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Full Length Research Paper

Research on the effect of phosphorus and molybdenum applications on the yield and yield parameters in lentil (*Lens culinaris* Medic.)

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Lentil is one of the oldest domesticated crops grown and used mostly in human diets in Turkey. The trial was laid out in a factorial randomized complete block design with three replications. Sazak-91 lentil variety was applied at three different phosphorus levels (0, 30 and 60 kg ha^{-1}) and four different molybdenum levels (0, 2, 4 and 6 g/kg seed) in 2005 - 2006 and 2006 - 2007. In the study, the effect of phosphorus and molybdenum levels on the plant height, number of branches, number of pods per plant, number of seeds per plant, 1000 seed weight, grain yield, harvest index, biological yield, number of nodules per plant, root dry weight, shoot dry weight protein ratio and phosphorus content in seed were investigated. Whereas the highest grain yield were obtained from 60 kg ha^{-1} P with 1086 kg ha^{-1} and from 6 g/kg seed molybdenum with 1231 kg ha^{-1} in the first year, the values were 80 kg ha^{-1} P with 1049 kg ha^{-1} and from 6 g/kg seed molybdenum with 1089 kg ha^{-1} in the second year.

Key words: Phosphorus, molybdenum, lentil and yield.

INTRODUCTION

Lentil is at the second rank among the grain legumes in Turkey in respect of sowing area and production, being 440,000 ha and 555,000 tonnes, respectively (Anonymous, 2005). The plant needs some macro- and micronutrients for its normal growth. Some of these elements play an important role in the process of *Rhizobium* symbiosis: for example, molybdenum is a constituent of the nitrogenase enzyme, and every bacteria which fixes nitrogen needs molybdenum during the fixation process. Molybdenum has a positive effect on yield, quality and nodule forming in legume crops. Application of molybdenum into the soils which are deficient in this element has increased the contents of potassium, phosphorus and crude protein in lentil.

Phosphorus is considered to be an important macro element for legumes. Phosphorus has very positive effects on nodule formation and nitrogen fixation in legume crops (Sepetoglu, 2002). Phosphorus in the soil has developmental activity in the plant's root growth. Depending on phosphorus applications, the contact area of the root expands with the growth of root which, in turn, gives rise to a flourishing in productivity, also making it easier for the plant to benefit from the other nutritional elements in higher proportions (Marschner, 1995). Chief among the basic nutritional problems which restrict crop yields in Mediterranean and West Asian countries including Turkey, is the inefficiency of phosphorus application in the soil necessary to be utilized for the plants (Cooper et al., 1987; Matar et al., 1992). 58% of the soils of Turkey have been found to be deficient in phosphorus (Eyuboglu, 1999). Phosphorus usually increases uptake of molybdenium.

This study was conducted in order to analyze the effect of different doses of phosphorus and molybdenium applications on yield and some yield parameters in lentil.

MATERIALS AND METHOD

The study was conducted in the fields of Agricultural Faculty of Yuzuncu Yıl University in a factorial randomized complete block design with three replications. In the trial, lentil cv. Sazak-91 was subjected to three different phosphorus levels (0, 30 and 60 kg ha^{-1}) and four different molybdenum levels (0, 2, 4 and 6 g/kg seed). Plots were 1 m wide and 5 m long. 140 DAP kg ha^{-1} was spread

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Table 1. Meteorological data of Van in 2005-2006 and 2006-2007 and long term (TSMS, 2007).

Month	Precipitation (mm)			Mean temperature (°C)			Relative humidity (%)		
	2005-06	2006-07	Long term	2005-06	2006-07	Long term	2005-06	2006-07	Long term
September	9.2	-	13.0	17.2	18.0	17.2	55.4	46.2	44.0
October	35.4	46.9	45.2	11.2	11.6	10.6	56.9	66.5	58.0
November	29.3	49.3	47.9	4.6	3.0	4.4	69.1	61.2	66.0
December	34.3	44.2	37.3	1.9	-3.4	-0.8	69.0	66.1	69.0
January	90.4	18.1	35.4	-3.1	-4.6	-3.6	73.7	68.0	68.0
February	47.7	10.6	32.5	-1.3	-0.9	-3.2	74.2	69.7	69.0
March	45.7	35.0	45.7	3.0	3.0	0.9	77.5	67.1	68.0
April	39.6	86.8	56.6	9.8	5.9	7.4	66.5	68.0	62.0
May	35.4	27.3	45.0	14.6	15.7	13.0	54.0	60.5	56.0
June	0.1	9.1	18.5	21.5	19.9	18.0	41.9	56.6	50.0
July	22.4	28.6	5.2	22.3	22.7	22.2	47.5	54.5	44.0
August	2.4	7.2	3.4	24.1	21.8	21.8	40.0	51.5	41.0
Total	391.9	363.1	385.7						
Average				10.5	9.4	9.0	60.5	61.3	57.0

Table 2. Some properties of the <2 mm fraction of the top 20 cm of soil used for each site.

Soil properties	Soil 1 2005-06	Soil 2 2006-07
pH[A]	8.45	8.7
Clay (%)[B]	18.2	22.1
$CaCO_3$ (%)[C]	17.9	18.9
Olsen soil test P (mg/kg)[D]	5.96	5.92
Total salt (%)[E]	0.020	0.021
Organic matter (%)[F]	1.81	1.83

[A]1:2.5 soil: water.
[B]Bouyoucos (1951).
[C]Lime by calcimetric methods.
[D]Olsen et al. (1954).
[E]Richard (1954).
[F]Walkey (1947).

over the soil surface by hand before sowing the crop. Phosphorus fertilizer was applied in bands 3 cm below lentil rows. The lentil seeds were sown 5 cm deep by hand in 10 cm inter rows down each plot, with a row spacing of 20 cm. The seeds were soaked in ammonium molybdate solution for 24 h, and then inoculated with *Rhizobium leguminasorum*.

The climatic data is summarized in Table 1. Some physical and chemical properties of soils are given in Table 2. The soils are classified as Entisols according to soil taxonomy (Soil Survey Staff, 1999). For the analyses of soils, texture was determined by Bouyoucus (1951) hydrometric method, pH in 1:2.5 soil-water suspension (Jackson, 1958), lime with 5 replicates by calcimetric methods, organic matter by modified Walkley Black method (Walkey, 1947), available phosphorus by the methods of Olsen et al. (1954), and total salt by Richard (1954).

Methods and procedures used to measure grain yields, yield components and concentrations of crude protein and P in grain, were undertaken as outlined by Ciftci and Sehirali (1984). On 29 June 2006 and 25 June 2007 10 mature plants were selected at random from near the center rows of each plot and the selected plants were cut at ground level. Sub samples of the harvested grain were used to measure crude protein by the Kjeldahl method (Bremner, 1965), and total N values were multiplied by 6.25 to provide % crude protein in grain. The P concentration in grain was measured by the vanado molibdo phosphoric acid yellow color procedure outlined by Kacar (1984). The influence of treatments on the lentil and differences among treatments were analysed using analysis of variance procedures for factorial randomized complete block design in SAS (1998) by using PROC GLM.

RESULTS AND DISCUSSION

The effects of different phosphorus and molybdenium applications on investigated characters of lentil were statistically significant for both years. The effects of different phosphorus and molybdenium applications were found to be statistically significant for plant heights in both years. In the first year, the highest plant heights were obtained from 60 kg ha^{-1} P and 6 g/kg seed Mo applications. In the second year the highest plant heights were obtained from 60 kg ha^{-1} P and 6 g/kg seed Mo applications. The difference between 60 kg ha^{-1} P and 30 kg ha^{-1} P applications was statistically insignificant (Table 3). The lowest values of plant height were recorded in control plots. Kumar et al. (1993) reported that the highest plant height was obtained from 50 kg ha^{-1} P application. Oguz (2004) in the study related with different Mo application in chickpea reported that the highest plant height was obtained from 6 g/kg seed Mo application.

The effects of phosphorus and molybdenium applications were statistically significant for branches/plant in both years. The maximum branches/plant was obtained from 60 kg ha^{-1} P and 6 g/kg seed Mo applications. But in the first year, the differences between 60 kg ha^{-1} P and 30 kg ha^{-1} P and 6 and 4 g/kg seed Mo applications were found to be statistically insignificant. In second year, the differences among 6, 4 and 2 g/kg seed Mo applications

Table 3. Effects of different phosphorus and molybdenum levels on yield and yield components of lentil (*Lens culinaris* Medic.).

Treatment	Plant height (cm)			Branches/plant (number/plant)			Pods/plant (number/plant)			Seeds/plant (number/plant)		
	05-06	06-07	Mean	05-06	06-07	Mean	05-06	06-07	Mean	05-06	06-07	Mean
P Doses (kg ha^{-1})												
0	26.1	25.8	25.9	2.0	1.9	1.95	12.3	10.2	11.3	13.5	11.4	12.4
30	28.7	26.5	27.6	2.6	2.5	2.55	15.5	12.0	13.8	17.7	13.9	15.8
60	29.4	26.7	28.1	2.6	2.7	2.65	17.3	16.1	16.7	18.3	18.6	18.4
LSD (p=0.05)	0.70	0.45		0.21	0.18		1.07	0.59		1.43	0.93	
Mo Doses (g/kg seed)												
0	25.5	24.6	25.1	2.1	2.1	2.10	11.9	9.6	10.8	13.1	10.9	12.0
2	27.0	25.7	26.4	2.3	2.3	2.30	15.2	10.8	13.0	17.1	12.5	14.8
4	28.6	27.1	26.9	2.5	2.5	2.50	16.5	14.1	15.3	17.5	16.3	16.9
6	31.2	27.8	29.5	2.6	2.5	2.55	16.5	16.3	16.4	18.5	18.8	18.6
LSD (p=0.05)	0.80	0.51		0.24	0.21		1.24	0.68		1.65	1.07	

Treatment	1000 seed weight (g)			Grain yield (kg ha^{-1})			Harvest index (%)			Biological yield (kg ha^{-1})		
P Doses (kg ha^{-1})												
0	51.7	50.6	51.1	853	874	863	31.5	31.1	31.3	2701	280.8	2754
30	53.4	52.3	52.8	1086	1042	1064	32.8	32.3	32.5	3323	324.7	3285
60	55.5	53.7	54.6	1086	1049	1067	34.2	33.0	33.6	3157	3148	3152
LSD (p=0.05)	.30	0.27		67	19		0.44	0.28		22	77	
Mo Doses (g/kg seed)												
0	52.3	51.6	51.9	866	905	88.5	31.4	30.8	31.1	2774	2936	2855
2	53.1	51.8	52.5	867	95.6	91.2	32.7	31.8	32.2	2653	2996	2824
4	54.1	52.2	53.2	1071	1004	103.7	33.2	32.7	32.9	3213	3068	3140
6	54.7	53.2	53.9	1231	1089	116.0	34.0	33.2	33.6	3602	3269	3435
LSD (p=0.05)	.35	0.32		77	23		0.51	0.32		26	89	

were insignificant (Table 3). Hattar and Hattad (1986) and Kumar and Agarwal (1993) reported that branches/plant increased with P applications. Oguz (2004) reported the maximum branches/plant from 6 g/kg seed Mo applications, as being similar to the present experiment.

The highest pods/plant and seed/plant were obtained from 60 P kg ha^{-1}and 6 g/kg seed Mo applications in both years. But the difference between 6 and 4 g/kg seed Mo application on pods/plant in the first year and the difference between 60 kg ha^{-1} P and 30 kg ha^{-1} P application and among 2, 4 and 6 g/kg seed Mo application on seed/plant were found to be statistically insignificant in the first year. The lowest values were obtained from control plots (Table 3).

The greatest 1000 seed weights were obtained from 60 P kg ha^{-1}and 6 g/kg seed Mo applications, wheras the lowest 1000 seed weights were obtained from control plots in both years (Table 3). Venkateswarlu and Ahlawat (1991) reported that 1000 seed weights increased with the increasing doses of phosphorus being statistically insignificant. Due to the fact that phosphorus fertilization was effective in the generative period of the plant, and that such fertilization led to a much better granulation, enhancement and improvement occured in 1000 seed weights with the increasing doses of phosphorus. Oguz (2004) reported that the greatest 1000 seed weights was obtained from 6 g/kg seed Mo applications in chickpea.

Although the highest grain yields was obtained from 60 kg ha^{-1} P application the difference between 60 kg ha^{-1} P and 30 kg ha^{-1} P applications was found to be statistically insignificant in both years. The highest grain yield in terms of Mo applications in both years of these trials were obtained from 6 g/kg seed Mo applications, wheras the lowest grain yields were found for control plots (Table 3). Kumar et al. (1993) reported that the highest grain yield in lentil was obtained 50 P kg ha^{-1} application. Pal (1986) reported that the highest seed yield was obtained with P + Mo application.

The effects of phosphorus and molybdenium applications were statistically significant for harvest index in both years. The maximum harvest index was obtained from 60 kg ha^{-1} P and 6 g/kg seed Mo applications. The highest biological yields in terms of P applications in both years of these trials were obtained from 30 kg ha^{-1} P, wheras the difference between 30 and 60 kg ha^{-1} P was found to be insignificant in the first year. The highest biological yields were obtained from 6 g/kg seed Mo applications in both years (Table 3).

Table 4. Effects of different phosphorus and molybdenum levels on nodules/plant, root and shoot dry weight, phosphorus content and protein ratio of lentil (*Lens culinaris* Medic.).

Treatment	Nodules/plant (number/plant)			Root dry weight (g)			Shoot dry Weight (g)			Phosphorus content (%)			Protein ratio (%)		
	05-06	06-07	Mean	05-06	06-07	Mean	05-06	06-07	Mean	05-06	06-07	Mean	05-06	06-07	Mean
P Doses (kg ha^{-1})															
0	11.25	9.80	10.52	0.116	0.099	0.107	0.60	0.47	0.54	0.24	0.22	0.23	21.8	20.8	21.3
30	12.43	10.57	11.50	0.133	0.119	0.126	0.67	0.54	0.61	0.26	0.25	0.26	22.7	22.8	22.8
60	14.40	12.35	13.37	0.153	0.132	0.142	0.71	0.65	0.68	0.29	0.29	0.29	24.3	22.8	23.5
LSD (p=0.05)	0.55	0.73		0.001	0.002		0.020	0.013		0.008	0.008		0.35	0.31	
Mo Doses (g/kg seed)															
0	9.26	7.75	8.50	0.112	0.104	0.108	0.61	0.50	0.56	0.23	0.24	0.24	21.7	21.3	21.5
2	11.75	9.76	10.75	0.126	0.113	0.119	0.63	0.53	0.58	0.25	0.25	0.25	22.9	21.8	22.3
4	13.48	11.72	12.60	0.142	0.120	0.131	0.69	0.56	0.63	0.28	0.26	0.27	23.5	22.5	23.0
6	16.26	14.38	15.27	0.156	0.130	0.143	0.70	0.60	0.65	0.28	0.27	0.28	23.7	22.9	23.3
LSD (p=0.05)	0.64	0.84		0.002	0.002		0.024	0.015		0.009	0.009		0.40	0.36	

While the highest nodules/plant was obtained from 60 P kg ha^{-1}and 6 g/kg seed Mo applications, the lowest values were obtained from control plots in both years (Table 4). Sekhon et al. (1986) reported that the application of *Rhizobium* and phosphorus improved nodulation, nitrogenase activity and yield. Kumar et al. (1993) reported that the highest nodules/plant was obtained 50 kg ha^{-1} P applications. Oguz (2004) in the study related with different Mo application in chickpea reported that the highest nodules/plant was obtained from 6 g/kg seed Mo application. Throughout the course of this investigation, coherence between the results of the study and those of the previous studies was observed.

Root and shoot dry weight were significantly affected from P and Mo fertilization in both years. While the greatest root and shoot dry weights were obtained from 60 kg ha^{-1} P and 6 g/kg seed Mo applications, the lowest values were obtained from control plots in both years (Table 4). The difference between 6 and 4 g/kg seed Mo applications on shoot dry weight was found insignificant in the first year. Kumar et al. (1993) reported that the greatest root and plant dry weight were obtained with 50 kg ha^{-1} P application. Oguz (2004) in the study related with different Mo application in chickpea reported that the greatest root and shoot dry weight was obtained from 6 g/kg seed Mo application.

The highest concentrations of P in grain were obtained from 60 kg ha^{-1} P and 6 g/kg seed Mo applications, whereas the lowest concentrations of P in grain were obtained from control plots. The difference between 6 and 4 g/kg seed Mo application was found to be insignificant in the first year of the trial (Table 4). Togay (2002), in her study on zinc and phosphorus fertilization in lentil, which lasted for two years, reported that the highest phosphorus content in the grain was obtained from 40 and 60 kg ha^{-1} P application, although it changed according to the years and the soil properties.

Whereas the highest crude protein ratios in both years were obtained from 60 kg ha^{-1} P and 6 g/kg seed Mo applications, the difference between 6 and 4 g/kg seed Mo applications in the first year and 30 and 60 kg ha^{-1} P applications in the second year were statistically insignificant (Table 4). Phosphorus plays an important role in the plant's root development, facilitating the earlier formation of nodules, improving them and contributing to an increase in their numbers, thereby leading to an enhancement in nitrogen fixation. Phosphorus deficiency in the soil not only decreases productivity but also causes a reduction in the protein contents of the grains (Sepetoglu, 1996). Togay (2002) reported that the highest protein ratio in the grain was obtained from 40 and 60 kg ha^{-1} P application but the difference among 20,40 and 60 P kg ha^{-1} applications were found to be statistically insignificant. Oguz (2004) in another study related with different Mo application in chickpea, reported that the highest protein ratio was obtained from 6 g/kg seed Mo application.

Conclusion

Phosphorus and molybdenium applications caused increases in all lentil characters. In the final course of the study, it was concluded that, in the soils of this region, which have poor phosphorus content and are highly alkaline, 60 kg ha^{-1} phosphorus and 6 g/kg seed molybdenum fertilization would bring good results and thus could be beneficial in order to have adequate lentil farming.

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