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FORAGE YIELD AND LODGING TRAITS IN PEAS (*Pisum sativum* L.) WITH DIFFERENT LEAF TYPES

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ABSTRACT

Two semi-leafless and four leafed pea (*Pisum sativum* L.) genotypes were evaluated for plant height, lodging scores, and forage yield in eight diverse locations with typical Mediterranean or Mediterranean-type climate in the 2001-2002 and 2002-2003 growing seasons. The genotypes used in this study were forage type with indeterminate growing habit. Significant differences among pea genotypes were found for all traits over years and locations. All interactions which related to G × E interaction showed significance (P>0.01) for all traits. The forage yield of the pea genotypes averaged 26605 kg ha^{-1} and the highest yield was obtained from the leafed genotype Urunlu. Its forage yield reached to 35970 kg ha^{-1} yield level at Samsun location.

Key words: pea; *Pisum sativum* L.; leafed; semi-leafless; yield; forage

INTRODUCTION

Peas (*Pisum sativum* L.) are grown for forage, grain (feed and food) and vegetable purposes. Consequently, peas have been differentiated different distinct types including forage and grain (Cousin, 1997).

Conventional leafed pea cultivars have some undesired traits: a dense leaf canopy that shadows the lower parts of the plant; a less well-lit crop interior that reduces photosynthetic activity of the lower leaves; and susceptiblity to pathogen attacks due to increased moisture under shaded conditions (Goldman et al., 1992). Semi-leafless genotypes are less susceptible to lodging (Davies, 1977), and produce satisfactory forage and seed yield as high as those of cultivars with conventional leaves (Heath and Hebblethwaite, 1985). Reduction in forage and seed yield have often been attributed to lodging, which is particularly evident in the leafed varieties, while the semi-leafless phenotypes are less susceptible (Koivisto et al., 2003 and Uzun et al., 2005). Semi-leafless peas help delay the onset of lodging, because their tendrils support the crop for an erect manner (Heath and Hebblethwaite, 1985), thereby allowing growers to harvest mechanically without soil contamination.

The objectives of this study were to evaluate forage yield, plant height and lodging of indeterminate type of leafed and semi leafless pea genotypes at selected locations with typical Mediterranean and Mediterranean-type climate in winter field peas.

Table 1. Locational and climatic characteristics (long-term average) of experimental locations

Location	Latitude	Longitude	Altitude (m)	Prec.[a] (mm)	Temp.[b] (°C)	W.Temp.[c] (°C)	H.Temp.[d] (°C)	L.Temp.[e] (°C)
Adana	36°59′N	35°18′E	20	647	18.7	10.2	45.6	-11.2
Antalya	36°53′N	30°42′E	42	1068	18.7	10.9	44.6	-4.6
Bursa	40°11′N	29°04′E	70	699	14.8	6.5	42.6	-25.7
Diyarbakir	37°55′N	40°12′E	660	496	15.9	3.2	46.2	-24.2
Dogankent	36°48′N	35°15′E	12	774	18.3	10.0	40.8	-10.2
Izmir	38°24′N	27°10′E	25	700	17.6	9.6	42.7	-8.2
Samsun	41°17′N	36°20′E	44	735	13.5	7.8	39.0	-9.8
Tekirdag	40°59′N	27°29′E	4	591	13.8	5.6	37.0	-13.5

[a]: Total precipitation, [b]: Annual average temperature [c]: Average winter temperature for the December-February period, [d]: Highest temperature recorded, [e]: Lowest temperature recorded

Table 2. Variance analysis of plant height, lodging scores, and forage yield.

Variation Source	DF	F- test			
		Plant Height	Logging Score		Forage Yield
			full flowering	pod filling	
Year (Y)	1	**	*	**	**
Location (L)	7	**	**	**	**
Genotype (G)	5	**	**	**	**
Block (Y x L)	32	**	ns	Ns	**
Y x L	7	**	**	**	**
Y x G	5	ns	**	**	**
L x G	35	**	**	**	**
Y x L x G	35	**	**	**	**

MATERIALS AND METHODS

Six pea genotypes were grown to test forage yield at eight different locations with typical Mediterranean or Mediterranean-type climate during the 2001-2002 and 2002-2003 growing seasons. The pea genotypes used in this study were improved by pea breeding program in Uludag University, Bursa, Turkey. The selection criteria to improve pea genotypes were: high forage yield, winter hardiness, early maturity, and indeterminate growth habit. Bulk selection method was applied in improvement of lines, as decribed by Acikgoz et al (2009). The pea genotypes tested in this study were Kirazli (semi-leafless, purple flowered), Ulubatli (semi-leafless, white flowered), P98, P101, Golyazi and Urunlu (all leafed and white flowered). Kirazli, Ulubatli, Golyazi and Urunlu were officially registered and released in Turkey in 2007. Yield trials were carried out in the following locations: Adana, Antalya, Bursa, Diyarbakir, Dogankent, Izmir, Samsun and Tekirdag. With the exception of Diyarbakir, all are situated in the coastal regions of Turkey, with very low altitudes as shown in Table 1.

In general, the soil in these areas was clay loam, slightly alkaline (pH = 7.2-8.0), rich in potassium (527-1100 kg ha^{-1}), medium in phosphorus (22-142 kg ha^{-1}) and containing 1.1-2.4% organic matter. Adana, Antalya and Dogankent have a typical Mediterranean climate while the other locations have a Mediterranean type climate. Typical Mediterranean climate is characterized with mild and wet winter and spring seasons; and hot and dry summers. Precipitation patterns are similar, but winters are generally cooler in the Mediterranean-type climate.

For the eight locations, long-term average total precipitation varied from 496 mm to 1068 mm $year^{-1}$, with 60-70% of the yearly precipitation occurring during the pea-growing season. Long-term average annual temperature of the locations was 16.4°C, with yearly average temperatures ranging from 13.5°C to 18.7°C, and with the highest temperature recorded exceeding 40°C in most locations. The average winter temperature varied from 3.2°C to 10.9°C between locations, with unusual drops observed in some years (Table 1).

At each location, field experiments were arranged in a randomized complete block design with four replicates. The plots were 14 m^2 (1.4 × 10.0 m), comprising 8 rows spaced 17.5 cm apart. In Bursa and Samsun, sowing was done with an experimental driller. At the other locations, seeds were hand planted. In all experiments seeding rate was 100 viable seeds m^{-2}. Fertilizers were applied before planting at the rate of 30 kg ha-1 N and 60 kg ha-1 P_2O_5. Experiments were carried out between 11 and 21 November, 2001 and 1 and 27 November, 2002. Throughout the experiment, irrigation was not applied and weeds were controlled by hand. Forage yield was measured at full flowering stage in an area of 3 m^2. The plants were cut from ground level and the forage was dried in the oven at 70°C for 48 h.

Five plants were randomly sampled from each plot at full flowering stage to determine plant height every year. At the full flowering and pod filling stages, lodging was rated on a 1-5 scale, where 5 = no lodging and 1= entire plot lodged.

Analysis of variance (ANOVA) and other statistical analyses were performed with the statistical package JMP 5.0.1 (SAS, 1989-2002). The significance of treatment, main effects and interactions were determined at the 0.05 and 0.01 probability levels, by the F-test. For multiple comparison of varieties, least significant difference ($LSD_{0.05}$) was used to separate means.

Table 3. Genotype x location interaction of average plant height values of pea genotypes (cm).

Locations	Genotypes					
	Ulubatli	Kirazli	Urunlu	Golyazi	P101	P98
Antalya	158.3 d	161.4 cd	155.9 d	152.3 d-f	154.7 de	151.7 d-g
Bursa	133.4 ıj	126.0 jk	131.1 ı-k	126.8 jk	133.9 ıj	131.9 ıj
Diyarbakir	96.1 m-o	90.9 n-p	79.1 p	80.8 p	90.5 n-p	81.9 p
İzmir	102.8 m-o	95.7 no	97.3 m-o	103.7 mn	89.3 op	102.0 m-o
Samsun	139.1 f-j	134.7 ıj	128.4 ı-k	132.5 ıj	137.7 h-j	138.7 g-j
Tekirdag	117.6 kl	127.5 ı-k	100.6 m-o	110.1 lm	101.4 m-o	98.6 m-o
Dogankent	172.9 a-c	161.0 cd	153.6 de	185.0 a	163.8 cd	176.9 ab
Adana	162.5 cd	141.7 e-ı	152.9 de	150.6 d-h	158.3 d	165.0 b-d

Table 4. Genotype x location interaction of average lodging score values of pea genotypes at full flowering stage.

Locations	Genotypes					
	Ulubatli	Kirazli	Urunlu	Golyazi	P101	P98
Antalya	5.0 a	4.8 ab	4.0 de	5.0 a	4.8 ab	4.2 cd
Bursa	3.8 d-f	4.2 cd	3.7 ef	3.8 d-f	2.8 h	3.5 fg
Diyarbakir	4.5 bc	4.7 ab	3.8 d-f	3.8 d-f	3.2 gh	3.5 fg
İzmir	5.0 a	5.0 a	4.0 de	4.0 de	3.0 h	3.1 gh
Samsun	3.8 d-f	3.8 d-f	3.0 h	3.5 fg	3.0 h	4.0 de
Tekirdag	4.8 ab	5.0 a	4.0 de	3.5 fg	3.5 fg	4.0 de
Dogankent	4.0 de	4.0 de	3.5 fg	3.5 fg	3.5 fg	3.5 fg
Adana	4.8 ab	5.0 a	4.0 de	3.8 d-f	3.7 ef	4.2 cd

Table 5. Genotype x location interaction of average lodging score values of pea genotypes at pod filling stage.

Locations	Genotypes					
	Ulubatli	Kirazli	Urunlu	Golyazi	P101	P98
Antalya	2.5 g-ı	2.5 g-ı	2.0 j-l	2.8 e-g	2.5 g-ı	2.0 j-l
Bursa	1.3 n-p	1.0 p	1.0 p	1.0 p	1.0 p	1.2 op
Diyarbakir	3.2 c-e	3.3 cd	2.3 h-j	2.3 h-j	2.3 h-j	1.7 l-n
İzmir	4.9 a	4.9 a	4.0 b	3.5 c	3.3 cd	3.5 c
Samsun	1.5 m-o	1.5 m-o	1.0 p	1.2 op	1.0 p	1.0 p
Tekirdag	3.0 d-f	3.0 d-f	2.0 j-l	2.0 j-l	2.0 j-l	2.0 j-l
Dogankent	1.5 m-o	1.5 m-o	1.5 m-o	1.5 m-o	1.5 m-o	1.5 m-o
Adana	2.7 f-h	3.0 d-f	2.3 h-j	2.3 h-j	1.8 k-m	2.2 ı-k

RESULTS AND DISCUSSION

Analysis of variance indicated that there were significant differences in plant height among locations (L), pea genotypes (G), and L x G interaction in 2-years averages (Table 2). Pea genotypes showed significance for plant height averaging 1.30 m (Table 3). Highest plant heights were obtained from leafed genotypes; Golyazı (185.0 cm) and P98 (176.9 cm), and semi leafless genotype; Ulubatlı (172.9 cm) in Dogankent location. Diyarbakır location gave the shortest plant heights in all genotpes. Plant heights were clearly longer than those observed in previous studies with determinate type genotypes grown at the same location (Uzun and Acikgoz, 1998) or in different climatic conditions (Monti, 1983). However, it is well known that pea cultivars with an indeterminate growth habit have a greater proportion of their vegetative growth after flowering as compared to determinate pea cultivars (Hauggaard-Nielsen and Jensen, 2001). A taller cultivar is also considered desirable for forage production (Koivisto et al., 2003).

Analysis of variance for yield showed that there was significant difference for forage yield among locations (L), pea genotypes (G), and L x G interaction in 2-year averages (Table 2). The forage yield of the genotypes averaged 26603 kg ha^{-1}. Forage yield produced by genotypes ranged from 16070 to 35970 kg ha^{-1} with an average protein concentration of 15.3 % in some genotypes and some locations (Table 6). Forage yield of leafed genotypes Urunlu, Golyazi and P98 and semi-leafless Ulubatlı were significantly higher than those of other two genotypes. Semi-leafless genotype Ulubatli produced forage yield as leafed genotype Urunlu. Lowest forage yields were obtained from P101 (18920 kg/ha) in Adana and P98 (16070 kg/ha) in Tekirdag location. The pea genotypes reached full flowering in mid or late April and were harvested for forage in late April or at the beginning of May in the different years and locations. The temperature and moisture conditions favored the vegetative development. In the early spring due to slightly increasing air temperature and longer days, natural flush of growth was observed. Thus, very high forage yield values were obtained. Average forage yield of our pea genotypes was clearly higher than that of previous experiment (Biederbeck and Boudman, 1994). Differences among leafed and semi-leafless genotypes for forage and dry matter yield were not consistent for experimental years.

Table 6. Genotype x location interaction of average forage yields values of pea genotypes (kg ha^{-1}).

Locations	Genotypes					
	Ulubatli	Kirazli	Urunlu	Golyazi	P101	P98
Antalya	35020 ab	29380 d-h	26980 f-j	25530 h-m	22680 k-q	29910 c-g
Bursa	35450 ab	31490 b-e	32440 a-d	33190 a-d	27580 e-ı	33340 a-d
Diyarbakir	22870 k-q	27520 e-ı	20480 o-q	24440 ı-o	23630 ı-p	20980 n-q
İzmir	29840 d-g	30800 c-f	32850 a-d	33990 a-c	20240 pq	32570 a-d
Samsun	29840 d-g	27680 e-ı	35970 a	32360 a-d	22280 l-q	32550 a-d
Tekirdag	20060 pq	23360 j-p	21690 m-q	26360 g-l	22360 l-q	16070 r
Dogankent	23700 ı-p	30120 c-g	25040 ı-n	30250 c-g	23650 ı-p	26730 f-k
Adana	20310 o-q	22860 k-q	21130 nq	20230 pq	18920 qr	20250 pq

Generally, the yield advantage of one leaf type over another was negligible when averaged across genotypes. Contrarily, in studies with different pea genotypes, the highest biomass was obtained in indeterminate leafed varieties, and the poor growth of semi-leafless pea was attributed to lower vigor, green area, photosynthate production and ground cover (Armstrong and Pate, 1994). Analysis of variance indicated that there were significant ($P < 0.01$) differences in lodging score among locations (L), pea genotypes (G), and L x G interaction during the flowering and pod filling stage for 2-years averages (Table 2). Although the best lodging score was taken from semi-leafless genotypes Ulubatli and Kirazlı in different location, worst lodging score was taken from leafed genotypes P101 and P98 (Table 4 and Table 5).

It is well known that leafed pea cultivars exhibit severe lodging after flowering (Stelling, 1997). In close agreement with previous studies (Uzun and Acikgoz, 1998) semi leafless pea genotypes had significantly better standing ability than leafed genotypes. However, semi leafless genotypes showed slightly lower forage yield. The superiority of semi-leafless genotypes in lodging was not observed at full podding. Although semi-leafless genotypes were slightly better than leafed genotypes, all the genotypes severely lodged at the seed harvesting stage (Uzun et al., 2005). The lodging scores were not associated with climatic conditions prevailing during the seed ripening stage. Increase in plant height and pod filling increased the risk of lodging in all experiments. Our results indicate that lodging may not be a serious problem in semi-leafless genotypes until full flowering stage in indeterminate pea genotypes, but all genotypes lodged at the full podding stage. In close agreement with our findings, lodging scores increased by increasing plant height in determinate type. Particularly tall indeterminate genotypes were more susceptible to lodging (Kilgore-Norwquest and Sneller, 2000).

CONCLUSION

Based on the yield trials of six pea genotypes tested in eight locations for two years under the Mediterranean and Mediterranean-type environmental climatic conditions in Turkey, three promising leaf type genotypes Urunlu, Golyazi and P98 could be accepted as desired genotypes for forage yield. However, semi leafless genotype Ulubatli may also be selected because of upright growing habit during cutting stage for forage yield.

Significant genotype × location (G × L) interaction also shows that the same genotype might not give the highest yield in all locations. Urunlu gave highest yield in Samsun. P101 exhibited the best performance in Dogankent and Diyarbakir. Kirazli (semi-leafless), P98 (leafed), and Ulubatli (semi-leafless) had the highest forage yield in Bursa, and Bursa, İzmir, Samsun, and Bursa, Antalya, respectively (Table 6). G × L interaction makes it very difficult to chose variety(ies), and in most cases, it is not practical to recommend specific ones for each location.

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