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THE EFFECTS OF VARYING ROW SPACING AND PHOSPHORUS DOSES ON THE YIELD AND QUALITY OF FENUGREEK (*Trigonella foenum-graecum* L.)

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ABSTRACT

This study was conducted to determine the effects of different row spacing (20, 30 and 40 cm) and phosphorus applications (0, 30, 60 and 90 kg ha^{-1}) on the yield and quality of fenugreek in Van-Turkey, in 2006 and 2007 growing seasons. Field experiments were arranged in Completely Randomized Block Design with three replications at the experimental fields of Agricultural Faculty of Yuzuncu Yil University. As a result of the research, while all the growth and yield parameters except for thousand seed weight and protein content were significantly affected by row spacing applications. Phosphorus fertilizer applications positively affected all the traits examined except for pod length. Consequently, the highest seed yield (777.0-785.0 kg ha^{-1}) was obtained from 30 cm row spacing in the both experimental years, respectively. In phosphorus applications, while the highest seed yield (731.0 kg ha^{-1}) was obtained from 60 kg P ha^{-1} applications in 2006 year, the highest seed yield (742.0 kg ha^{-1}) was obtained from 90 kg P ha^{-1} applications in 2007 year. But, between 60 and 90 kg P ha^{-1} applications there was not an important difference in the both experimental years. However, the highest protein content (23.0 %) was obtained from 20 cm row spacing and 30 kg P ha^{-1} applications in the 2006 year.

Key words: Fenugreek, phosphorus, row spacing, yield

INTRODUCTION

Fenugreek (*Trigonella foenum graecum* L.), an important plant in traditional medicine, is widely grown in Mediterranean countries, India and China (Ahmad et al. 2005). It is commonly used as a condiment and seasoning in food preparations; is assumed to possess nutritive and restorative properties and has been used in folk medicine for centuries for a wide range of diseases including diabetes (Eidi et al. 2007).

Seeds of fenugreek have locally been used as a natural yellow dye material, for cosmetics production and medicinal purposes. Fenugreek is also a good soil renovator and has widely been used as a green manure in agricultural production (Abdelgani et al. 1999). Fenugreek seeds and leaves are rich in minerals, proteins and carbohydrates, but low in oil (Gad et al. 1982). The seeds are used as spice on the worldwide, whereas the leaves are used as green leafy vegetables in diets. Fenugreek seeds are bitter to taste and have been known over 2500 years for their medicinal qualities (Srinivasan, 2006).

Ground seeds of fenugreek are consumed for producing spice and pastrami, a kind of traditional meat product in Turkey (Altuntaş et al. 2005). It is also used to produce a semisolid paste which consists of some natural flavors (garlic-flavored sausage) known as çemen. Çemen is used as edible coating material in the production of traditional meat product, pastrami. In pastrami production, the dried meat is dipped and kept into fenugreek paste (çemen) for coating the meat surface until forming a relatively thick film. Çemen provides some special appearance, color, texture, taste, and flavor to pastrami and prevents from the microbial contamination and excess drying of pastrami (Işıklı and Karababa, 2005).

In Turkey, fenugreek is widely cultivated as a spice crop for a long time. Production area of fenugreek is about 850 hectares and an annual seed production is about 1000 tones. Average seed yield is about 1180.0 kg ha^{-1} in 2004. Production area of fenugreek has decreased recently and recorded as 188 hectares, an annual seed production as 195 tones and seed yield as 1040.0 kg ha^{-1} in 2008. It is one of the most important industrial and export crops in Turkey, as well. According to 2008 year datas, export amount of fenugreek is about 51 tones and annual revenue is 74000 dollar (Bayram et al. 2010).

Phosphorus (P) is critical in plant metabolism which plays an important role in cellular energy transfer, respiration, photosynthesis and it is a key structural component of nucleic acids coenzymes, phosphorproteins and phospholipids. Phosphorus fertilization is a major input in crop production (Blackshaw et al. 2004).

One of the significant subject increasing yield and quality is to regulate the optimum plant density on the field. Plant density varies according to the cultivar, yield capacity of the soil, irrigation condition and cultivation objectives. The aim of this study was to determine the effects of different row spacing and phosphorus fertilizer levels on the yield and yield components of fenugreek in Van ecological conditions.

MATERIAL AND METHODS

Fenugreek cv. Gurarslan was used as seed material. The seeds were obtained from the Department of Field Crops, Faculty of Agriculture, Ankara University. The soil in the

experimental area was sandy-clay-loam texture, and the potassium content was 560.1 ppm. Phosphorus content (595.2 ppm) of the soil was adequate; organic matter (% 1.51), nitrogen (% 0.078) and salt (%0.072-0.091) contents were low. Total lime content (19-21.9 %) was high and the soil was light alkalin (pH 7.8).

In the experimental years, the amount of rainfall received in the second year (349.4 mm) was lower than the first year (424.1 mm). Average temperature values were about 10.0 °C, 9.5 °C and 9.0 °C for 2006, 2007 and long years, respectively. The rainfall amount was 109 mm in the growing period of 2007, while it was 99.9 mm in 2006 growing period (April-August). Also, rainfall distribution to months was irregular in both years. Relative humidity was higher than the long year's averages (57 %) in both years (59.6 -60.9 %) (Anonymous, 2008).

Field trials were conducted in the fields of Yuzuncu Yil University according to "Completely Randomized Block Design" with three replications in the growing seasons of 2006 and 2007. In the study, four different phosphorus doses (P_o= 0, P_3 = 30, P_6= 60 and P_9 =90 kg P_2O_5 ha^{-1}) and three different row spacings (20, 30 and 40 cm) were applied. Sowing dates were 4th April in 2006 and 7th April in 2007.

In the research, the plot lengths were 3 m. Plot widths varied according to the row spacing. Plot sizes of the experiment were 1 x 3 = 3 m^2 for 20 cm row spacing, 1.5 x 3 = 4.5 m^2 for 30 cm row spacing and 2 x 3 = 6 m^2 for 40 cm row spacing. Seeds were sown by hand. Nitrogen fertilization was applied to all plots in two splits, the first part in the sowing time and the last part in the beginning of generative stage as 100 kg N ha^{-1} ammonium sulphate (21 %). Irrigation was made 7 times in 2006 and 8 times in 2007. Weeding was made three times. In the harvest, one row from each side and 0.5 m from the heads of plots were eliminated as side effects. All observations were taken from 1.2 m^2 area for 20 cm row spacing, 1.8 m^2 area for 30 cm row spacing and 2.4 m^2 area for 40 cm row spacing.

Plant height, number of branches, first pod height, number of pods, number of seeds in pod and pod length in 10 plants chosen randomly were measured. Harvested plants were dried in shade during 3-4 days on the field. They were threshed and seed yields were calculated for plots. Harvests were completed until the end of July for both years.

The data were subjected to statistical analyses in Completely Randomized Block Design using COSTAT computer program. Means were compared with LSD % 5 (Düzgünes et al. 1987).

RESULTS AND DISCUSSION

Yield and the yield components of fenugreek were significantly affected by different row spacing applications in both years. There were no statistically differences among the row spacings on seed protein content in the experimental years. Thousand seed weight was affected by row spacing only in 2006. Some yield parameters like plant height, number of branches, first bean height, number of pods, number seeds per pod, pod length and thousand-seed weight increased with increasing row spacing. The effects of different phosphorus doses on the other yield parameters were found significant except for the plant height and protein content in 2006. Pod length was not affected with phosphorus doses in both years (Table 1).

Plant Height

Table 1 indicates that the effects of different row spacing and phosphorus doses on the plant height were found to be significant. There were statistical differences for plant height between the years (Table 1). Average plant heights were found as 36.4 and 38.7 cm in 2006 and 2007, respectively (Table 2).

The highest plant height (37.2-40.3 cm) was obtained from 40 cm row spacing in both experimental years. The lowest values were obtained from 20 cm row spacing as 35.5 and 37.3 cm in 2006 and 2007, respectively (Table 2). Plant height increased with increasing row spacing. Singh et al. (2005) reported higher plant heights in 22.5 cm row spacing while Halesh et al. (2000) and Gowda et al. (2006) obtained the highest plant heights from the 30 cm row spacing. On the other hand, Mohamed (1990) reported that plant height of fenugreek was not affected by increase in row spacing.

Table 1. Variance analysis results of the effects of varying row spacing and phosphorus applications on the yield and yield components of fenugreek

	Years	Plant height	Number of branches	First pod height	Number of pods	Number of seeds in pod	Pod lenght	Thousand-seed weight	Seed yield	Protein content	Protein yield
	2006	**	**	**	**	**	**	**	**		**
Row spacing (RS)	2007	**	**	**	**	**	**		**		**
	Means	**	**	**	**	**	**		**		**
	2006		**	**	**	**		**	**		**
Phosphorus (P)	2007	**	*	**	**	**		**	**	*	**
	Means	*	**	**	**	**		**	**	*	**
Year (Y)		**	**	**	**	**		**	**	**	**
	2006	*		*						**	
RS x P	2007	*		**							
	Means	**		**					*	**	**
RS x Y				**				**			
P x Y		*		**		*		**			
RSxPxY											

* significant at P<0.05 level ** significant at P<0.01 level

There were significant differences among the plant heights of fenugreek in terms of phosphorus doses in 2007 ($P<0.01$) and average of the years ($P<0.05$) (Table 1). While the highest plant height was obtained from 30 kg P ha^{-1} application as 40.0 cm in 2007, the lowest plant heights (37.5 and 38.3 cm) were obtained from the control plots and 90 kg ha^{-1} phosphorus doses, respectively (Table 2). These values were in the same Duncan groups. Halesh et al. (2000) and Mavai et al. (2000) reported that the higher plant heights in fenugreek were obtained from the higher P doses (75 and 90 kg P ha^{-1}, respectively). In different studies related to phosphorus doses in fenugreek; Jat (2004), Thapa and Maity (2004) and Nehara et al. (2006) reported that the highest values in the yield parameters of fenugreek were obtained from 80 kg P ha^{-1}, 60 kg P ha^{-1} and 50 kg Pha^{-1}, respectively.

Row spacing x phosphorus interaction was found statistically significant in both years ($P<0.05$) and average of the years ($P<0.01$). The highest plant height (38.3 cm) in this interaction was obtained from 30 cm row spacing and 90 kg P ha^{-1} applications. The lowest value (34.7 cm) was determined in 20 cm row spacing and control plots in 2006. In the second experimental year, the highest plant height was obtained from 40 cm row spacing x 30 kg P ha^{-1} interaction as 41.3 cm and the lowest value was resulted in 30 cm row spacing x control plot interaction as 35.9 cm (Table 2).

Number of Branches

There were significant ($P<0.01$) differences on the number of branch values of fenugreek in the experimental years (Table 1). The highest number of branches was counted as 2.7 branches $plant^{-1}$ in 2006 and 2.8 branches $plant^{-1}$ in 2007 (Table 2).

The effect of different row spacing on the number of branches was found statistically significant ($P<0.01$) in both experimental years and in average of the years. As the highest number of branches (3.0-3.2 branches $plant^{-1}$) was obtained from 40 cm row spacing in both trial years respectively, 20 cm row spacing gave the lowest values (2.5 branches $plant^{-1}$ for first and second years) (Table 2). The number of branches increased with increasing row spacing. In previous studies, similar results were reported by Mohamed (1990), Halesh et al. (2000) and Gowda et al. (2006) for the number of branches in fenugreek.

The effects of different phosphorus levels on the number of branches of fenugreek were found significant ($P<0.01$) in 2006 and in average of the years, ($P<0.05$) in 2007 (Table 1). As the highest numbers of branches (2.8-2.9) were obtained from 60 and 90 kg P ha^{-1} applications in the first and second experimental years which were in the same Duncan groups, whereas the lowest values (2.7 branches $plant^{-1}$) were obtained from the control plots for both years and from the 30 kg ha-1 phosphorus application in 2006 (Table 2). All the yield parameters were positively affected with increasing P fertilizer levels. These results were supported by the findings of Chaudhary (1999), Bothe et al. (2001), Jat and Shaktawat (2001), Jat (2004), Thapa and Maity (2004) and Nehara et al. (2006). On the other hand, Khan et al. (2005) reported that the number of branches was not affected by phosphorus application, as well. Our findings were in harmony with the results of many researchers.

First Pod Height

The results indicated that the effects of different row spacing and phosphorus doses on the first pod height were found statistically significant ($P<0.01$) in both years (Table 1). The first pod heights were 15.1 and 15.7 cm in 2006 and 2007, respectively (Table 2).

The highest first pod heights were obtained from 40 cm row spacing (15.6-16.1 cm) in both experimental years, respectively. While the lowest first pod heights (14.7-15.0 cm) were obtained from 20 cm row spacing and 30 cm row spacing in the first year, 20 cm row spacing gave the lowest value (15.4 cm) in the second trial year (Table 2). These results were in agreement with the findings of Halesh et al. (2000) and Gowda et al. (2006) who reported that row spacing applications increased yield characters in fenugreek.

The highest first pod heights (15.4-16.0 cm) were obtained from 30 kg P ha^{-1} application in both years, whereas the lowest values were recorded in 60 kg P ha^{-1} application (14.8 cm) in 2006) and from the control plots (15.4 cm) in 2007. Similar results were reported by Khiriya and Singh (2003) who received the highest first pod height from 40 kg P ha^{-1} application among the four phosphorus levels (0, 20, 40 and 60 kg P ha^{-1}). Apart from our findings, Nehara et al. (2006) reported that the yield characters increased significantly with increasing phosphorus levels.

Row spacing x phosphorus interaction significantly affected the first pod height in 2006 ($P<0.05$), 2007 and average of years ($P<0.01$). While the highest first pod height value (15.9 cm) was obtained from 30 kg P ha^{-1} and 40 cm row spacing applications in 2006, 40 cm row spacing and 30 kg P ha^{-1} applications gave highest first pod heights (16.3 cm) in 2007.

Number of Pods

There were statistically significant differences ($P<0.01$) between the experiment years for number of pods. As the lower number of pods (8.1 pods $plant^{-1}$) was obtained in the first year, second year gave higher number of pods (8.3 pods $plant^{-1}$) (Table 1 and 2).

The effects of row spacing on the number of pods of fenugreek were statistically significant ($P<0.01$) in both years and the average of the two years (Table 1). The highest number of pods (8.9-9.0 pods $plant^{-1}$) was recorded in 40 cm row spacing, while the lowest value (7.2-7.3 pods $plant^{-1}$) was obtained from the 20 cm row spacing in both experimental years, respectively (Table 2). The number of pods increased with increasing row spacings in both years. The results of Mohamed (1990) who reported that the number of pods increased by increasing row spacing in fenugreek supported our results. In contrast, Singh et al. (2005) reported that the yield and yield traits decreased with increasing row spacing.

The effect of increasing phosphorus doses on the number of pods of fenugreek was statistically significant ($P<0.01$) in both years and average of the years (Table 1). In terms of

average values, the highest number of pod (8.4-8.5 pods plant^{-1}) was obtained from 60 kg ha^{-1} phosphorus application in both years (Table 2). The control plots gave the lowest number of pods, 7.7-7.9 pods plant^{-1} in 2006 and 2007, respectively. Ram and Verma (2001) and Khan et al. (2005) reported that the number of pods was not affected by phosphorus applications. However, Bhati (1993) and Khiriya et al. (2001) stated that growth parameters of fenugreek significantly increased with increasing phosphorus levels up to 40 kg P ha^{-1} among the 0, 20, 40, and 60 kg P ha^{-1} applications in fenugreek. Our findings were compatible with the previous studies' results.

Number of Seeds in Pod

There were statistical differences (P<0.01) between the years in terms of the number of seeds in pod. Lower values (11.8 seeds pod^{-1}) was obtained in the first experimental year than that of the second experimental year (12.3 seeds pod^{-1}) (Table 1 and 2).

Variance analysis showed that the number of seeds in pod was affected significantly (P<0.01) by different row spacing in both years and average of the two years (Table 1). The highest number of seeds in pod (12.1 seeds pod^{-1}) was obtained from 40 cm row spacing in the first experimental year. The values for this character were 12.4 seeds pod^{-1} in 30 and 12.5 seeds pod^{-1} in 40 cm row spacings for the second experimental years. 20 cm row spacing applications gave the lowest number of seeds in pod (11.5-12.0 seeds pod^{-1}) for the two years (Table 2). The number of seeds in pod increased with increasing row spacing. The results were in agreement with the results of Halesh et al. (2000) and Gowda et al. (2006) who found positive effects in row spacing applications on the yield characteristics of fenugreek. On the contrary, Singh et al. (2005) reported that yield characteristics decreased by increasing of row spacing. These differences can be attributed to the environmental conditions. Our results were harmony with the results of many researchers.

The effects of different phosphorus levels on the number of seeds in pod of fenugreek was found statistically significant (P<0.01) in the experimental years (Table 1). The highest values were obtained from 90 kg P ha^{-1} application (12.1 seeds pod^{-1}) in 2006, whereas 60 kg P ha^{-1} application gave 12.6 seeds pod^{-1} in 2007 (Table 2). The lowest values (11.4-12.1 seeds pod^{-1}) were obtained from the control plots in both years. Bhati (1993), Khiriya et al. (2001), Khiriya and Singh (2003) stated that increasing phosphorus levels up to 40 kg P ha^{-1} increased significantly the growth parameters and yield of fenugreek among the fertilizer applications of 0, 20, 40, and 60 kg P ha^{-1}. On the contrary, Bothe et al. (2001) reported that the all yield parameters of fenugreek increased with increasing levels of P fertilizer, whereas Ram and Verma (2001) announced that particularly the number of seeds in pod increased with P doses. However, it was reported by Sheoran et al. (1999) that P had no significant effect on the number of seed in pod. Our results were in agreement with the results of many researchers.

Table 2. Means of some yield components at different row spacing and phosphorus applications in fenugreek

		Plant height (cm)		Number of branches (branch plant^{-1})		First pod height (cm)		Number of pods (pods plant^{-1})		Number of seeds in pod (seeds pod^{-1})	
		2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
	P_0	34.7 d	36.9c-e	2.4	2.5	15.2b-d	15.4b-d	6.7	7.0	11.1	11.7
RS_1	P_3	36.6a-d	39.6 ab	2.5	2.5	15.6 ab	15.9 ab	7.3	7.3	11.6	12.1
	P_6	35.6b-d	36.6 de	2.7	2.6	14.5 e	15.5 bc	7.5	7.4	11.5	12.3
	P_9	35.1 cd	36.1 e	2.5	2.6	14.7 e	14.9 d	7.4	7.5	11.8	12.0
RS_1 mean		35.5 b	37.3 b	2.5 c	2.5 c	15.0 b	15.4 c	7.2 c	7.3 c	11.5 c	12.0 b
	P_0	36.8a-c	35.9 e	2.7	2.7	14.4 e	15.2 cd	7.9	8.1	11.4	12.2
RS_2	P_3	35.6b-d	39.1a-c	2.7	2.8	14.8c-e	15.8 ab	8.2	8.4	11.7	12.4
	P_6	35.4b-d	38.7b-d	2.8	2.8	14.4 e	15.9 ab	8.6	8.8	12.1	12.6
	P_9	38.3 a	39.8 ab	2.9	2.9	15.4a-c	16.2 a	8.4	8.7	12.1	12.4
RS_2 mean		36.5 b	38.4 b	2.8 b	2.8 b	14.7 b	15.7 b	8.3 b	8.5 b	11.8 b	12.4 a
	P_0	37.4 ab	39.5 ab	2.9	3.1	15.5 ab	15.7 a-c	8.7	8.7	11.7	12.4
	P_3	37.3 ab	41.3 a	3.0	3.2	15.9 a	16.3 a	9.0	9.1	12.3	12.3
RS_3	P_6	37.4 ab	41.2 ab	3.1	3.2	15.4a-c	16.2 a	9.1	9.3	12.2	13
	P_9	36.7a-d	39.1a-c	3.1	3.2	15.6 ab	15.9 ab	9.0	9.1	12.2	12.2
RS_3 mean		37.2 a	40.3 a	3.0 a	3.2 a	15.6 a	16.1 a	8.9 a	9.0 a	12.1 a	12.5 a
P_0 mean		36.3	37.5 b	2.7 b	2.7 b	15.0 bc	15.4 c	7.7 c	7.9 c	11.4 b	12.1 b
P_3 mean		36.5	40.0 a	2.7 b	2.8 ab	15.4 a	16.0 a	8.1 b	8.3 b	11.8 b	12.3 b
P_6 mean		36.2	38.8 ab	2.8 a	2.9 a	14.8 c	15.8 ab	8.4 a	8.5 a	11.9 b	12.6 a
P_9 mean		36.7	38.3 b	2.8 a	2.9 a	15.2 ab	15.7 b	8.2 b	8.4 ab	12.1 a	12.2 b
Means		36.4 b	38.7 a	2.7 b	2.8 a	15.1 b	15.7 a	8.1 b	8.3 a	11.8 b	12.3 a
CV (%)		3.8	5.4	9.0	9.6	3.8	2.8	9.4	9.3	3.4	3.0

*There were no significant differences between the mean values shown with the same letters in 5 % probability level

Pod Length

The results of statistical analysis indicated that different row spacing and phosphorus doses had no statistically significant differences on the pod length between years (Table 1). Statistically important differences (P<0.01) were found among the row spacing for the pod length of fenugreek in both years and average of the years (Table1). While the highest value (11.9 cm) was obtained from 30 and 40 cm application in the first experimental year, 40 cm application gave 12.1 cm pod length in second year. The lowest value (11.1 cm) was taken from 20 cm applications in both years.

Pod length increased with increasing row spacing (Table 3). On the contrary, Singh et al. (2005) reported that the pod length decreased with increasing row spacing applications.

Different phosphorus doses had no significant effects on the pod length in two experimental years (Table 1). Pod lengths were between 11.4 and 11.8 cm in the experiment years (Table 3). Khiriya et al. (2001), Khiriya and Singh (2003) and Bhunia et al. (2006) reported that increasing phosphorus levels up to 40 kg P ha^{-1} significantly increased growth traits in fenugreek. Our results were found similar with the results of these researchers.

Thousand-seed Weight

There were statistically significant ($P<0.01$) differences between the experimental years in terms of thousand-seed weight of fenugreek (Table 1). The values were 17.5 and 17.7 g for 2006 and 2007, respectively. Thousand-seed weights was affected significantly ($P<0.01$) by different row spacings in 2006, whereas the differences were not important for 2007 and average of the years (Table 1). As the highest thousand-seed weight was obtained from 40 cm row spacing (17.7 g), the lowest values were obtained from 20 cm row spacing (17.4 g) and 30 cm row spacing (17.5 g) in 2006 (Table 3). It was reported by Singh et al. (2005) that closer spacing treatments gave the higher yield and yield components in fenugreek.

Thousand-seed weights were significantly affected ($P<0.01$) by phosphorus doses in the experimental years and average of the years (Table1). While the highest value (17.8 g) was obtained from 60 kg P ha^{-1} P fertilizer application in 2006, 90 kg P ha^{-1} application gave 18.0 g thousand-seed weights in 2007 (Table 3). The lowest values (17.2-17.5 g) were obtained from the control plots in 2006 and 2007, respectively. Bhati (1993), Khiriya and Singh (2003) and Sheoran et al. (1999) reported that increasing phosphorus levels up to 40 kg and 60 kg ha^{-1} significantly increased the yield-attributing characters. Moreover, Khan et al. (2005) reported that phosphorus application improved the performance of fenugreek plants in terms of 1000-seed weight. These results were compatible with our findings for thousand-seed weight.

Seed Yield

There were statistically significant ($P<0.01$) differences for the seed yields between experimental years (Table 1). Seed yields were 696.0 and 711.0 kg ha^{-1} for 2006 and 2007, respectively (Table 3). These differences may be resulted from the differences in meteorological conditions.

The effects of row spacings on the seed yield were statistically important ($P<0.01$) in both years and the average of two years (Table 1). The highest seed yields (777.0-785.0 kg ha^{-1}) were recorded from 30 cm row spacing application, while the lowest values (625.0-641.0 kg ha^{-1}) were obtained from 40 cm row spacing applications in two years (Table 3). In releated studies, Singh and Nand (1984), Gill et al. (2005) and Singh et al. (2005) found that the maximum seed yields were obtained from the closer row spacing treatments.

The effect of phosphorus doses was statistically important ($P<0.01$) between the years (Table 1). As the highest seed yields (731.0 and 730 kg ha^{-1}) were obtained from 60 and 90 kg P ha^{-1} application in the first trial year, the highest seed yields (742.0 and 738 kg ha^{-1}) were also obtained from 90 and 60 kg P ha^{-1} applications in second years, respectively. The lowest seed yields (645.0 and 677.0 kg ha^{-1}) were obtained from the control plots. In many researches it was reported that highest seed yields in fenugreek were obtained from maximum P applications (Bhati, 1993; Chaudhary, 1999; Halesh et al., 2000; Mavai et al., 2000, Ram and Verma, 2001; Dayanand, 2004; Thapa and Maity, 2004 and Khan et al., 2005). Some researchers reported that an increase in the seed yield of fenugreek was obtained with P doses of 40 and 60 kg ha^{-1} (Khiriya et al., 2001; Khiriya et al., 2003 and Sheoran et al., 1999). Row spacing x phosphorus interaction had no statistical effect on the seed yield in the years studied, but this interaction was significant ($P<0.05$) in the average of the years (Table 1).

Protein Content

As shown in Table 1, significant ($P<0.01$) differences were found for seed protein content between the first and second year (Table 1). Seed protein content was 22.4 % and 22.7 % in 2006 and 2007, respectively (Table 3).

The effects of row spacing applications on the seed protein content of fenugreek was not significant in the experimental years and average of two years (Table 1). Seed protein contents ranked between 22.2 % and 22.8 % in 2006 and 2007 years (Table 3)

There were no statistical differences among the phosphorus doses for seed protein contents of fenugreek in 2006, but this effect was significant ($P<0.05$) in 2007 and average of the years (Table 1). The highest value with 23.0 % was obtained from 90 kg ha^{-1} P doses, and the lowest value with 22.5 % was obtained from control plots in the second trial year (Table 3). As Bothe et al. (2001) and Thapa and Maity (2004) reported that all the yield parameters increased with increasing levels of P fertilizer, whereas Bhati (1993) and Khiriya and Singh (2003) recorded that the increasing phosphorus levels up to 40 kg ha^{-1} significantly increased all the yield parameters of fenugreek.

Row spacing x phosphorus interaction ($P<0.01$) significantly affected the seed protein content of fenugreek in 2006 and average of the two years. It was unimportant in 2007. The highest protein content (23.0 %) in the interaction was obtained from 20 cm row spacing and 30 kg P ha^{-1} fertilizer application (Table 3).

Protein Yield

The results indicated that the effects of different row spacing and phosphorus doses on the protein yield of fenugreek were statistically significant ($P<0.01$) between the years (Table 1). Average data of protein yields were varied from 156.0 kg to 162.0 kg ha^{-1} in 2006 and 2007, respectively (Table 3).

The highest protein yields were 174.0 and 179.0 kg ha^{-1} in 30 cm row spacing and the lowest values were 140 and

Table 3. Means of some yield components at different row spacing and phosphorus applications in fenugreek

		Pod lenght (cm)		Thousand-seed weight (g)		Seed yield (kg ha^{-1})		Protein content (%)		Protein yield (kg/ ha^{-1})	
		2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
	P_0	10.9	11.2	17.1	17.8	636.0	675.0	22.1 ab	22.4	141.0	151.0
RS_1	P_3	10.8	11.1	17.2	17.8	666.0	698.0	23.0 a	22.8	153.0	159.0
	P_6	10.9	11.0	17.6	17.7	709.0	718.0	22.3 ab	22.7	158.0	163.0
	P_9	11.6	11.1	17.6	18.1	732.0	762.0	21.9 ab	22.9	161.0	175.0
RS_1 mean		11.1 b	11.1 c	17.4 b	17.9	686.0b	713.0b	22.3	22.7	153.0b	162.0b
	P_0	12.1	11.9	17.0	17.4	741.0	762.0	22.8 ab	22.9	169.0	175.0
RS_2	P_3	12.1	11.5	17.5	17.8	757.0	762.0	22.2 ab	22.9	168.0	175.0
	P_6	11.6	11.7	18.0	17.7	803.0	808.0	21.5 b	22.5	172.0	182.0
	P_9	12.0	11.7	17.6	18.1	809.0	808.0	22.9 a	23.1	185.0	187.0
RS_2 mean		11.9 a	11.7 b	17.5 b	17.6	777.0a	785.0a	22.2	22.8	174.0a	179.0a
	P_0	12.0	11.7	17.6	17.3	558.0	595.0	22.5 ab	22.3	125.0	133.0
	P_3	11.9	12.2	17.7	17.9	612.0	627.0	21.9 ab	22.3	134.0	140.0
RS_3	P_6	11.8	12.2	18.0	17.6	681.8	688.0	22.5 ab	23.0	154.0	158.0
	P_9	11.9	12.1	17.6	17.8	647.0	655.0	22.8 ab	23.0	148.0	151.0
RS_3 mean		11.9 a	12.1 a	17.7 a	17.7	625.0c	641.0c	22.4	22.8	140.0c	145.0c
P_0 mean		11.6 ab	11.5	17.2 c	17.5 c	645.0c	677.0b	22.5	22.5 b	145.0b	153.0b
P_3 mean		11.6 ab	11.6	17.5 b	17.8 ab	678.0b	696.0b	22.4	22.7 ab	152.0b	158.0b
P_6 mean		11.4 b	11.6	17.8 a	17.7 bc	731.0a	738.0a	22.1	22.7 ab	161.0a	167.0a
P_9 mean		11.8 a	11.6	17.6 b	18.0 a	730.0a	742.0a	22.6	23.0 a	165.0a	171.0a
Means		11.6	11.6	17.5 b	17.7 a	696.0b	711.0a	22.4 b	22.7 a	156.0b	162.0a
CV (%)		4.5	4.5	1.9	1.6	11.0	9.8	2.7	1.7	11.2	10.4

*There were no significant differences between the mean values shown with the same letters in 5 % probability level

145 kg ha^{-1} in 40 cm row spacing for 2006 and 2007, respectively (Table 3).

The effects of phosphorus doses on protein yield were significant (P<0.01) in both experimental years and average of the years. As the highest protein yields were obtained from 90 and 60 kg ha^{-1} phosphorus doses for each years, the lowest values were obtained from the control plots and from the plots received 30 kg ha^{-1} phosphorus (Table 1 and 3). As Bhati (1993) and Khiriya and Singh (2003) recorded that increasing phosphorus levels up to 40 kg ha^{-1} significantly increased all yield parameters of fenugreek, Bothe et al. (2001) and Thapa and Maity (2004) reported that all the yield parameters increased with increasing levels of P fertilizer, too. Row spacing x phosphorus interaction had no significant effects on the protein yield for the years studied, but significant effects were found in the average of the years (Table 1).

CONCLUSION

In this study, increasing row spacing up to 40 cm affected positively all the yield-attributing characters, except for seed yield and protein yield. Seed and protein yields were positively affected by row spacing application up to 30 cm. The phosphorus doses had positive effect on the investigated traits, except for the first pod height.

In the other hand, many yield characteristics, except for the first pod height (in the 30 kg P ha^{-1} application) and the number of pod (up to 60 kg P ha^{-1} application) were positively affected by phosphorus doses up to 90 kg P ha^{-1}. As the first pod height was affected from 30 kg P ha^{-1} application, the number of pod was affected from 60 kg P ha^{-1}. As a result, it can be said that the row spacing of 30 cm and phosphorus dose of 90 kg ha^{-1} were the optimum for the highest yield and quality in fenugreek under Van ecological conditions.

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