Turkish Journal of Field Crops, 2011, 16(2): 137-141

EFFECT OF SEEDING RATE ON THE FORAGE YIELDS AND QUALITY IN PEA CULTIVARS OF DIFFERING LEAF TYPES

Mevlüt TÜRK* Sebahattin ALBAYRAK Osman YÜKSEL

Süleyman Demirel University, Faculty of Agriculture, Department of Field Crops, Turkey
Corresponding author's e-mail: mevlutturk@sdu.edu.tr

Received: 22.09.2011

ABSTRACT

This study aimed to determine the effects of four seeding rates (75, 100, 125 and 150 plant m^{-2}) on forage yield and quality of pea cultivars (*Pisum sativum* L.) of differing leaf types. Two semi-leafless cultivars (Ulubatli and Kirazli), two leafed cultivars (Golyazi and Urunlu) were used in this research. Plant height, plants number per m^2, seeds number per pod, lodging scores, 1000 seed weight, forage yield, DM yield, seed yield, forage CP yield and seed CP yield were determined. According to two years averages, Golyazi had the highest 1000 seed weight, forage yield, DM yield, seed yield, forage CP yield and seed CP yield. Semi-leafless pea cultivars (Ulubatli and Kirazli) had significantly better standing ability than normal leaf cultivars (Urunlu and Golyazi). Increasing seed rates resulted in an increase in plants per m^2, lodging scores, forage yield, DM yield and forage CP yield. However, increasing seed rates caused decrease in seeds per pod and seed CP yield in two years averages.

Keywords: Dry matter yield, Lodging scores, *Pisum sativum*, Seed yield, Semi-leafless

INTRODUCTION

Field pea *(Pisum sativum* L.), a native of southwest Asia, was among the first crops cultivated by man (Zohary and Hopf 2002). Field pea has a benefit over many other crops in that it has the ability to fix its own nitrogen. This makes it useful not only as an alternative crop but also adds rotational benefits. Peas are widely grown for hay, pasturage or silage production either alone or mixed with cereals (McKenzie and Sponer 1999). As a forage crop, pea hay and seed is rich in crude protein content, and most mineral elements (Acikgoz et al. 1985).

There are two main leaf types in field pea. One has normal leaves; the second type is the semi-leafless type that has modified leaflets reduced to tendrils with vine lengths of two to four feet (Zohary and Hopf 2002). The first commercial cultivars of semi-leafless pea were released in the early 1980s (Martin et al. 1994). The main reason for the semi-leafless pea becoming popular was because of their improved standing ability (Heath and Hebblethwaite 1985 b). In semi-leafless cultivars, the leaflets are replaced with tendrils, the end result being less leaf area but better resistance to lodging (May et al. 2003). Reduced lodging aids in mechanical harvesting (Martin et al. 1994). Previous work showed that semi-leafless pea genotypes with reduced plant height had better light interception and canopy aeration than normal leaf types (Zain et al. 1983; Cawood 1987). It also showed increased dry matter partitioning to fruits, improved water use efficiency and decreased susceptibility to fungal diseases (Berry 1985; Snoad 1985; Armstrong 1989). The ability of semi-leafless cultivars to withstand lodging and disease, and the fact that their morphology allows better aeration within the canopy, has all contributed to their commercial importance (Cote et al. 1992). In recent years, semi-leafless peas were preferred in mixtures over the leafed varieties (Rauber et al. 2001). However, semi-leafless peas were reported to be less competitive than leafed peas (Semere and Froud-Williams 2001).

Previous studies have shown that seeding rate is an important factor affecting yield of grain legumes. Therefore, yield response of grain legumes to seeding rates were discussed by several workers, and different relative values between hay and seed yield with seeding rate were found (Murray and Auld 1987, McEwen et al. 1988, Stutzel and Aufhammer 1992, Martin et al. 1994, Uzun and Acikgoz 1998).

The main objectives of this study were to evaluate the influence of seeding rate upon plant development, dry matter and seed yield of four pea cultivars varying in foliage type.

MATERIALS AND METHODS

The field experiments were conducted in 2009 and 2010 at Isparta (37^o 45' N, 30^o 33' E, elevation 1035 m) located in the Mediterranean region of Turkey. Total precipitation was 189 mm in 2009 (March – June) and 177 mm in 2010. The long-term average is 208 mm. Average temperature was 13.1 ^oC in 2009 and 13.9 ^oC in 2010. The long- term average is 12.8 ^oC.

The major soil characteristics, based on the method described by Rowell (1996) were as follows: the soil texture was clay-loam (clay: 29,3%, silt: 46.8%, sand: 23.9%); organic matter was 1.2% by the Walkley-Black method; total salt was 0.35%; lime was 8%, sulphur was 16 mg kg^{-1}, extractable P by 0.8N $NaHCO_3$ extraction was 3.1 mg kg^{-1}; exchangeable K by 1N NH_4OAc was 125 mg kg^{-1}; pH was 7.1 in soil saturation extract. Soil type was a calcareous fulvisol.

The experiments were established in a randomised complete block design with three replications in March in 2009 and 2010. Two semi-leafless cultivars (Ulubatli and Kirazli), two leafed cultivars (Golyazi and Urunlu) were used in this research. All cultivars were seeded at four different seeding rates (75, 100, 125 and 150 seeds m^{-2}). Germination tests were conducted prior to seedling so that the targeted plants m^{-2} could be achieved. Individual plot size was 1.8 × 6 m = 10.8 m^2, consisting of eight row spaced 30 cm. A fertilizer application (30 kg ha^{-1} N, 50 kg ha^{-1} P_2O_5) was uniformly sprayed after sowing. The experiment was repeated on an adjacent site in the second year.

The number of seedlings was counted in area of 1 m^2 in the center of each plot.

Five plants were randomly sampled from each plot near maturity to determine plant height, pods number per plant, seeds number per pod and seeds number per plant characteristics every year. At maturity, plots were harvested by hand. Seed yield was determined after cleaning the seeds. Four replicated 100-seed lots were weighed to determine 1000 seed weight.

The lodging scores (on a scale of 1-5: 1: severely lodged, 5: upright) were taken for each plot at the flowering stage and ripening seed stage (Uzun et al. 2005).

Every year, nitrogen was determined by the micro kjeldahl technique on duplicate dry matter and seed samples for each cultivars. Crude protein content (N×6.25) and then crude protein yields were calculated.

The data from 2009 and 2010 were analysed together using the Proc GLM (SAS 1999). Means were separated by LSD at the 5 % level of significance.

RESULTS

The cultivar x seeding rates interactions for pods number per plant, seeds number per plant, 1000 seed weight and seed yield were statistically significant in two years averages (Table 1). These interactions indicated that seeding rates affected pods number per plant, seeds number per plant, 1000 seed weight and seed yield differently according to different cultivars (Table 2).

Table 1. Results of Analysis of Variance Traits Determined.

Source of Variance	DF	Plant Height	Plant Number /m^2	Pods Number /Plant	Seeds Number /Pod	Seeds Number /Plant	1000 Seed Weight	Lodging Scores Flowering Stage	Lodging Scores Ripening Seed	Forage Yield	Dry Matter Yield	Seed Yield	CP Yield Forage	CP Yield Seed
Year (Y)	1	ns	**	ns	**	**	**	ns	Ns	ns	ns	**	ns	**
Block (year)	4	ns	**	ns	ns	ns	ns	ns	Ns	ns	ns	ns	ns	ns
C	3	ns	ns	**	ns	**	**	**	**	**	**	**	**	**
C x Y int.	3	ns	ns	ns	ns	ns	**	ns	Ns	ns	ns	ns	ns	ns
SR	3	ns	**	**	**	**	**	**	**	**	**	**	**	**
SR x Y int.	3	ns	ns	ns	ns	ns	ns	ns	Ns	ns	ns	ns	ns	ns
C x SR int.	9	ns	ns	**	Ns	**	*	ns	Ns	ns	ns	*	ns	ns
C x SR x Yint.	9	ns	ns	ns	Ns	ns	ns	ns	Ns	ns	ns	ns	ns	ns

DF, degrees of freedom; ns, not significant. * : P < 0.05, ** : P < 0.01.

The ANOVA for all components except plant height, plants number per m^2 and seeds number per pod indicated that there were statistically significant differences among pea cultivars in two year averages (Table 1). The semi-leafless cultivars (Ulubatli and Kirazli) had the highest lodging scores at the flowering and ripening seed stages. According to averages of two year, Golyazi had the highest forage yield, DM yield, forage CP yield and seed CP yield **(Table 3).**

The effects of seeding rates were significant for all components except plant height in two year averages. Increasing seed rates resulted in an increase in plants number per m^2, lodging scores, forage yield, DM yield and forage CP yield (Table 3). However, increasing seed rates caused decrease in seeds number per pod and seed CP yield.

DISCUSSION

The differences of the pods number per plant between 75 and 100 seeds per m^2 in all cultivars were statistically insignificant while it was significant in Golyazi cultivars (Table 2). This variation caused significant cultivar x seeding rates interaction for pods number per plant. Plant densities affect all yield components. The number of pods per plant is one of the most important components in determining the yield of several legume crops including pea (Pandey and Gritton 1975). The response of pods per plant at differing densities has been well documented (Meadley and Milbourn 1970). A reduction in flowers and pods per plant with increased density has been frequently reported in grain legumes (Salter and Williams 1967; Meadley and Milbourn

Table 2. The cultivars x seeding rates interactions for pods number per plant, seeds number per plant, 1000 seed weight and seed yield. Figures followed by the same letter do not differ significantly ($P < 0.05$).

	Seeding Rates (seeds m^{-2})			
Cultivars	75	100	125	150
Pods Number/Plant				
Ulubatli	4.07 c-e	3.69 c-f	3.61 d-f	3.94 c-f
Kirazli	4.33 cd	4.43 b-d	3.06 f	3.89 c-f
Urunlu	5.34 ab	5.68 a	5.97 a	4.62 bc
Golyazi	6.18 a	4.33 cd	5.73 a	3.25 ef
Seeds Number/Plant				
Ulubatli	22.88 c-e	19.04 d-f	18.04 ef	20.85 c-f
Kirazli	23.85 b-d	20.71 c-f	15.51 f	20.75 c-f
Urunlu	26.31 a-c	23.59 c-e	29.40 ab	20.04 d-f
Golyazi	31.57 a	23.46 c-e	32.00 a	16.64 f
1000 Seed Weight (g)				
Ulubatli	154.5 e-g	149.4 g-i	145.9 h-j	142.9 ij
Kirazli	173.5 ab	164.4 cd	161.5 c-e	151.8 f-h
Urunlu	143.9 h-j	151.5 f-h	144.3 h-j	139.7 j
Golyazi	177.7 a	169.8 a-c	159.0 d-f	165.3 b-d
Seed Yield (t ha^{-1})				
Ulubatli	1.02 d-g	0.99 e-h	0.97 g-i	0.95 hi
Kirazli	1.12 ab	1.06 cd	1.04 de	0.98 f-i
Urunlu	0.95 hi	1.00 e-h	0.96 hi	0.93 i
Golyazi	1.15 a	1.1 a-c	1.03 d-f	1.07 b-d

1970; Stoker 1975; Kruger 1977; Dominguez and Hume 1978; Bakry et al. 1984; Knott and Belcher 1998). This results in a net loss of total seed yield per individual plant with increases in plant density.

The number of seeds per plant decreased from 75 to 125 seeds per m^2 at the semi-leafless cultivars (Ulubatli and Kirazli) (Table 2). However, the highest numbers of seeds per plant were obtained from 125 seeds per m^2 at the leafed cultivars (Urunlu and Golyazi). Those variations caused significant cultivar x seeding rates interaction for number of seeds per plant.

The thousand seed weight and seed yield decreased linearly as seeding rate increased in semi-leafless cultivars (Ulubatli and Kirazli). However, since the variations in leafed cultivars (Urunlu and Golyazi) were found irregular, significant cultivar x seeding rates interaction for thousand seed weight and seed yield were determined (Table 2). Mean seed weight was inversely correlated with seed yield (Ayaz et al. 2004). Shaukat and et al (1999) reported a decline in the mean seed weight of pea genotypes with increased plant population. This agrees with Moot (1993) who reported a decline in the mean seed weight of pea genotypes with increasing plant population. Seed size is genetically pre-set. Different environmental conditions allow the seed to be filled to its genetic potential. With increased plants per area, each plant has fewer resources available which could translate into smaller seeds. In some situations, plants can abort flower sites so that all fertile seeds can fill to larger sizes. The reduction in the number of pods per plant, seeds per pod and seed weight at the higher densities might be due to increased interplant competition (Shaukat et al. 1999).

An analysis of variance indicated that there were no statistically significant differences in plant height among pea cultivars and seeding rates (Table 1). While the effects of cultivars on plant number per m^2 were insignificant, the effects of seeding rates were significant. High seeding rates resulted in high plant number per m^2 (Table 3). The actual seedlings numbers determined by counts were less than the target stands. An average 68.8% of 75 seeds per m^2, 63.9% of 100 seeds per m^2, 62.6% of 125 seeds per m^{2}and 57.7% of 150 seeds per m^2 were established. Johnston et al. (2002) documented that the proportion of seedlings that emerged at lower seeding rates was greater when compared with higher seeding rates for all pea cultivars. The emergence rates relative to the corresponding target seeding rates progressively decreased as seeding rate increased (Johnston et al. 2002). At higher seeding rates, the number of surviving plants was also reduced as the growth of the plants progressed (Kruger 1977). Seedling mortality in pea increased dramatically with planting rates above 50 seeds m^2 (Johnston et al. 2002). Increased mortality occurs at the higher plant densities because of increased inter-specific plant competition.

It was not found significant differences among cultivars in point of seeds number per pod (Table 1). According to averages of two years, increasing seeding rates decreased number of seeds per pod in this research (Table 3). The number of seeds per pod depends partially on the cultivar and on the environmental conditions (Cousin 1997) but has also been documented to be affected by plant density. The average number of seeds per pod was inversely related to plant population (Ayaz et al. 2004). A progressive and consistent reduction in the number of seeds per pod occurred with increased plant population (Bakry et al. 1984). Shaukat et al. (1999) also found that maximum seeds per pod were recorded at low populations and declined with increase in planting density.

Cultivars had significant effects on lodging scores at the flowering stages and ripening seed stages (Table 1). Semi-leafless pea cultivars (Ulubatli and Kirazli) had significantly better standing ability than normal leaf cultivars (Urunlu and Golyazi) (Table 3). Similar results were reported by Heath and Hebblethwaite (1984), Stelling (1989), Biarnes-Dumoulin et al. (1996), Uzun and Acikgoz (1998), Banniza et al. (2005). The semi-leafless phenotype is caused by a recessive mutation that replaces leaflets by tendrils, making semi-leafless cultivars less susceptible to lodging than normal leaf cultivars because plants cling to neighboring plants (Davies et al. 1985; Stelling 1989; Biarnes-Dumoulin

Table 3. Mean values of yield components measured in different cultivars and seeding rates (averages of 2 years). Figures followed by the same letter do not differ significantly ($P < 0.05$).

	Plant Height (cm)	Plant/m² (number)	Seeds /Pod (number)	Lodging Scores: Flowering Stage	Lodging Scores: Ripening Seed	Forage Yield (t ha^{-1})	DM Yield (t ha^{-1})	CP Yield (t ha^{-1}): Forage	CP Yield (t ha^{-1}): Seed
Cultivars									
Ulubatli	88.30	69.82	5.28	4.50 a	2.79 a	24.36 c	4.39 c	0.75 c	0.204 c
Kirazli	88.30	70.20	5.08	4.58 a	2.38 a	27.37 b	5.07 b	0.87 b	0.219 b
Urunlu	86.27	70.24	4.88	2.17 b	1.58 b	23.39 d	4.48 c	0.77 c	0.200 c
Golyazi	90.03	70.03	5.31	2.29 b	1.75 b	30.06 a	5.50 a	0.94 a	0.226 a
Seeding Rates (Seeds/ m^{-2})									
75	91.92	51.60 d	5.32 a	3.00 c	2.00 b	19.82 d	3.66 d	0.63 d	0.221 a
100	86.56	63.92 c	5.13 b	3.33 b	1.96 b	22.89 c	4.23 c	0.72 c	0.216 a
125	88.36	78.22 b	4.98 c	3.50 ab	2.04 b	29.84 b	5.51 b	0.94 b	0.208 b
150	86.05	86.54 a	5.03 c	3.71 a	2.50 a	32.62 a	6.03 a	1.03 a	0.204 b

et al. 1996; Uzun and Acikgoz 1998; Banniza et al. 2005). Lodging may not be a serious problem in semi-leafless lines until full flowering stage but all genotypes lodged in later stages (Uzun et al. 2005). This has prompted the development of semi-leafless plant types with improvements in standing ability (Snoad 1974).

Although semi-leafless cultivars had reduced lodging than normal leaf cultivars, all the cultivars lodged at the seed harvesting stage, in agreement with Uzun et al. (2005).

The lodging increased with increased plant population. This result was consistent with the findings of Heath and Hebblethwaite (1985a). At higher plant densities, there was a tendency for increased and earlier lodging as well as more difficulty in harvesting (Heath and Hebblethwaite 1985c).

An analysis of variance indicated that there were statistically significant differences in forage yield among pea cultivars in two year averages. The forage yield of leafed cultivar Golyazi was significantly higher than those of the other three cultivars (Table 3). The DM yield showed a similar trend. Average forage yield and DM yield of our pea cultivars were lower than that of previous experiments (Uzun et al. 2005; Biederbeck and Boudman,1994). The reason for these differences was sowing season. The experiments were established in March in 2009 and 2010 due to the harsh climate conditions in winter in the region because the winter of our region is too hard. Uzun and Acikgoz (1998) found that all cultivars produced higher forage yield, DM yield and seed yield.

Forage yields and DM yields increased linearly with increasing seeding rates (Table 3). According to average of two years, an increase in seeding rate from 75 to 150 seeds per m^2 produced an approximately 65% increase in forage yield and DM yield. These results were consistent with the findings of Townley-Smith and Wright (1994) and Uzun and Acikgoz (1998).

Statistically significant CP yields differences among cultivars were observed in averages of two years (Table 1). Golyazi cultivar had the highest forage CP yield (0.95 t ha^{-1}) and seed CP yield (0.226 t ha^{-1}). High seeding rates resulted in high forage CP yield while it resulted in low seed CP yield (Table 3). The CP content of seeds differed between 20 and 21%, the CP content of forages differed between 17 and 18%. Therefore, the CP values followed the same pattern of the DM and seed yield values. Our results confirm those of Uzun and Acikgoz (1998).

CONCLUSION

The results from the different cultivars and seeding rates applied in pea in Mediterranean conditions of Turkey can be summarised as follows:

Golyazi had the highest 1000 seed weight, forage yield, DM yield, seed yield, forage CP yield and seed CP yield.

Semi-leafless pea cultivars (Ulubatli and Kirazli) had significantly better standing ability than normal leaf cultivars (Urunlu and Golyazi).

Increasing seed rates resulted in an increase in plants per m^2, lodging scores, forage yield, DM yield and forage CP yield. However, increasing seed rates caused decrease in seeds per plant and seed CP yield in two years averages.

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