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Effect of plant density and phosphorus fertilization levels on yield and quality of lupin (*Lupnus termis* L.)

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Abstract

The objective of this study was to investigate the effect of three plant densities (33, 44 and 55 plants /m^2) and three phosphorus levels (15.5, 31 and 46.5 kg P_2O_5 /feddan) (feddan = 0.420 hectares = 1.037 acres) on yield, components and seed protein percentage of lupin cv. Giza-2. Two field trials were carried out at the Agricultural Experimental Farm of Al-Azhar University, Assiut governorate, Egypt, during two successive seasons of 2018/2019 and 2019/2020. Split plot design was used with three replicates; where plant density treatments were assigned to the main plot, while phosphorus levels were distributed randomly in the sub plot. The main effects could be summarized as follows: The results indicated that increasing plant population densities from 33 to 55 plant /m^2 measurably tended to increase plant height and protein percentage, whereas reduced number of branches /plant, number of pods /plant, number of seeds /plant, 100- seed weight, seed yield /plant and seed yield /feddan. Seed yield per feddan reached its maximum with sowing 33 plant /m^2 (20 cm between hills) in both seasons. Increasing phosphorus fertilizer levels from 15.5 to 46.5 kg P_2O_5 /feddan increasing all studied traits in both seasons, where the highest values were obtained from the application of 46.5 kg P_2O_5 /feddan in the two experimental seasons. The interaction effect between plant density and phosphorus fertilizer levels had significant effect on seed yield per feddan and seeds protein content in both seasons and plant height and number of pods per plant in the first and second seasons, respectively. Therefore, the study recommends population density 33 plant /m^2 and phosphorus fertilization at the level of 46.5 kg P_2O_5 /feddan, in order to improve the production of lupin under the conditions of Assiut governorate, Egypt.

Keywords: lupin, *Lupnus termis*, plant density, phosphorus fertilization.

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1. Introduction

Lupin (*Lupnus termis* L.) is considered one of the legumes with the promising future potential due to its high protein content as well as its adaptation to poor soils and dry climates. It has been used as a green manure, forage and seeds for human usage because of its high protein content. Like other seed legumes, lupin plant is able to fix atmospheric nitrogen in the soil that increase soil fertility with no additional cost or effort particularly in reclaimed soils and, therefore lupin appear to have useful effect in such areas (Hassan *et al.,* 2012). Plant population density and distribution of plants play an important role in the productivity of Lupin. El- Attar (1992) showed that increase in plant height, the number of pods /plant, seed index and seed yield /plant were found by increasing planting densities from 70000 to 175000 plant /feddan. Prasad *et al.,* (1993) showed that seed yield was the highest with 333 thousand plant/ ha. and deceased with the reduction in plant density below this level. Sharief (1997) reported that increasing plant population density to140000 plants /feddan significantly decreased stem diameter, number of branches, pods, seeds per plant and seed yield per plant and significantly increased plant height and seed yield/ feddan. El-Murshedy (2008) revealed that the lowest density *i.e*. 33 plants /m^2 gave significantly the highest number of branches and pods/plant, seed yield/plant and seed index, but the shortest plants with the fewest number of seeds/ pods and the lowest averages of seed yield /feddan and seed protein content. Phosphorus is one of the major nutrients for plant. It is true that the increase of the economic yield of lupin and other seed legumes in Egypt due to the response to phosphorus fertilizer application. lupin requires relatively large amount of phosphorus fertilizer for its effect on pod formation, maturity and promoting growth of the root system. Sharief *et al*. (1997) reported that increasing phosphorus fertilizer rates up to 31 kg P_2O_5 /feddan increased plant height, stem diameter, number of branches and pods per plant, 100- seed weight, seed yield per plant and feddan. Hafiz and El-Kholy (2000) and Mokhtar (2002) reported that increasing phosphorus from 15.5 to 31 kg /feddan increased lupin yield components and seed /feddan. El- Murshedy (2008) revealed that increasing phosphorus from level 15.5 to 46.5 kg P_2O_5 /feddan increased yield and its components. The seed yield/fed was increased as applied P_2O_5 level was increased up to the highest level i.e. 46.5 kg P_2O_5 /feddan Adding phosphorus at a level of 46.5 kg P_2O_5 /feddan increased seed yield /feddan over the plants fertilized by 15.5 or 31 kg P_2O_5 /feddan levels by 20.23 and 3.89 %, respectively, as average of the two seasons. The present study was carried out to find out the effect of planting density and the level of P fertilization on lupin yield, some its components and quality.

2. Materials and methods

The present study was carried out at the Agricultural Experimental Farm of Al-Azhar University, Assiut, Egypt during

2018/2019 and 2019/2020 seasons to study the effect of plant density and phosphorus fertilization levels on yield, yield components and seed protein percentage of lupin cv. Giza-2. A randomized completed blocks design in split plot arrangement with three replications were used plant density treatments were assigned to the main plot and phosphorus fertilization levels were allocated to the sub plots. The experimental unit consisted of 5 ridges, 4 m long and 0.60 m width (12 m^2). The three plant densities (33, 44 and 55 plants/ m^2) were achieved through varying the spaces between hills (20, 15 and 10 cm) on both sides of the ridge. The physical and chemical analyses of the experimental site are presented in Table (1).

Table (1): The physical and chemical analyses of the experimental site.

Mechanical analysis	2018/2019	2019/2020	Chemical analysis	2018/2019	2019/2020
Sand (%)	24.10	25.20	Organic matter (%)	0.93	1.02
Silt (%)	39.20	39.50	Available N (ppm)	74.54	76.30
Clay (%)	36.70	35.30	Available P (ppm)	9.70	10.56
Soil texture	Clay loam		Available K (ppm)	355.05	363.25
			Ph	7.76	7.98
			E.C. (ds. m^{-1})	1.17	1.18
			Total $CaCo_3$ (%)	2.85	2.60

Seeds of Egyptian lupin cv. Giza-2 were planted on November 21st and 19th in the first and second seasons, respectively. Calcium superphosphate (15.5 % P_2O_5) at rates of 15.5, 31 and 46.5 kg /feddan (feddan = 0.420 hectares = 1.037 acres). were applied before sowing in both seasons. The preceding summer crop was maize in both seasons. All other practices were uniformly applied as recommended for *Lupnus termis* L. production in the region.

2.1 Studied characters

2.1.1 Yield and yield components

At harvest, samples of 10 plants were chosen randomly from the inner rows and the following characters were recorded:

- Plant height (cm).
- Number of branches /plant.
- Number of pods /plant.
- Number of seeds /pod.
- 100- seed weight (g).
- Seed yield (g /plant).

Seed yield (kg /feddan): Seed yield in kg was determined form the whole area of each experimental unit and then adjusted to yield per feddan.

2.1.2 Chemical analysis

At harvesting, seed samples were ground

and kept for chemical analysis.

2.2 Protein percentage

Total nitrogen content in seeds were estimated by using microkjeldahl method as described by A.O.A.C (1980) and percentage of protein was calculated by multiplying the nitrogen percentage by 6.25.

2.3 Statistical analysis

All data were statistically analyzed according to the technique of analysis variance (ANOVA) and the least significant difference (L.S.D.) method was used to compare the difference between the means of treatment values to the methods described by Gomez and Gomez (1984). All statistical analyses were performed using analysis of variance technique by means of MSTAT-C Computer Software.

3. Results and Discussion

3.1 Yield and yield components

3.1.1 Effect of plant density

Planting distances had significant effect on all estimated characters in the two growing seasons (Tables 2, 3, 4, 5, 6, 7 and 8). Increasing plant density from 33 plants m^2 (20 cm among the hills) to 44 plants /m^2 (15 cm between hills) or 55 plants /m^2 (10 cm between hills) decreased the number of branches per plant, the number of pods per plant, the number of seeds per plant, 100–seed weight, seed yield per plant and seed yield per feddan, while plant height increased with increasing plant density. Increasing plant height with increasing plant density may be due to increasing competition for hight due to dense planting. Similar observation was reported by El-Attar (1992), Sharief (1997) and El-Murshedy (2008).

Table (2): Effect of plant density, phosphorus fertilization and their interaction on plant height (cm) of lupin in 2018/2019 and 2019/2020 seasons.

Seasons	2018/2019				2019/2020			
Plant density (plants /m^2)	P-levels (kg P_2O_5/feddan)			Mean	P-levels (kg P_2O_5/feddan)			Mean
	15.5	31	46.5		15.5	31	46.5	
33	94.5	97.3	100.7	97.5	98.8	101.4	104.1	101.4
44	98.2	102.1	105.7	102.0	103.4	107.3	110.3	107.0
55	115.8	116.9	119.8	117.5	116.0	119.2	121.8	119.0
Mean	102.8	105.4	108.7		106.0	109.3	112.0	
	F test		L.S.D. at 0.05		F test		L.S.D. at 0.05	
Density (D)	*		0.99		*		0.83	
Phosphorus (P)	*		0.39		*		0.53	
D X P	*		0.67		N.S.		-	

Table (3): Effect of plant density, phosphorus fertilization and their interaction on branches number/plant of lupin in 2018/2019 and 2019/2020 seasons.

Seasons	2018/2019				2019/2020			
Plant density (plants /m^2)	P-levels (kg P_2O_5 /feddan)			Mean	P-levels (kg P_2O_5 /feddan)			Mean
	15.5	31	46.5		15.5	31	46.5	
33	5.0	5.3	5.6	5.3	5.7	5.8	5.9	5.8
44	3.7	4.2	4.4	4.1	4.2	4.5	4.8	4.5
55	2.6	2.8	3.0	2.8	3.1	3.4	3.7	3.4
Mean	3.7	4.1	4.3		4.3	4.5	4.8	
	F test		L.S.D. at 0.05		F test		L.S.D. at 0.05	
Density (D)	*		0.29		*		0.11	
Phosphorus (P)	*		0.29		*		0.21	
D X P	N.S.		-		N.S.		-	

Table (4): Effect of plant density, phosphorus fertilization and their interaction on pods number/plant of lupin in 2018/2019 and 2019/2020 seasons.

Seasons	2018/2019				2019/2020			
Plant density (plants /m^2)	P-levels (kg P_2O_5 /feddan)			Mean	P-levels (kg P_2O_5 /feddan)			Mean
	15.5	31	46.5		15.5	31	46.5	
33	15.5	31	46.5		15.5	31	46.5	
44	17.8	20.1	22.1	20.0	19.7	20.7	22.0	20.8
55	14.2	16.2	18.5	16.3	14.7	17.1	19.2	17.0
Mean	10.1	13.3	15.6	13.0	12.7	13.8	15.2	13.9
	F test		L.S.D. at 0.05		F test		L.S.D. at 0.05	
Density (D)	*		0.28		*		0.64	
Phosphorus (P)	*		0.88		*		0.27	
D X P	N.S.		-		*		0.46	

Table (5): Effect of plant density, phosphorus fertilization and their interaction on seeds number/pod of lupin in 2018/2019 and 2019/2020 seasons.

Seasons	2018/2019				2019/2020			
Plant density (plants /m^2)	P-levels (kg P_2O_5 /feddan)			Mean	P-levels (kg P_2O_5 /feddan)			Mean
	15.5	31	46.5		15.5	31	46.5	
33	3.6	4.0	4.1	3.9	4.1	4.3	4.5	4.3
44	3.4	3.5	3.6	3.5	3.7	3.8	3.9	3.8
55	3.1	3.2	3.3	3.2	3.3	3.5	3.7	3.5
Mean	3.3	3.5	3.6		3.7	3.8	4.0	
	F test		L.S.D. at 0.05		F test		L.S.D. at 0.05	
Density (D)	*		0.20		*		0.16	
Phosphorus (P)	*		0.17		*		0.24	
D X P	N.S.		-		N.S.		-	

Moreover, seed yield per feddan reached its maximum with sowing 33 plant / m^2 (20 cm between hills) and this may be gained due to the great amount of light energy intercepted by the canopy per unit area. It is important to explain that for low density all the characters (except plant height). Were in higher value because the low number of the plants per unit area had a bigger chance to get more light and different nutrients and elements. These results are in line with those obtained by El- Attar (1992), Prasad *et al.* (1993), Sharief (1997) and El-Murshedy (2008).

3.2 Chemical analysis

3.2.1 Effect of plant density on protein percentage

The results recorded in Table (9) indicate that the plant spacing had significant influence on protein content in lupin seeds in both seasons. Increased plant spacing between hills from10 or 15 to 20 cm decreased protein percentage.

Table (6): Effect of plant density, phosphorus fertilization and their interaction on 100-seed weight (g) of lupin in 2018/2019 and 2019/2020 seasons.

Seasons	2018/2019				2019/2020			
Plant density (plants /m^2)	P-levels (kg P_2O_5 /feddan)			Mean	P-levels (kg P_2O_5 /feddan)			Mean
	15.5	31	46.5		15.5	31	46.5	
33	37.8	38.4	39.3	38.5	38.0	38.8	39.9	38.9
44	34.0	34.7	35.8	34.8	34.0	35.6	36.9	35.5
55	28.9	29.8	30.7	29.8	29.3	31.1	32.6	31.0
Mean	33.5	34.3	35.2		33.7	35.1	36.4	
	F test		L.S.D. at 0.05		F test		L.S.D. at 0.05	
Density (D)	*		0.11		*		0.55	
Phosphorus (P)	*		0.12		*		0.49	
D X P	N.S.		-		N.S.		-	

Table (7): Effect of plant density, phosphorus fertilization and their interaction on seed yield (g) /plant of lupin in 2018/2019 and 2019/2020 seasons.

Seasons	2018/2019				2019/2020			
Plant density (plants /m^2)	P-levels (kg P_2O_5 /feddan)			Mean	P-levels (kg P_2O_5 /feddan)			Mean
	15.5	31	46.5		15.5	31	46.5	
33	15.3	17.1	18.6	17.0	16.7	17.8	18.9	17.8
44	13.4	15.0	16.3	14.9	14.1	15.3	16.8	15.4
55	10.7	12.1	13.5	12.1	11.4	13.1	14.5	13.0
Mean	13.1	14.7	16.1		14.0	15.4	16.7	
	F test		L.S.D. at 0.05		F test		L.S.D. at 0.05	
Density (D)	*		0.30		*		0.56	
Phosphorus (P)	*		0.18		*		0.25	
D X P	N.S.		-		N.S.		-	

The highest protein percentage values (32.2 and 31.9 %) were obtained when density was applied at 55 plant /m^2 in the 1st and 2nd seasons, respectively. Similar results were obtained by El-Attar (1992), Sharief (1997) and El-Murshedy (2008).

Table (8): Effect of plant density, phosphorus fertilization and their interaction on seed yield (kg) /feddan of lupin in 2018/2019 and 2019/2020 seasons.

Seasons	2018/2019				2019/2020			
Plant density (plants /m^2)	P-levels (kg P_2O_5 /feddan)			Mean	P-levels (kg P_2O_5 /feddan)			Mean
	15.5	31	46.5		15.5	31	46.5	
33	895.6	930.5	981.0	935.7	909.8	940.9	978.3	943.0
44	760.3	803.0	851.7	805.0	782.8	819.7	853.0	818.5
55	712.5	759.3	809.7	760.5	738.8	771.1	810.0	773.3
Mean	789.4	830.9	880.8		810.4	843.9	880.4	
	F test		L.S.D. at 0.05		F test		L.S.D. at 0.05	
Density (D)	*		1.24		*		2.47	
Phosphorus (P)	*		0.69		*		1.04	
D X P	*		1.19		*		1.81	

Table (9): Effect of plant density, phosphorus fertilization and their interaction on seed protein content (%) of lupin in 2018/2019 and 2019/2020 seasons.

Seasons	2018/2019				2019/2020			
Plant density (plants /m^2)	P-levels (kg P_2O_5 /feddan)			Mean	P-levels (kg P_2O_5 /feddan)			Mean
	15.5	31	46.5		15.5	31	46.5	
33	29.6	30.4	31.5	30.5	29.4	30.1	30.8	30.1
44	30.7	31.8	33.0	31.8	30.7	31.0	31.9	31.2
55	31.6	32.1	32.9	32.2	31.7	31.7	32.3	31.9
Mean	30.6	31.4	32.4		30.6	30.9	31.6	
	F test		L.S.D. at 0.05		F test		L.S.D. at 0.05	
Density (D)	*		0.15		*		0.28	
Phosphorus (P)	*		0.21		*		0.19	
D X P	*		0.36		*		0.33	

3.2.2 Effect of phosphorus fertilizer on protein percentage

The illustrated results in Table (9) clearly indicate that phosphorus fertilizer levels had significantly increased protein percentage in the two experimental seasons. The highest values (32.4 and 31.6 %) were obtained when phosphorus was applied at a level of 46.5 kg P_2O_5 /feddan during 2018/2019 and 2019/2020 seasons, respectively. The positive effect of phosphorus fertilizer on crude protein per dry seeds at harvest date may be due to phosphorus has a major role in photosynthesis activities, energy transfer and carbohydrates metabolism of plants. Moreover, it is a part of the cells, nucleus and it is present in the cytoplasm and its role in cell division in very essential. Similar results were recorded by El-Murshedy (2008). The presented data in Table (9) results show that protein percentage were significantly affected by the interactions of (density x phosphorus) in the two seasons. The highest protein percentage values (32.9 and 32.3 %) were obtained when density was applied at 55 plant/m^2 with fertilized 46.5 kg P_2O_5 /feddan in 1st and 2nd seasons, respectively.

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