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Research Article

The Effect of Strip Tillage Method Applied in Cotton Cultivation in Ceyhan Plain on Yield

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Abstract

Considering the food security of the increasing world population, it is extremely important to create sustainable agricultural production systems that will reduce greenhouse gas emissions, are resistant to and sensitive to climate change, prevent erosion, and protect the soil. In the strip tillage method, which is one of the conservation tillage methods, 30%-40% of the field surface is allowed to be tilled in a strip form before planting for seed bed preparation. The soil between seed planting rows are left no-tilled, covered with stubble. The research was carried out in a trial field in the Ceyhan Plain of the Çukurova Region in 2023. In the research, the conventional tillage method (CT) and the strip tillage (ST) methods were compared in terms of cotton yield. Field trials were arranged with 4 replicates. The cotton *(Gossypium hirsutum* L.*)* variety used in the research was Ceyhan 520 and its thousand-grain weight was 105 g. As a result of the research, higher cotton yield was obtained with an average yield of 427.5 kgda^{-1} compared to the conventional tillage method with strip tillage. The yield in the strip tillage method was 417.5 kg/da on average.When the conventional tillage and strip tillage methods were compared, no statistically significant difference was found in terms of the cotton yield ($P<0.05$). Therefore, since the yield results of the two methods are close to each other, it is recommended to prefer the strip tillage method, which is a conservation and sustainable method, as an alternative to conventional tillage.

Keywords: Strip tillage, conservation tillage, sustainable agriculture, cotton *(Gossypium hirsutum L.)*

Ceyhan Ovası Pamuk Yetiştiriciliğinde Uygulanan Şeritvari Toprak İşleme Yönteminin Verim Üzerine Etkisi

Öz

Artan dünya nüfusunun gıda güvenliği göz önünde bulundurulduğunda, sera gazı emisyonlarını azaltacak, iklim değişikliğine dayanıklı ve duyarlı, erozyonu önleyen ve toprağı koruyan sürdürülebilir tarımsal üretim sistemlerinin oluşturulması son derece önemlidir. Koruyucu toprak işleme yöntemlerinden biri olan şeritvari toprak işleme yönteminde, ekim öncesinde tohum yatağı hazırlığı amacıyla tarla yüzeyinin yalnızca %30-40'lık kısmı şeritler halinde işlenmektedir. Ekim sıra hattı işlenilip, bunun dışında kalan sıralar arası anızla kaplı olarak işlenmeden bırakılır. Araştırma, 2023 yılında Çukurova Bölgesi'nde yer alan Ceyhan Ovası'ndaki bir deneme alanında yürütülmüştür. Araştırmada pamuk verimi açısından geleneksel toprak işleme (CT) yöntemi ile şeritvari toprak işleme (ST) yöntemi karşılaştırılmıştır. Tarla denemeleri 4 tekerrürlü olarak kurulmuştur. Araştırmada kullanılan pamuk *(Gossypium hirsutum* L.*)* çeşidi Ceyhan 520 olup, bin tane ağırlığı 105 gramdır. Araştırma sonuçlarına göre, şeritvari toprak işleme yönteminde ortalama 427,5 kgda^{-1} verim elde edilerek, geleneksel işleme yöntemine kıyasla daha yüksek pamuk verimi sağlanmıştır. Geleneksel toprak işleme yönteminde ise ortalama verim 417,5 kgda^{-1} olarak gerçekleşmiştir. Ancak, geleneksel toprak işleme ile şeritvari toprak işleme yöntemleri karşılaştırıldığında, pamuk verimi açısından istatistiksel olarak anlamlı bir fark bulunmamıştır ($P<0,05$). Bu nedenle, her iki yöntemin verim sonuçları birbirine yakın olduğundan, sürdürülebilir ve koruyucu bir yöntem olan şeritvari toprak işleme yöntemi, geleneksel toprak işleme yöntemine alternatif olarak önerilmektedir.

Anahtar Kelimeler: Şeritvari toprak işleme, koruyucu toprak işleme, sürdürülebilir tarım, pamuk (*Gossypium hirsutum L.)*

Introduction

Global warming, one of today's problems, has disrupted the agricultural ecosystem and caused unexpected changes in agricultural climate elements such as drought, temperature, precipitation, weather events and sunlight. In terms of agricultural production, these negative changes lead to a decrease in product yield and quality, a decrease in soil fertility, an increase in soil erosion due to heavy precipitation, and an increase in diseases and pests. It is a well-known problem that climate change increases the fluctuation in agricultural production and generally harms agricultural production. Therefore, considering the food security of the increasing world population, it is extremely important to create sustainable agricultural production systems that will reduce greenhouse gas emissions, are resistant to and sensitive to climate change, and to develop technological, innovative agricultural mechanization tools and machines. For this reason, the search for new sustainable production systems that protect natural resources such as soil, water and air in agricultural production has accelerated. As a result of these searches, alternative conservation tillage to conventional tillage and the development of new tools and machines to be used in this process have come to the fore (Çay, 2018; Özpınar et al., 2018).

The main purpose in conservation tillage is to keep the pre-crop residues on the field surface and to minimize field traffic by reducing the intensity of soil tillage. In conservation tillage; soil moisture loss and water and wind erosion decrease (ASABE, 2013; Barut, 2006; Karayel and Özmerzi, 2003; Özpınar, 2018). Conservation tillage is a sustainable practice in the long term where the plough that works by turning the soil is not used and the machine traffic is less.

The conventional tillage method widely used in our country; soil degradation, soil compaction, fuel and energy consumption are high due to the plough that works by turning the soil and the intensive field traffic (Barut and Çelik, 2009; Barut and Özdemir, 2024).

The problem of drought and the limited water resources of the world bring the conservation of water and moisture in the soil to the forefront. In agricultural production areas where cover crops are applied, since plant residues cover the soil surface and block the sunlight, moisture rates are higher than in areas without plant residues (Klocke et al., 2009). In regions where the soil is intensively and continuously tilled, soil degradation caused by soil preparation is clearly observed (Özpınar and Çay, 2006).

In the strip tillage method, which is one of the conservation tillage methods, %30-%40 of the field surface is allowed to be tilled as a band before planting for seed bed preparation. A 15 to 35 cm wide band coming above the planting row line is tilled. The remaining rows are left untilled, covered with stubble (Licht and Al-Kaisi, 2005; Özdemir and Barut, 2022). This method can be perceived as a mixture of reduced tillage and no tillage method (Figure 1).

Figure 1. Cotton plant applied with strip tillage method in the study

Although cotton is a plant that can grow in all types of soil, some factors are important to achieve high yield and quality. These are factors such as climate requirements, soil preparation, planting method, fertilization, irrigation and maintenance. In terms of soil requirements, soil structure, structure, reaction, salinity and soil organic matter affect the plant's growing conditions. Businesses should implement practices that improve soil structure. These are conscious soil cultivation (appropriate time, with appropriate tools, not excessive soil cultivation) and practices that increase soil organic matter (such as rotation, green fertilization, use of barnyard manure and not burning stubble). Although cotton is not very selective in terms of soil requirements, it develops better in soils with deep profiles, rich in organic matter and high water retention capacity (Yüreğir Chamber of Agriculture, 2017).

The effects of strip tillage on various agricultural parameters, such as yield, soil health, carbon emissions, water use, and energy consumption, have been studied in numerous works. A review of these studies reveals some common trends, particularly concerning strip tillage's benefits in water management, organic matter retention, and carbon emissions reduction. However, the influence of strip tillage on yield and other parameters varies depending on several factors, including soil type, climate conditions, and the characteristics of the crops being cultivated.

Studies on strip tillage's effect on yield have shown variable results. For example, Różewicz et al. (2024) observed that while traditional tillage yielded the highest wheat production (7.88 t/ha), strip tillage provided nearly equivalent results (7.16 t/ha). Similarly, Sleiderink et al. (2020) found that strip tillage improved root development and enhanced soil biological activity in maize cultivation, leading to higher yields compared to no-till systems. These findings indicate that strip tillage can offer yields comparable to conventional tillage under the right conditions. However, the yield benefits of strip tillage are often contingent on specific soil types and climatic conditions, which affect water retention and nutrient availability in the soil. For example, strip tillage has been shown to be particularly beneficial in soils with high organic matter content and good moisture retention, leading to more stable yields, especially in drought-prone regions.

Strip tillage has consistently been reported to have a positive impact on soil health, particularly in terms of organic matter accumulation, water retention, and microbial activity. Jaskulska & Jaskulski (2020) demonstrated that strip tillage reduced fuel consumption by 20-30 L ha^{-1}, increased soil moisture content, and sustained microbial populations. Similarly, Hossain et al. (2014) found that strip tillage reduced the time and fuel consumption by %70 and %60, respectively, compared to conventional tillage. Górski et al. (2022) reported that strip tillage increased root yield by %6.6 and sugar yield by %8,2 in sugar beet production. These studies suggest that strip tillage has significant benefits for soil health, including improved microbial activity and moisture retention. In areas with limited water resources or where water management is critical, such as regions with average annual rainfall of 400-800 mm, strip tillage has been shown to help optimize water usage and reduce soil erosion.

The role of climate conditions in the effectiveness of strip tillage is also evident in various studies. Li et al. (2015) reported that strip tillage optimizes soil moisture balance in regions with annual rainfall between 400-800 mm, improving water use efficiency. Darapuneni et al. (2019) found that strip tillage enhanced root growth and increased yield by % 5,4 to %10,29 in cold climates, where the seedbed conditions were improved. These findings highlight that strip tillage's effectiveness can vary depending on regional climate, with cold climates and regions with limited rainfall benefiting most from its water-conserving properties.

From an environmental perspective, strip tillage contributes to sustainability by reducing carbon emissions. Donald (1998) showed that strip tillage reduces CO_2 emissions, while conventional tillage resulted in the highest CO_2 release. Bilen et al. (2023) also observed that strip tillage reduced CO_2 emissions, decreased bacterial populations, but increased fungal populations, which enhanced soil biodiversity. These findings align with the broader trend that strip tillage contributes to a reduction in greenhouse gas emissions, making it an environmentally sustainable practice.

Literature generally supports the notion that strip tillage offers multiple environmental and agronomic benefits, particularly in terms of water management, organic matter retention, and carbon emissions reduction. However, yield responses to strip tillage are highly dependent on local conditions such as soil type, climate, and crop characteristics. For instance, strip tillage has shown to provide stable or improved yields in areas with suitable soil types and favorable climatic conditions, but its performance can be limited in more extreme environments. This aligns with the findings of the present study, which confirms that strip tillage's effectiveness in cotton production is influenced by local soil conditions, climate, and crop characteristics. The study further emphasizes the importance of adapting strip tillage practices to specific regional conditions to maximize its benefits, particularly in areas prone to drought or with limited water availability.

While strip tillage presents clear advantages for sustainable agriculture, its application must be carefully tailored to the specific conditions of each region. The broader patterns observed in the literature, including the influence of soil type, climate, and crop characteristics, are crucial for understanding the generalizability

Cotton is a globally significant crop, valued for its diverse uses. Its fibers are essential in textile production, while its seeds serve as a source for oil and animal feed. The global cotton market is highly competitive, with leading producers including China, India, and the United States, followed by countries such as Pakistan, Brazil, Turkey, Bangladesh, and Indonesia (Nacak, 2004; Anonymous, 2022). Attaining optimal yield and quality in cotton production relies on multiple factors, including climatic conditions, soil management, planting techniques, fertilization, irrigation, and cultivation practices.

Key soil characteristics such as texture, structure, pH, salinity levels, and organic matter content are critical for successful cotton cultivation. Farmers should adopt methods that enhance soil quality, such as mindful tillage practices (timely and precise use of equipment, avoiding over-tillage) and strategies to boost organic matter levels, including crop rotation, applying green and farmyard manure, and refraining from burning crop residues. While cotton is adaptable to various soil types, it performs best in soils with a deep profile, rich in organic matter, and with high water-retention capacity (Muhammad et al., 2020; Yeşilayer et al., 2024).

For sustainable cotton cultivation:

- Proper plant protection methods and balanced applications should be ensured,
- Water resources must be managed wisely and effectively,
- Fertilization and tillage operations should prioritize long-term soil health,
- Practices that maintain fiber quality should be carefully implemented,
- Efforts should be made to safeguard natural habitats,
- The surrounding ecosystems in production areas must be conserved,
- Beneficial insect populations should be supported,
- Crop rotation should be routinely practiced (Yüreğir Agricultural Chamber, 2017; Muhammad et al., 2020).

This research explores strip tillage as an alternative to conventional tillage for cotton cultivation in the Çukurova region, with a specific focus on plant emergence characteristics.

The Çukurova Region, Turkey's largest coastal plain, is a cornerstone of agricultural production thanks to its fertile lands. Approximately %70 of the region's agricultural area is irrigated, a significant proportion compared to other regions. Çukurova supports the cultivation of a diverse array of crops, including wheat, barley, cotton, sesame, watermelon, corn, sunflower, citrus fruits, peanuts, tomatoes, olives, and peas. Agriculture serves as the main source of income for the local population. The economic benefits of irrigated farming in the region are substantial, with agricultural income increasing by 5 to 6 times compared to dry farming. While the average income per hectare from rainfed farming is around $500, this figure rises dramatically when irrigation is employed, highlighting the transformative impact of water management on agricultural productivity (Özdemir and Barut; 2025).

The primary aim of this study is to develop a conservation tillage system within the framework of sustainable agricultural practices, with the dual objective of preserving natural resources and improving environmental conditions, while also enhancing productivity and reducing production costs. Instead of the conventional tillage method, which requires more time, labor, and energy consumption, this study seeks to demonstrate the advantages of a more economically and ecologically sustainable tillage approach that prioritizes soil conservation and restoration.

Materials and Methods

The research was carried out in a trial field located in the Ceyhan plain of the Çukurova region in 2023. In the research, the conventional soil tillage method and the strip tillage method were compared in terms of yield (Figure 2, Figure 3). The Ceyhan Plain ((37°03'23.6"N 35°46'49.8"E) is influenced by the Mediterranean climate, with hot and dry summers and mild, rainy winters. The annual average temperature is approximately 18,4°C, while the annual average precipitation is around 726 mm.

Figure 2. Trial plots where strip tillage method is applied

Figure 3. The cotton growth process and harvest maturity in experimental plots where strip tillage method was applied

Cotton *(Gossypium hirsutum L.)* was tested in the research, the seed variety used was Ceyhan 520, 1000-grain weight was 105 g. The soil structure in which the field trials were carried out was clayey loam consisting of %24, 2 sand, %38,45 silt and %36,4 clay. In the research, the trial plot covered with wheat stubble, where the strip tillage method was applied, was processed with a 6-row strip tillage machine (Figure 4).

Table 1. Tillage methods used in the researchfor cotton cultivation

Tillage method	**Equipment used for research**
Conventional	- Stubble chopping - Moldboard plough - Disc harrow (2 passes) - Float - Drill
Strip Tillage	-Strip Tillage -Drill

Figure 4. Strip tillage machine used in the experiment

Planting was carried out on strips processed at 20 cm intervals with a 4-row pneumatic precision seeder machine at 70 cm row spacing, 4 cm row to row and 4 cm planting depth (Figure 5).

Figure 5. 4-row pneumatic precision seeder machine used in the experiment

In order to calculate the yield values, cotton bolls that had reached harvest maturity were harvested manually from random points of the trial plots with a 1 m^2 circle and yield values were taken, and they were also calibrated with the data collected from 1 ha with a harvesting machine (Figure6).

Figure 6. Sampling of cotton bolls that have reached harvest maturity with a 1m^2 circle

In the statistical analysis of the results obtained from the random trial plots in the research area, analysis of variance (ANOVA) was used. Differences between the means of the experimental variables were evaluated using Tukey's multiple comparison test.

Results and Discussion

As a result of the research, with an average yield of 427, 5 kg da^{-1}, higher cotton yield was obtained than conventional tillage, and the strip tillage yield were an average of 417, 5 kg da^{-1} (Figure 7).

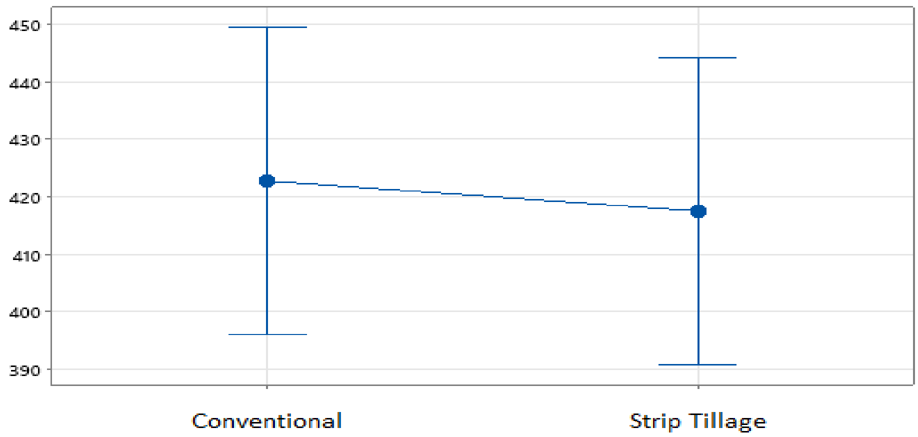

Figure 7. Effect of different tillage methods on yield (kg da^{-1})

When the conventional tillage and strip tillage methods were compared, no statistically significant difference was found in terms of the cotton yield (Table 2).

Table 2. Variance Analysis of different tillage methods

	DF	Adj SS	Adj MS	F-Value	P-Value
Method	1	55.12	55.12	0.12	0.745
Error	6	2855.75	475.96		
Total	7	2910.88			

Table 3. Statistical effects of different tillage methods on yield (kg da^{-1})

Tillage method	N	Mean Grouping	P- Value 0,745ns*
Conventional	4	427,5 [a]	
Strip tillage	4	417,5 [a]	

Significant at *P<0,05, **P<0,01 and ns, not significant

These results show that the yield results of both methods are very close to each other (Table 3). Therefore, it has been shown that similar yields can be obtained with strip tillage and conventional tillage. These results suggest that strip tillage can achieve yields comparable to conventional tillage, making it a viable alternative.

The literature on strip tillage supports these findings. For instance, Różewicz et al. (2024) found that conventional tillage resulted in slightly higher grain yields (7.88 t/ha^{-1}) compared to strip tillage (7.16 t/ha^{-1}), yet both methods demonstrated similar productivity levels. Similarly, Khalilian et al. (2012) reported no significant yield differences in cotton, but emphasized the reduced energy and labor requirements of strip tillage, making it a more sustainable choice.

A comprehensive meta-analysis by Dou et al. (2024), which included 290 comparative datasets from 53 studies, highlighted that strip tillage yields were generally similar to conventional tillage, while offering advantages over no-till methods. This is particularly relevant in regions with cold climates or continuous cropping systems, where strip tillage aids in resource efficiency.

Soil conditions and climate play crucial roles in determining yield outcomes under different tillage methods. Morrison (2002) underscored the long-term benefits of strip tillage, particularly in drought conditions, as it enhances soil moisture retention. Similarly, Licht and Al-Kaisi (2005) found that strip tillage increased soil temperature by 1,5–2,5°C, improving root development and crop establishment. Although the present study did not specifically assess soil temperature or moisture dynamics, the comparable yields between strip and conventional tillage suggest that strip tillage effectively mitigates potential drawbacks associated with minimal soil disturbance.

Further supporting this, Thomson (2012) noted that strip tillage reduces soil compaction, enhances root development, and contributes to long-term soil conservation. This aligns with the current study's emphasis on the sustainability benefits of strip tillage, particularly in regions like Çukurova, where soil degradation is a pressing concern. The integration of these findings highlights that strip tillage not only maintains yield levels but also promotes sustainable agricultural practices through reduced energy input, lower carbon emissions, and improved soil health.

To enhance the applicability of these results across diverse agricultural settings, future studies should investigate additional parameters such as soil health indicators, long-term yield trends, and economic feasibility. By examining the broader impacts of strip tillage beyond yield, researchers can further substantiate its role as a sustainable alternative to conventional tillage.

In order to demonstrate the differences in performance of tillage methods in this study, factors such as crop type, soil properties, and environmental conditions are important for the observed yield results to be universally applicable. Future studies can expand on these findings by examining additional parameters such as soil health indicators, energy consumption, and long-term yield trends. Since previous studies have shown that strip tillage has less field traffic, lower fuel consumption, lower energy requirement and lower carbon emissions compared to conventional tillage, the applicability of strip tillage has been foreseen.The discussion highlights the importance of strip tillage as a viable alternative to conventional tillage that offers comparable yields while promoting soil conservation and sustainability. This makes it particularly valuable in regions such as Çukurova, where sustainable agricultural practices are essential for long-term productivity. Although further research is needed to validate these findings in various contexts, the evidence to date positions strip tillage method as a critical tool for modern agriculture.

Conclusion

This study demonstrates the potential of strip tillage as an effective and sustainable alternative to conventional tillage in cotton cultivation, particularly in the Ceyhan Plain of the Çukurova Region. In the strip tillage method, a %2, 39 lower yield was obtained compared to the conventional tillage method. While the yield differences between the two methods were not statistically significant, strip tillage offers comparable productivity with added environmental benefits, aligning with conservation agriculture principles. The findings support the adoption of strip tillage for its ability to minimize soil disturbance, conserve resources, and reduce production costs, without compromising yield. These advantages make it particularly suitable for regions prioritizing sustainable agricultural practices in response to challenges such as climate change and soil degradation. Therefore, since the yield results of both methods are close to each other, it is recommended to prefer the strip tillage method, strip tillage method is a sustainable, environmentally friendly method that protects soil and water resources, provides less field traffic and low energy requirements, as an alternative to the conventional tillage method. We need to explain to our farmers in our country that they can achieve similar yields without tiring their land and increase their profitability with lower costs, instead of constantly cultivating their land intensively with intensive production practices. And it is important to conduct economic analyses following these studies. By integrating conservation tillage methods like strip tillage into farming practices, regions like Çukurova can advance toward more sustainable and resilient agricultural systems, ensuring productivity and environmental stewardship for future generations.

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