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Effects of Row Spacing on Yield and Quality of Forage Pea (*Pisum sativum* ssp. *arvense)*

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A R T I C L E I N F O

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Peas are globally used as forage, haylage, silage or straw in ruminants' diet. Winter forage pea is also becoming an important forage crop, particularly for haylage production in Türkiye. Row spacing produce different spatial arrangements that influence competition for resources, especially radiation, in forage pea production. The aim of this study is to determine the appropriate row spacing for forage peas depending on hay yield and quality. Field experiments were performed Kızıltepe district, Mardin province of Türkiye during winter growing seasons of 2018-2019 and 2019-2020. Özkaynak pea variety was used in the experiments. Three row spacings (RS) (20, 30 and 40 cm) were applied. The experimental units had an area of 12 m2 (2.4×5) in size and equal seed rate was used in each experimental unit (on 150 kg ha $^{-1}$). Higher plant height (127.8 cm) was recorded under 20 cm RS, compared to 30 (121.8 cm) and 40 cm (121.2 cm). The average green forage yield was 26.7, 27.7, and 28.8 t ha^{-1} for 40, 30, and 20 cm RS, respectively. Whereas the average hay yields for 20, 30, and 40 cm RS were 5.20, 5.34, and 5.79 t ha^{-1}, respectively. Crude protein (CP) ratio was significantly lower for 40 cm (20.2%) RS compare to 20 (22.5%) and 30 (21.6%) cm RS. Average raw ash, dry matter uptake (DMI) and relative nutritional value (RFV) ratios significantly increased in 30 cm and 40 cm RS compared to the 20 cm. However neutral detergent fiber (NDF) ratio decreased in 30 cm and 40 cm RS compared to 20 cm. Acid detergent fiber (ADF) and digestible dry matter (DDM) were not significantly affected from RS. In conclusion, 20 cm RS would be more suitable and economical due to higher plant height, green forage and hay yields, and higher CP and NDF rates for commercial feed producers in the region. However, 30 cm RS may be more suitable for farmers producing feed for their own livestock due to higher DMI and RFV values.

1. Introduction

Pea is a palatable and nutritious cool-season legume (Mihailovic et al., 2013), which is an essential component of human nutrition (Sapre et al., 2021). Like other legumes, peas are rich source of proteins, dietary fiber, micronutrients, and bioactive phytochemicals (Nithiyanantham et al., 2010). There is increasing interest in plant-based protein sources for human and animals due to high contents (23-33%) (Renata et al., 2021). Pea seeds contain high amounts of carbohydrates, proteins,

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amino acids, vitamins C and A, phosphorus, and calcium (Jovicic et al., 2010).

Peas are used as forage, haylage, silage or straw in ruminants' diet in Europe, West Asia and North Africa (Mihailovic and Mikic, 2014). Winter forage pea is becoming an important forage crop, particularly for haylage production in Türkiye. It gives high yield of quality forage even under drought stress. Therefore, dry pea cultivation in Türkiye could be practiced utilizing empty fields by growing it as an intermediate crop in the winter months. In addition, a new/alternative species will be added to the legume crops, which are of great importance for sustainable agriculture and crop rotation. Therefore, it will significantly contribute towards agricultural and economic sustainability.

Local forage pea (*Pisum sativum* ssp. *arvense* L.) ecotypes are commonly cultivated in the Eastern Anatolia region of Türkiye recently. Dry matter yield and yield components of 18 forage pea ecotypes selected from 61 materials collected from Erzurum, Bayburt, Kars and Ardahan provinces were determined under irrigated conditions. Dry matter yield of the ecotypes ranged between 4.86-6.85 t ha^{-1} (Tan et al., 2013). Besides, straw yield of promising local ecotypes selected from different locations in the northern part of Eastern Anatolia varied between 3.37-4.57 t ha^{-1}, whereas seed yield ranged between 1.50-2.21 t ha^{-1} (Tan et al., 2012).

Row spacing affects crop density that drives inter-specific (between crop and weeds) and/or intra-specific (among crop plants) competition (Özer et al., 2001; Liu et al., 2017). Reducing row spacing produces more square spatial arrangements that affects competition for resources, particularly radiation (Mattera et al., 2013). Therefore, row spacing influences both plant size and density throughout initial growth period (Mattera et al., 2009). Row spacing has a great importance in the forage pea production.

This study was carried out to determine the effect of different row spacing on the yield and quality of forage peas under ecological conditions of Kızıltepe district, Mardin province, Türkiye. Optimizing row spacing for pea cultivation in the region was the major objective of the study.

2. Materials and Methods

The study was conducted in Köprübaşı village, Kızıltepe district, Mardin province in South Anatolia region of Türkiye during winter growing seasons of 2018-2019 and 2019-2020. According to the soil analysis (0-30 cm); soil was clay-loam, pH neutral, slightly saline, low in lime, poor in organic matter, high in potassium and low in phosphorus. The soil properties of the study area are given in Table 1.

Table 1. Soil properties of the research area prior to sowing

Soil properties	**2018**	**2019**
Texture	Clay-Silt	Clay-Silt
Ph	7,35	7,28
Salt	0,3	0,28
Organic matter	1,45	1,51
$CaCO_3$ (%)	4,63	4,41
N	0,84	0,95
Phosphorus (P_2O_5) (kg ha^{-1})	27,2	26,4
Potassium (K_2O) (kg ha^{-1})	2580	2620

Total amount of precipitation during the first and second year of study was 396 mm and 488 mm, respectively. Total precipitations in both years were higher than long-term average (272 mm). Average temperature and relative humidity values were similar during both years (Table 2).

Özkaynak pea variety registered by Selcuk University, Agricultural Faculty, Konya/Türkiye in 2008 was used in the experiments. Seeds were sown in November during both years. The field was deeply plowed prior to planting, and a cultivator and press were used for seedbed preparation. The experimental units had an area of 12 m^2 (2.4×5) in size. Row spacing was 20 cm (12 rows/experimental unit), 30 cm (8 rows) and 40 cm (6 rows). Equal seed rate was used in each experimental unit (on 150 kg ha^{-1}). Although the number of rows in the experimental units varied, the amount of seed sown remained constant. A total of 175 kg ha^{-1} DAP (18.46.0) and 20 kg ha^{-1} Urea (46% N) were applied at sowing. Therefore, a total of 80 kg ha^{-1} pure P_2O_5 and 40 kg ha^{-1} pure N were applied to the experimental fields in both years. Weeds were manually controlled. The harvesting was done on 2 April in 2019 and on 5 April in 2020. Hay yield was determined by drying a 500 g fresh plant sample in an oven at 70 °C until constant weight. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined by the method of ENISO 13906, (2008). Nitrogen contents were determined by Kjeldahl method, and crude protein (CP) ratios (%) were calculated by multiplying the obtained values with a coefficient of 6.25 (AOAC, 1990). The method proposed by Moore and Undersander (2002) was used to calculate the digestible dry matter (DDM), dry matter uptake (DMI) and relative nutritional value (RFV) parameters. The equations used in the calculations are given below.

$$DDM = 88.9 - (0.779 * ADF) \quad (1)$$

$$DMI = 120/NDF \quad (2)$$

$$RFV = (DMI \times DDM)/1.29 \quad (3)$$

Statistical analysis was conducted according to Randomized Complete Block Design. The JMP statistical package program was used for variance analysis (Kalaycı, 2005).

Table 2. Weather (temperature, precipitation, and humidity) data during experimental years and long-term averages data of Kızıltepe/Mardin

	Years	Janu	Febr	March	April	May	June	July	Agus	Sept	Oct	Nov	Dec
	2018	8.5	10.2	14.3	17.7	21.8	28.1	30.9	30.2	27.0	21.6	13.2	9.1
Temperature (°C)	**2019**	6.6	8.8	10.7	13.9	22.7	29.5	30.8	31.7	26.3	22.3	13.5	9.9
	2020	3.6	3.8	10.7	14.1	19.9	26.2	31.5	29.9	29.3	22.8	12.0	
	LTA	6.9	9.0	12.2	16.0	21.7	28.5	32.1	30.9	26.2	20.5	13.3	8.1
	2018	48.3	35.7	5.2	12.1	103.8	0.8	0.9	0.2	0.1	48.6	32.2	51.5
Precipitation (mm)	**2019**	44.1	27.4	95.8	79.7	49.2	16.3	1.7	0.1	0.3	32.7	11.8	54.5
	2020	75.9	102.8	157.3	51.6	30.5	31.5	4	0	0	0	35.7	
	LTA	36.0	33.15	59.18	37.62	38.77	3.53	0.73	0.20	1.47	24.51	33.29	33.53
	2018	67.4	70.9	64.1	53.0	60.8	33.9	31.3	38.3	35.3	47.4	77.8	88.1
Humidity (%)	**2019**	86.5	87.5	86.7	94.3	9.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	2020	71.9	71.4	65	59.7	43.4	26	20.6	22.1	20.6	22.5	55.8	
	LTA	71.6	66.1	69.0	63.0	47.0	25.1	21.0	27.6	30.5	38.3	50.7	65.5

*LTA= Long Term Average. Data was obtained from Mardin Meteorology Provincial Directorate.

3. Results and Discussion

Row spacing (RS) and Year × RS interaction was significant for plant height. Higher plant height (127.8 cm) was recorded under 20 cm RS, compared to 30 (121.8 cm) and 40 cm (121.2 cm). The highest plant height was recorded for 20 cm RS in 2019 considering the year × RS interaction. However, the plant heights were the lowest under 30 cm and 40 cm RS in 2018 and 2019, respectively (Table 3).

The RS, year and year ×RS interaction were significant for green forage yield. The average green forage yield was statistically higher in 2019 (27.9 t ha$^{-1)}$ than 2018 (27.6 t ha^{-1}). The average green forage yield decreased as RS increased. The average green forage yield was 26.7 t ha^{-1}, 27.7 t ha^{-1}, and 28.8 t ha^{-1} for 40, 30, and 20 cm RS, respectively (Table 3).

Table 3. Plant heights and green herbage yields depending on row spacing

	Plant heights (cm)			**Green forage yields (t ha^{-1})**		
Row spacing(cm)	**Years**		**Averages**	**Years**		**Averages**
	2018	**2019**		**2018**	**2019**	
20	125.3 b	130.2 a	127.8 a	28.4 b	29.2 a	28.8 a
30	119.2 e	124.3 bc	121.8 b	27.5 d	27.9 c	27.7 b
40	122.3 cd	120.1 de	121.2 b	26.8 e	26.6 f	26.7 c
Average	122.27	124.87		27.6 B	27.9 A	
LSD	RS**: 1.937; Year x RS**: 2.739			Year **: 7.631; RS**: 7.494; Year x RS**:10.598		
CV (%)	1.18			0.20		

RS: Row spacing

The average hay yield and CP ratios (%) decreased as RS increased. The RS, year and year × RS interaction was significant for Hay yield. However, no difference was observed in the CP ratio for years and year by RS interaction. The overall means of CP ratios were statistically different depending on RS. Hay yield was significantly lower in 2018 (5.41 t ha^{-1}) than 2019 (5.48 t ha^{-1}). Hay yield ranged from 5.20 t ha^{-1} to 5.86. The average hay yields for 20, 30, and 40 cm RS were 5.20, 5.34, and 5.79 t ha^{-1}, respectively (Table 4).

Table 4. Hay yields and CP ratios values depending on row spacing

Row spacing (cm)	Hay yields (t ha^{-1})			CP Ratios (%)		
	Years		Averages	Years		Averages
	2018	2019		2018	2019	
20	5.79	5.86	5.79 a	22.1	22.8	22.5 a
30	5.29	5.40	5.34 b	22.1	21.1	21.6 a
40	5.21	5.20	5.21 c	20.3	20.0	20.2 b
Averages	5.41 B	5.48 A		21.3	21.5	
LSD	Year *: 7.103 IRD**: 8.703			IRD**: 1.139		
CV (%)	1.20			4.00		

RS: Row spacing

The RS, year and year ×RS interaction were non-significant for ADF and DDM ratios (Tables 5 and 6). Besides, no difference was observed in raw ash, NDF, DMI, and RFV ratios for years and year by RS interaction. Overall means of raw ash, NDF, DMI, and RFV ratios significantly varied among RS (Table 5, 6, and 7).

Average raw ash, DMI and RFV ratios significantly increased in 30 cm and 40 cm RS compared to the 20 cm. However, NDF ratio decreased in 30 cm and 40 cm RS compared to 20 cm (Table 5, 6, and 7).

Average raw ash contents were %8.0, %8.9 and %8.7 for 20, 30 and 40 cm RS, respectively (Table 5).

Two years' average values of NDF ratio decreased from 44.9% to 42.4% - 42.7% with increase in row spacing (Table 6). However, DMI and RFV ratios increased from 2.67% and 129.9% to 2.82-2.89% and 139.1-139.7%, respectively (Table 7).

Table 5. Raw ash ratios and ADF ratios depending on row spacing

Row spacing (cm)	Raw ash ratios (%)			ADF ratios (%)		
	Years		Averages	Years		Averages
	2018	2019		2018	2019	
20	8.10	7.90	8.0 b	33.90	33.40	33.65
30	9.30	8.50	8.9 a	32.70	33.10	32.90
40	8.80	8.60	8.7 a	32.20	31.80	32.00
Averages	8.73	8.33		32.93	32.77	
LSD	IRD**: 0.442			---		
CV (%)	3.890			5.92		

RS: Row spacing

Table 6. The NDF ratios and DDM ratios depending on row spacing

Row spacing (cm)	NDF ratios (%)			DDM ratios (%)		
	Years		Averages	Years		Averages
	2018	2019		2018	2019	
20	44.50	45.30	44.9 a	62.49	62.88	62.69
30	41.50	43.30	42.4 b	63.43	63.12	63.27
40	42.80	42.60	42.7 b	63.82	64.13	63.97
Averages	42.93	43.73		63.24	63.38	
LSD	IRD*: 1.768			---		
CV (%)	3.07			2.39		

RS: Row spacing

Table 7. The DMI and RFV values depending on row spacing

Row spacing (cm)	DMI			RFV		
	Years		Averages	Years		Averages
	2018	2019		2018	2019	
20	2.70	2.65	2.67 b	130.66	129.11	129.9 b
30	2.89	2.77	2.83 a	142.22	135.94	139.1 a
40	2.81	2.82	2.82 a	138.94	140.45	139.7 a
Averages	2.80	2.75		137.27	135.17	
LSD	IRD*: 0.112			IRD*: 7.851		
CV (%)	3.10			4.329		

RS: Row spacing

Fresh forage yield ranged between 10.4-23.8 t ha$^{-1,}$ whereas dry matter yield varied between2.52-5.89 t ha^{-1} in Mardin province, Türkiye (Sayar and Han, 2016). Total fresh forage yield vales in the current study were higher than reported earlier from the same province. The differences are most probably due to the row spacing differences and varieties used. In addition, the total precipitation amount in two consecutive experiment years was considerably higher than the long-term average precipitation. Therefore, increase in the precipitation positively affected the pea yield. Several researchers emphasized that water stress has a significant effect on the yield of peas; therefore, it is important to use varieties suitable for the agro-climatic conditions of the region (Martin et al., 1993; Olle 2017; Krizmanic 2020). Similarly, dry matter yield of different ecotypes tested by Tan (2013) ranged between 4.86 and 6.85 t ha^{-1}, and the plant height varied between 68.8 and 102.0 cm. The hay yield values were similar to our results. Therefore, the results are generally in agreement with the current study. However, plant height was higher in the current study. The differences in plant height are probably due to the ecological condition and varieties used in the experiments.

4. Conclusions

- The plant height, green forage yield, and hay yield values were increased as RS decreased. Thus, the highest vegetative growth parameters were recorded under 20 cm RS.
- The highest CP and NDF ratios were recorded for 20 cm RS.
- Raw ash, DMI, and RVF values were lowest in 20 cm RS, whereas these values were higher and almost similar for 30 and 40 cm RS.

In conclusion, 20 cm RS would be more suitable and economical due to higher plant height, green forage and hay yields, and higher CP and NDF rates for commercial feed producers. However, 30 cm RS may be more suitable for farmers producing feed for their own livestock due to higher DMI and RFV values.

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