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YIELD AND NUTRITIONAL CHARACTERISTICS OF EDIBLE CLUSTER BEAN GENOTYPES

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ABSTRACT

Cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.), also called as guar, is used in industry, animal feeding and green pods are used as a fresh vegetable in some countries. This research is the first study in Turkey carried out nutritional composition. Ten edible guar lines were used as plant material. Green pod yield, yield components (number of pods per plant, single pod weight, pod length and pod width) and nutritional attributes (crude protein, digestible protein and dry matter ratios) of 10 guar lines were investigated with field experiments conducted in two growing seasons (2016-2017). Green pod yields per plant varied between 63.70 and 81.34 g; number of pods per plant varied between 18.78 and 25.98 piece. Single pod weights of the guar lines varied between 2.91 and 3.76 g and differences in single pod weights of the guar lines were found to be significant. Pod lengths varied between 10.86 and 12.43 cm and pod widths varied between 10.32 and 11.31 mm. Crude protein contents of guar lines varied between 14.38 and 17.22% DM and differences were not found to be significant; digestible protein contents varied between 65.40 and 75.25% CP and differences were found to be significant. Dry matter ratios of the green pods varied between 15.92 and 21.16%. Considering the correlations among the investigated traits, it was observed that green pod yields had significant positive correlations with the number of pods per plant, pod weights and pod lengths. Pod weights decreased with increasing number of pods; decreasing dry matter ratios were observed with increasing pod weights and pod lengths. A similar change was also observed in digestible protein contents based on crude protein contents.

Keywords: Edible guar (*Cyamopsis tetragonoloba*), genotype, protein, yield

INTRODUCTION

Majority of world guar (*Cyamopsis tetragonoloba*) or cluster bean production comes from India and Pakistan. These two countries constitute about 95% of world production (75% by India and 20% by Pakistan). The remaining 5% is produced in the other countries (United States of America, Australia, South Africa, Tunisia, Germany, Brazil, Zaire, Myanmar, Italy, Spain and Sri-Lanka) (Kumar et al., 2013; Falasca et al., 2015).

Guar is produced in India especially for guar gum production, unripe fruits are also consumed as fresh vegetable, animal feed and green fertilizer (Singh and Bhagwati, 2016). The basic purpose of production is to produce guar gum, but green pods are sometimes sold as foodstuff especially in India and Pakistan and in some local markets of Atlanta and Georgia of the USA (Morris and Wang, 2017). Industrially guar gum is a cost-effective natural thickener, binder and stabilizer. It is an important raw material in a wide range of industries like oil and gas wells, food, paper, textile, cosmetics, mining and explosives (Dhugga et al., 2004). Guar gum is also considered as a potential drug in treatment of diseases like high cholesterol (Hosobuchi et al., 1999), diabetes (Saeed et al., 2012) and irritable bowel syndrome (Russo et al., 2015). Guar seeds and leaves were reported to be used in treatment of various diseases in India and Pakistan (Saleem et al., 2002).

There are not many studies about the nutritional characteristics of guar. Goyal and Sharma (2009) carried out a study about nutritional composition of locally consumed vegetables of India including guar and reported that edible pods of guar were quite rich in digestible fiber and non-starch polysaccharides.

Zanoni et al. (1980) reported that cluster beans, when raised as a vegetable, had quite appreciable nutritional values and were rich in proteins, fat, carbohydrate, vitamin A, vitamin C, calcium and iron.

With the present study, edible guar was studied for the first time in Turkey. Number of studies conducted on plant and nutritional characteristics of edible guar is quite limited even in India and Pakistan. Ntatsi et al. (2018) says that "The use of different legume species as vegetables for fresh consumption is not yet very common, apart from the well-known green pods of beans, peas and faba beans, and immature seeds of peas and faba bean".

As it was indicated by several researchers, guar is used for various purposes. Therefore, researches around the world mostly focused on cultivation of guar. The purpose of this research was to study the yield and nutritional characteristics of green pods of vegetable type guar genotypes grown in Canakkale Province located in the western Turkey.

MATERIALS AND METHODS

Ten edible guar lines selected through single plant selection method from guar populations supplied from Haryana and Guajarat provinces of India were used as the plant material (Table 1). Experiments were conducted over the experimental fields of Dardanos Experimental Research Farm of Canakkale Onsekiz Mart University Agricultural Faculty. Experimental area was clay-loam in texture, unsaline and slightly alkaline with low lime and organic matter content (Ozcan et al., 2003; Parlak et al., 2017).

Table 1. Edible guar lines used in the study and their origins

Line No	Selection No	Origin
1	COMU SFY 011- 468-5	India
2	COMU SFY 011- 493-6	India
3	COMU SFY 011- 494-6	India
4	COMU SFY 011- 495-1	India
5	COMU SFY 011- 497-3	India
6	COMU SFY 011- 498-6	India
7	COMU SFY 011- 503-2	India
8	COMU SFY 011- 508-5	India
9	COMU SFY 011- 509-6	India
10	COMU SFY 011- 510-2	India

Field trial was conducted for two years (2016 and 2017) in the Randomized Complete Block Design (RCBD). Sowing was performed on 13 May 2016 in the first year and on 5 May 2017 in the second year. Considering the sowing recommendations of Cebeci et al. (2016), who worked with different guar genotypes, sowing was performed at 40 cm row spacing and 10 cm on-row plant spacing. Seeds were sown in circular seedbeds to a depth of 2-4 cm and 3 seeds were manually sown to each seedbed. Following the emergence, thinning was performed as to have a single plant in each seedbed. As recommended by Batirca et al. (2017), 3 kg da^{-1} pure nitrogen and 6 kg da^{-1} pure phosphorus were supplied at sowing. Drip irrigation was used for irrigations. Four irrigations were performed throughout the plant growth season and about 100 mm water was applied in each irrigation. Hoeing was performed once two weeks after the emergence. For weed control, herbicides with Benfluraline active ingredient was used before sowing and herbicides with Bentazone active ingredient was used after the emergence.

For green pod harvest, 3 plants were selected and labeled in each plot from the emergence. Again, 3 plants were also labeled for kernel yield as to leave them until the harvest maturity. Side effects were taken into consideration while selecting these plants for green pod and kernel yield. Green pod harvests were continued at certain intervals for each line until the physical maturity.

In the first year, the 1st harvest was performed on 2 August 2016, the 2nd harvest on 23 August 2016 and the 3rd harvest on 13 October 2016. In the second year, the 1st harvest was performed on 3 August 2017, the 2nd harvest on 18 August 2017 and the 3rd harvest on 5 October 2017.

For nutrient analyses, green pod samples were taken throughout about the half of vegetation period started with the 1st harvest. For this purpose, 3 plants were selected from each plot and 3 pods were sampled from mid-sections of the plants. Then, the pods until the sampling point were harvested as the 1st harvest.

Following the vegetative characteristics, samples were dried in an aerated-oven (Nuve FN-500) at 80ºC. Dried samples were then ground in plant mill with steel blades (Multi-Functional High-Speed Disintegrator L-1250g).

Vegetative characteristics of the pods harvested at the 1st, 2nd and 3rd harvests were determined in accordance with the methods provided in Table 2 (Morris, 2010; Sultan et al., 2012; Girish et al., 2012; Jukanti et al., 2015).

Experiments were conducted under the climate conditions of Canakkale province located in "Mediterranean Climate Transition Zone". Climate data for experimental years are presented in Figure 1.

The lowest mean temperatures in September-October 2017 were lower than the mean temperatures of 2016 and precipitations in July and September of 2017 were greater than the precipitations of 2016.

Experimental data were subjected to variance analysis (ANOVA) with MINITAB 16.0 software and means were compared by using the standart LSD test (Steel and Torrie, 1980).

Table 2. Yield and quality characteristics measured in the study

Characteristics	Unit	Measurement Method
Green pod yield	g plant^{-1}	Green pods of each plant were weighed with a precise balance
Number of pods	pods plant^{-1}	Green pods of each plant were counted.
Pod weight	g	Each pod was weighed with a precise balance.
Pod length	mm	The length from pedicel to stigma was measured with a ruler.
Pod width	mm	The widest section of the pod was measured with a digital caliper.
Crude protein	dry matter %	Kjeldahl (1883) nitrogen of wet-digested samples was determined and crude protein contents were determined in accordance with Chemists and Horwitz (1990).
Digestible protein	posine pepsin digestibility %	Samples were incubated at 37ºC for 2 hours in accordance with Mertz et al. (1984) and digestible protein contents were determined in accordance with Aboubacar et al. (2001).
Dry matter	green pod weight %	Post-harvest weighed green pod samples were dried in an oven at 70ºC for 48 hours and dry matter contents were determined in accordance with Kacar and Inal (2010).

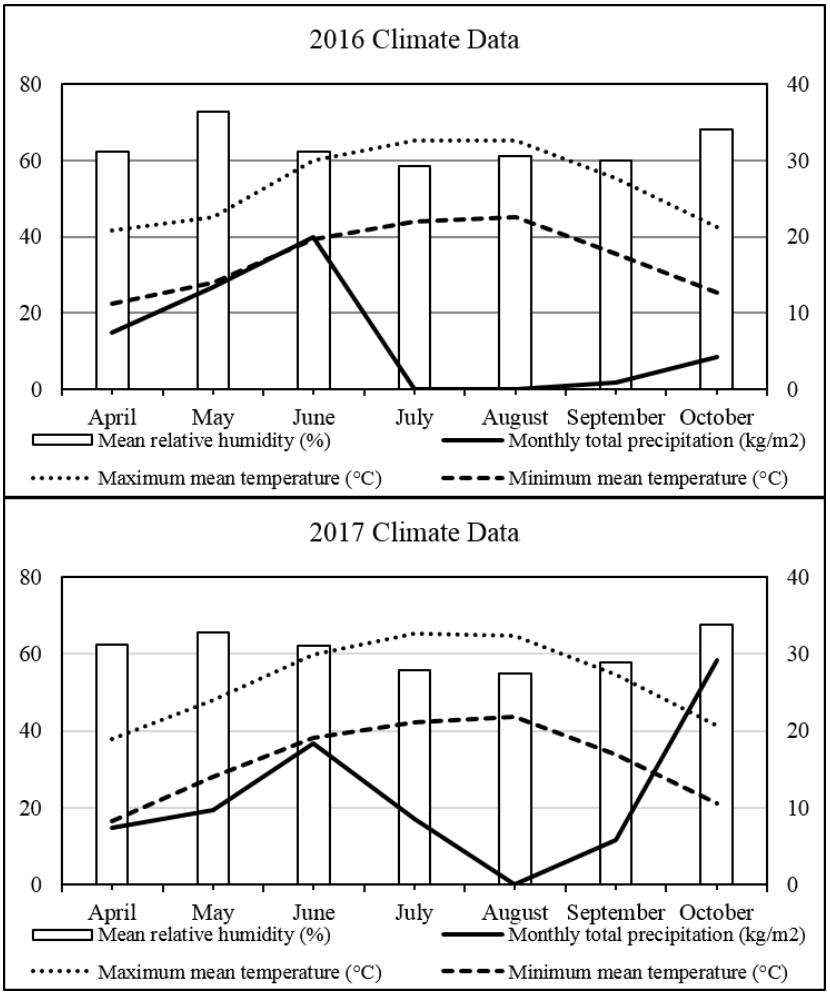

Figure 1. Climate data for Canakkale province during the experimental years (2016-2017)

RESULTS AND DISCUSSION

In the first year of the experiments (2016), the time-period between the sowing and the last harvest was 153 days of which 81 days were between sowing and the 1st harvest, 21 days were between the 1st and the 2nd harvest and 51 days were between the 2nd and the 3rd harvest. In the second year of the experiments (2017), the total duration between the sowing and the last harvest was again 153 days of which 90 days were between the sowing

and the 1st harvest, 15 days were between the 1st and the 2nd harvest and 48 days were between the 2nd and the 3rd harvest. The differences in days of harvest were attributed to differences in temperature and precipitation of the experimental years. Total number of days for harvest was kept constant, but the decisions for the 1st and 2nd harvest days were taken based on phenological observations.

Yield and yield components

Green pod yields and some other yield components of investigated edible guar lines are provided in Table 3.

As the average of two years, green pod yields varied between 63.70 and 81.34 g. There were significant differences in green pod yields of the guar lines in 2017. The differences in yields of 2016 and mean yields of two years were not found to be significant. The greatest green pod yield was obtained from the line 8 and it was respectively followed by the lines 7, 10, 6, 5, 2, 9, 3, 1 and 4. Again as the average of two years, number of pods per plant values varied between 18.78 and 25.98 and the differences in number of pods per plant of the guar lines were not significant. The greatest value was obtained from the line 2 and it was respectively followed by the lines 9, 10, 8, 7, 6, 3, 5, 1 and 4. Single green pod weights varied between 2.91 and 3.76 g and the differences in single pod weight of the lines were significant. The greatest value was obtained from the line 7 and it was respectively followed by the lines 8, 5, 6, 1, 4, 10, 3, 9 and 2.

Table 3. Green pod yield components of edible guar lines

Line no	Green pod yield (g plant^{-1})			Number of pods plant^{-1}			Pod weight (g)		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
1	86.23	44.83 ab	65.53	22.89	14.85	18.87	3.82 bc	3.00 bc	3.41 bcd
2	91.99	50.90 ab	71.44	26.96	25.00	25.98	3.42 d	2.40 de	2.91 e
3	92.12	40.07 ab	66.09	24.74	15.30	20.02	3.75 bcd	2.62 cd	3.18 de
4	90.70	36.70 b	63.70	24.96	12.59	18.78	3.68 cd	2.94 bc	3.31 cd
5	96.80	51.10 ab	74.00	22.26	16.85	19.56	4.41 a	2.96 bc	3.68 ab
6	110.07	39.49 ab	74.78	26.70	13.48	20.09	4.02 bc	2.96 bc	3.49 abc
7	94.66	63.54 a	79.10	25.48	17.41	21.44	3.75 bcd	3.76 a	3.76 a
8	103.83	58.84 ab	81.34	25.41	17.96	21.69	4.06 ab	3.34 ab	3.70 a
9	100.40	37.57 ab	69.00	26.00	22.78	24.39	3.88 bc	1.97 e	2.92 e
10	100.60	50.69 ab	75.64	27.56	18.07	22.81	3.67 cd	2.94 bc	3.31 cd
P value	0.895^{ns}	0.010*	0.516^{ns}	0.920^{ns}	0.245^{ns}	0.285^{ns}	0.001**	0.000**	0.000**

*: P> 0.050, **: P> 0.010, ns: nonsignificant

Green pod characteristics

Green pod length and width of edible guar lines investigated in this study are provided in Table 4.

As the average of two years, pod lengths varied between 10.86 and 12.43 cm. While there were significant differences in pod lengths in 2016 and in average of two years, the differences in pod lengths of the lines in 2017 were not found to be significant. The greatest value was obtained from the line 8 and it was respectively followed by the lines 5, 7, 6, 3, 10, 9, 4, 1 and 2.

Pod widths of the guar lines varied between 10.32 and 11.31 mm and the differences in pod widths of the guar lines were not found to be significant. The greatest value was obtained from the line 3 and it was respectively followed by the lines 1, 8, 7, 10, 6, 5, 2, 9 and 4.

Table 4. Pod length and width of guar lines

Line no	Pod length (cm)			Pod width (mm)		
	2016	2017	Mean	2016	2017	Mean
1	12.92 c	9.67	11.29 de	11.15	10.98	11.06
2	13.12 bc	8.60	10.86 e	11.30	9.77	10.53
3	13.45 abc	10.23	11.84 abcd	11.22	11.39	11.31
4	13.27 bc	9.32	11.29 de	10.44	10.19	10.32
5	14.51 a	10.06	12.28 ab	10.89	10.20	10.54
6	13.76 abc	10.26	12.01 abc	11.22	10.21	10.72
7	13.75 abc	10.73	12.24 ab	11.19	10.57	10.88
8	14.29 ab	10.57	12.43 a	11.19	10.64	10.91
9	13.92 abc	9.10	11.51 cde	11.00	9.74	10.37
10	13.00 c	10.46	11.73 bcd	11.22	10.54	10.88
P value	0.000**	0.239^{ns}	0.018*	0.064^{ns}	0.459^{ns}	0.233^{ns}

*: P> 0.050, **: P> 0.010, ns: nonsignificant

There were not any studies conducted on green pod yields and yield components of edible guar lines in Turkey. Therefore, comparisons could be made only with the other international studies. Present green pod yields were greater than the values reported by Santhosha et al. (2013) (5.10 - 15.53 ton ha^{-1}), but were quite similar with the values of Malaghan et al. (2013) (15.65 - 268.90 g $plant^{-1}$).

Protein characteristics

Crude protein, digestible protein and dry matter contents of green pods of investigated edible guar lines are provided in Table 5.

Mean crude protein contents of the lines varied between 14.38 and 17.22% DM. The differences in crude protein content of the guar lines were not found to be significant (Table 5). The greatest value was obtained from the line 2 and it was respectively followed by the lines 10, 6, 4, 7, 8, 9, 1, 3 and 5. Considering the dry matter contents, crude protein values in weight varied between 2.32 and 3.08 g. For 100 g green pod production, the greatest protein quantity was obtained from the line 3 and it was respectively followed by the lines 9, 10, 2, 1, 4, 7, 6, 5 and 8.

Goyal and Saharma (2009) reported that 100 g green pod of edible guar had 81 g water, 3.2 g protein, 0.4 g oil, 1.4 g ash, 3.2 g fiber, 10.8 g carbohydrate, 16 kcal energy, 49 mg vitamin C, 1.08 mg iron, 130 mg calcium and 57 mg phosphorus. Resultant crude protein content (16.84%) then complies with the present findings.

Table 5. Protein characteristics of green pods of guar lines

Line No	Crude protein (%)			Digestible protein (%)			Dry matter (%)			Digestible protein taken (g)		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
1	14.31	14.74	14.53	71.70	66.04 bc	68.87	18.12 a	18.84 b	18.48 bc	1.85	1.82	1.85
2	17.17	17.27	17.22	73.15	77.34 a	75.25	16.35 bcd	15.97 b	16.16 cd	2.06	2.09	2.08
3	13.05	15.97	14.51	73.17	65.89 bc	69.53	17.93 ab	24.39 a	21.16 a	1.71	2.65	2.15
4	14.16	15.91	15.04	70.97	65.14 bc	68.06	16.43 abcd	17.49 b	16.96 cd	1.66	1.81	1.74
5	14.15	14.61	14.38	80.27	62.59 bcd	71.43	16.74 abcd	17.29 b	17.02 cd	1.89	1.61	1.74
6	15.26	14.94	15.10	79.56	53.19 d	66.38	15.76 cd	16.70 b	16.23 cd	1.91	1.32	1.63
7	14.96	14.19	14.57	77.15	60.28 bcd	68.71	17.67 ab	16.71 b	17.19 cd	2.05	1.44	1.73
8	14.05	15.07	14.56	72.19	69.55 ab	70.87	15.50 d	16.34 b	15.92 d	1.57	1.72	1.64
9	15.12	14.01	14.56	74.88	55.93 cd	65.40	17.38 abc	23.44 a	20.41 ab	2.01	1.83	1.95
10	17.08	14.51	15.79	79.48	66.12 bc	72.80	16.70 abcd	18.35 b	17.52 cd	2.28	1.77	2.02
P value	0.111^{ns}	0.618^{ns}	0.401^{ns}	0.425^{ns}	0.015*	0.126^{ns}	0.027*	0.001**	0.000**	0.364^{ns}	1.129^{ns}	0.338^{ns}

*: P< 0.050, **: P<0.001, ns: nonsignificant

As the average of two years, digestible protein contents varied between 65.40 and 75.25% (Table 5). While the differences in digestible protein content of the guar lines were found to be significant at 5% level in 2017, the values were not significantly different in 2016 and in average of two years. The greatest value was obtained from the line 2 and it was respectively followed by the lines 10, 5, 8, 3, 1, 7, 4, 6 and 9. Considering the dry matter contents values in varied between 21.16% and 15.92% and the differences in dry matter were significant. Considering the dry matter contents, digestible protein values in weight varied between 1.63 and 2.15 g. For 100 g green pod production, the greatest digestible protein quantity was obtained from the line 3 and it was respectively followed by the lines 2, 10, 9, 1, 5, 4, 7, 8 and 6.

Relationships between green pod characteristics

The correlations between green pod characteristics are provided in Table 6. Except for green pod yield and crude protein, the correlations between the other characteristics were found to be significant. Of these significant correlations, negative correlations were observed only between dry matter and green pod yield and the correlations between the other characteristics were all positive. Except for the correlations of number of pods per plant with crude protein and dry matter, all the other correlations were found to be significant. Pod weight positively correlated with pod length, pod width and digestible protein and negatively correlated with dry matter. Pod length had significant positive correlations with pod width and digestible protein and significant negative correlations with dry matter.

Genotype-Trait bi-plot graph was generated for visual presentation of the relationships among the investigated traits (Figure 2) (Yan and Kang, 2003). The bi-plot graph was able to explain 63.7% of total variation. Such an explanation ratio is quite high for this kind of bi-plot graphs. High explanation ratios allowed traits to be positioned over the bi-plot graph based on correlation coefficients among them (Yan, 2014). While the dry matter and crude protein with negative correlations with the other traits were placed in left side of the graphs, positively correlated traits were placed on the right side of the graph (Figure 2).

Some of the correlations between the investigated traits (i.e. between green pod yield and pod characteristics) were expected correlations. However, negative correlations between dry matter and green pod yield were not expected and considered as quite different from the expected outcomes.

Table 6. Correlations among yield and nutritional traits of edible guar lines

	Green pod yield	Number of pods	Pod weight	Pod length	Pod width	Crude protein	Digestible protein
Number of pods	0.78**						
Pod weight	0.79**	0.31*					
Pod length	0.87**	0.53**	0.82**				
Pod width	0.53**	0.31*	0.47**	0.55**			
Crude protein	-0.08^{ns}	-0.03^{ns}	-0.19^{ns}	-0.14^{ns}	-0.04^{ns}		
Digestible protein	0.63**	0.48**	0.49**	0.54**	0.28*	0.23^{ns}	
Dry matter	-0.36**	-0.09^{ns}	-0.47**	-0.36**	-0.06	-0.03^{ns}	-0.22^{ns}

*: P> 0.050, **: P> 0.010, ns: nonsignificant

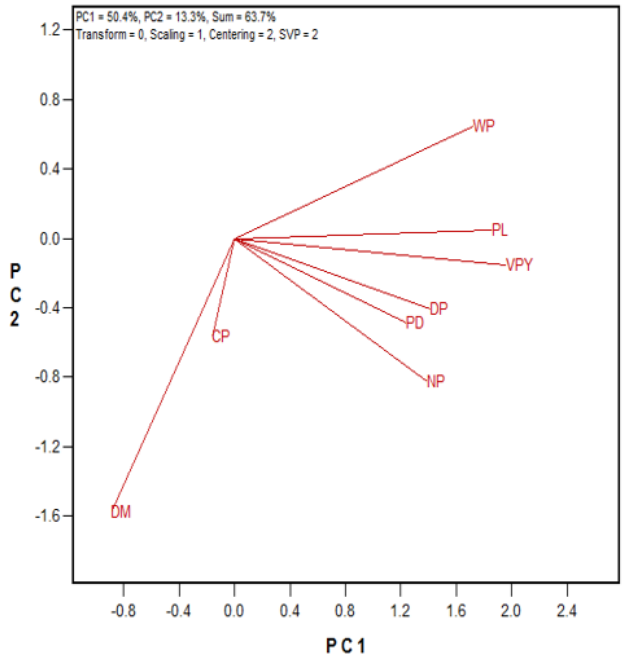

Figure 2. Genotype-trait bi-plot graph for characters studied

There were not any studies in literature investigating the relationships between green pod yield and protein characteristics. Therefore, present findings could not be discussed with the earlier studies.

CONCLUSION AND RECOMMENDATIONS

In present study, edible guar lines (10 of them) were investigated for the first time under provincial conditions of Canakkale (Turkey). Green pod yield per plant of the guar lines varied between 63.70-81.34 g. Number of pods per plant varied between 18.78 and 25.98 piece. Single green pod weights varied between 2.91 and 3.76 g. Pod lengths varied between 10.86 and 12.43 cm; pod widths varied between 10.32 and 11.31 mm. Crude protein contents varied between 14.38 and 17.22% DM; digestible protein contents varied between 65.40 and 75.25% CP. Dry matter ratios of green pods varied between 15.92 and 21.16%. There were positive correlations between yield components and protein characteristics. With regard to protein intake, it was observed that high rates of digestible protein were not taken when the lines with high crude protein contents were consumed. Dry matter contents of the pods decreased with increasing pod weights and lengths.

With this study, sufficient data were generated about 10 vegetable-type guar genotypes, but sufficient previous data are not available to discuss present findings. Of these 10 guar genotypes, plant characteristics (13 attributes), nutritional characteristics (7 attributes) and mineral composition (17 minerals) were investigated together, but partial data were presented in this study and the rest of data are planned to be presented in other papers in a short time.

The first recommendation is to name “Guar” (*Cyamopsis tetragonoloba* (L.) Taub.), which is a new product in Turkey, as “Sakız Fasulyesi” and to use this term in further studies to be carried out by Turkish scientist.

The second recommendation is to fully elucidate the nutritional composition of edible guar pods. In this way, type and quantity of nutrients taken through consumption of green pods could be well-identified and effects (either positive or negative) of such nutrients on human health could be assessed.

The third recommendation is to widespread similar research under different provincial conditions of Turkey. Guar seems to have a potential to be grown in Turkey. Further research is recommended to be carried out about the adaptation of guar types grown for industrial uses and as a feed source to local conditions.

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