VOL. 8, NO. 2, FEBRUARY 2013 ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science

www.arpnjournals.com

IMPACT OF PLANT DENSITY ON YIELD AND YIELD COMPONENTS OF PEA (*Pisum sativum ssp. sativum* L.) CULTIVARS

Derya Ozveren Yucel
The Eastern Mediterranean Agricultural Research Institute Adana, Turkey
E-Mail: deryaozveren@yahoo.com

ABSTRACT

This research was carried out to investigate association between yield and other agronomical characters of different pea cultivars (BOLERO, SPRING and UTRILLO) and plant densities (30, 40 and 50 plants per square metre) under the Mediterranean-type conditions of Turkey, in 2009-10 and 2010-11 growing seasons. All examined traits were influenced by growing seasons and these parameters were higher in 2010-11 compared with 2009-10 due to higher rainfall in the second growing season. Cultivars had significant effect on full pod number, total pod number, seed number, and seed yield. Plant height, first pod height, total pod number and seed yield were affected by plant densities. The SPRING cultivar with plant density of 40 plant m^{-2} may be suggested for winterly pea grown in the Mediterranean-type conditions.

Keywords: pea, plant density, yield, correlation, regression.

INTRODUCTION

Field pea (*Pisum sativum ssp. sativum* L.) is one of the most important grain legume crops, and consumed fresh or canned food, and also dried pea grains are used to make soup after broken in human died. As a rich source of proteins, carbohydrates and vitamins, peas are containing 18 to 28.4% rate of protein in dry grains (Şehirali, 1988). Pea is the fourth leading legume in terms of consumption in the world with a total production of 10.2 million tones (FAO, 2010). On the other hand, field pea plants are used green and dry forage production for animal feeding. As a forage crop, pea hay and seed is rich in crude protein content and most mineral elements (Açıkgöz *et al*., 1985). Further, this crop also plays a significant role in soil fertility restoration as a suitable rotation crop that fixes atmospheric nitrogen and also serves as rotational crop that plays great role in controlling disease epidemics and weeds (Hoorman *et al*., 2009).

Earlier studies show that seeding rate and cultivar are important factors affecting yield and quality of grain legumes (Kibe and Kamithi, 2007; Shirtliffe and Johnston, 2002; Dahmardeh *et al*., 2010). Increasing seeding rate may increase the competition ability of crops, on the other hand profitability of the crop may or may not increase owing to high seed cost in pulses. There is a few research and known information about growth and development response of field pea cultivars to change in plant population. Producers urgently need this information, and a choice of pea cultivars for optimum seed yield and quality in the Mediterranean-type conditions.

The objectives of this study were:

- To determine the most suitable pea cultivar which can be grown under rainfed condition of the Mediterranean,
- To determine the most suitable seeding rate of the pea cultivars under rainfed condition of the Mediterranean,
- To investigate association between yield and other agronomical characters of different pea cultivars and seeding rate in the Mediterranean-type conditions of Turkey.

MATERIALS AND METHODS

Site

The experiments were conducted two consecutive winter seasons from 2009 to 2011. The site located at the Research area of Department of Field Crops of Cukurova University in Adana (35o 18' E, 37o 01' N; 23 m above sea level) in the south of Turkey.

The experiment site had clay soil with pH of 6.7, 1.2% organic matter, 23.6% CaCO3 and 0.09% salt content.

The site has a Mediterranean climate with wet winters and hot dry summers. According to the long-term average from four decades of records, there is early total precipitation of 625 mm and mean temperature 18.7°C.

Mean temperature and total precipitation of the growing seasons during 2009-2010 and 2010-2011 are shown in Figure-1 and Figure-2.

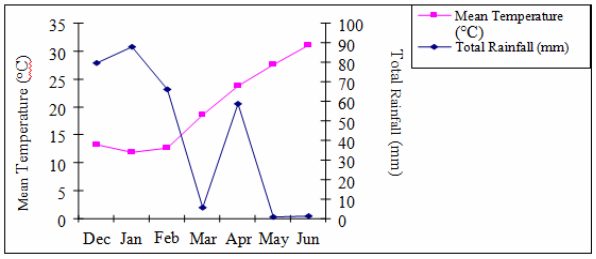

Figure-1. Mean temperature (°C) and total rainfall (mm) in 2009-2010 growing seasons.

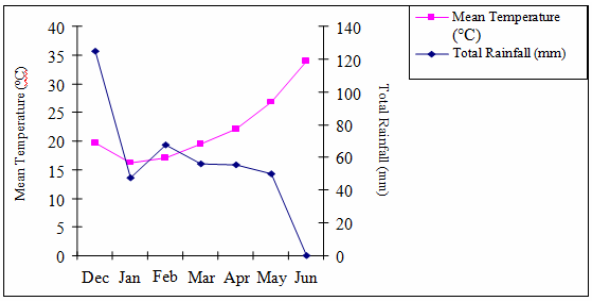

Figure-2. Mean temperature (°C) and total rainfall (mm) in 2010-2011 growing seasons.

Experiment design

In two years, the experiments were conducted in a randomised complete block design (RCBD) with three replicates. The experiment included three pea cultivars (BOLERO, SPRING and UTRILLO) as main plots. Each cultivar was sown at a density of 30, 40 and 50 plants per square metre as sub plots. Each plot was 4 m length and consisted of four rows of pea with 45 cm row-spacing. Experiment area was fertilized with equivalent to 40 kg ha^{-1} N, and 40 kg ha^{-1} P_2O_5 prior to sowing in both growing seasons. Sowings were completed on December 6, 2009 and December 10, 2010.

Data collection

Emergence, Flowering and podding date was recorded when 50% plant emerged, flowered and podded in each sub plot. With references to this, the emergence (December 31, 2010 and January 10, 2011), flowering (March 16, 2010 and March 25, 2011) and podding (March 29, 2010 and from March 26 to April 8, 2011) of the plants were occurred. All plants were harvested at the end of the June during both growing seasons.

The following measurements were recorded from five randomly selected plants from mid-row of each plot: plant height (PH: cm), first pot height (FPH: cm), branch number (BN: number per plant), pod number (PN: number per plant), seed number (SN: number per plant), and seed weight (SW: g per plant). During both seasons, blackish-brown and dried plants were harvested in late June. After harvest, 1000-SW (1000-SW: g) was determined by mixing the whole sample and than 100 seeds were randomly counted, weighted and crossed 10. For seed yields (SY: kg ha^{-1}), all rows were harvested, threshed, cleaned, weighted and converted into kg ha^{-1}.

Statistical analysis

All data for each trait were statistically analysed combine the experimental years according to a randomized complete block design (RCBD) with split plot arrangements. Comparisons between means were made using least significant differences (LSD) at 0.05 probability level. Correlation coefficients were used to determined relationships among the examined traits. Regression analysis was also performed between seed yield and plant densities. All statistical analyses were performed using the SAS program (SAS Institute, 1999).

RESULTS AND DISCUSSIONS

Effect of years

Combined data presented in Table-1 indicated that years were differed significantly in all examined traits. The values of seed yield and yield components were higher in the second growing season compared with the first growing season. Total precipitation and mean temperature in the second growing season was higher than in the first growing season (Figure-1 and Figure-2). Average plant height and first pod height were ranged between 56.4-75.0 cm, and 25.7-33.1 cm, in 2009/10 and 2010/11 growing seasons, respectively. As seen Figures 1 and 2, higher rainfall during the month of March of the second growing season, corresponding to the period of the filling of the podding stage and after the this stage resulted in higher full pod number (average 9.1 and 16.3 number per plant, respectively), total pod number (average 9.3 and 17.4 number per plant, respectively), seed number (average 41.4 and 91.8 number per plant), seed weight (average 7.7 and 18.9 number per plant) 1000-seed weight (average 202.0 and 224.5 g) and seed yield (average 1801.9 and 3163.5 kg ha^{-1}) than that in the first growing season.

These results indicated that seed yield and yield components greatly influenced by environmental factors such as temperature and precipitation. These results are in agreement with results from Anlarsal *et al*. (2001), Bilgili *et al*. (2010) who reported that yield and yield components were significantly affected by years. Further, Gan *et al*. (2003) stated that plants suffered severely from lack of the available soil water during the grown period of legumes.

Besides, positive and significant relationships were found between seed yield and some yield components in this research as seen Table-4. These result illustrated that yield and yield components could be affected by both climatic factors and each other.

Table-1. Summary of main and interaction effects for examined traits (combined analysis of 2009/10 and 2010/11 growing seasons).

Source of variance	Plant height	First pod height	Full pod No.	Total pod No.	Seed No.	Seed weight	1000 SW	Seed yield
Y	*	*	*	*	*	*	*	*
C	NS	NS	*	*	*	NS	NS	*
D	*	*	NS	*	NS	NS	NS	*
Y X C	*	*	NS	NS	NS	NS	*	NS
Y X D	NS	NS	NS	NS	NS	NS	NS	NS
C X D	NS	*	NS	NS	NS	NS	NS	*
Y X C X D	NS	NS	NS	NS	NS	NS	NS	NS

Y: Year; C: Cultivar; D: Plant Densities; Y X C: Year and Cultivar interaction; Y X D: Year and Plant Densities interaction; CXD: Cultivar and Plant Densities interaction; Y X C X D: Year, Cultivar and Plant Densities interaction
* Significant and, NS not significant

Table-2. Effect of pea cultivars and plant densities on seed yield and its components (2009/10, 2010/11 growing seasons and combined years).

	Plant height (cm)			**First pod height** (cm)			**Full pod No.** (No. per plant)			**Total pod No.** (No. per plant)		
Cultivars	**09/10**	**10/11**	**Comb.**	**09/10**	**10/11**	**Comb.**	**09/10**	**10/11**	**Comb.**	**09/10**	**10/11**	**Comb.**
Bolero	57.0 B	71.4	64.2	28.0	29.9 B	28.9	11.9 A	16.0	13.9 A	12.0 A	18.7	15.3 A
Spring	53.0 C	77.5	65.3	23.2	32.3 B	27.8	10.7 A	19.0	14.8 A	10.9 A	19.3	15.1 A
Utrillo	59.1 A	76.1	67.6	25.9	36.9 A	31.4	4.8 B	14.0	9.4 B	5.0 B	14.2	9.6 B
LSD	1.68	NS	NS	NS	3.95	NS	2.25	NS	3.30	2.15	NS	2.24
Plant densities (plant m^{-2})												
30	52.7 B	71.3	62.0 B	23.9	31.6	27.7 B	9.2	15.4	12.3	9.4	16.8 B	13.1 AB
40	55.0 B	74.4	64.7 B	25.1	33.4	29.3 AB	9.5	18.6	14.1	9.6	20.1 A	14.9 A
50	61.4 A	79.3	70.4 A	28.1	34.2	31.1 A	8.7	15.0	11.8	8.9	15.3 B	12.1 B
LSD	2.67	NS	3.34	NS	NS	2.33	NS	NS	NS	NS	2.78	2.10

LSD: Least significant difference (P = 0.05); NS: not significant

Effect of cultivars

According to Table-2, results of statistical analysis indicated that, UTRILLO cultivar recorded the highest plant height in the first growing season and first pod height in the second growing season. Further, as seen Table-4, plant height was positively and significantly correlated with first pod height. Cultivars had a significant effect on full pod number, total pod number, seed weight, 1000-seed weight and seed yield. BOLERO and SPRING cultivars produced the highest full, total pod number and seed weight in the first growing season; however there was no significant effect on these traits in the second growing season (Table-2 and Table-3). The data presented in Table-3 shows that the highest 1000-seed weight was obtained from UTRILLO cultivar, which had the least full and total pod number. Negatively correlation between 1000-seed weight and full, total pod number indicated that increasing these traits in pea cultivar decrease 1000-seed weight of the pea cultivar. According to data regarding seed yield of pea cultivars, BOLERO and SPRING cultivars gave the highest seed yield in both growing seasons. Highly significant positive correlations between seed yield and full pod, total pod number, seed number and seed weight illustrate the importance of these traits for seed yield of pea.

Combined data presented in Table-1 showed that, cultivars had significant effect on full pod number, total pod number, seed number, and seed yield. The highest full pod, total pod, seed number and seed yield were obtained from the BOLERO and the SPRING cultivars, whereas the lowest values were recorded in the UTRILLO cultivar (Table-2 and Table-3). These results are in agreement with Spies *et al*. (2010), Tekeli and Ates (2003), Anlarsal *et al*. (2001). As seen Table-4, seed number was significantly and positively correlated with full pod and total pod number. In terms of seed yield, data given in Table-4 showed that positive and significant correlation between seed yield and full pod, total pod, seed number and seed

weight functioned as major contributors to seed yield of pea. These results represented that selection based on full pod, total pod, seed number and seed weight increase seed yield. Similar results were obtained by Togay *et al*. (2008) and Anlarsal *et al*. (2001). On the other hand, there were no significantly differences among cultivars in terms of plant height, first pod height, seed weight and 1000-seed weight (Table-2). Similar result was reported by Türk *et al*. (2011) who reported that there were no significantly differences among cultivars in terms of plant height.

Table-3. Effect of pea cultivars and plant densities on seed yield and its components (2009/10, 2010/11 growing seasons and combined years).

	Seed No. (No. per plant)			**Seed weight** (g per plant)			**1000-Seed weight** (g)			**Seed yield** (kg ha^{-1})		
Cultivars	**09/10**	**10/11**	**Comb.**	**09/10**	**10/11**	**Comb**	**09/10**	**10/11**	**Comb.**	**09/10**	**10/11**	**Comb.**
Bolero	45.2	97.7	71.4 A	8.6 A	19.5	14.1	168.7B	242.9	205.8	2038.6 A	3179.3 B	2608.9 A
Spring	50.1	107.7	78.9 A	8.8 A	19.2	14.0	180.1B	184.9	182.5	2061.7 A	3722.1 A	2891.9 A
Utrillo	28.9	70.0	49.5 B	5.7 B	18.1	11.9	257.1 A	245.8	251.5	1305.6 B	2589.2 C	1947.4 B
LSD	NS	NS	16.35	2.10	NS	NS	19.84	NS	NS	585.3	390.1	383.4
Plant densities (plant m^{-2})												
30	36.6	89.2	62.9	8.3	18.5	13.4	199.4	226.8	213.1	1748.4	2833.3B	2290.9 B
40	45.3	98.3	71.8	7.8	21.3	14.6	207.5	226.2	216.9	1861.1	3497.5A	2679.3 A
50	42.3	87.8	65.1	7.1	17.0	12.1	199.0	220.6	209.8	1796.3	3159.7AB	2478 AB
LSD	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	377.53	222.0

LSD: Least significant difference (P = 0.05); NS: not significant

Effect of plant densities

According to Table-1, results of statistical analysis indicated that, plant density had a significant effect on plant height in the first growing season, total pod number and seed yield in the second season. The highest plant height in the first growing season recorded from 50 plant m^{-2} of plant density, also 40 plant m^{-2} of plant density produced the highest total pod number and seed yield in the second year.

Combined data presented in Table-2 showed that, plant height, first pod height, total pod number and seed yield were affected by plant densities. In term of plant height 50 plant m^{-2} of plant density was ranked as first. Similar to plant height, the highest first pod height was obtained from 50 plant m^{-2} of plant density and, fallowed by 40 plant m^{-2} of plant density. Plant height and first pod height were increased linearly by increasing plant population due to competition of plants in higher densities on light, resulting in taller plants. Similar findings were achieved by Inanç and Yıldırım (2007), who indicated that denser plant population of pea increased plant height due to competition among plants. Furthermore, plant height was significantly and positively correlated with first pod height. Thus, 50 plant m^{-2} of plant density with the highest plant height had the highest first pod height in this research. Togay et al. (2008) and Çokkızgın and Çölkesen (2007) stated that positive and significant relationship was found between plant height and first pod height in pea cultivars. In terms of total pod number, 40 plant m^{-2} of plant density gave the highest value and followed by 30 plant m^{-2} of plant density, whereas the lowest value was obtained from 50 plant m-2 of plant density (Table-2).

According to data regarding to seed yield of pea showed that the highest seed yield was obtained from 40 plant m^{-2} of plant density with 2679.3 kg ha^{-1} and followed by 50 plant m^{-2} of plant density with 2478.0 kg ha-1 (Table-3).

The response of seed yield could be explained by quadratic equations and also to increasing the plant density revealed a peak seed yield at approximately 40 plant m^{-2} in the Mediterranean-type conditions (Figure-3). As plant density increased from 30 plant m^{-2} to 40 plant m^{-2}, seed yield of pea increased by 16.95% in the combined of the two years. Further increases in plant density result in additional input cost, but increasing plant density does not significantly return an increase in seed yield. These results are in agree with results of Gan *et al*. (2003) who reported that the seed yield of dry pea increased with increasing plant population densities from 30 to 80 plant m^{-2} and optimum plant population for maximizing seed yield as 60 to 70 plants m^{-2} for dry pea.

Effect of interaction between year and cultivar

Data presented in Table-1 showed that the interaction between pea cultivars and years had significant effect on plant height, first pod height and 1000-seed weight. The highest plant height was obtained from the SPRING cultivar and, followed by the UTRILLO cultivar in the second growing season, whereas the lowest value was obtained from the SPRING cultivar in the first growing season. In terms of first pod height, the UTRILLO cultivar in the second growing season recorded the highest value, but the SPRING cultivar in the first growing season gave the lowest value. The UTRILLO cultivar in both growing season and the BOLERO cultivar

in the second growing season produced the highest 1000-seed weight. On the other hand, the SPRING cultivar in both growing seasons and the BOLERO cultivar in the first growing season produced the lowest 1000-seed weight. There were no significantly differences among genotypes in terms of plant height, first pod height and 1000-seed weight (Table-2). On the other hand, interaction between pea cultivars and years had significant effect on these traits. This result shows that these traits were influenced by environmental factors. These results are in agreement with Bilgili *et al*. (2010), who reported that genotype X environment interaction showed significance for plant height of pea.

Effect of interaction between cultivar and plant densities

Combined data demonstrated that the interaction between cultivar and plant density had significant effect on first pod height and seed yield (Table-1). Although, there was no significantly differences among pea cultivars, the UTRILLO cultivar had the highest value with regard to first pod height. Similarly, the highest value was obtained from the highest plant density. Thus, the highest first pod height was obtained from the UTRILLO cultivar in the highest plant density. As reasons described above, the lowest value was recorded from the SPRING cultivar in the lowest plant density.

The SPRING cultivar in plant density of 30 and 40 plant m^{-2} and the BOLERO cultivar in plant density of 40 and 50 plant m^{-2} produced the highest seed yield, also followed by the SPRING in plant density of 50 plant m^{-2}. On the other hand, the UTRILLO cultivar in plant density of 30 plant m^{-2} recorded the lowest seed yield. These results demonstrate that, performance of the pea cultivars may vary according to plant density. This result has previously been described (Gan et al., 2003; Spies et al., 2010; Türk et al., 2011).

Table-4. Correlation among seed yield and its components during 2009-2011 years (n=54).

Variable	by Variable	Correlation	Signif Prob	Plot Corr
First Pod Height	Plant Height	0,7693	<,0001	
Full Pod Number	Plant Height	0,5479	<,0001	
Full Pod Number	First Pod Height	0,3448	0,0107	
Total Pod Number	Plant Height	0,5457	<,0001	
Total Pod Number	First Pod Height	0,3482	0,0099	
Total Pod Number	Full Pod Number	0,9467	<,0001	
Seed Number	Plant Height	0,6707	<,0001	
Seed Number	First Pod Height	0,4318	0,0011	
Seed Number	Full Pod Number	0,7841	<,0001	
Seed Number	Total Pod Number	0,8392	<,0001	
Seed Weight	Plant Height	0,6987	<,0001	
Seed Weight	First Pod Height	0,4898	0,0002	
Seed Weight	Full Pod Number	0,8340	<,0001	
Seed Weight	Total Pod Number	0,8470	<,0001	
Seed Weight	Seed Number	0,7753	<,0001	
1000 Seed Weight	Plant Height	0,1909	0,1667	
1000 Seed Weight	First Pod Height	0,1206	0,3851	
1000 Seed Weight	Full Pod Number	-0,2653	0,0525	
1000 Seed Weight	Total Pod Number	-0,1281	0,3561	
1000 Seed Weight	Seed Number	-0,0490	0,7249	
1000 Seed Weight	Seed Weight	0,0454	0,7443	
Seed Yield	Plant Height	0,6161	<,0001	
Seed Yield	First Pod Height	0,3996	0,0028	
Seed Yield	Full Pod Number	0,7900	<,0001	
Seed Yield	Total Pod Number	0,8043	<,0001	
Seed Yield	Seed Number	0,7988	<,0001	
Seed Yield	Seed Weight	0,7695	<,0001	
Seed Yield	1000 Seed Weight	-0,1875	0,1747	

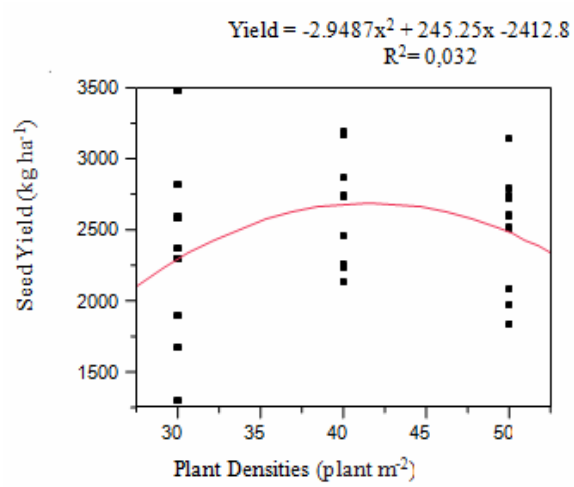

Figure-3. Relationship between planting densities and seed yield in combined of the two years.

CONCLUSIONS

From the above results and discussion, the used cultivars have different seed's characters which can significantly affect their performance and the SPRING cultivar may be suggested for winterly pea grown due to higher seed yield than that of the UTRILLO cultivar in this research. Plant density of approximately 40 plant m^{-2} may be more suitable for pea grown in the Mediterranean-type conditions and increasing in plant density does not significantly return from the increase in seed yield.

REFERENCES

Açıkgöz E., V. Katkat, S. Omeroğlu and B. Okan. 1985. Mineral elements and amino acid concentrations in field pea and common vetch herbages and seeds. J. Agron. Crop Sci. 55: 179-185.

Anlarsal A.E., C. Yücel and D. Özveren. 2001. A Research on Determination of Yields and Adaptation of Some Pea (*Pisum sativum ssp. sativum* L. ve Pisum sativum ssp. avense L.) Lines at Conditions of Çukurova. J. Agric. Fac. Ç.Ü. 16 (3): 11-20.

Bilgili U., A. Uzun, M. Sincik, M. Yavuz, B. Aydınoğlu, S. Çakmakcı, H. Geren, R. Avcıoğlu, İ. Nizam, A.S. Tekeli, İ. Gül, E. Anlarsal, C. Yücel, M. Avcı, Z. Acar, İ. Ayan, A. Üstün and E. Açıkgöz. 2010. Forage Yield and Lodging Traits in Pea (*Pisum sativum* L.) with Different Leaf Types. Turkish J. of Field Crops. 15(1): 50-53.

Çokkızgın A and M. Çölkesen. 2007. The determination of relationship between yield and yield components by using correlation and path coefficient analysis methods for pea (*Pisum sativum* L.). Turkish VII. Field Crops Congress, 25-27 July 2007, pp. 649-652 Erzurum.

Dahmardeh M, M Ramroodi and J Valizadeh. 2010. Effect of Plant Density and Culticars on Growth, Yield and Yield Components of Faba Bean (*Vicia faba* L.). Afr J. of Biot. 9(50): 8643-8647.

FAO. 2010. http://faostat.fao.org/site/339/default.aspx.

Gan Y.T., P.R. Miller, B.G. McConkey, R.P. Zentner, P.H. Liu and C.L. McDonald. 2003. Optimum Plant Population Density for Chickpea and Dry pea in a Semiarid Environment. Can. J. Plant Sci. 83: 1-9.

Hoorman J.J., R. Islam and A. Sundermeier. 2009. Sustainable Crop Rotations with Cover Crops. OSU, Agriculture and Natural Resources. Fact Sheet.

Inanç S and B. Yıldırım. 2007. The Effect of Different Row Space Applications on the Yield and Yield Components in Pea (*Pisum sativum* L.). Turkish VII. Field Crops Congress, 25-27 July, Erzurum.

Kibe A.M. and D.K. Kamithi. 2007. Production Potential of Desi Chickpea Grown under Various Nitrogen and Planting Densities at Naivasha. Agricultural Journal. 2(4): 520-525.

SAS Institute. 1999. SAS/STAT user's guide. 8. Version. SAS Institute Inc. Cary. NC.

Shirtliffe S.J. and A.M. Johnston. 2002. Yield-Density relationships and Optimum Plant Populations in two Cultivars of Solid-Seeded Dry Bean (*Phaseolus vulgaris* L.) Grown in Saskatchewan. Can. J. Plant Sci. 82: 521-529.

Spies J.M., T. Warkentin and S.J. Shirtliffe. 2010. Basal Branching in Field Pea Cultivars and Yield-Density Relationships. Can. J. Plant Sci. 90: 679-690.

Şehirali S. 1988. Yemeklik Tane Baklagiller. Ankara. p. 314, 435.

Tekeli A.S. and E. Ateş. 2003. Yield and Its Components in Field Pea (*Pisum arvense* L.) Lines. J. of Central European Agriculture. 4(4): 313-317.

Togay N., Y. Togay, B. Yıldırım and Y. Doğan. 2008. Relationships Between Yield and Some Yield Components in Pea (*Pisum sativum ssp arvense* L.) Genotypes by using Correlation and Path Analysis. African J. of Biotechnology. 7(23): 4285-4287.

Türk M., S. Albayrak and O. Yüksel. 2011. Effect of Seeding Rate on the Forage Yields and Quality in Pea Cultivars of Different Leaf Types. Turkish J. of Field Crops. 16(2): 137-141.