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EFFECTS OF ROW SPACING AND SEEDING RATE ON HAY AND SEED YIELD OF EASTERN ANATOLIAN FORAGE PEA (*Pisum sativum* ssp. *arvense* L.) ECOTYPE

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ABSTRACT

The Eastern Anatolian forage pea ecotype generally has a thin stem, small leaves and small seeds. The ecotype is different from the improved breeds and thus cultural techniques for this ecotype are somehow different. Current study was conducted to investigate the effects of row spacing and seeding rate on yield and some other characteristics of the Eastern Anatolian forage pea (*Pisum sativum* ssp. *arvense* L.) ecotype. Experiments were carried out in randomised complete blocks design with three replications under irrigated conditions of Erzurum during the years 2010 and 2011. Three different row spacing (20, 40 and 60 cm) and four different seeding rates (60, 90, 120 and 150 kg ha^{-1}) were used in experiments. Hay yield, hay crude protein, ADF and NDF ratios, seed yield, straw yield, biological yield and harvest index parameters were investigated in this study. Results can be summarised as follows: Row spacing and seeding rate had significant effects on dry matter and seed yield of the forage pea. Based on the results of the present study and under Erzurum conditions, it was recommended that the Eastern Anatolian forage pea ecotype should be cultivated with 40 cm row spacing and 120 kg ha^{-1} seeding rate for hay yield and with 40 cm row spacing and 90 kg ha^{-1} seeding rate for seed yield.

Key Words: Forage pea, ecotypes, seed yield, plant traits

INTRODUCTION

Grain feed cultured in the Eastern Anatolia Region are limited only with barley and common vetch. Short vegetation periods and low summer temperatures of Bayburt, Erzurum, Agri, Kars and Ardahan plateaus hinders the cultivation of important grain forage crops like corn and soybean. Therefore, beside roughage production, there is a significant deficit also in grain forage production. There is a need in the region for alternative grain forage crops to be used beside barley and able to provide support to meet the forage demand of the region.

The forage pea (*Pisum sativum* ssp. *arvense* L.) has promising potential to be widespread in the region to meet the forage demand. It has been commonly cultivated in Ardahan, Kars and Bayburt like Eastern Anatolian Provinces for many years for both hay and grain. It is highly resistant to cold climate conditions and adapted to the ecology of East Anatolia. The forage pea is a nutritious forage source for livestock breeders. The crude protein ratio is approximately 18.05% during the flowering period (Tan et al., 2012), 8.94% after seeds were taken (Deniz, 1967) and 26.5% in grains (Acikgoz, 2001). Forage peas with their rich protein contents are also used as forage additives in Western European Countries.

Current local forage pea ecotypes in the regions are used both for hay and seed production. However, there were no studies carried out about the cultivation techniques of these ecotypes. The 1000-kernel weights (60-80 g) of these ecotypes, also known as Eastern Anatolian populations, are significantly lower than improved cultivars (Tan et al., 2012). The sowing densities of Eastern Anatolian ecotypes are also partially different from the improved cultivars. Therefore, there is a need for basic studies to be carried out on seeding rate and row spacing of local population since such cultivation techniques vary based on plant characteristics and ecological conditions of the region.

Cultivation techniques for hay yield and seed yield may exhibit differences from each other. Uzun and Acikgoz (1998) reported that dense sowing decreased the lodging rate, harvest index, 1000-kernel weight and seed yield of the plants. Chayferus and Okuyucu (1987) reported increasing grain and crude protein yields, although decreasing 1000-kernel weights with decreasing row spacing in peas. Previous researches recommend row spacing for peas as 15-60 cm based on the purpose of production and ecological conditions (Senel, 1958; Johnston et al., 2002; Bozoglu et al., 2004; Inanc, 2007). Seeding rate may sometimes reach 20 kg ha^{-1} (Potts, 1980).

MATERIALS AND METHODS

Experiments were conducted with the local forage pea ecotype (*Pisum sativum* ssp. *arvense* L.), commonly cultivated in Ardahan Province, over the experimental fields of Ataturk University Faculty of Agriculture under irrigated conditions during the years 2010 and 2011. This ecotype has a thin stem and small leaves; flowers are violet and seeds are spherical with greenish-brown colour; 1000 kernel weight is approximately 60-80 g (Tan et al., 2012). Field experiments were designed in a factorial arrangement of a randomised complete blocks design with 3 replications. Three different row spacing (20, 40 and 60 cm) and four different seeding rates (60, 90, 120 and 150 kg ha^{-1}) were used in 12 combinations in each replication. Plot size was arranged as 2.4 x 5 m. There were 12 plant rows at 20 cm spacing, 6 rows at 40 cm spacing and 4 rows at 60 cm spacing. Sowing was performed within the last week of April of both years with a hand drill. Pre-sowing fertilisation was performed during seed-bed preparation as to have 50 kg N ha^{-1} and 80 kg P_2O_5 ha^{-1} standard fertiliser rates (Tan and Serin, 2013). The flooding irrigation method was used to meet the water requirements of the plants during the summer months.

Harvest for hay yield was performed in July during the formation of lower pods and harvest for seed yield was performed in August when 75% pods were ripened. Half of each plot was harvested for dry matter and the other half for seed yield. Some characteristics related to dry matter yield and seed yield were investigated in this study. The two-year results were statistically evaluated using MSTAT-C procedures and mean separations were made on the basis of the Least Significant Differences (LSD).

Experimental soils have clay-loam texture, salt-free and with slight alkalinity (pH: 7.82). Soils have medium level available phosphorus (88 kg P_2O_5 ha-^{1}) and low organic matter content (1.79%), and soils are rich in potassium (1980 kg K_2O ha-^{1}).

Long-term and experimental period monthly average temperatures and total precipitations of the years 2010 and 2011 for Erzurum Province are provided in Table 1. The monthly average temperatures of both years were close to long-term averages, although the monthly total precipitations were above the long-term averages. This was more distinctive in April and May of the year 2011.

Table 1. Temperature and rainfall values of the research periods in 2010 and 2011 and long-term average (1975-2009) in Erzurum.

Months	**Average temperature (°C)**			**Total rainfall (mm)**		
	2010	2011	LTA*	2010	2011	LTA*
April	5.6	5.6	5.4	54.2	147.7	58.4
May	10.4	9.6	10.5	63.6	105.2	70.0
June	15.9	14.6	14.9	50.5	55.3	41.6
July	19.5	19.6	19.3	55.5	26.6	26.2
August	20.3	19.4	19.4	9.0	21.8	15.1
Mean/total	14.3	13.8	13.9	232.8	356.6	211.3

*LTA: Long Term Average (1975-2009)

RESULTS AND DISCUSSION

Different row spacing and seeding rates had significant effects on dry matter yield of the forage pea (Table 2). While the highest dry matter yield (4237 kg ha^{-1}) was obtained from 40 cm row spacing, yields of larger and narrower row spacing were found to be lower. Increasing seeding rates also increased dry matter yields of forage pea. However, such an increase was not found to be significant above the seeding rate of 90 kg ha^{-1}. The effects of row spacing x seeding rate interaction on dry matter yield were also found to be significant. Such a case indicates the interactions between row spacing and seeding rate. The highest dry matter yields (4560 and 5021 kg ha^{-1}) were observed at 40 cm row spacing with 120 and 150 kg ha^{-1} seeding rates. Dry matter yields of the first year were higher than the yield of the second year. Year x row spacing interaction was also significant. The row spacing of 40 cm had the highest dry matter yields in both years (Figure 1).

The effects of different row spacing and seeding rates on crude protein ratios were found to be insignificant. Crude protein ratios of different row spacing treatments varied between 16.28-16.38% and ratios of different seeding rates varied between 16.00-16.62%. The effects of years on crude protein ratios were not also significant. While the crude protein ratio of the first year with better plant growth and higher dry matter yield was 15.02%, the value of the second year was found to be 17.61%.

With regard to ADF ratios of the forage pea, only the effects of seeding rate and row spacing x seeding rate interaction were found to be significant ($P<0.05$). ADF ratios of 60, 90, 120 and 150 kg ha^{-1} seeding rates were respectively observed as 23.71, 22.59, 24.22 and 22.12%. Row spacing was not effective on ADF ratios, although it was found to be effective in interaction with seeding rate. Considering both treatments, while the highest ADF ratio (25.50%) was obtained from 20 cm row spacing with 60 kg ha^{-1} seeding rate, the lowest value (21.28%) was obtained from 60 cm row spacing with the highest seeding rate (Table 1). Conversely, treatments did not have significant effects on NDF ratios, which is another indicator of fibrous parts. NDF ratios of row spacing treatments varied between 32.61-33.11% and ratios of seeding rate treatments varied between 31.89-33.45% (Table 2).

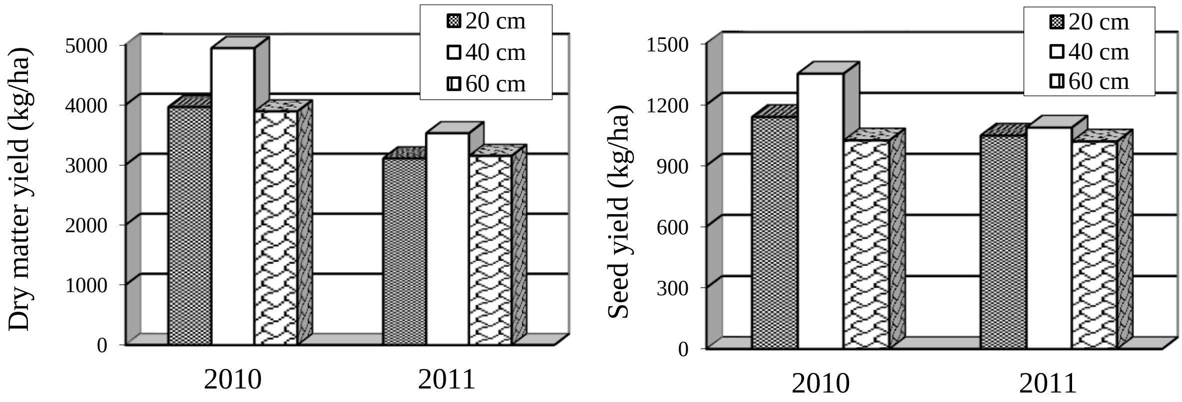

Figure 1. Row spacing x year interaction on dry matter and seed yields

Table 2. Dry matter yield, crude protein, ADF and NDF ratios of forage pea as affected by row spacing and seeding rate (average of 2 years).[1]

Row spacing (cm)	Seeding rates (kg ha^{-1})	Dry matter yield (kg ha^{-1})	Crude protein ratio (%)	ADF ratio (%)	NDF ratio (%)
	60	2728	15.49	25.50	33.10
	90	3740	16.17	21.43	32.18
20	120	3593	16.67	25.08	34.20
	150	4081	16.81	22.97	33.00
Mean		3536 B	16.28	23.74	33.11
	60	3154	16.60	22.85	33.65
	90	4214	16.34	23.58	31.62
40	120	4560	16.53	24.32	32.25
	150	5021	16.06	22.11	34.14
Mean		4237 A	16.38	23.21	32.92
	60	3255	15.91	22.79	33.15
	90	3611	16.42	22.77	31.87
60	120	3661	16.67	23.28	32.21
	150	3554	16.15	21.28	33.21
Mean		3520 B	16.29	22.53	32.61
	60	3046 B	16.00	23.71 AB	33.30
Seed Rates	90	3855 A	16.31	22.59 BC	31.89
	120	3938 A	16.62	24.22 A	32.89
	150	4219 A	16.34	22.12 C	33.45
Year	2010	4267 A	15.02 B	23.37	32.91
	2011	3262 B	17.61 A	22.96	32.85
F-test (LSD Value)					
	Row spacing	** (343)	ns	ns	ns
	Seed rate	** (396)	ns	* (1.16)	ns
	R spacing x S. rate	** (687)	ns	* (2.02)	ns
	Year	* (210)	** (0.85)	ns	ns
	R. spacing x Year	* (364)	ns	ns	ns
	S. rate x Year	ns	ns	ns	ns
	RS x SR x Y	ns	ns	ns	ns

[1]Values followed by different letters in a column represent significant differences.
ns: no significance, *: P<0.05, **: P<0.01

The effects of row spacing, seeding rate, row spacing x seeding rate, row spacing x year interactions on seed yield of forage pea ecotype were found to be significant (Table 3). The highest seed yield (1220 kg ha^{-1}) was observed in 40 cm row spacing, although seed yield of 20 cm row spacing (1094 kg ha^{-1}) was also significantly high. The lowest seed yield (1025 kg ha^{-1}) was obtained from the largest row spacing treatment. Seeding rates of 90, 120 and 150 kg ha^{-1} also had high seed yields, although the differences between them were not significant. The seeding rate of 60 kg ha^{-1} had low seed yield (922 kg ha^{-1}). Considering row spacing and seeding rate together, seed yields of 20 cm x 150 kg ha^{-1} and 40 cm x 90-150 kg ha^{-1} treatments seemed to be high. With regard to row spacing x year interaction, 40 cm row spacing had higher yields in both years (Figure 1).

While the effects of row spacing on straw yield were not significant, seeding rate, year and row spacing x year interaction had significant effects on straw yields. As it was in dry matter and seed yields, the increasing seeding rates generally increased straw yields. However, such an increase was not significant above the seeding rate of 90 kg ha^{-1}. A similar case was also observed in biological yield. While the lowest biological yield (3080 kg ha^{-1}) was obtained from the lowest seeding rate, increasing seeding rates also increased biological yields, although again, such an increase was not significant for seeding rates above 90 kg ha^{-1}. Biological yield was effected by the changes in row spacing ($P<0.05$). A biological yield of 40 cm row spacing was higher than the yield of other treatments and this yield was also significantly higher than the yield of 60 cm row spacing. Both straw and biological yields were found to be higher in the first year (2010) with better plant growth.

The harvest index was not affected from single row spacing and seeding rate treatments, although it was significantly affected by the interaction of these two treatments. The highest harvest index values were observed in 20 cm x 150 kg ha^{-1}, 40 cm x 90-150 kg ha^{-1} and 60 cm x 60-120 kg ha^{-1} treatments (Table 3).

Table 3. Seed, straw and biological yields and harvest index of forage pea as affected by row spacing and seeding rate (average of 2 years).[1]

Row spacing (cm)	Seeding rates (kg ha^{-1})	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
	60	969	2377	3346	28.9
	90	1044	2860	3904	26.5
20	120	1134	2772	3906	29.4
	150	1229	2646	3876	31.3
Mean		1094 AB	2664	3758 AB	29.0
	60	886	2130	3016	29.9
	90	1251	2464	3715	34.7
40	120	1338	3029	4367	31.6
	150	1404	3214	4618	30.5
Mean		1220 A	2709	3929 B	31.7
	60	922	1956	2877	34.0
	90	1079	2494	3573	31.0
60	120	1134	2681	3814	30.4
	150	951	2759	3710	27.1
Mean		1025 B	2472	3494 B	30.6
	60	926 B	2155 B	3080 B	30.9
Seed Rates	90	1124 A	2606 AB	3731 A	30.7
	120	1202 A	2872 A	4029 A	30.4
	150	1195 A	2873 A	4068 A	29.6
Year	2010	1172	2866 A	4038 A	28.9 B
	2011	1051	2364 B	3415 B	31.9 A
F-test (LSD Value)					
	Row spacing	** (139)	ns	* (354)	ns
	Seed rate	** (161)	** (495)	* (545)	ns
	R spacing x S. rate	* (209)	ns	ns	* (4.2)
	Year	ns	** (350)	** (386)	ns
	R. spacing x Year	* (148)	* (455)	* (501)	* (4.5)
	S. rate x Year	ns	ns	ns	ns
	RS x SR x Y	ns	ns	ns	ns

[1]Values followed by different letters in a column represent significant differences.
ns: no significance, *: $P<0.05$, **: $P<0.01$

The number of plant per unit area is the most significant factor effective on yield and it mostly depends on row spacing and seeding rate. Yield decrease is evident at seeding rates above or below the optimum rates (Martin et al., 1994; Johnston et al., 2002). Increasing the seeding rates generally increases the hay yield of peas (Turk et al., 2011). In a study carried out in Erzurum, the highest dry matter yield of common vetch, which has a very similar seed size and plant height with Eastern Anatolian forage pea ecotypes, was obtained from 24 cm row spacing with 120 kg ha^{-1} seeding rate (Serin et al., 1996). The effects of sowing density on hay quality were not distinctive. The effects of seeding rate were found to be significant only on ADF ratios. The ADF ratio was higher in lower seeding rates. This may be due to increasing fibrous stem and branches parallel to decrease the number of plants per unit area. Small effects of sowing density on forage quality were also reported by Juskiw et al. (2000). Yavuz et al. (2011) reported insignificant effects of row spacing and seeding rate on the ADF and NDF ratios of vetch.

In the present study, seed, straw and biological yields were higher at 40 cm row spacing and 90-120 kg ha^{-1} seeding rate. For higher seed yields in peas, Inanc (2007) recommended a row spacing of 35 cm and Bozoglu et al. (2004) recommended 40 cm. With regard to seeding rates, Uzun and Acikgoz (1998) had the highest seed yield with a seeding rate of 100 seeds/m^2. Turk et al. (2011) reported a decreasing number of seeds per pod and seed yield with increasing seeding rates. Yavuz et al. (2011) investigated the effects of seeding rates on vetch yields and observed increasing seed and biological yield until a seeding rate of 100 kg ha^{-1}. Conversely, Girgel (2006) indicated increasing straw yields with dense seeding rates.

In the present study, it was proven that row spacing and seeding rate were significant parameters to be considered in the cultivation of the Eastern Anatolian forage pea ecotype. While the proper row spacing was not found to be different from the previously recommended ones, the seeding rate was found to be relatively lower than the values reported in previous pea studies. This was mostly due to some morphological characteristics such as the small seed size, thin stem and small leaves of Eastern Anatolian forage pea ecotype. Considering the row spacing x seeding rate interaction, 40 cm row spacing with 120 kg ha^{-1} seeding rate was recommended for hay yield and 40 cm row spacing with 90 kg ha^{-1} seeding rate was recommended for seed yield.

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