of 40% of the farmers is less than or equal to 3 members (*Table 2*).

Table 2. Descriptive statistics results for the livestock farmers

	MBA		MT		General	
	Number	%	Number	%	Number	%
Gender						
Male	147	98.0	146	97.3	293	97.7
Female	3	2.0	4	2.7	7	2.3
Total	150	100.0	150	100.0	300	100.0
Age						
21-40	90	60.0	40	26.7	130	43.3
41-60	48	32.0	88	58.7	136	45.3
≥61	12	8.0	22	14.7	34	11.3
Total	150	100.0	150	100.0	300	100.0
Education level (year)						
Uneducated (<1)	3	2.0	63	42.0	66	22.0
Primary school (1-6)	142	94.7	86	57.3	228	76.0
College (7-10)	5	3.3	1	0.7	6	2.0
Total	150	100.0	150	100.0	300	100.0
Household size						
≤3	94	62.7	26	17.3	120	40.0
4-7	44	29.3	72	48.0	116	38. 7
8-11	12	8.0	51	34.0	63	21.0
≥12	-	-	1	0.7	1	0.3
Total	150	100.0	150	100.0	300	100.0

3.2. Econometric analysis

The Binary Logistic Regression Model was used to determine the factors affecting the MBA market choice of farmers. Binary Logistic Regression is a method used to determine the causal relationship between the dependent

variable and the independent variables if the dependent variable is binary or sequential (Şeref et al., 2016). In this study, those who chose MBA as the dependent variable were taken as Y=1 and those who did not choose Y=0. Model fit hypotheses are as follows.

H_0 : The model fits the data.

H_1 : The model doesn't fit the data.

According to the analysis results, the Nagelkerke R^2 value of the model was calculated as 0.724; according to the coefficient of this value, the variables found in the model explain 54% of the model. According to the results of the analysis -2Log Probability Value is 181.033 (*Table 3*).

Table 3. The Significance Values of the Model Parameters

-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
181.033	0.543	0.724

The *Table 4* shows the Sig. value found for the Hosmer and Lemeshow test is 0.900, which provides information about the goodness of fit of the created model, shows that the model is fitted (May and Hosmer, 2003). The Hosmer and Lemeshow test statistic, which shows the Chi-Square distribution, is used to test the goodness of fit of all the variables of the model (Shrestha, 2019; Altekin and Demirbaş, 2021).

Table 4. Results of Hosmer and Lemeshow

Hosmer and Lemeshow Test		
Chi-square	**df**	**Sig.**
3.485	8	0.900

The Binary Logistic Regression Model results showed that access to market information, payment type, age, pasture use, cooperative partnership, beef cattle herd size, sheep herd size, distance to market and education level significantly influenced the participation of livestock farmers in MBA markets in the Republic of Benin.

Beef cattle herd size had a significant positive correlation with MBA market participation (*Table 5*), implying that as the size of the livestock increases, the incentive to sell increases and the participation in the market increases. Regression results also showed beef cattle herd size had a significant positive association with participation in the MBA market at 1% significant level (*Table 7*). This confirms the findings of Barrett et al. (2003) and Lutta et al. (2021), who stated that the decision to participate or not in market was significantly determined by pastoralists attaining and maintaining sufficiently large herd sizes and hence become willing to liquidate animals through the market. Kyeyamwa et al. (2008) stated that having a bigger herd size positively influences the probability of selling. Higher herd size increases households' market participation (Ehui et al., 2009; Vincent et al., 2010; Terfa, 2012; Ayele et al., 2019).

As expected, correlation test (*Table 5*) and regression analysis (*Table 7*) showed that the distance to market had a significant negative association with the MBA market participation at 1% significant level. It suggests that the further away the market is, the less the participation. This may also be due to poor road conditions in rural areas. Farmers therefore go to the nearest markets to avoid wasted time and high transportation costs. This is in the line with the result of Lutta et al. (2021) who found that the distance to market negatively influences the decision to participate in market. They also stated that the closer a household is to the nearest market, the lesser would be the transportation cost, loss of livestock weight due to longer trekking hours, and better access to market information and facilities. Key et al. (2000) and Makhura et al. (2001) found that distance to market negatively influences both the decision to participate in market and the proportion of output sold. In contrast, Kyeyamwa et al. (2008) found that distance to market does not significantly influence the decision to sell at the market.

Chi-square tests showed a significant association between the payment type and market participation (*Table 6*). Moreover, regression results also showed payment type had a significant positive influence on market participation at 1% significant level (*Table 7*). This implies that the farmer's participation in the market increases if the sales result in cash payments. This result indicates that farmer prefer payment in cash than credit. One of the critical bases of MBA market is to make the animal trading system different from MT market by improving the payment system (Onibon, 2004). This point attracts more the farmers to MBA markets. Because they know they will sell and get their money in cash.

Table 5. Correlations between continuous independent variables and market participation (N = 300)

Independent variables	Market participation
Beef cattle herd size	0.422*
Sheep herd size	0.055
Goat herd size	-0.038
Household size	0.131*
Farmland ownership	-0.006
Distance to market	-0.377*

* means correlation is significant at 5%

Cooperatives partnership showed a significant association with market participation (*Table 6*), yielding a significant positive coefficient at 1% significant level (*Table 7*), which suggests that farmers who are members of a livestock farmers cooperative tend to have a high market participation. Partnership in groups is used as a proxy for group marketing (Lutta et al., 2021). This allows farmers not to depend on traders (middlemen) for market information, because they can benefit from this service with the cooperatives. Alene et al. (2008) and Lutta et al. (2021) found that being a group member positively influences the decision to participate in livestock market. Agricultural cooperatives reduce the likelihood of traders being sources of market information by increasing the probability of selling (Girma and Abebaw, 2012).

Table 6. Chi-square test results for categorical independent variables and market participation

		Market participation		Non-market participation			
		Freq. (N=150)	Proportion (%)	Freq. (N=150)	Proportion (%)	x^2	Sig.
Gender	male	149	99.3	144	96.0	3.657	0.056
	Female	1	0.7	6	4.0		
Access to market	Yes	84	56.0	67	44.7	3.854	0.050
information	No	66	44.0	83	55.3		
Payment type	Cash	63	42.0	18	12.0	34.247	0.000*
	Credit	87	58.0	132	88.0		
Pasture use	Yes	144	96.0	125	83.3	12.987	0.000*
	No	6	4.0	25	16.7		
Cooperative	Yes	67	44.7	7	4.7	64.578	0.000*
partnership	No	83	55.3	143	95.3		
Access to credit	Yes	44	29.3	46	30.7	0.063	0.801
	No	106	70.7	104	69.3		

* significant at 5 %

The number of sheep owned (herd size) had a significant positive effect on market participation at the level of 10% significance (*Table 7*). As the sheep herding increases, market participation increases. Sheep occupy the second place in animal sales after beef cattle. Especially during the periods of Eid al-Adha, New Year celebrations and traditional holidays, its demand increases (Moussa, 2014).

Access to market information had a positive and significant effect on the market participation at 5% significant level (*Table 7*). Ayele et al. (2019) and Lutta et al. (2021) found that farmers' access to market information had positively and significantly influenced the probability of farmers' decision to sell beef cattle. Access to market information boosts confidence of farmers who are willing to participate in the market (Zamasiya et al., 2014; Bahta and Bauer, 2007). Market information in the livestock sector remains one of the major challenges. But it is necessary for farmers to be well informed about the market demand and prices offered, as they are very important for the decision making to sell or not their animals (Musemwa et al., 2007). Farmers with price information are

more likely to participate in the market than those without (Barrett, 2008). Although access to market information is difficult in pastoral settings, MBA markets offer participants the advantage of acquiring it easily, mainly through farmers' organizations, management committee, livestock organizations network, etc. Due to poor and asymmetric access to market information, farmers receive low prices and this leads to high marketing cost (Alene et al., 2008; Sehar, 2018). The non-participation of farmers in livestock markets is not due to market information problems (Girma and Abebaw, 2012). The availability of complete and timely market information on supply, demand and price, enhance spatial market integration and price transmission (Rahman et al., 2019). Relevant information enables farmers to increase their income (Nechar et al., 2021). Market information can be an important instrument in the support of rural development and poverty alleviation in developing countries (Rad et al., 2013).

Table 7. Factors influencing the decision to participate in MBA markets

Variables	B	S.E.	Wald	Sig.	95% C.I.for EXP(B)	
					Lower	Upper
Access to market information (1 = Yes, 0 = No)	0.934	0.429	4.725	0.030**	1.096	5.902
Payment type (1 = Cash, 2 = Credit)	1.876	0.498	14.207	0.000*	2.461	17.317
Pasture use (1 = Yes, 0 = No)	0.765	0.725	1.112	0.292	0.519	8.905
Cooperative partnership (1 = Yes, 0 = No)	2.636	0.624	17.868	0.000*	4.112	47.388
Access to credit (1 = Yes, 0 = No)	-0.159	0.472	0.114	0.736	0.338	2.150
Distance to market =1	-	-	23.248	0.000*	-	-
Distance to market =2	1.138	0.522	4.746	0.029**	1.121	8.681
Distance to market =3	-1.827	0.534	11.726	0.001*	0.057	0.458
Beef cattle herd size =1	-	-	15.046	0.002*	-	-
Beef cattle herd size =2	0.887	0.570	2.422	0.120	0.794	7.423
Beef cattle herd size =3	1.414	0.590	5.752	0.016**	1.295	13.069
Beef cattle herd size =4	3.348	0.897	13.944	0.000*	4.907	164.867
Sheep herd size =1	-	-	4.881	0.087***	-	-
Sheep herd size =2	1.177	0.536	4.834	0.028**	1.136	9.273
Sheep herd size =3	0.835	0.531	2.471	0.116	0.814	6.529
Goat herd size =1	-	-	17.423	0.000*	-	-
Goat herd size =2	0.234	0.545	0.184	0.668	0.434	3.678
Goat herd size =3	1.833	0.466	15.474	0.000*	2.508	15.577
Household size =1	-	-	2.432	0.296	-	-
Household size =2	0.692	0.492	1.978	0.160	0.761	5.242
Household size =3	0.111	0.533	0.043	0.835	0.393	3.179
Farmland ownership =1	-	-	3.970	0.137	-	-
Farmland ownership =2	1.031	0.518	3.963	0.046**	1.016	7.738
Farmland ownership =3	0.681	0.533	1.631	0.202	0.695	5.620
Education level =1	-	-	0.000	1.000	-	-
Education level =2	17.425	18875.984	0.000	0.999	0.000	-
Education level =3	19.150	25216.392	0.000	0.999	0.000	-
Constant	-5.451	1.168	21.775	0.000*	-	-
Nagelkerke R^2=0,724; -2Log Likelihood=181.033; Percentage Correct=%88,3						

*, ** and *** mean that variable is significant at 1%, 5% and 10%, respectively.

The number of goats owned (herd size) has a significant and positive effect on market participation at 1% significant level. Small ruminants such as goats play an important role in livestock (Ayele et al., 2003), and in improving the livelihoods of farmers of farmers. Farmers raise them both for consumption and for markets.

Farmland ownership has a significant and positive effect on the participation of farmers in the MBA at the level of 5%. Agricultural land is an important factor of production allowing households to produce more in order to sell the surplus in the market (Alene et al., 2008).

4. Conclusions

Livestock farming plays a crucial role in the livelihood of pastoralists and agro-pastoralists in the Republic of Benin. However, the marketing of animals is not well structured and developed. Livestock farmers have limited access to the market due to various factors. In this context, this study sought to determine the factors that influence the decision of livestock farmers to participate in livestock markets, particularly in MBA markets, which are a new model of

livestock trade in the Republic of Benin.

The results of Logistic Regression model showed that access to market information, payment type, cooperative partnership, beef cattle herd size, sheep herd size, goat herd size, distance to market and farmland ownership determine the degree of participation of farmers in the MBA market in the study area.

Making relevant market information available to livestock farmers is crucial to increase the probability of their market participation decision and as well as receiving fair price for their commodity (Ayele et al., 2019). Cooperative partnership should be encouraged because it increases market participation, provides real-time market information and increases the likelihood of market sales. It is important to encourage and support the young livestock farmers to participate in MBA markets. This could create employment opportunities for unemployed youth in rural areas by allowing them to engage in the livestock trade. The inclusion of women in the livestock trade at all levels is also important. The pastoral system should be improved to increase animal production and productivity. The government should invest more in the education of livestock farmers to increase their decision-making capacity and productivity. MBA markets, as formal and well-structured markets, should be multiplied throughout Benin to allow farmers to easily sell their animals and animal products through short marketing channels and then improve their income.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Analysis of Energy Use Efficiency and Greenhouse Gas Emission in Rainfed Canola Production (Case study: Çanakkale Province, Turkey)

Kuruda Kanola Üretiminin Enerji Kullanım Verimliliği ve Sera Gazı Emisyonun Analizi (Örnek Çalışma: Çanakkale ili, Türkiye)

Sakine ÖZPINAR*

Abstract

Agriculture and energy are two closely related issues, agriculture not only consumes energy, but it also supplies energy. While increasing energy use in agriculture causes environmental problems such as greenhouse gas emissions, it also leads to the depletion of non-renewable energy resources. On the other hand, decreasing greenhouse gas emissions and enhancement the efficiency of energy use is among the important issues of sustainable agriculture. Therefore, this study was done to determine the energy inputs and greenhouse gas emissions in rainfed canola production. Data were collected by conducting face-to-face interviews in the period of 2021-2022 in 42-farm in Çanakkale province, located in the northwest of Turkey. Results introduced that the energy use efficiency and net energy gain were 3.63 and 72786.16 MJ ha^{-1}, respectively. In energy consumption, the highest rate of 46.62% belongs to fuel, and then nitrogen with 40.44%. The consumption of total energy is obtained as direct (46.46%), indirect (53.54%), renewable (1.07%) and non-renewable (98.93%). It has been determined that the energy requirements of the farms belong to non-renewable energy with an amount of 27384.03 MJ ha^{-1}, and this is especially prominent in diesel fuel and nitrogen fertilizer. The results show that the agricultural production in the area where the study is carried out mostly depends on non-renewable energy sources, whereas the use of renewable energy is very low. Total greenhouse gas emissions per hectare were equivalent to 1921.66 kg CO_2, and the highest amount was determined to belong to machinery and diesel fuel, with 53.20% and 32.66%, respectively. According to the results obtained in the farms where the study was carried out, it was revealed that the economic use and sustainability of energy can be strongly recommended in rainfed canola production using mechanization, especially considering the non-renewable energy inputs.

Keywords: Energy use in agriculture, Input energy, Output energy, Carbon dioxide emission, Canola

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Öz

Tarım ve enerji birbiriyle yakından ilişkili iki konu olup, tarım sadece enerji tüketmekle kalmıyor, aynı zamanda tarımsal üretim için gerekli enerji üretimini de sağlıyor. Tarımda enerji kullanımının artması, sera gazı emisyonları gibi çevresel sorunlara neden olurken, yenilenemeyen enerji kaynaklarının da tükenmesine yol açmaktadır. Öte yandan, sera gazı emisyonlarının azaltılması ve enerji kullanım verimliliğinin artırılması sürdürülebilir tarımın önemli konuları arasında yer alıyor. Bu nedenle, bu çalışma, kuru koşullarda kanola üretiminde enerji girdilerini ve sera gazı emisyonlarını belirlemek amacıyla ele alınmıştır. 2021-2022 üretim döneminde Türkiye'nin kuzeybatısında yer alan Çanakkale ilinde bulunan 42 kanola üretimi yapan çiftlikte yüz yüze görüşmeler yapılarak gerekli olan veriler elde edilmiştir. Sonuçlar, enerji kullanım verimliliği ve net enerji kazancının sırasıyla 3.63 ve 72786.16 MJ ha^{-1} olduğunu göstermiştir. Enerji tüketiminde en yüksek oran %46.62 ile dizel yakıtına ait olup, onu %40.44 ile azotlu gübrenin izlediği saptanmıştır. Toplam enerji tüketimi doğrudan (%46.46), dolaylı (%53.54), yenilenebilir (%1.07) ve yenilenemez (%98.93) olarak elde edilmiştir. Kanola üretimi yapan çiftliklerin enerji ihtiyacının 27384.03 MJ ha^{-1} miktarı ile yenilenemeyen enerjiye ait olduğu ve bunun özellikle dizel yakıtı ve azotlu gübre ile öne çıktığı belirlenmiştir. Elde edilen veriler, çalışmanın yürütüldüğü alanda tarımsal üretimin büyük ölçüde yenilenemeyen enerji kaynaklarına bağlı olduğunu, yenilenebilir enerji kullanımının ise çok düşük düzeyde kaldığını göstermiştir. Hektar başına toplam sera gazı emisyonu 1921.66 kg CO_2 eşdeğer olduğu, en yüksek miktarın sırasıyla %53.20 ve %32.66 ile makine ve dizele yakıtına ait olduğu saptanmıştır. Çalışmanın yürütüldüğü çiftliklerde elde edilen sonuçlara göre, özellikle yenilenemeyen enerji girdileri dikkate alındığında, mekanizasyon kullanılarak kuru koşullarda kanola üretiminde enerjinin ekonomik kullanımının ve sürdürülebilirliğinin tavsiye edilebileceği sonucu ortaya çıkmıştır.

Anahtar Kelimeler: Tarımda enerji kullanımı, Girdi enerjisi, Çıktı enerjisi, Karbondioksit salınımı, Kanola

1. Introduction

Energy consumption, environmental quality and even the economy are reciprocally interdependent issues. There is also a significant relevance between agriculture and energy, which is heavily dependent on non-renewable and other sources (Pimentel and Pimentel, 2007). The use of more energy than necessary in agriculture leads negative effects on the environment; in this respect, while agriculture creates climate change, it has an impact on the environment and is also affected by climate change. In recent years, the rapid increase in the world's population and, the spread of new techniques in agriculture and the amount of energy required for their application has led to a continuous increase (Kitani, 1999). Thus, energy is an important component in agriculture and an essential input for every cultivation, transport, and social development. In this respect, agriculture will become heavily dependent on energy use in future times to ensure food for the steadily growth of world peoples. Energy efficient in agriculture is one of the necessities of sustainable agriculture, and it will be also had positive effects on the use of fuels and the protection of natural resources (Mousavi-Avval et al., 2010). While agriculture consumes energy directly on the farms as diesel fuel to run equipment, it is used indirectly to produce the machinery and chemicals (fertilizers, pesticides) out of farm (Pimentel and Pimentel, 2007). Energy is needed on farms, especially in field practices such as seedbed preparation, sowing, intercultural practices, water pumping, harvesting and transportation (Lal, 2004). Field practices require a huge energy to operate machinery (Pishgar-Komleh et al., 2012), for example, tillage is a field practice that consumes about 30% of the total energy use in agriculture (Lal, 2004). The high use of energy resources like fertilizers, pesticides, and fuel which constitute a high energy input, causes significant threats to environmental pollution. The use of low energy input also reduces the amount of CO_2 gas emissions, which have negative effects on the environment (Khoshnevisan et al., 2013). The emissions as greenhouse gas from agriculture are 19.9 Giga tons of CO_2 equivalent annually, which corresponds to 24% of the total global amount (IPCC, 2014), while this rate for Turkish agriculture is quite small with 3% (TUIK, 2021). From this point of view, agriculture is considered to have a great function in the gas emissions due to the acquisition of inputs used and the applications with tractor-driven equipment (Mousavi-Avval et al., 2017). However, in the last two decades, the application of high inputs in conventional production systems and the intensive use of agricultural machinery (Pishgar-Komleh et al., 2012) have further increased the emissions as greenhouse gas (Choudhary et al., 2017). Considering all these, the efficient use of energy resources and the development environmental appearances of agricultural production in order to reduce the emissions are the basic requirements of sustainable agriculture (Lal, 2004). So far, lots of studies have been done to calculate the energy use to produce field crops in Turkey or other countries, but very few have been combined with the analysis of energy and greenhouse gas emissions for canola under rainfed conditions. According to the results obtained in a study on rainfed potato production in Iran, it has been revealed that the total input energy of 47 thousand MJ ha^{-1} causes about 993 kg of CO_2 emissions per hectare (Pishgar-Komleh et al., 2012). In another study conducted by Soltani et al. (2014) for many rainfed canola production systems in Iran, energy and greenhouse gas emissions analysis were carried out. They showed that the conventional system consumes 12953 MJ ha^{-1} of energy, resulting in an energy output of 52355 MJ ha^{-1} and greenhouse gas emissions equivalent to 1028.1 kg of CO_2 per hectare. They also recorded that energy efficiency, productivity and net return were 4.1, 0.14 kg MJ^{-1} and 39402 MJ ha^{-1}, respectively. In a study conducted by Unakitan et al. (2010) in Turkey, an energy use of canola was analysed using three farm size scenarios. The results showed that total energy input on average farm size was 18297.61 MJ ha^{-1}, which about 65% of this was related to chemical fertilizers. The average of energy efficiency, net and productivity energy are 4.68, 67259.36 MJ ha^{-1} and 0.17 kg MJ^{-1}, respectively, and these values increase with the size of the farm. Optimizing energy efficiency and reducing energy input, applying nitrogen with actual crop requirements, and adopting reduced tillage are the most efficient techniques (Ozpinar, 2006). Ozpinar and Ozpinar (2015) concluded that under long-term tillage and crop rotation with wheat-vetch/maize using green manure in both rainfed and irrigation conditions can increase the maize grain yield without chemical fertilizer application.

Canola is produced in an area of approximately 38 million hectares in the world and 75 million tons of production is made per hectare. The most important rate belongs to Canada, followed by China, India, Germany, France, Australia, Poland, and other countries in the Mediterranean basin (FAOSTAT, 2020). In the countries in basin, the yield per unit area and thus the production amount is lower than the rainy middle European part (Rathke and Diepenbrock, 2006). For example, in Turkey, which does not have a long history in canola cultivation, it has increased amount of canola, which was 110 thousand tons in 2012, to over 125 thousand tons in 2020 on an area of 45 hectares (TUIK, 2021), with the support provided by the government for fertilizers, diesel fuel and certified seeds per kilogram or hectare. Canola is mainly grown in the European part of Turkey, but also in other parts of

the country, mostly for oil and rarely for animal feed. While winter varieties are grown in Thrace, Marmara and Black Sea regions located in the northwest of the country, spring varieties can be grown in Mediterranean, Aegean, Central and Southeastern Anatolia regions. Çanakkale, partly in the Thrace region, is one of the provinces at the coast to the Marmara Sea and is the third canola producing province in the region. It produces approximately 39% of the country's canola production with an average yield of 3550 kg per hectare, but yield reaches over 4000 kg ha^{-1} in well-irrigated areas (TUIK, 2021). In this regard, in rainfed conditions of the study area, canola, which is an alternative to sunflower, is produced in rotation with cereals such as winter wheat in order to increase the yield per unit area under sustainable production systems and to enrich the soil in terms of organic matter. On the other hand, the canola-cereals cropping system is the largest system in the area under conventional systems require vigorous number of inputs, which contributes high energy and results in low economic returns. Despite the sustainable characteristics of canola, widespread cultivation of the product has various harmful effects on the environment, such as consumption of natural resources and gas emissions. So, it has become important to analyse rainfed canola production in terms of energy and greenhouse gas emissions as CO_2. While studies on different products with energy analysis have been published for different regions of the country (Baran et al., 2021), there have been studies on only olive (Özpınar, 2020) and rice (Ozpinar, 2022) in Çanakkale province. However, none of these studies have been analysed by combining energy and greenhouse gas emissions using conventional production systems under rainfed conditions, further, the results of studies in other parts of the country are not representative of the country's remaining larger production areas. For this reason, it has been concluded that there is a need for energy use data, which can be a reference and guide for energy saving and reducing gas emissions in agriculture, both in the country and in the canola production area where the study was conducted. Thus, this study was undertaken in Çanakkale, located in the northwest of Turkey, to fill the lack of data on the efficient use of energy for canola production in the country. In this regard, it is necessary to carry out energy analysis studies that will contain environmental effects in canola production in the study area. This energy analysis was conducted using questionnaire data from canola producing farms, as well as other data from field observation studies. Moreover, the aim of the study is to determine the energy inputs, output, energy efficiency, gas emissions of rainfed canola production and to guide the technological developments necessary to reach the high energy use efficiency of the existing production systems in the study area.

2.Materials and Methods

2.1. Study area

The study was carried out in the Çanakkale province, northwest of Turkey, which is located within 25°40′-27°30′ east longitude and 39°27′-40°45′ north latitude. The total area of the province is 993 thousand hectares, of which approximately 332 thousand hectares are belongs to agricultural areas. Most of these areas are covered with rainfed agriculture, usually the canola crop is grown in rotation with wheat, barley, and sunflower, except in irrigated areas where usually maize/corn, rice, vegetables, and orchard crops such as peaches, apples, cherries are grown (Özpınar and Ürkmez, 2017). The climate is under the influence of Ida Mountain, Marmara and Aegean Seas where is semiarid subtropical. While the northern parts of the province are under the influence of a colder climate, the southern parts have a more obvious tropical climate, the summer period is between May and September and the winter is between October and April. Annual average of maximum temperature is about 28°C (in August) according to the long-term period (*Figure* 1), and annual average of minimum temperature is 6 °C (in January) (*Figure* 1). The annual rainfall increases from south to north part regardless of the altitude and varying from 460 mm to 715 mm according to years, and about 65% of annual rainfall events occur from December to May (*Figure 2*). For studied farms for the canola production, agricultural practices commonly include tillage, sowing, fertilizing, weed and pest control, and harvesting. Seedbed preparation is one of the main practices in the studied area where is under conventional production systems using mainly mouldboard plough. For this reason, the soil is first tilled by plough at 20-25 cm followed by twice double action disk harrowing in opposite directions at 10 cm between 15 September and 30 October, and then roller application. Finally, sowing is done using pneumatic drills or grain row-planter at average rate of around 8.20 kg ha^{-1} of seed with varying 4 and 9 kg ha^{-1} usually using DK Exstorm hybrid. Soil preparation is very effective practice to reduce weeds which can be controlled by using herbicide with 1.63 litre ha^{-1} on average using a tractor mounted sprayer. Trifluralin is usually applied to the soil two weeks before sowing, while Azotrax is used for narrow-leaved weeds such as wheat and oats at the sowing, Agil Extra and Formula Super after canola emergence, and Lontrel Extra for broad-leaved weeds. Considering the fertilizer

application, only nitrogen and phosphorus are applied since potassium is sufficient in the soils. Basic fertilizers in canola production are usually urea (46% N), triple super phosphate (43-46% P_2O_5).

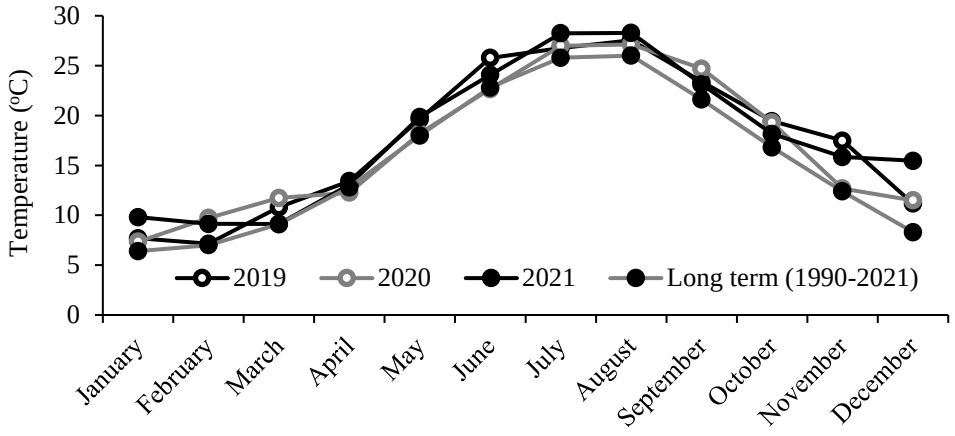

Figure 1. Average temperature according to months for three years and long-term

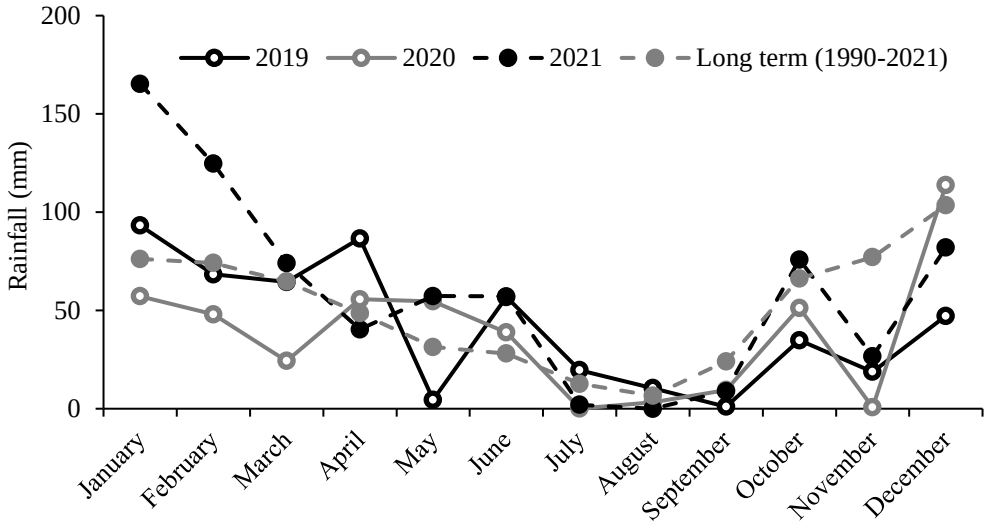

Figure 2. Rainfall distribution according to months for three years and long-term period

Thus, canola needs relatively higher levels of both nitrogen and phosphorus fertilizers. Nitrogen was applied (150-175 kg ha^{-1}) as 1/3 at the seeding stage [the September-October/November (%21 N as 18-46-0/20-20-0 DAP compound)], 1/3 at the stem elongation [December-January (%46 N urea) and March-April (%26 N ammonium nitrate)], and 1/3 before flowering in studied farms *(Table 1)*. Phosphorus fertilizer was used only during the sowing stage and in the amount of 50-80 kg per hectare. Canola is harvested in the last quarter of May with a self-propelled grain combine.

2.2. Data collection and evaluation

Data were obtained from farms by visiting 42-farmer producing canola in 15 villages of the districts (Bayramiç, Biga, Eceabat, Lapseki, Ezine) of Çanakkale province during the June-September 2021 period. Most of the district areas is generally in flat lands with cereal fields, and the economy is mostly based on agriculture. In order to collect the necessary data about various inputs (seed, fertilizer, herbicide, fuel, etc.), a questionnaire containing detailed information about the inputs including working time and machinery usage, and canola grain yield, etc. was prepared. Some of the data was taken from similar studies and statistics published by relevant organizations such as Turkish Statistical Institute and Agricultural Ministry, and some of it was measured in farmer fields or directly on machinery. For farms, the random method was used for sampling and the sizes of sample were determined as 42 farms from the population using the Neyman method equation (Yamane, 1967).

Table 1. Amount of inputs used in canola production and output

Inputs/output	Amount of input (ha^{-1})	
	Average	**Lowest-Highest**
Human labour (h)	28.85	27-35
Diesel fuel (l)	227.40	220-230
Nitrogen (N, kg)	184.70	160-190
Phosphorous (P_2O_5, kg)	85.00	70-87
Herbicide (active ingredient) (l)	1.63	1-2
Machinery (h)	14.40	10-18
Seed rate (kg)	8.20	8-9
Grain yield (kg)	3550	2500-4550

2.3. Energy and greenhouse gas emissions analysis

The considered inputs and output have been converted to energy values using their energy equivalents *(Table 2).* The determination of energy efficiency was based on the energy rate between output and inputs. Inputs include seeds, fertilizers and herbicides, diesel fuel, machinery and human labour, and output consists of the yield of canola grain. Energy consumption was obtained from the amount of input application *(Table 1)* by the energy equivalents *(Table 2)* and expressed in MJ per hectare. Classical mathematical equations (1-8) were used to calculate the equivalent energy of rainfed canola production. Labour is used at various stages of canola production on farms, for example, tillage, sowing, application of fertilizers and herbicides, harvesting and operating agricultural machinery. Labour energy input is calculated by multiplying the person number doing work in an operation (Kösemani and Bamgboye, 2020). The total hours (H_h, h ha^{-1}) for the operations *(Table 1)* were multiplied by the energy equivalent *(Table 2)* for human (H_{eqv}, MJ h^{-1}).

$$E_h = H_h \text{ x } H_{eqv} \quad \text{(Eq.1)}$$

The diesel fuel energy (Ed) is obtained by multiplying the total amount of fuel (l ha^{-1}) *(Table 1)* consumed in all cultural operations with the heating value of the fuel *(Table 2).*

$$E_d = D \text{ x } F_{eqv} \quad \text{(Eq.2)}$$

Where, E_d, the diesel energy consumed (MJ ha^{-1}); D, the fuel used for operations (l ha^{-1}) *(Table 1);* F_{eqv}, fuel energy equivalent (MJ l^{-1}) *(Table 2).* To calculate energy for the machinery manufacturing in the farms, it is assumed that the embodied energy will be depreciated during the economic lifetime (L, h). So, the machinery weight (W, kg ha^{-1}) to produce one-hectare canola was calculated using the time used (W_h, h ha^{-1}) in farm.

$$W = \frac{M \text{ x } W_h}{L} \quad \text{(Eq.3)}$$

The machinery energy was calculated by determining the production energy for tractors and machinery.

$$E_m = \frac{M \text{ x } E}{L \text{ x } C_e} \quad \text{(Eq.4)}$$

Where, E_m, total farm machinery input energy in the lifetime for one hectare (MJ ha^{-1}); M, the machinery weight (kg); E, the energy equivalent of the machinery weight; L, the machinery life (h); C_e, the field capacity of farm machinery (ha h^{-1}). Energy equivalent for machinery considered energy used to produce the raw materials (22-60 MJ kg^{-1} for steel), the manufacturing process (86.38 MJ kg^{-1}), the transportation (8.8 MJ kg^{-1}). The amount of fuel used for tillage operations depending on the depth and width of tillage, the type of soil and moisture content, the size of tractor and machinery. Effective field capacity of farm machinery (C_e) calculated using following equation.

$$C_e = \frac{V \text{ x } W \text{ x } F_e}{10} \quad \text{(Eq.5)}$$

Where W, the working width (m); V, the working speed (km h^{-1}); F_e, the field efficiency. Chemical energy input was obtained from the amount (kg) of fertilizers and herbicides used. Total energy input for fertilizers was obtained by using the amount of fertilizer *(Table 1)* by the energy value *(Table 2).*

$$E_{fert} = \sum_{n=1}^{n} \left(\frac{N x N_{eqv}}{SA} + \frac{P_2O_5 x P_{eqv}}{SA} \right) \quad \text{(Eq.6)}$$

Where, E_{fert}, input for the fertilizer; N_{eqv}, the energy value of N; P_{eqv}, the energy value of P_2O_5; N, the fertilizer as percentage of N ingredient (kg); P_2O_5, the fertilizer as percentage of P_2O_5 ingredient (kg); SA, the area (ha); n, the application number nth. The NPK 20:20:0 was widely used in the study area because of K_2O sufficient in the area soils, thus, it was not considered in the calculation. The amount of the herbicide applied *(Table 1)* were multiplied with the energy value *(Table 2)* to get the energy of the herbicide.

$$E_{herb} = H_h \text{ x } H_{eqv} \quad \text{(Eq.7)}$$

Where, E_{herb}, the energy input for herbicide (Mj ha^{-1}); H_h, the quantity of herbicide applied (kg ha^{-1}); H_{eqv}, the energy equivalent value of herbicide (MJ kg^{-1}). The energy input of the seed was obtained by using the number of seed used (S_s, kg ha^{-1}) *(Table 1)* and the energy equivalent (S_{eqv}, MJ kg^{-1}) *(Table 2).*

$$E_s = S_s \text{ x } S_{eqv} \quad \text{(Eq.8)}$$

The output energy (E_o, MJ ha^{-1}) is estimated by multiplying the canola grain yield ($Q_{grain\text{-}yield}$, kg ha^{-1}) *(Table 1)* by energy equivalent (Q_{eqv} MJ kg^{-1}) *(Table 2).*

$$E_o = Q_{grain\text{-}yield} \text{ x } Q_{eqv} \quad \text{(Eq.9)}$$

Energy indicators in an agricultural production include various parameters such as energy use efficiency, energy productivity (kg MJ^{-1}), specific energy (MJ kg^{-1}) and net energy (MJ ha^{-1}).

$$\text{Energy use efficiency} = \frac{\text{Total energy output (MJ ha}^{-1})}{\text{Total energy input (MJ ha}^{-1})} \quad \text{(Eq.10)}$$

$$\text{Energy productivity (kg MJ}^{-1}) = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Total energy input (MJ ha}^{-1})} \quad \text{(Eq.11)}$$

$$\text{Specific energy (MJ kg}^{-1}) = \frac{\text{Total energy input (MJ ha}^{-1})}{\text{Grain yield (kg ha}^{-1})} \quad \text{(Eq.12)}$$

$$\text{Net energy (MJ ha}^{-1}) = \text{Energy output} - \text{Energy input} \quad \text{(Eq.13)}$$

Table 2. Energy equivalents for inputs and output

Input/Output	Equivalent	Reference
Human labour (MJ man h^{-1})	1.96	Kitani, 1999
Diesel fuel (MJ l^{-1})	56.31	Kitani, 1999
Nitrogen (N) (MJ kg^{-1})	60.60	Kitani, 1999
Phosphate (P_2O_5) (MJ kg^{-1})	11.10	Kitani, 1999
Herbicides (active ingredient) (MJ kg^{-1})	238.00	Mousavi-Avval et al., 2017
Machinery (MJ kg^{-1})⏚	142.70	Alimagham et al., 2017
Seed (MJ kg^{-1})	3.60	Mousavi-Avval et al., 2010
Grain yield (MJ kg^{-1})	28.30	Rathke and Diepenbrock, 2006

⏚ The value was considered for manufacturing (86.38 MJ kg^{-1}), repairs, maintenance (0.55 x energy for manufacture), and transportation (8.8 MJ kg^{-1}) energy for tractors and machinery.

Table 3. Equivalents of CO_2 emissions from canola farms

Input	Emission equivalent⏚		
	Mean	Range	References
Diesel fuel (l MJ^{-1})	2.76		Dyer and Desjardins, 2003
Nitrogen (N) (kg MJ^{-1})	1.30	0.9-1.8	Lal, 2004
Phosphorous (P_2O_5) (kg MJ^{-1})	0.20	0.1-0.3	Lal, 2004
Herbicide (kg MJ^{-1})	6.30	1.7-12.6	Lal, 2004
Machinery (kg MJ^{-1})	0.071		Dyer and Desjardins, 2003
Labour (kg MJ^{-1})	0.36		Nguyen and Hermansen, 2012

⏚ kg CO_2 equivalent per unit; including production, transportation, storage and transfer.

Energy sources used in agriculture consist of two main groups: natural and supplementary. Natural energy is essential for crop growth and includes solar energy and various forms of chemical energy stored biologically in the soil. The supplementary energy was divided into renewable and non-renewable forms, and direct and indirect forms. Direct energy contains those quantities that are consumed during the canola production period such as human labour and diesel fuel, while indirect energy includes seed, fertilizer, pesticide, and machinery. Renewable energy consists of human labour and seed, while non-renewable energy consists of diesel fuel, pesticide, fertilizer, and machinery. The greenhouse gas emissions were obtained by using CO_2 emission factor of agricultural inputs *(Table 3).* The amount of produced CO_2 was calculated by using the input application rates *(Table 1)* and the emission equivalent *(Table 3)* and expressed as kg $CO2_{eq}$. ha^{-1} (Pishgar-Komleh et al., 2012; Soltani et al., 2014).

3.Results and Discussion

3.1. The energy inputs and output in canola production

The total energy input is calculated as 27678.84 MJ ha^{-1} and the output as 100465.0 MJ ha^{-1} *(Table 4).* The energy input varied from 24812.72 to 28807.00 MJ ha^{-1} according to the amount of highest and lowest inputs comparable with the range of 5187.98-27887.15 MJ ha^{-1} to produce canola in Iran (Mousavi-Avval et al., 2017), 7420-16100 MJ ha^{-1} in Germany (Rathke and Diepenbrook, 2006). In another study, the highest energy input was reported as 30889 MJ ha^{-1} for irrigated canola production (Sheikh-Davoodi and Houshyar, 2009), while Taheri-Garavand et al. (2010) reported the total energy input and output values lower than the present study as 28705.3 MJ ha^{-1} and 41230 MJ ha^{-1}, respectively. Considering the energy consumption according to the energy requirement of the inputs, it is evident that fuel is the highest, dominating about 12805 MJ ha^{-1} with 47% of total energy *(Table 4).* In previous studies, fuel founded for the highest rate of input energy (Rabiee et al., 2021), which agrees with this study results *(Table 4).* One of the main reasons using the high diesel is coming from more field operations performed by machinery, for example for seedbed preparation and intercultural practices because of using fuel mainly for all tractor operations. Another reason is a temporal depreciation of agricultural machinery due to the use of dated machinery and equipment. It may be decreasing the amount of energy input by applying new machinery or equipment with more energy efficiency. Beyond diesel fuel, fertilizers (nitrogen, phosphorous) were among the other high energy inputs contributing to the consumption of 12136.32 MJ ha^{-1} (43.85%) of the total energy, for example nitrogen with 40.44% *(Table 4).* There are two important reasons for the high fertilizer consumption. One of the reasons is the lack of knowledge of the farmers about the use of fertilizers. They do not know the amount of chemical fertilizer required for different crops, and they have a common belief that excessive use of fertilizer will increase the yield without soil analysis. Another reason is the prices of government subsidies which is significantly affected the amount of fertilizer use, especially during the pandemic period of the last two years, as it increased market prices and reduced the amount of use per unit area. As a result of the inefficient (more than crop need) use of chemical fertilizers, it will cause soil and water, and as well as air pollution. Some researchers indicated that energy used in the production of chemical fertilizer accounts approximately 40% of total energy used in agricultural production in developed countries (Pishgar-Komleh et al., 2012). Others have also reported that fertilizer and fuel were the most intensive energy inputs in canola production (Mousavi-Avval et al., 2017; Soltani et al., 2014) because canola has relatively high demands for nitrogen (N) per yield unit. Similarly, the others found the highest rate of nitrogen in total energy input was related to canola (37%) (Mohammadzadeh et al., 2017) and (47%) Mousavi-Avval et al. (2017). In this study, diesel and fertilizer were the two highest energy inputs and accounted as 92.14%. The energy inputs required for canola production in different countries strongly supports this view (Khoshnevisan et al., 2013; Mousavi-Avval et al., 2017). This study is also in agreement with the findings of Mousavi-Avval et al. (2010) and Mousavi-Avval et al. (2017) who reported that 85% and 81% of total energy input in canola production is consumed by both fuel and fertilizer. This was higher (96%) in the study of Taheri-Garavand et al. (2010) and lower (59%) in the study of Sheikh-Davoodi and Houshyar (2009) compared with the present study. Taheri-Garavand et al. (2010) was also found that the fertilizers (usually N) had the highest rate in the total energy with a rate of 65.5% (average of 18809.8 MJ ha^{-1}) followed by fuel with 30% (8604.2 MJ ha^{-1}). According to Rathke and Diepenbrock (2006) the rate of nitrogen ranges between 20% and 51% depending on the amount of nitrogen in winter canola production in Germany. The results of energy analysis in canola production of the north Iran led to the highest rate of energy input for nitrogen (42.9%) and fuel (39.81%) (Kazemi et al., 2016), which agrees with the results of the study *(Table 4).* In this study, therefore, it is necessary to focus more on fuel and fertilizer consumption due to high energy inputs than the other components to effectively reduce energy consumption in canola production under rainfed conditions. Because fertilizer and fuel are closely related

to the profitability of canola production in the study area, farmers are also highly receptive to integrated machinery and nitrogen-saving technologies that can achieve high energy use efficiency. It is also necessary to reduce the use and consumption of the machinery operation and diesel consumption in the production systems to overcome the growing energy demands in agriculture because intensive tillage operations accounted for higher machinery use and fuel consumption (Yadav et al., 2018).

Table 4. Energy of inputs and output for various operations in rainfed canola production

Input/Output	Average		Lowest		Highest	
	(MJ ha^{-1})	(%)	(MJ ha^{-1})	(%)	(MJ ha^{-1})	(%)
Human labour	55.37	0.20	52.92	0.21	68.60	0.24
Diesel fuel	12804.89	46.62	12388.20	49.93	12951.30	44.96
Nitrogen (N)	11192.82	40.44	9696.00	39.08	11514.00	39.97
Phosphorous (P_2O_5)	943.50	3.41	777.00	3.13	965.70	3.35
Herbicide	387.94	1.40	238.00	0.96	476.00	1.65
Machinery	2054.88	7.42	1427.00	5.75	2568.60	8.92
Seed	239.44	0.87	233.60	0.94	262.80	0.91
Total	27678.84	100.00	24812.72	100.00	28807.00	100.00
Grain yield	100465.00		70750.00		128765.00	

It can be supported with different applications to reduce the energy input of fertilizer without reducing the yield and production, for example, by using appropriate types of fertilizer sources such as legumes to reduce chemical fertilizer use, especially nitrogen (Ozpınar and Ozpınar, 2015). The use of nitrogen in the required amount has an important effect on ensuring the nutrient balance in the soil, increasing the efficiency of nitrogen use and maintaining the yield of canola. In contrast, excessive use of nitrogen can lead to serious problems such as the leakage of nitrogen into the environment and polluting the food chain and increasing carbon emissions in the atmosphere (Soltani et al., 2014). Therefore, to reduce the fertilizer and fuel use in agriculture, inclusion of legumes in crop rotation (Ozpinar and Baytekin, 2006), increment of soil organic matter and using efficient machinery (Rathke and Diepenbrock, 2006) are apparently a reasonable integrated approach. The results revealed that 55.37 MJ ha^{-1} (0.20%) of labour energy, varying from 52.92 to 68.60 MJ ha^{-1} in lowest and highest input amounts, respectively, and 2054.88 MJ ha^{-1} (7.42%) of machinery energy are needed per hectare *(Table 5)*. The higher value of machinery than labour can be mainly attributed the increasing tractor and machinery working operations and hours. Similar results have been reported in previous studies, labour and as well as herbicide energy inputs are low in total energy (Alimagham et al., 2017). In agreement with previous studies (Kazemi et al., 2016; Mousavi-Avval et al., 2017), the data revealed that in addition to machinery, nitrogen also has a high contribution with 14553.2 MJ ha^{-1} to total energy consumption. Bonari et al. (1995) indicated that reducing of tillage resulted in 55% less fuel consumption than conventional tillage without a significant difference in yield. Similarly, Rabiee et al. (2021) concluded that conventional tillage increased total energy input and greenhouse gas emissions compared reduced or no-tillage at the different fertilizer level. Seed energy has the lowest energy with 0.87% among all the inputs *(Table 4)*. One of the practices for further reduction of seed energy is to use less seed per hectare by using qualified varieties which may also reduce the possibility of weed infestation and the energy needed for weeding. Herbicides are another input with the lowest energy consumption with 1.40%. The yield of canola grain was considered as 3550 kg ha^{-1} from the questioned farms, and the energy was resulted to be 100465.00 MJ ha^{-1}, ranging from 70750.00 to 128765.00 MJ ha^{-1} due to the different input amounts of the farms, in agreement with Rabiee et al. (2021) because of similar canola grain yield from unit area by 3458 kg ha^{-1}. These results were higher than in others (Mousavi-Avval et al., 2017) due to higher grain yield per hectare who declared that 2076.76 kg ha^{-1} produced 56695.6 MJ ha^{-1}, varying from 23205 MJ ha^{-1} to 107016 MJ ha^{-1}, while lower energy output of 50091 MJ ha^{-1} and 41230 MJ ha^{-1} for canola have been reported by (Kazemi et al. (2016) and Taheri-Garavand et al. (2010), respectively.

3.2. Energy indicators and forms

Efficiency of use of energy is an index of environmental impacts, which is related to crop production systems (Rathke and Diepenbrock, 2006) and expresses how much energy is produced in return for the energy used *(Table 5)*. Efficiency of use of energy calculated especially for the canola grain was found to vary between 2.85 and 4.47

in all the farms studied, with an average of 3.63. This is similar to the 3.50 (Mousavi-Avval et al., 2010) and 3.73 (Mousavi-Avval et al., 2017) in Iran, but it is lower than the 4.68 (Unakitan et al., 2010) in Turkey. This is also lower than the values reported by Soltani et al. (2014) who founded 4.1 for the common canola production system which represents about 70% of farmers using in the Gorgan region, Iran. In order to improve the of energy use in the farms, it can be achieved by including applications such as crop rotations, green manure production systems and reduced tillage that increase soil fertility. Lal (2004) indicated that energy efficiency tends to increase with the reduction of tillage operations which can lead to reduced fuel consumption and the time and energy needed for seedbed preparation. In general, for a sustainable crop production, the renewability and efficiency of energy should be increased in farms (Rathke and Diepenbrock, 2006). In *Table 5*, the energy productivity was found to be 0.13 kg MJ^{-1}, which means that 0.13 kg of canola grain are produced per one MJ of energy. These are in accordance with Rabiee et al. (2021) and Mousavi-Avval et al. (2010) as the averages of 0.13 kg MJ^{-1}, while Mousavi-Avval et al. (2017) reported that this value was 0.14 kg MJ^{-1}. Furthermore, a previous study by (Kazemi et al., 2016) reported energy efficiency as 0.12 for canola production. The energy per amount of product was found as 7.80 MJ kg^{-1} with the highest and lowest of 6.33 and 9.93 MJ kg^{-1}, respectively *(Table 5).* Similarly, Soltani et al. (2014) reported that this was 7.80 MJ kg^{-1} for canola while Kazemi et al. (2016) and Mousavi-Avval et al. (2010) found higher as 8.26 and 7.13 MJ kg^{-1}, respectively. Net energy gain recorded as 72786.16 MJ ha^{-1} on average, while it varied from 45937.28 to 99958.00 MJ ha^{-1} in lowest and highest quantities, respectively *(Table 5).*

Table 5. Energy indicators of canola production

Indicator	Average	Lowest	Highest
Energy use efficiency (dimensionless)	3.63	2.85	4.47
Energy productivity (kg MJ^{-1})	0.13	0.10	0.16
Specific energy (MJ kg^{-1})	7.80	9.93	6.33
Net energy (MJ ha^{-1})	72786.16	45937.28	99958.00

Table 6. Energy inputs for different energy forms

Energy form	Average		Lowest		Highest	
	(MJ ha^{-1})	(%)	(MJ ha^{-1})	(%)	(MJ ha^{-1})	(%)
Direct	12860.26	46.46	12441.12	50.14	13019.90	45.20
Indirect	14818.58	53.54	12371.60	49.86	15787.10	54.80
Total	27678.84	100.00	24812.72	100.00	28807.00	100.00
Renewable	294.81	1.07	286.52	1.15	331.40	1.15
Non-renewable	27384.03	98.93	24526.20	98.85	28475.60	98.85
Total	27678.84	100.00	24812.72	100.00	28807.00	100.00

Energy as indirect is found slightly higher than direct with 14818.58 MJ ha^{-1} (53.54%) and 12860.26 MJ ha^{-1} (46.46%) respectively *(Table 6).* In previous studies conducted by Kazemi et al. (2016) and Taheri-Garavand et al. (2010), the corresponding values were of 59.91% and 40.09%, 69.8 % and 30.2%, respectively. *Table 6* shows that the renewable and non-renewable energy were obtained as 1.07% and 98.93%, respectively. Considering this issue ecologically, non-renewable energy resources will eventually deplete (Rathke and Diepenbrock, 2006). This is not only specific to the area where the study was conducted, but also the results of a long-term study in the country made it clear that agriculture is largely dependent on non-renewable energy (Unakitan et al., 2010). The rates of non-renewable and renewable energy were found to be 97.98% and 2.02%, respectively by Kazemi et al. (2016) and these are in accordance with the findings of this study. In general, the country has a great potential for renewable energy sources (solar, wind, etc.) due to the existence of different geographical regions. Despite the energy long history in energy production from wind, renewable resources are used very low, mainly due to the lack of suitable technology for renewable resources, as well as no-government subsidies.

3.3. Greenhouse gas emissions

The management of energy consumption in agriculture, the use of non-renewable energy in various applications (use of machinery, water pumping and irrigation, fertilization, chemical spraying, etc.) have recently been the subject of interest because of growing greenhouse gas emissions all over the world. The total amount of the emissions was determined as 1921.66 kg CO_2 equivalent per hectare *(Table 7).* This is mainly due to the intensive machinery use, the application of high amounts of fuel and nitrogen. It can be indicated that one of the applications of reducing greenhouse gas emissions is the reduction of field operations where a significant portion of fuel is consumed, and the other is the use of less nitrogen in canola production are issues to be considered. In a canola production study conducted in the northern regions of Iran, the value of 1063.5 kg CO_2 equivalent per hectare (Mohammadi et al., 2014) was lower than this study value. In this study, the highest emissions belonged to machinery with 53.20% and then 32.66% of fuel and 13.37% of nitrogen, and the rate of all remaining emissions remained below 1.5% *(Table 7).* The lowest emissions were belonging to herbicide with 0.53% represents 10.27 kg CO_2 equivalent ha^{-1}. Alimagham et al. (2017) reported that emissions from machinery using for soybean was very important for production systems using full mechanization varying from 10.2% to 22.8% in total, except for the electricity consumption used in irrigation. However, they also concluded that in conventional soybean production systems typically labour-intensive, while fuel (33.6-40.7%) and electricity consumption (29.8-33.6%) were the predominant greenhouse gas emitters. The same authors noted that conventional soybean production in comparison with mechanized systems, produce less greenhouse gas emissions per kg of grain, indicating that conventional systems are more environmentally. In the present study, nitrogen had the first rank in greenhouse gas emissions of 12.49% followed by phosphorus with portion of 0.88%. Lal (2004) reported that the nitrogen accounting for 20% and 30% in large and small-scale farms, respectively. On the other hand, the reason for the high emissions of fuel in farms may be attributed to the use of worn-out tractors, improper machinery-tractor matching, as well as intensive tillage and intercultural operations with high energy consumption (Dyer and Desjardins, 2003). These are consistent with the findings concluded by Soltani et al. (2014) who presented that canola produces 1028.1 kg of CO_2 equivalent ha^{-1} due to the use of intensive machinery and fertilizers. They also reported that nitrogen (48%), fuel used in field operations (25%) and machinery (14%) are the most important contributors in terms of increasing emissions. Moreover, the same researchers concluded that a better seedbed preparation and selection of appropriate sowing methods can help reduce energy inputs, which can contribute to reducing greenhouse gas emissions. Further, they suggested that introducing appropriate machinery that can work in conservation tillage systems such as reduced tillage or no-tillage would help as measures to reduce input energy. Mousavi-Avval et al. (2017) reported that fertilizers, especially nitrogen, are the main energy consuming inputs and this is the main reason that increases greenhouse gas emissions. A study was managed to determine the greenhouse gas emissions of the simplified tillage practices by Saljnikov et al. (2014). They found that shallow tillage, which maintains higher levels of soil nutrients, reduces CO_2 emissions compared to intensive and deep tillage. Lal (2004) indicated that the reduction of nitrogen and the using of no-tillage methods may be advantageous to reduce global warming without reducing crop yield.

Table 7. CO_2 emissions from inputs used in canola production

Input	CO_2 emission (kg CO_2 equivalent ha^{-1})	Percentage (%)
Diesel fuel	627.62	32.66
Nitrogen (N)	240.11	12.49
Phosphorous (P_2O_5)	17.00	0.88
Herbicide	10.27	0.53
Machinery	1022.40	53.20
Seed		
Total emission	1921.66	100.00

4.Conclusions

Energy inputs and output were investigated for rainfed canola in Çanakkale province, northwest Turkey. While the average, lowest and highest energy inputs per hectare were 27678.84, 24812.72 and 28807.00 MJ ha^{-1}, respectively, the values for net energy were 72786.16, 45937.28 and 99958.00 MJ ha^{-1} with the same order. Diesel fuel energy consumption contributed the highest rate of 46.62%, 49.93% and 44.96% to the total, while labour had

the lowest of 0.20%, 0.21% and 0.24%, respectively. It was determined that the production of canola mainly depends on non-renewable (98.93%) and indirect (53.54%) energy, especially on fertilizer and diesel. Direct energy in average, lowest and highest input quantities were 46.46%, 50.14% and 45.20%; while indirect were 53.54%, 49.86% and 54.80%, respectively. Energy productivity ranged from 0.10 in lowest to 0.16 in highest kg MJ^{-1} while the energy per produced product ranged from 6.33 to 9.93 MJ kg^{-1} for the same ranges, respectively. Corresponding values for the energy use efficiency was from 2.85 to 4.47. In the study area, it should be tried to increase the production by shifting the energy use from non-renewable sources to renewable to reach a self-sufficient and sustainable production for canola. For example, it has been concluded that practices such as reduced tillage systems and effective fertilizer use will lead to significant improvements in energy efficiency.

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

In Silico Phylogeny, Sequence and Structure Analyses of Fungal Thermoacidophilic GH11 Xylanases

Fungal Termoasidofilik GH11 Ksilanazlarının *İn Siliko* Filojeni, Dizi ve Yapı Analizleri

Yusuf SÜRMELİ[1*]

Abstract

Thermoacidophilic xylanase enzymes are mostly preferred for use as animal feed additives. In this study, we performed *in silico* phylogeny, sequence, structure, and enzyme-docked complex analyses of six thermoacidophilic GH11 xylanases belonging to various fungal species (*Gymnopus androsaceus* xylanase = *Ga*Xyl, *Penicilliopsis zonata* xylanase = *Pz*Xyl, *Aspergillus neoniger* xylanase = *An*Xyl, *Calocera viscosa* xylanase = *Cv*Xyl, *Acidomyces richmondensis* xylanase = *Ar*Xyl, *Oidiodendron maius* xylanase = *Om*Xyl). To do this, amino acid sequences of six fungal thermoacidophilic GH11 xylanases, belonging to unreviewed protein entries in the UniProt/TrEMBL database, were investigated at molecular phylogeny and amino acid sequence levels. In addition, three-dimensional predicted enzyme models were built and then validated by using various bioinformatics programs computationally. The interactions between enzyme and the substrate were analyzed via docking program in the presence of two substrates (xylotetraose = X_4 and xylopentaose = X_5). According to molecular phylogeny analysis, three clusters of these enzymes occurred: the first group had *Pz*Xyl, *An*Xyl, and *Cv*Xyl, and the second group possessed *Ga*Xyl and *Om*Xyl, and the third group included *Ar*Xyl. Multiple sequence alignment analysis demonstrated that the five xylanases (*Ar*Xyl, *Om*Xyl, *Cv*Xyl, *Pz*Xyl, *An*Xyl) had longer N-terminal regions, indicating greater thermal stability, relative to the *Ga*Xyl. Homology modeling showed that all the predicted model structures were, to a great extent, conserved. Docking analysis results indicated that *Cv*Xyl, *Om*Xyl, and *An*Xyl had higher binding efficiency to two substrates, compared to the *Ga*Xyl, *Pz*Xyl, and *Ar*Xyl xylanases, and *Cv*Xyl-X_4 docked complex had the highest substrate affinity with a binding energy of -9.8 kCal/mol. *Cv*Xyl, *Om*Xyl, and *An*Xyl enzymes commonly had arginine in B8 β-strand interacted with two substrates, different from the other enzymes having lower binding efficiency. As a result, it was concluded that the three thermoacidophilic xylanase enzymes might be better candidates as the animal feed additive.

Keywords: Thermoacidophilic xylanase, Molecular docking, GH11 xylanase, Animal feed additive, UniProt/TrEMBL database

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Öz

Termoasidofilik ksilanaz enzimleri, çoğunlukla hayvan yemi katkı maddesi olarak tercih edilmektedir. Bu çalışmada, çeşitli mantar türlerine ait altı termoasidofilik GH11 ksilanazın (*Gymnopus androsaceus* ksilanazı = *Ga*Xyl, *Penicilliopsis zonata* ksilanazı = *Pz*Xyl, *Aspergillus neoniger* ksilanazı = *An*Xyl, *Calocera viscosa* ksilanazı = *Cv*Xyl, *Acidomyces richmondensis* ksilanazı = *Ar*Xyl, *Oidiodendron maius* ksilanazı = *Om*Xyl) *in siliko* filojeni, dizi, yapı ve enzim-docking kompleks analizleri gerçekleştirilmiştir. Bunu yapmak için, UniProt/TrEMBL veri tabanındaki gözden geçirilmemiş protein girdilerine ait altı mantar termoasidofilik GH11 ksilanazının amino asit dizileri moleküler filojeni ve dizi açısından araştırıldı. Ayrıca, üç boyutlu tahmini enzim modelleri oluşturuldu ve daha sonra çeşitli biyoinformatik programları kullanılarak hesaplamalı olarak doğrulandı. Enzim ve substrat arasındaki etkileşimler, iki substratın (ksilotetraoz = X_4 ve ksilopentaoz = X_5) varlığında docking programı aracılığıyla analiz edildi. Moleküler filojeni analizine göre, bu enzimlerin üç kümesi oluştu: birinci grup *Pz*Xyl, *An*Xyl ve *Cv*Xyl'e sahipti ve ikinci grup *Ga*Xyl ve *Om*Xyl'e sahipti ve üçüncü grup *Ar*Xyl'i içeriyordu. Çoklu dizi hizalama analizi, beş ksilanazın (*Ar*Xyl, *Om*Xyl, *Cv*Xyl, *Pz*Xyl, *An*Xyl) daha uzun N-terminal bölgelerine sahip olduğunu gösterdi, bu da *Ga*Xyl'e göre daha yüksek termal stabiliteye sahip olduklarını işaret etmiştir. Homoloji modelleme, tahmin edilen tüm model yapılarının büyük ölçüde korunduğunu gösterdi. Docking analizi sonuçları, *Cv*Xyl, *Om*Xyl ve *An*Xyl'in *Ga*Xyl, *Pz*Xyl ve *Ar*Xyl ksilanazlara kıyasla iki substrata daha yüksek bağlanma verimliliğine sahip olduğunu ve *Cv*Xyl-X_4 docking kompleksinin -9.8 kCal/mol'lük bir bağlanma enerjisiyle en yüksek substrat afinitesine sahip olduğunu gösterdi. *Cv*Xyl, *Om*Xyl ve *An*Xyl enzimleri, daha düşük bağlanma verimliliğine sahip diğer enzimlerden farklı olarak, yaygın olarak B8 β-kolunda iki substrat ile etkileşime giren arjinin içeriyordu. Sonuç olarak, bu üç termoasidofilik ksilanaz enziminin hayvan yemi katkı maddesi olarak daha iyi adaylar olabileceği sonucuna varılmıştır.

Anahtar Kelimeler: Termoasidofilik ksilanaz, Moleküler docking, GH11 ksilanaz, Hayvan yem katkısı, UniProt/TrEMBL veritabanı

1. Introduction

Endo-1,4-β-D-xylanases (E.C. 3.2.1.8) cleave the β-1,4-glycosidic bonds in the main chain of the xylan, which is a part of hemicellulose, the biggest portion of lignocellulosic material after cellulose (Nordberg Karlsson et al., 2018; Sánchez and Cardona, 2008; Wood et al., 1989). The xylanase enzymes are classified within seventeen glycoside hydrolase (GH) families (mainly GH10 and GH11), as indicated in the Carbohydrate Active Enzymes (CAZy) database (Drula et al., 2022) (http://www.cazy.org/) based on the resemblance of the structure of the active region and their sequences.

The xylanase enzyme market, annually estimated at 500 million US Dollars, has been growing for approximately 30 years (Bajpai, 1999; Kumar et al., 2017). In recent times, the xylanase enzymes are of big interest in many biotechnological areas including animal feed, biofuel, food, and pulp and paper industries (Beg et al., 2001; Chadha et al., 2019; Subramaniyan and Prema, 2002). GH11 xylanase enzymes are considered more favorable for many industrial processes (e.g. an improvement of animal feed digestibility) because they generally possess a bigger catalytic region, higher catalytic action, greater substrate specificity, and relatively small size facilitating the penetration into the fiber (Biely et al., 2016; Paës et al., 2012).

In fact, an addition of exogen enzyme (e.g. xylanase) into the animal feeds and the silage is one of the main strategy to increase the animal feed digestibility (Koçyiğit and Tüzemen, 2012; Park and Carey, 2019; Alagawany et al., 2018; Başkavak et al., 2008). The xylanase enzymes are expected to conserve most of the activity and stability in extreme conditions and therefore, xylanolytic extremozymes with great extreme stability and thermostability are favorable for the biotechnological fields including animal feed industry (Algan et al., 2021; Basu et al., 2018; Collins et al., 2005). Thermoacidophilic GH11 xylanase enzymes are helpful for a variety of industrial processes including an increase of animal feed digestibility, which is required for high temperature and acidic pH conditions, because of heat processes and passing in low pH areas of the digestive system (Ravindran, 2013; Smeets et al., 2014). However, most of the xylanolytic enzymes are not active under these extreme conditions (Boonyapakron et al., 2017; Collins et al., 2005; Xia and Wang, 2009). Comprehensive investigations of thermoacidophilic GH11 xylanase enzymes are in progress.

Microorganisms, particularly bacteria and fungi, are the most important sources of industrial xylanase enzymes (Beg et al., 2001; Motta et al., 2013). Fungi, rather than bacteria, mostly produce the industrial xylanase with thermoacidophilic aspect because they optimally work at acidic pH conditions (Chakdar et al., 2016). For example, a recent work has shown that thermoacidophilic xylanase enzyme of *Aspergillus tubingensis* possessed an optimum pH and temperature of 5.0 and 50^{o}C, respectively (Intasit et al., 2022). In another study, Galanopoulou et al. (2021) have characterized thermophilic, acid-stable xylanase from *Byssochlamys spectabilis*, optimally working at 65^{o}C and pH 3.5 (Galanopoulou et al., 2021).

As omics technologies have evolved, large volumes of fungal-derived whole genome sequences have quickly increased. In UniProt/TrEMBL database, these data-derived gene sequences are annotated as unreviewed sequences (The UniProt Consortium, 2021). In a recent study, it has been shown that 1302 unreviewed amino acid sequences of bacterial GH11 xylanase enzymes were available in UniProt/TrEMBL database (Sürmeli, 2022). Therefore, a broad range of sequences of unreviewed fungal thermoacidophilic GH11 xylanase enzyme may be acquired from UniProt/TrEMBL database. In this work, the investigation of the six fungal thermoacidophilic GH11 xylanases was carried out to determine their phylogenetical relatedness, amino acid sequence resemblance, the comparative aspects of their three-dimensional predicted structures, and the interactions with the substrates. For this purpose, the *in silico* analysis of the evolutionary relationship, multiple sequence alignment, the predicted homology model structures, and protein docking of the six fungal thermoacidophilic GH11 xylanase enzymes was carried out by utilizing the unreviewed and full-length amino acid sequences of these enzymes from the UniProt/TrEMBL database. The results acquired from the *in silico* analyses were confirmed and discussed with data of other experimental researches in literature.

2. Materials and Methods

2.1. Amino acid sequences of xylanases: the retrieval and selection

The sequences of unreviewed fungal GH11 xylanase enzymes were obtained from the UniProt/TrEMBL database (The UniProt Consortium, 2021). The sequences with the thermoacidophilic character were selected according to high melting temperature (T_m) by T_m predictor program (Ku et al., 2009) and low isoelectric point (pI) by the ProtPram tool

(Gasteiger et al., 2005). The other biophysicochemical features (positively charged residues = PCR), threonine:serine ratio = T/S, and negatively charged residues = NCR), of the enzymes were detected via the ProtPram tool (Gasteiger et al., 2005). Among these enzymes, six fungal GH11 xylanases with the lowest pI were potentially accepted as thermoacidophilic enzymes, and they were used for the next analyses.

2.2. Molecular phylogeny and sequence analyses

The six fungal thermoacidophilic GH11 xylanases were analyzed at their molecular phylogeny and sequence levels. For doing this, phylogeny investigation was fulfilled using the maximum likelihood (ML) statistical technique having 500 bootstrap replications, and Jones-Taylor-Thornton (JTT) substitution model by MEGA11 software (Tamura et al., 2021). In addition, multiple sequence alignment was performed for comparison of their the xylanase sequences via Clustal Omega program (Madeira et al., 2019).

2.3. Homology modeling

The three-dimensional predicted model structures of fungal thermoacidophilic xylanases was carried out by ProMod3 software in SWISS-MODEL server (Mirdita et al., 2017; Steinegger et al., 2019; Studer et al., 2020; Studer et al., 2021). The validation of the six predicted models was performed by RaptorX (Wang et al., 2016). The models were evaluated at the overall and local quality levels and their Z-scores were determined via the ProSA server (Wiederstein and Sippl, 2007). Stereochemical qualities and dihedral angles of the 3D models were analyzed by ProCheck forming the Ramachandran plot (Laskowski et al., 1996). Also, Verify3D was used to predict the good match between the 3D models and their amino acid sequences compared with the known structures (Bowie et al., 1991). The Stride was applied to predict the secondary structures of the 3D models (Heinig and Frishman, 2004).

2.4. Molecular docking

The docking analysis of the six fungal thermoacidophilic xylanase enzymes was carried out to investigate the enzyme-substrate interactions on two different substrates (xylotetraose=X_4, and xylopentaose=X_5) by Autodock Vina (version 1.5.6) that uses the Lamarckian Genetic Algorithm (LGA) (Trott and Olson, 2010). To do this, the spatial data files (SDFs) belonging to the ligands were obtained using the PubChem database, and protein data bank (PDB) files were formed by PyMOL Molecular Graphics System (Version 2.0) (Schrödinger, LLC). Then, the substrate preparations for molecular docking were performed using Autodock Vina. The predicted model structures were also prepared for molecular docking by deleting the water molecules, adding the polar hydrogens, and selecting the Kollman atom charges. The grid values were fixed 90 × 90 × 90 by a grid spacing of 0.375, and the other parameters were adjusted as default. Thus, nine poses were obtained for each enzyme-substrate docked complex. The pose of each docked complex with the highest binding affinity was used for the analysis of the protein-ligand interaction.

2.5. Data representation

The figures were represented using GraphPad Prism (version 6.00) for Windows (GraphPad Software, La Jolla, CA, USA) (www.graphpad.com), MEGA11 software, and PyMOL Molecular Graphics System (Version 2.0) (Schrödinger, LLC).

3. Results and Discussion

In the present work, *in silico* analysis of the six fungal thermoacidophilic GH11 xylanase enzymes was comparatively carried out to determine their evolutionary relationships, the similarities between their amino acid sequences, three-dimensional structure resemblance, and the interaction between the enzymes and ligands. To do this, the six amino acid sequences of the GH11 thermoacidophilic xylanase from various fungal species were chosen among 2584 UniProt/TrEMBL unreviewed entries, according to the high melting temperature T_m (above 65°C), and low theoretical pI values. These six enzymes were *Gymnopus androsaceus* xylanases (*Ga*Xyl) (Barbi et al., 2020), *Penicilliopsis zonata* xylanase (*Pz*Xyl) (de Vries et al., 2017), *Aspergillus neoniger* xylanase (*An*Xyl) (The UniProt Consortium, 2021), *Calocera viscosa* xylanase (*Cv*Xyl) (Nagy et al., 2016), *Acidomyces richmondensis* (*Ar*Xyl) (Mosier et al., 2016), and *Oidiodendron maius* (*Om*Xyl) (The UniProt Consortium, 2021).

3.1. The determination of biophysicochemical properties of the enzymes

Biophysicochemical properties, such as theoretical pI value, a ratio of negatively charged residues to positively charged residues (NCR/PCR), and threonine:serine ratio (T/S), of the amino acid sequences of six enzymes were investigated by ProtParam tool (Gasteiger et al., 2005) as summarized in *Table 1*. The results indicated that the

theoretical pI values, a ratio of NCR/PCR and T/S of the xylanases were in a range of 3.64-4.16, 2.44-10.5 and 0.85-1.95, respectively (*Table 1*).

Table 1. Some biophysicochemical properties of the thermoacidophilic xylanases

Protein ID	Protein name	Fungal source	Enzyme length (aa)	Molecular weight (kDa)	Theoretical pI	NCR/ PCR*	T/S
A0A6A4H8W9	*Ga*Xyl	*Gymnopus androsaceus*	185	19.62	3.64	10.5	0.94
A0A1L9SJU9	*Pz*Xyl	*Penicilliopsis zonata*	213	23.56	3.86	4.57	0.85
A0A318YH97	*An*Xyl	*Aspergillus neoniger*	231	24.84	3.92	3.4	1
A0A167IM53	*Cv*Xyl	*Calocera viscosa*	225	23.95	4.13	2.62	1.95
A0A150VDR5	*Ar*Xyl	*Acidomyces richmondensis*	215	23.23	4.13	2.62	1.33
A0A0C3CZX7	*Om*Xyl	*Oidiodendron maius*	226	24.05	4.16	2.44	1.08

* NCR/PCR refers to a ratio of negatively charged residues to positively charged residues.

NCR/PCR and T/S, which are two biophysicochemical properties, might be clues for thermoacidophilic feature of the GH11 xylanases. Accordingly, the acidophilic property is characterized by a high number of acidic residues (glutamate and aspartate) on the enzyme surface and less number of PCR, which causes a high ratio of NCR/PCR (Fushinobu et al., 1998). For instance, the xylanase from *Neocallimastix patriciarum*, which works in an optimum pH of 5.8 (Pai et al., 2010), has an NCR/PCR ratio of 1.17 (*Figure S1*), whereas *Aspergillus niger* xylanase B, which possesses a 5.0 of optimum pH (Deng et al., 2006), has relatively a higher NCR/PCR ratio of 1.45 (*Figure S1*). Furthermore, a greater T/S ratio is an indicator of the thermostability of GH11 xylanase enzymes (Hakulinen et al., 2003). For instance, *Phanerochaete chrysosporium* xylanase (Decelle et al., 2004) and *Penicillium oxalicum* xylanase (Liao et al., 2012) optimally working at 60ºC and 50ºC had a T/S ratio of 0.85 and 0.52, respectively (*Figure S1*). Taken together, the present work proposed that the six GH11 xylanase enzymes might highly be thermoacidophiles.

3.2. The phylogenetic relationship and a comparison of the xylanase amino acid sequences

The molecular phylogeny of the six GH11 thermoacidophilic xylanases was analyzed with an output group, *Arabidopsis thaliana* beta-amylase amino acid sequence (Lao et al., 1999) by ML statistical technique in MEGA11 software. The results indicated that the enzymes can be evaluated as three different groups according to their closeness to the amino acid sequences: the first group included *Pz*Xyl, *An*Xyl, and *Cv*Xyl, the second group had *Ga*Xyl and *Om*Xyl, and the third group had only one member *Ar*Xyl, distant from the former two groups (*Figure 1*).

The multiple sequence alignment analysis results showed that each GH11 xylanase possessed various lengths of the N-terminal regions (NTRs). The five thermoacidophilic GH11 xylanase enzymes (*Ar*Xyl, *Om*Xyl, *Cv*Xyl, *Pz*Xyl, *An*Xyl) had a similar NTR size to each other and were clearly longer than *Ga*Xyl and Tx-xyl having similar NTR length (*Figure 2*). Tx-xyl, optimally working at 75ºC and having a low molecular weight (20.6 kDa), was highly thermostable exhibiting a great T_m above 12 h at 60ºC (Debeire-Gosselin et al., 1992; Harris et al., 1994). In fact, the size of NTRs positively affects the thermostability of the GH11 xylanase enzymes (Han et al., 2017). Accordingly, GH11 xylanase enzymes of *Neocallimastix patriciarum and Nonomuraea flexuosa* possess large NTRs and high thermostability (Cheng et al., 2014; Hakulinen et al., 2003; Han et al., 2017). Amino acid replacements enhance the thermostability of these enzymes generally located at the NTRs (Turunen et al., 2001; Xiong et al., 2004). Recent work has shown that engineered N-terminal sequence resulted in an increase in thermal

stability of GH11 xylanase from *Talaromyces leycettanus* (Wang et al., 2017). The present work indicated that the five enzymes might have greater thermostability, relative to the *Ga*Xyl and Tx-xyl, which might possess a similar thermostability.

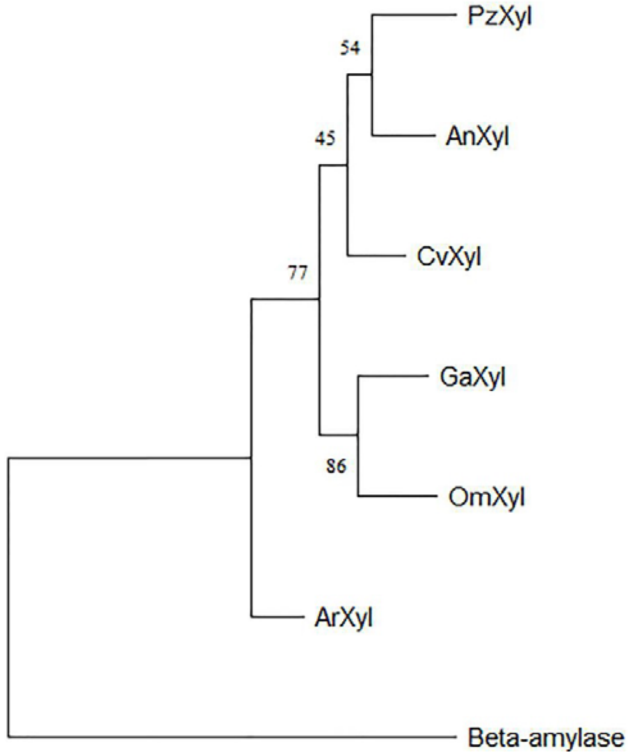

Figure 1. The evolutionary relationship of the six thermoacidophilic fungal xylanase enzymes. Arabidopsis thaliana beta-amylase was used as output group.

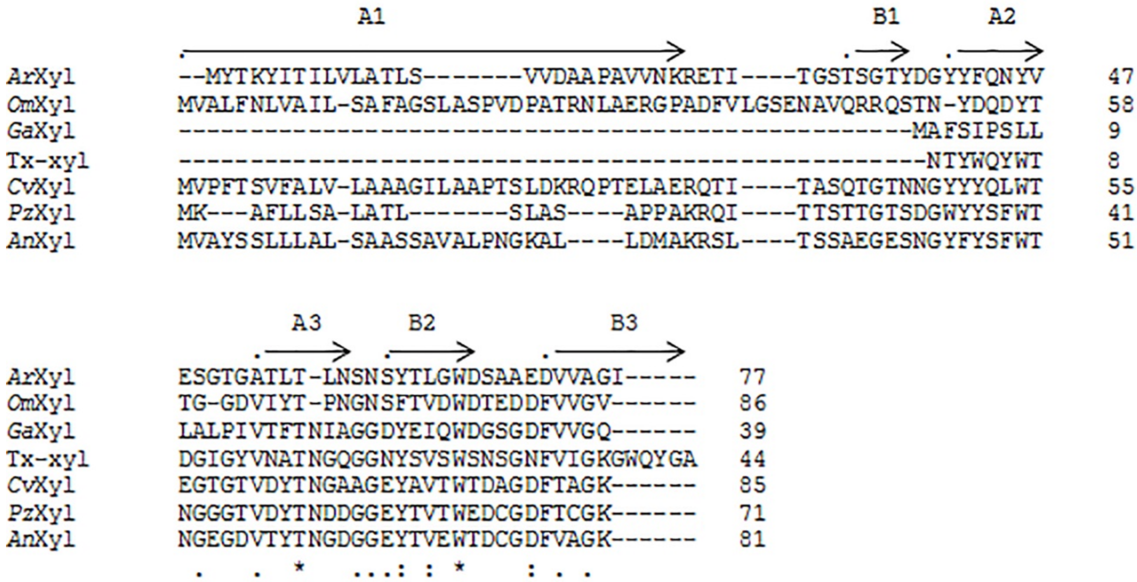

Figure 2. The sequence alignment of the N-terminal sites of the six thermoacidophilic fungal xylanases, relative to the Tx-xyl.

Paës et al. (2012) have shown that 17 residues from the GH11 xylanase active site are highly similar as a result of the structural investigation of the superimposed xylanase enzyme of *Thermobacillus xylanilyticus* (Tx-xyl). This work has also indicated that triple residues (P114-S115-I116) settled in the thumb site of the GH11 xylanase enzymes had a similarity of above 90% frequency, and I116 is occasionally substituted by valine or leucine. In addition, P88 from the active site is available in 80% of the enzyme amino acid sequences (Paës et al., 2012). The present work showed that the 11 amino acids in the thermoacidophilic enzymes such as catalytic residues

(acid/base and nucleophile residues), and serine-isoleucine of the triple residues were highly conserved in reference to Tx-xyl (*Figure 3*).

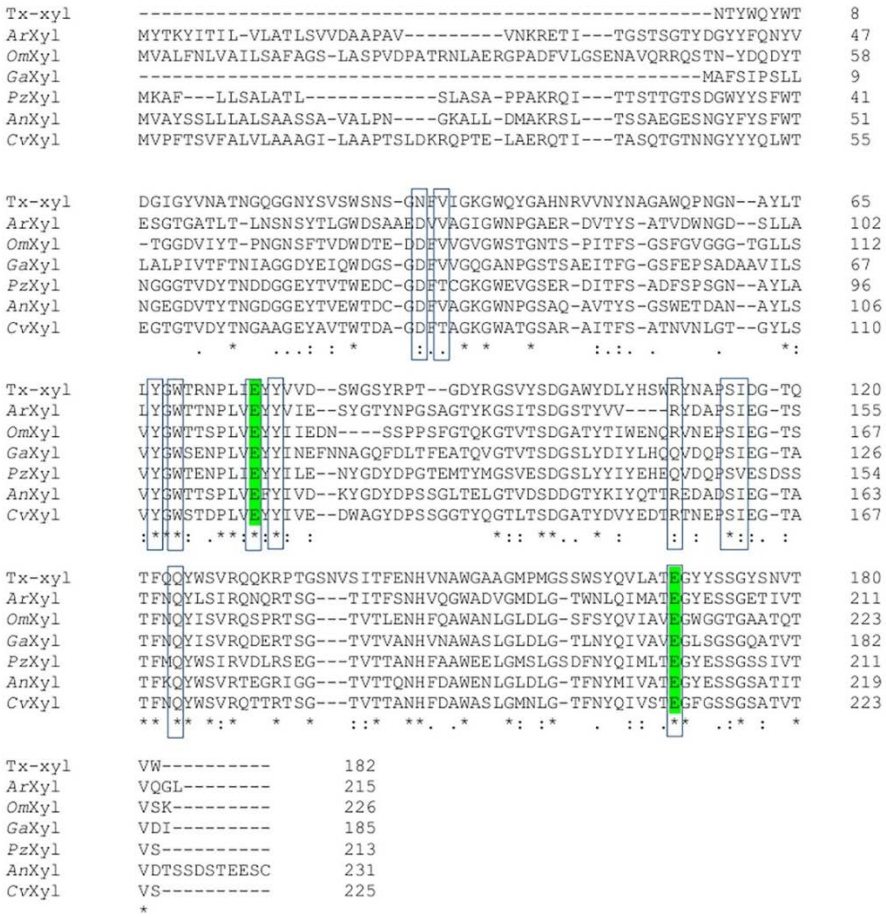

Figure 3. The sequence alignment of the six thermoacidophilic enzymes, compared to the Tx-xyl. The highlighted amino acids show the conserved residues including catalytic amino acids with green highlighted amino acids.

3.3. The predicted structures of thermoacidophilic xylanases

The predicted model structures of the six thermoacidophilic xylanases were determined via the SWISS-MODEL homology modeling server according to their sequences, and the validation of the structures was performed by

Table 2. The modeling scores of three-dimensional predicted structures of the six thermoacidophilic enzymes and their template selections

No	Protein ID	Protein name	Template	Sequence identity (%)	Coverage (%)	GMQE	QMEAN	QMEAN Disco	Sequence similarity (%)
1	A0A6A4H8W9	*Ga*Xyl	6JWB	56.55	91	0.84	0.59	0.83 ± 0.07	46
2	A0A1L9SJU9	*Pz*Xyl	3WP3	62.83	90	0.84	0.01	0.87 ± 0.06	51
3	A0A318YH97	*An*Xyl	3WP3	69.63	83	0.81	1.09	0.87 ± 0.06	53
4	A0A167IM53	*Cv*Xyl	3WP3	62.24	87	0.81	-0.52	0.86 ± 0.06	50
5	A0A150VDR5	*Ar*Xyl	7EO6	51.35	86	0.77	-1.05	0.76 ± 0.06	46
6	A0A0C3CZX7	*Om*Xyl	1XYN	71.75	78	0.78	0.36	0.91 ± 0.07	54

RaptorX. The template selection was carried out based on sequence identity, sequence similarity, the global model quality estimate (GMQE) value, and coverage.

The best template of the *Ga*Xyl was determined as 6JWB, chain 1A from *Trichoderma reesei* (Li et al., 2020) possessing a sequence identity of 56.55% and a coverage of 91%. In addition, the most convenient template of *Ar*Xyl was 7EO6, chain 1A of *Actinomycetia* bacterium (Yi et al., 2021) with 86% of coverage and 51.35% of sequence identity. As for *Om*Xyl, the best template was selected as 1XYN chain 1A of *Trichoderma reesei* (Törrönen and Rouvinen, 1995), having 71.75% and 78% of sequence identity and coverage, respectively. For the remaining three enzymes (*Pz*Xyl, *An*Xyl, *Cv*Xyl), the common template was selected as 3WP3, chain 1A of *Talaromyces cellulolyticus* (Kataoka et al., 2014) with a range of 62-69% and 83-90%, of sequence identity and coverage, respectively. Three quality parameters (GMQE, QMEAN, and QMEANDisCo values) showed that the predicted models had a high quality (*Table 2*).

The predicted models (*Figure S2*) built via SWISS-MODEL were validated by various bioinformatics tools. Regarding this, the secondary structures belonging to the predicted models were monitored in *Figure S3*. The 3D structure alignment indicated that each predicted model structure and its template had great compatibility and similarity in terms of overall and local structural patterns (*Figure S4*). Ramachandran plot analysis results indicated that most of the amino acids in the enzymes, with a range of 83.6%-91.9%, were found in the most favored regions. The enzymes *Ga*Xyl, *An*Xyl, *Ar*Xyl, and *Om*Xyl did not possess a Ramachandran outlier, but *Pz*Xyl and *Cv*Xyl had two outlier residues (*Figure S5*). As for the qualitative model energy analysis (QMEAN) scores, major geometrical features of the predicted models indicated that they had a high resemblance to the native structures giving the scores in the range of -1.05 to 1.09, around zero (*Figure S6*). Consideration of the predicted structures with three-dimensional profiles was performed by Verify 3D and the averaged 3D-1D score ≥ 0.2 was found as about 100% of the amino acids in structures of *An*Xyl, *Cv*Xyl, *Ar*Xyl, and *Om*Xyl. This score encompassed 97.09% and 90.1% of the residues for the structures of *Ga*Xyl and *Pz*Xyl, respectively (*Figure S7*). Also, the global quality of the predicted enzyme structures was considered by Z-scores obtained from the ProSA server. This analysis showed that all models except *Ar*Xyl (having -5.33) had an estimated Z score of above -6.0 (ranging from -6.01 to -6.91). These scores were intervals of the negative energy cut-off, validating the high quality of the predicted enzyme structures (*Figure S8*). The Z scores are estimated by a comparison of the Z-scores of the other existing structures of similar size, acquired using experimental techniques (e.g. X-ray and/or NMR).

The GH11 xylanase enzymes are structurally consisted of a β-jelly roll domain, which resembles a partially closed right hand. They have an α-helix and two-bent antiparallel β-sheets turning to each other and including 14 β-strands. One β-sheet constitutes five β-strands A2-A6, whereas another possesses nine β-strands B1-B9. Many (above 60%) of the residues are placed in two β-sheets and the α-helix (Paës et al., 2012; Törrönen et al., 1994). Also, the active cleft includes two grooves architectured with two β-sheets (Collins et al., 2005). The present work indicated that these structural characters were common in the six predicted model structures. Regarding this, *Pz*Xyl, *An*Xyl, *Cv*Xyl, and *Ar*Xyl possessed a full set of β-strands having an A4/B4-extended β-strand. Among these, *An*Xyl and *Ar*Xyl possessed one long A5 strand, whereas *Pz*Xyl and *Cv*Xyl had two small portions of this strand. On the other hand, *Ga*Xyl did not have A2 and B1 strands, whereas *Om*Xyl included no B1 strand (*Figure 4*).

3.4. The interactions between enzymes and the substrates

The docking analysis of the thermoacidophilic enzymes was carried out using xylotetraose (X_4) and xylopentaose (X_5) as the substrates and assessed the pose having the highest substrate affinity. The results indicated that *Cv*Xyl-X_4 docked complex possessed the highest substrate affinity with a binding energy of -9.8 kCal/mol, whereas X_4-docked complexes of *Ga*Xyl, *Pz*Xyl, and *Ar*Xyl had binding energy of -7.4 to -7.5 kCal/mol, having the lowest binding efficiency. In addition, *Cv*Xyl-X_5 docked complex had a binding energy of -8.9 kCal/mol with the greatest binding efficiency, whereas the smallest substrate efficiency belonged to *Ar*Xyl and *Ga*Xyl-X5 docked complexes by a binding energy of -7.1 kCal/mol (*Table 3*).

The results of the analysis of protein-ligand interaction were shown in *Figure 5*. According to the results, the five common residues (T82 in B3-strand, Y206 in B4-strand, Y108 and Y112 in B5-strand, R157 in B8-strand) were involved in X_4 and X_5 substrate interactions in *Cv*Xyl. Similarly, corresponding residues in *Om*Xyl (Y206 in B4-strand, Y114 in B5-strand, and R157 in B8-strand), involved in the stabilization of *Cv*Xyl-docked complexes, could also form polar interactions with two substrates. In *An*Xyl, four residues (E208 in B4-strand, Y104 in B5-strand, T151 and R153 in B8-strand) might act on the stabilization of the *An*Xyl-docked complexes.

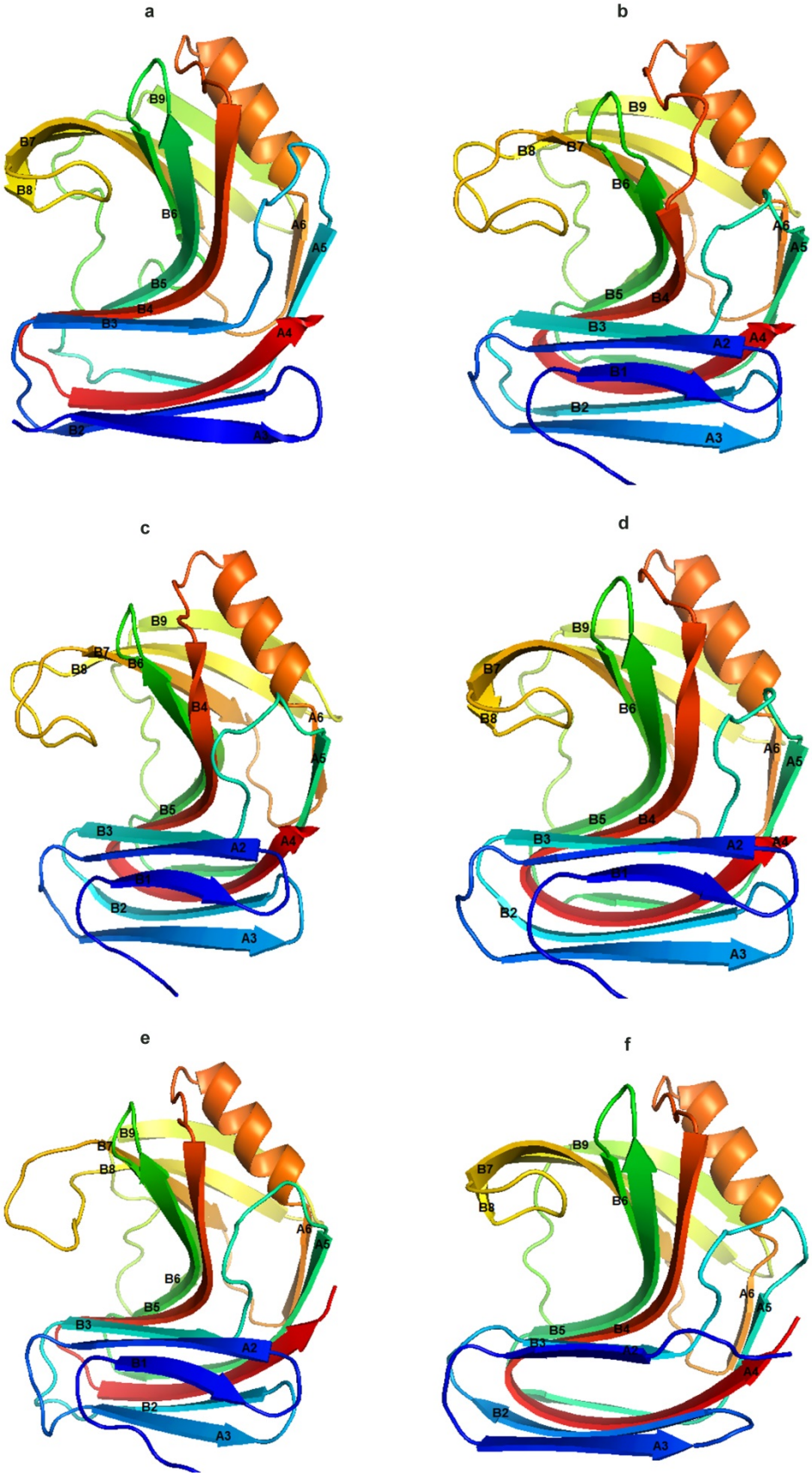

Figure 4. The predicted three-dimensional model structures of the fungal thermoacidophilic GH11 xylanases. a) GaXyl, b) PzXyl, c) AnXyl, d) CvXyl, e) ArXyl, f) OmXyl.

Among substrate-binding site residues, three residues (T82, Y112, R157) in *Cv*Xyl, two residues (Y114 and R157) in *Om*Xyl, and two residues (E208 and R153) in *An*Xyl (*Figure 3*) were commonly conserved in the active site of the GH11 xylanases (Paës et al., 2012). These three xylanases had the highest binding efficiency with the substrates (*Table 3*). On the other hand, *Ar*Xyl-docked complexes commonly had interactions between three residues (Y115 in B6-strand, Q159 in B7-strand, I151 in loop between B7-strand and B8-strand) and the substrates. Besides this, three residues in *Ga*Xyl (Q116 in B8-strand, Q130 in B7-strand, Y165 in B4-strand) interacted with two substrates. Also, *Pz*Xyl-docked complexes included polar contacts between three residues (T121 in the loop between B6-strand and B9-strand, Y98 in B5-strand, E200 in B4-strand) and the substrates. Among substrate-binding site residues, three residues (Y115, Q159, and I151) in *Ar*Xyl, two residues (Q116 and Q130) in *Ga*Xyl, and two residues (Y98 and E200) in *Pz*Xyl (*Figure 3*) were commonly conserved in the active site of GH11 xylanase enzymes (Paës et al., 2012). These enzymes (*Ar*Xyl, *Ga*Xyl, and *Pz*Xyl) had relatively lower binding efficiency, compared to the *Cv*Xyl, *Om*Xyl, and *An*Xyl (*Table 3*). Arginine residue in B8-strand was conserved in *Cv*Xyl, *Om*Xyl, and *An*Xyl enzymes. A recent study indicated that this residue in the thermoalkaliphilic GH11 xylanases commonly interacted with the X_2-X_5 substrates by a higher binding efficiency (Sürmeli, 2022). Also, the replacement of the arginine with asparagine or lysine leads to the activity reduction in *Bacillus circulans* xylanase (Wakarchuk et al., 1994). In addition, arginine was placed in GH11 xylanases at a great prevalence of 88% (Paës et al., 2012). Thus, this study suggests that this conserved arginine residue in B8-strand may play a crucial role in the catalytic action.

Table 3. The docking analysis scores of the poses with the smallest free energy.

No	UniProt ID	Protein name	X_4 affinity (kcal/mol)	X_5 affinity (kcal/mol)
1	A0A6A4H8W9	*Ga*Xyl	-7.4	-7.1
2	A0A1L9SJU9	*Pz*Xyl	-7.4	-8.1
3	A0A318YH97	*An*Xyl	-8.0	-8.4
4	A0A167IM53	*Cv*Xyl	-9.8	-8.9
5	A0A150VDR5	*Ar*Xyl	-7.5	-7.1
6	A0A0C3CZX7	*Om*Xyl	-9.0	-8.6

4. Conclusions

The present work had *in silico* analyses of six bacterial thermoacidophilic GH11 xylanases (*Ga*Xyl, *Pz*Xyl, *An*Xyl, *Cv*Xyl, *Ar*Xyl, and *Om*Xyl) to consider their phylogenetic closeness, amino acid sequence resemblance, three-dimensional predicted model structures, and the interactions with the substrates. According to the results, the six GH11 xylanase enzymes might highly have thermoacidophile aspect since they had a high ratio of T/S and NCR/PCR. Also, phylogenetic analysis indicated that the xylanases were clustered into three different parties as first group (*Pz*Xyl, *An*Xyl, and *Cv*Xyl), the second group (*Ga*Xyl and *Om*Xyl), and the third group (*Ar*Xyl). The amino acid alignment results demonstrated that 11 amino acids in the active region of GH11 xylanase enzymes were conserved in the six thermoacidophilic xylanases using *Thermobacillus xylanilyticus* xylanase (Tx-xyl) as a superimposed reference enzyme. The alignment analysis also showed that the five xylanases (*Ar*Xyl, *Om*Xyl, *Cv*Xyl, *Pz*Xyl, *An*Xyl) had greater NTR size, compared to the *Ga*Xyl and Tx-xyl, indicating that they might have higher thermostability. Homology model analysis results indicated that the six enzymes highly possessed similar structural patterns composed of the β-jelly roll domain, which resembles a partially closed right hand. The docking analysis showed that *Cv*Xyl, *Om*Xyl, and *An*Xyl possessed greater binding efficiency with two substrates (X_4, and X_5), relative to the *Ga*Xyl, *Pz*Xyl, and *Ar*Xyl enzymes. The former three enzymes had the conserved arginine residue in the B8 β-strand involved in the substrate interaction, indicating that it may play a crucial role in their catalytic action. Thus, this study proposed that three thermoacidophilic xylanases (*Cv*Xyl, *Om*Xyl, and *An*Xyl) may be more favorable as the animal feed additive.

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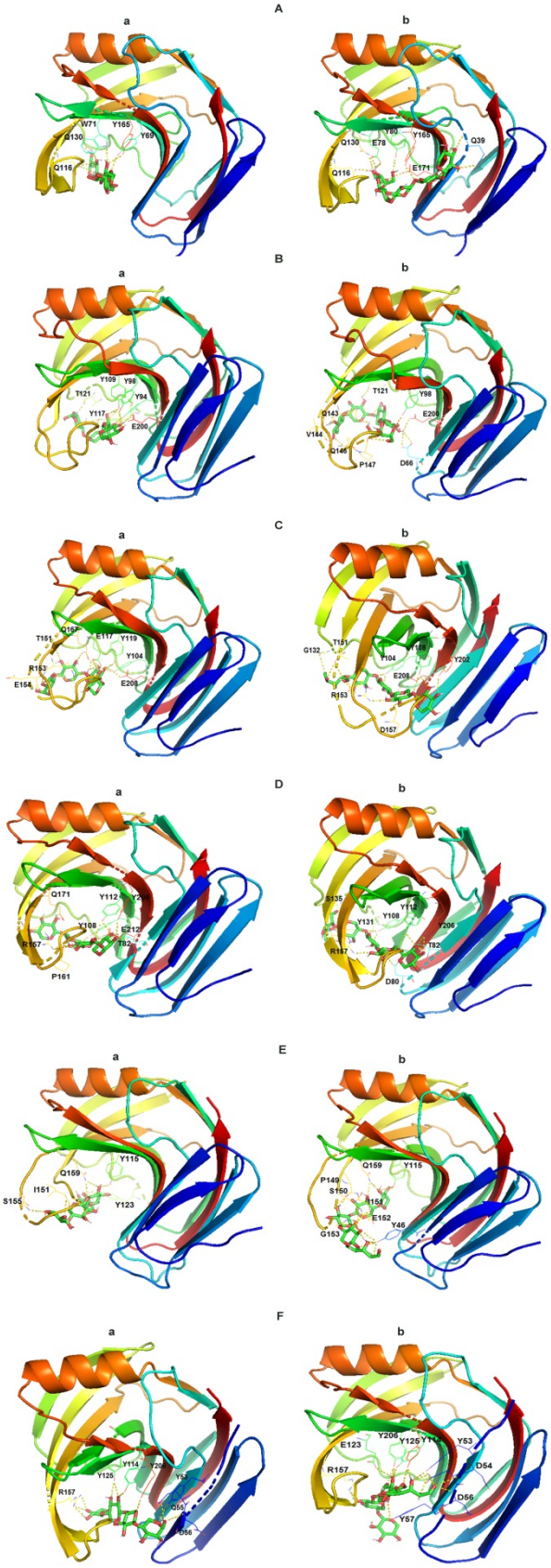

Figure 5. The interactions between each thermoacidophilic xylanase and the substrates. A) GaXyl, B) PzXyl, C) AnXyl, D) CvXyl, E) ArXyl, F) OmXyl. Left indicates enzyme-docked xylotetraose complexes, and the right indicates enzyme-docked xylopentaose complexes.

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Supplementary Material

> *Neocallimastix patriciarum* xylanase (UniProt ID: B8YG19)
MRLGVALSTIAVLLTATSARNLDKRQWGWPNFGGGNGGNGGNGGKTINDYKREQGAGRDIHVYAPSNLAPNSPLL
LSLHGMDQDPNYQQSNTHWETLADSEGFVVVYPRGGTGMSTWDIQGTKDTQWVSQIIDQMKKEYNIDTKRVYLSG
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NNAKHSGESVTVTSNKVGDINGIGYELWADSGNNSATFYDDGSFSCSFQRAKDYLCRSGLSFDSTKTHKQIGHIY
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GDTNFKQYFSIRQQPRDCGTIDITAHFEQWEKLGMTMGKMHEAKVLGEAGSNNGGTSGTADFPFAKVYVKN

> *Aspergillus niger* xylanase B(UniProt ID: P55330)
MLTKNLLLCFAAAKAALAVPHDSVAQRSDALHMLSERSTPSSTGENNGFYYSFWTDGGGDVTYTNGDAGAYTVEW
SNVGNFVGGKGWNPGSAQDITYSGTFTPSGNGYLSVYGWTTDPLIEYYIVESYGDYNPGSGGTYKGTVTSDGSVY
DIYTATRTNAASIQGTATFTQYWSVRQNKRVGGTVTTSNHFNAWAKLGMNLGTHNYQIVATEGYQSSGSSSITVQ

> *Penicillium oxalicum* xylanase B (UniProt ID: E7EF85)
MISLSSVAIALTTVVGALALPSDQSVNLAARQAITSSQTGTNNGYYYSFWTNGAGSVSYSNGAAGQFSVNWANQG
GGDFTCGKGWNPGKAQDISFSGTFTPNGNAYLSIYGWTTGPLVEYYILENFGSYNPGNGMTHVGTLTSDGSDYDI
YKHTQVNQPSIVGTSTFDQYWSIRKNKRSSGTVTTANHFSAWASHGMNLGSHNYQILSVEGYQSSGSASMTVSAG
SSSSGGSGSGSGSGSGSGSGSGSQTTTAGSSTGTGTGSGSGSGSGGSGGNCAAQWGQCGGQGWNGPTCCSSGTCK
ASNQWYSQCL

> *Phanerodontia chrysosporium* xylanase B(UniProt ID: B7SIW1)
MVSFNSLLVAVSAATCALAFPFEFHNGTHVFPRQSTPAGTGTNNGYFYSFWTDGGGSVTYNNGPAGEYSVTWSNA
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EGTRVNEPSIQGTATFNQYWSIRSSKRSSGTVTTANHFAAWKQLGLPLGTFNYQIVATEGYQSSGSSTVTVNPAG
GVTSPIAPTGPSSVSTTPSGPSSSPSPVGTCSALYGQCGGQGWTGPTCCSSGTCKFSNNWYSQCL

Figure S1. Amino acid sequences of four biochemically characterized GH11 xylanase enzymes. These enzymes were compared with the six fungal thermoacidophilic GH11 xylanases in this study for NCR/PCR and T/S ratios.

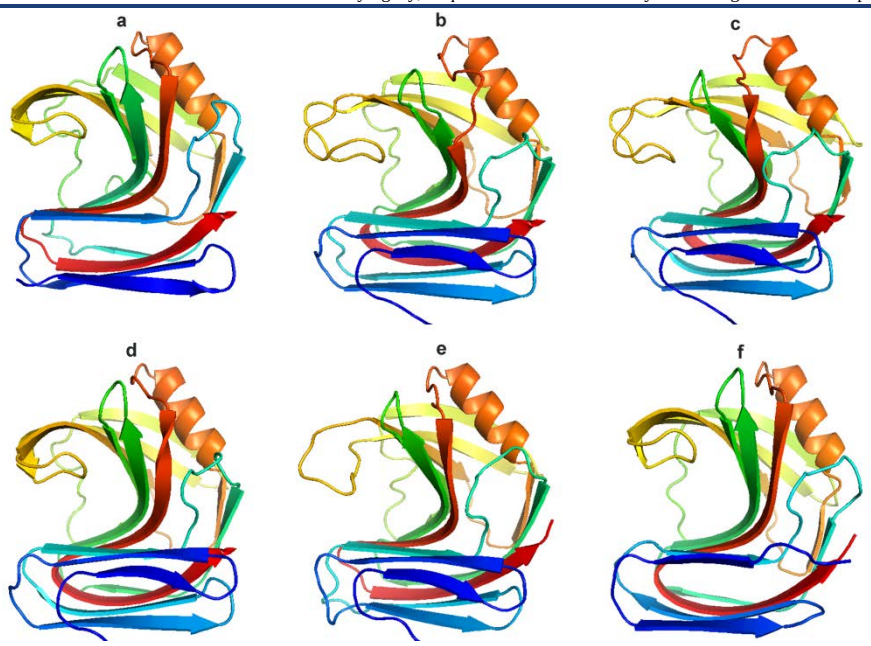

Figure S2. The predicted model structures of the six fungal thermoacidophilic GH11 xylanases by SWISS-MODEL. a) GaXyl, b) PzXyl, c) AnXyl, d) CvXyl, e) ArXyl, f) OmXyl

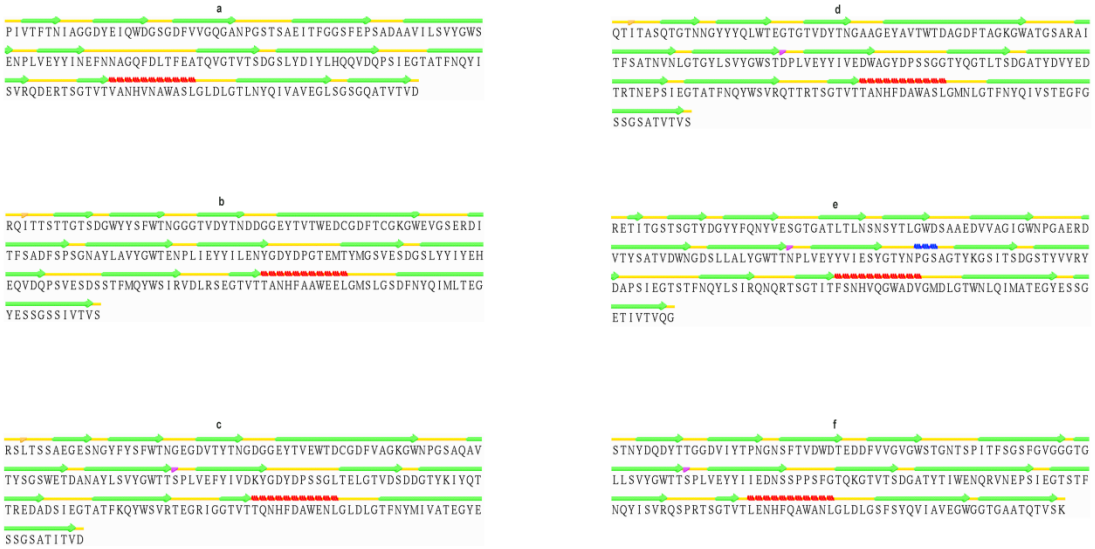

Figure S3. The secondary structure of the predicted model structures of six fungal thermoacidophilic GH11 xylanases evaluated by Stride. a) GaXyl, b) PzXyl, c) AnXyl, d) CvXyl, e) ArXyl, f) OmXyl

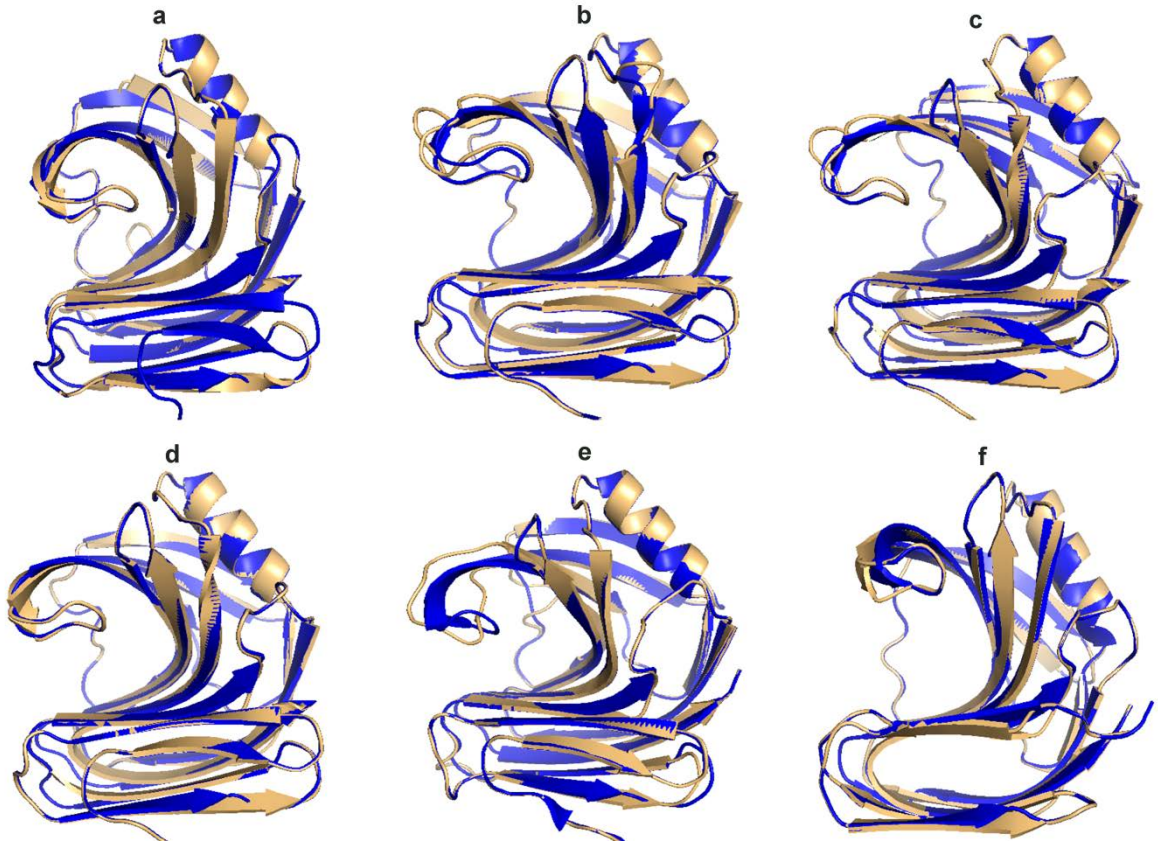

Figure S4. The model-template structural alignment monitored by PyMOL. a) GaXyl, b) PzXyl, c) AnXyl, d) CvXyl, e) ArXyl, f) OmXyl. Blue refers to template, and light orange indicates to the each thermoacidophilic xylanase

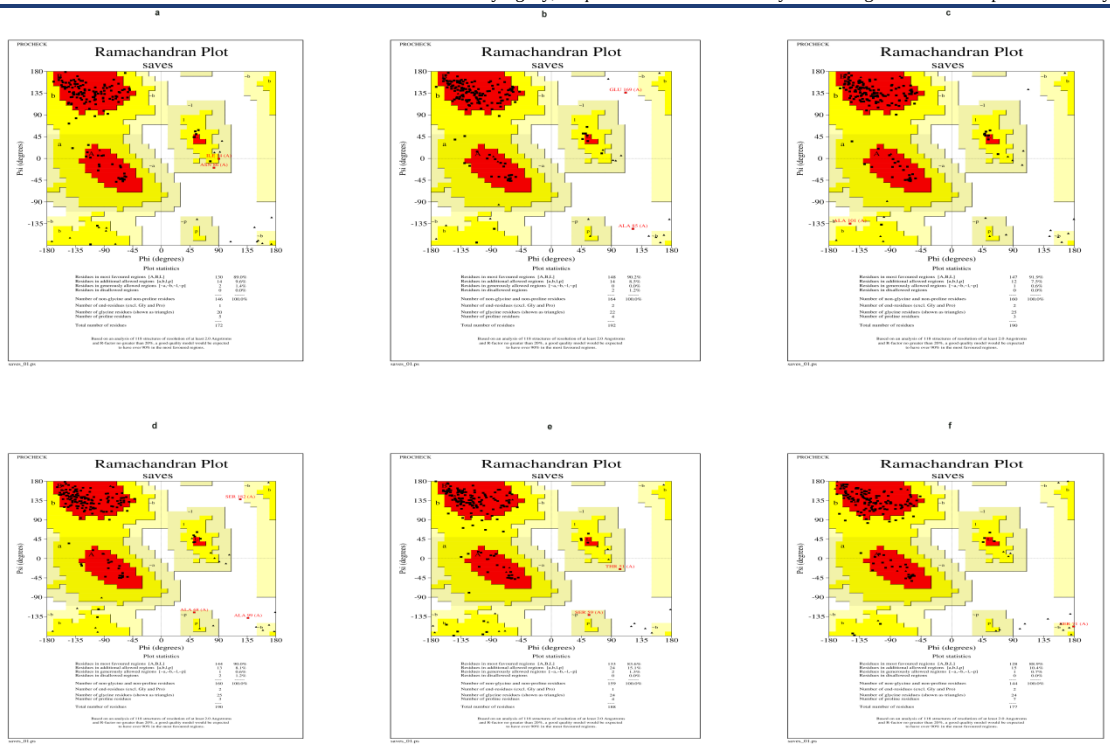

Figure S5. Ramachandran plots of the six fungal thermoacidophilic GH11 xylanases estimated using ProCheck. a) GaXyl, b) PzXyl, c) AnXyl, d) CvXyl, e) ArXyl, f) OmXyl.

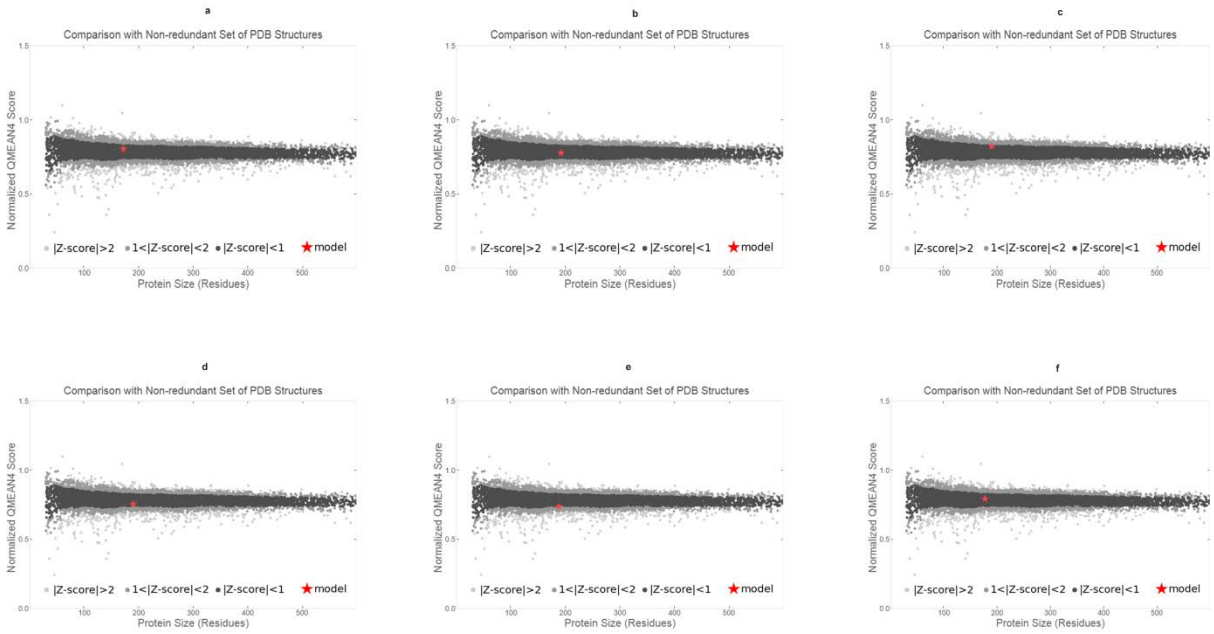

Figure S6. QMEAN value of the six fungal thermoacidophilic GH11 xylanases.

a) GaXyl, b) PzXyl, c) AnXyl, d) CvXyl, e) ArXyl, f) OmXyl.

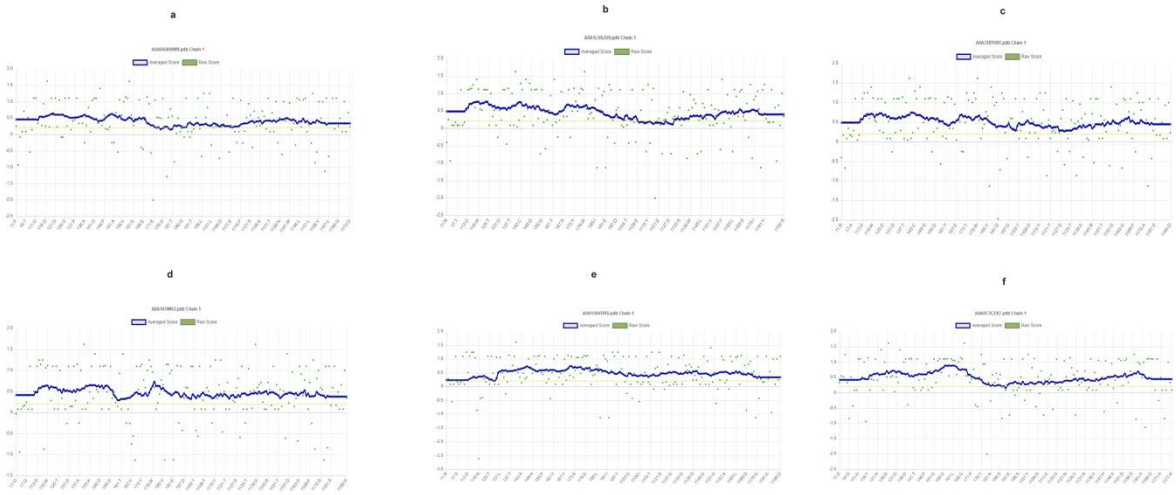

Figure S7. Verify 3D assessment for compatibility of the each predicted model of the six fungal thermoacidophilic GH11 xylanases. a) GaXyl, b) PzXyl, c) AnXyl, d) CvXyl, e) ArXyl, f) OmXyl.

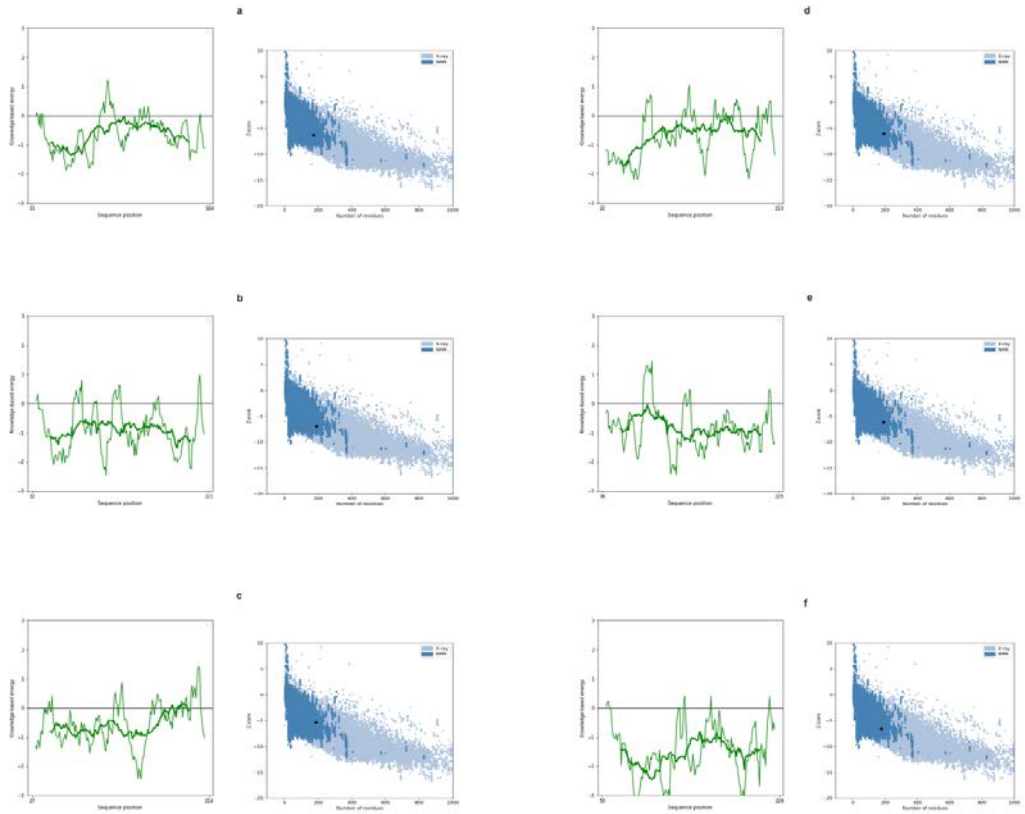

Figure S8. The global (right) and the local (left) quality of the each predicted model of the six fungal thermoacidophilic GH11 xylanases by ProSA. a) GaXyl, b) PzXyl, c) AnXyl, d) CvXyl, e) ArXyl, f) OmXyl.