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Influence of Phosphorus on Growth and Yield of Promising Varieties of Lentil (*Lens culinaris* L. Medik)

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A B S T R A C T

A field experiment was undertaken during the *rabi* season of 2016-17 at Research Farm of Agronomy, College of Agriculture, CAU, Imphal to study the effect of phosphorus (0, 20, 40 and 60 kg P_2O_5/ha) on growth and yield of three lentil varieties (PL4, HUL 57 and DPL 62).Application of 40 kg P_2O_5/ha significantly enhanced the plant height, number of branches per plant, dry weight per plant, number and dry weight of nodules per plant, number of pods per plant, seeds per pod, seed yield (11.07 q/ha), stover yield (18.21 q/ha), crude protein content in seed and protein yield over control. Varieties showed significant influence in all characters except number and dry weight of nodules per plant and protein content. The highest seed yield was recorded in HUL 57(10.45 q/ha) which remained at par to DPL 62 (10.11 q/ha) and the lowest was observed in PL 4 (9.42 q/ha). Among the varieties, HUL 57 and DPL 62 were superior to PL 4 in respect of growth, yield and quality. HUL 57 fertilized with 40 kg P_2O_5/ha produced the highest seed yield.

Introduction

Pulses are an important group of crops which provide high quality protein for the predominantly vegetarian population of India. Pulses are the integral component of a cropping system in India as these crops fit well in crop rotation and mixed or inter cropping system followed under different agro-ecological regions.

Though India is the largest producer and consumer of pulses in the world, the average productivity is very low. The area, production and productivity under pulse crops accounts for 252.59 lakh ha, 16.47 million tonnes and 652 kg/ha respectively (Anon., 2016). Therefore, there is need to increase the pulse production in our country.

Lentil is one of the important pulse crops of India which can adapt well to a wide range of climate and soil condition. India occupies second position in lentil production in the world after Canada and is the fifth most important pulse crop in India in terms of production after chickpea, pigeon pea, mungbean and urdbean (Singh *et al.,* 2015). In the country, lentil is cultivated in an area of about 1.27million hectares with production of 0.97 million tonnes and average productivity of 765kg/ha. (Anon., 2015-16). Lentil, being a leguminous pulse crop, fixes atmospheric nitrogen through root nodules by Rhizobium bacteria in which atmospheric nitrogen is converted into a plant usable form in the presence of nitrogenase enzyme. Thus, lentil restores the soil fertility and improves the soil health keeping the soil alive and productive.

Phosphorus is the key element for successful pulse production. Phosphorus enhances the root proliferation and nodulation in legume crops, increases dry matter production and seed yield (Sharma and Sharma, 2004; Balyan and Singh, 2005). Phosphorus is involved in several plant functions, including energy storage and transfer, photosynthesis, transformation of sugars and starches, nutrient movement within the plant and transfer of genetic characteristics from one generation to the next. Phosphorus is a constituent of ATP, nucleic acid, phospholipid, ADP, sugar phosphate, phytin, protein and several co-enzyme. However, phosphorus is one of the major limiting nutrients for leguminous crops in acidic soil condition

Lentil yields at the farm level are far below the genetic potential of its cultivars. Growing of lentil in marginal and sub-marginal land, inadequate and imbalanced use of fertilizers as well as unavailability of site tested specific lentil varieties could be the contributing factors towards these lower production of yields. Most of the soils under lentil cultivation are low to medium in available phosphorus (P), therefore they respond positively to P-fertilizer application (Singh *et al.,* 2005). The productivity of lentil can be improved by adopting suitable agro-techniques. Among the agro-techniques, growing of suitable variety well adapted to the climatic condition of the area and adequate application of phosphorus will result in better crop performance, seed yield and quality of lentil. However, the information on these aspects are lacking in the state. Keeping this in view, a field experiment was carried out during *rabi* season of 2016-17 to evaluate the most suitable variety of lentil and to identify the suitable dose of phosphorus.

Materials and Methods

The field experiment was carried out at the Research Farm of Agronomy, College of Agriculture, Central Agricultural University, Imphal, Manipur during the *rabi* season of 2016-17.The experimental site is located at 24˚ 45’ N latitude and 93˚56’ E longitude at an altitude of 790m above the mean sea level. The soil of the experimental field was clay in texture with pH 5.57 and having organic carbon 1.2%, available nitrogen 288.51 kg/ha, available phosphorus 17.20 kg/ha and available potassium 242.02 kg/ha. The mean minimum and maximum temperature recorded during the cropping season was 10.41 and 24.30℃, respectively. During the experiment, the total rainfall recorded was 552.8 mm. The average relative humidity in the morning hours was 87.39% and in the evening was 51.14%. The average bright sunshine hour was 6.3.

The treatment consisted of four levels of phosphorus (P_0-control, P_1- 20 kg P_2O_5/ha, P_2- 40 kg P_2O_5/ha, P_3-60 kg P_2O_5/ha) and three varieties (V_1- PL 4, V_2- HUL 57 and V_3- DPL 62). The experiment was laid out in factorial randomized block design with three replications. Phosphorus as per treatment was applied through single superphosphate (SSP). A uniform dose of 20 kg N/ha and 20 kg K_2O/ha were applied through urea and muriate of potash to all the plots along an open furrow at a distance 20 cm apart one day before sowing. The crop was sown by line sowing method at the rate of 50 kg/ha on 10th December, 2016. Thinning was done to maintain plant to plant distance of 5 cm. Five representative plant samples were randomly selected from each plot and tagged. Height of the tagged plants was measured from ground level to the top of the shoot at harvest. The mean height was calculated and expressed in cm. Five plants were collected from the destructive sampling rows at harvest . These fresh samples were air dried and then dried in an oven at 60±5℃ till a constant weight was obtained and then weighed to record the average dry weight of plant (g).

From the sampling rows of each plot, five plants were uprooted carefully and the soil adhering to the roots were washed out in clean water. The nodules from the roots were detached and counted to record the average number of nodules per plant at 60 and 90 DAS. After recording the number of nodules per plant, these nodules were dried in an oven to a constant weight to record the dry weight of nodules per plant (mg).

The number of primary branches per plant, pods per plant and seeds per pod were counted from the randomly selected plants of each plot and average was calculated. After complete sun drying, the weight of thoroughly sun dried plants of net plot were recorded and expressed as biological yield. After threshing and winnowing, grain and straw yield per plot were weighed and expressed as quintal per hectare. The sun dried 1000 seeds were randomly drawn from each plot for recording test weight (g). The nitrogen percentage in lentil seeds was estimated in grounded seeds by using modified Kjeldahl's method (Jackson, 1967) and crude protein content was calculated by using the formula

$$\text{Crude protein content (\%)} = \%N \times 6.25$$

Protein yield (kg/ha) was calculated by multiplying protein content (%) and seed yield (q/ha). The data obtained was subjected to statistical analysis using the F-test (Gomez and Gomez, 1984).

Results and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under the following heads:

Effect of phosphorus

Growth parameters like plant height, number of branches per plant, dry weight (g/plant), number of nodules per plant and dry weight of nodules per plant were significantly influenced by different phosphorus levels. A perusal of Table 1 revealed that plant height, number of branches per plant and dry weight of plant at harvest increased significantly with increasing phosphorus levels up to 40 kg P_2O_5/ha over 20 kg P_20_5/ha and control. However, it remained statistically at par to 60 kg P_2O_5/ha. The maximum plant height (35.13 cm), branches per plant (5.8) and dry weight (4.31g/plant) were recorded at 60 kg P_2O_5/ha. The highest number of nodules per plant was recorded at 60 kg P_2O_5/ha (26.91) where it remained at par to 40 kg P_2O_5/ha (26.62) at 60 and 90 DAS. Again, in both the growth stages, the number of nodules per plant did not differ significantly between 40 and 20 kg P_2O_5/ha but significantly higher than the control. Application of phosphorus showed marked improvement in dry weight of nodules per plant over control. The dry weight of nodules per plant increased significantly with every increase in the level of phosphorus up to 60 kg P_2O_5/ha at 60 and 90 DAS except that application of 40 kg P_2O_5/ha remained at par to 20 kg P_2O_5/ha at 60 DAS. Phosphorus is essential for cell division, root development and proliferation, nodulation and nitrogen fixation. It is the main constituent of co-enzymes, ATP, ADP and nucleic acid which acts as "energy currency" within plants. Almost every metabolic activity is regulated by phosphate derivatives. Thus, phosphorus is involved in energy transfer, photosynthesis, nucleic acid synthesis, membrane transport and cytoplasmic streaming. Increase in growth parameters owing to phosphorus application in the soil might be due to increase availability and uptake of soil nutrients by the crop contributed by phosphorus fertilization. The greater uptake of nutrients might have increased the photosynthetic ability and translocation of the metabolites to different parts which ultimately increased the root and shoot development of the crop. These findings corroborate the results of Zafar *et al.,* (2003), Pandey *et al.,* (2016) and Singh *et al.,* (2016) in lentil and Kumawat *et al.,* (2014) in green gram.

Application of phosphorus significantly increased the yield attributes like number of pods per plant and seeds per pod (Table 2). Though an increasing trend in test weight was observed with increasing application of phosphorus, phosphorus could not bring significant influence to test weight. Number of pods per plant increased significantly with increasing levels of phosphorus up to 40 kg P_2O_5/ha (77.71) and further increase in the level of phosphorus up to 60 kg P_2O_5/ha (79.79) did not bring significant difference in the number of pods per plant. The maximum number of seeds per pod (1.74) was recorded with the application of 60 kg P_2O_5/ha and it remained at par to 40 kg P_2O_5/ha (1.68). Again, application of 40 kg P_2O_5/ha did not differ significantly with 20 kg P_2O_5/ha (1.64). The lowest number of pods per plant (61.49) and seeds per pod (1.54) were recorded in control. The probable reason might be attributed to phosphorus fertilization in ensuring availability of other plant nutrients which increased carbohydrate accumulation and their remobilisation to reproductive parts of the plant, being the closest sink. Phosphorus is known to encourage flowering and fruiting which might have stimulated the plants to produce more pods per plant and also enables development of more number of seeds per pod. Similar findings were reported by Maqsood *et al.,* (2000), Shah *et al.,* (2000), Togay *et al.,* (2008), Fatima *et al.,* (2013) and Ali *et al.,* (2017) in lentil.

Significant increase in the seed yield was recorded with the application of phosphorus up to 40 kg P_2O_5/ha over 20 kg P_2O_5/ha and control but remained statistically at par to 60 kg P_2O_5/ha (Table 2). Such a positive yield response of phosphorus application is obvious when it is limiting in acid soil. The soil samples= analysed before starting the experiment indicated that the available phosphorus status of the soil in the experimental site was in medium range and thus responded well to the applied phosphatic fertilizer. Application of phosphatic fertilizer, therefore provided balance nutrition to the crop which resulted in higher seed yield of lentil. Phosphorus also increased the photosynthesis and translocation of assimilates to different plant parts for enhanced growth and yield attributing characters of the crop as observed in number of pods per plant and number of seeds per pod. In the later stage, the excess assimilates stored in the leaves was translocated towards sink development which ultimately contributed to higher seed yield. Significant increase in stover yield with the application of phosphorus up to 40 kg P_2O_5/ha was also observed where it remained at par to 60 kg P_2O_5/ha (Table 2).The higher stover yield with suitable dose of phosphorus might be contributed by better growth of the plant as expressed in terms of plant height, number of branches per plant, fresh and dry weight of the plant as a result of improved nutrient uptake. These findings were supported by Choubey *et al.,* (2013), Zeidan (2007) and Rasool and Singh (2016) in lentil.

Application of phosphorus significantly increased the crude protein content in seed and crude protein yield (Table 2). The maximum crude protein content in seed was recorded in

60 kg P_2O_5/ha (24.19%) which remained at par to 40 kg P_2O_5/ha but significantly superior to other levels of phosphorus. Again, 40 kg P_2O_5/ha did not differ significantly in protein content as compared to 20 kg P_2O_5/ha. Crude protein yield increased significantly and consistently with every increase in the level of phosphorus up to 40 kg P_2O_5/ha (264.81 kg/ha) and remained at par to 60 kg P_2O_5/ha. Phosphorus is an essential component of DNA and various forms of RNA which are needed for protein synthesis. As such application of phosphorus in adequate quantity enhanced the protein synthesis which resulted in higher protein content. Also, protein content is affected by nodulation which improved N concentration in seed. Increased N concentration might have increased the protein content which might be influenced indirectly by phosphorus application in improving the uptake of nutrients by the crop. The increase in crude protein yield may be attributed to increase in crude protein content in seed and seed yield with increasing phosphorus application. These results are in conformity with Niri *et al.,* (2010), Pandey *et al.,* (2016) and Sahu *et al.,* (2017) in lentil.

Effect of varieties

Different varieties significantly influenced the growth parameters like plant height, number of branches per plant and dry weight of plant. Among the varieties, HUL 57 recorded the highest plant height at harvest and remained statistically at par to DPL 62. Again, DPL 62 remained at par to PL 4. The maximum number of primary branches was observed in HUL 57 and it showed significant superiority over DPL 62 and PL 4. The minimum number of branches was recorded in PL 4 which remained at par to DPL 62. The variety HUL 57 recorded the maximum dry weight per plant which remained at par to DPL 62 but significantly higher than PL 4. The minimum dry weight of plant was observed in PL 4 and it was at par to DPL 62. Varieties could not significantly influence the number of nodules per plant and dry weight of nodules per plant. However, the maximum number and dry weight of nodules per plant was recorded in DPL 64 and the lowest in PL 4. The difference in growth parameters among the varieties might be due variation in genetic make-up and cell division rate. These results are in agreement with those of Sen *et al.,* (2016) and Singh *et al.,* (2016).

Yield attributes like number of pods per plant, seeds per pod and test weight differed significantly with increasing application of phosphorus (Table 2). Among the varieties the number of pods per plant differed significantly. HUL 57 (76.7) recorded significantly higher number of pods per plant as compared to DPL 62 (72.18) and PL 4 (70.65).

However, DPL 62 and PL 4 remained statistically at par. The highest number of seeds per pod was recorded in the variety HUL 57 (1.71) and it remained at par to variety PL 4 (1.68). The lowest number of seeds per pod was recorded in DPL 62 (1.55) and was significantly inferior to HUL 57 variety and PL 4 variety. DPL 62 (29.2 g) gave significantly higher test weight compared to HUL 57 (19.5 g) and PL 4 (18.01 g). Again, HUL 57 recorded significantly higher test weight than variety PL 4. The difference in yield attributes among the varieties might be due to the variation in genetic constitution. Similar findings were also reported by Datta *et al.,* (2013), Yadav *et al.,* (2016) and Zike *et al.,* (2017) in lentil.

Seed yield and stover yield differed significantly among the different varieties (Table 2). The maximum seed yield was recorded in HUL 57 (10.45 q/ha) and it remained at par to DPL 62 (10.11 q/ha and) but significantly superior to PL 4 (9.84 q/ha).

Table.1 Effect of phosphorus levels and varieties on growth characters of lentil

Treatments	Plant height (cm) at harvest	Number of primary branches/plant	Dry weight (g/plant) at harvest	Number of nodules/plant		Dry weight of nodules (mg/plant)	
				60 DAS	90DAS	60 DAS	90DAS
Levels of Phosphorus (kg/ha)							
Control	29.81 c	4.20 c	3.11 c	23.24 c	15.13 c	26.76 c	19.47 d
20 kg P_2O_5/ha	32.39 b	4.62 b	3.75 b	25.00 b	17.02 b	28.69 b	20.64 c
40 kg P_2O_5/ha	34.59 a	5.51 a	4.12 a	26.62 ab	18.31 ab	29.68 b	21.83 b
60 kg P_2O_5/ha	35.13 a	5.80 a	4.31 a	26.91 a	19.24 a	31.10 a	23.34 a
SEd(±)	0.66	0.15	0.15	0.77	0.61	0.67	0.47
CD (P=0.05)	1.37	0.30	0.30	1.60	1.26	1.40	0.98
Varieties							
PL 4	32.06 b	4.80 b	3.65 b	25.53	17.03	28.92	21.16
HUL 57	33.74 a	5.30 a	3.99 a	25.13	17.43	28.95	21.24
DPL 62	33.15ab	5.00ab	3.82 ab	25.67	17.82	29.31	21.56
SEd(±)	0.57	0.13	0.13	0.67	0.53	0.58	0.41
CD (P=0.05)	1.19	0.26	0.26	NS	NS	NS	NS
Interaction P×V							
SEd(±)	1.14	0.25	0.25	1.34	1.05	1.17	0.82
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS

In a column figures having same letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly.

Table.2 Effect of phosphorus and varieties on yield attributes, yield and quality of lentil

Treatments	Number of pods/plant	Number of seeds/pod	Test weight (g)	Seed yield (q/ha)	Stover yield (q/ha)	Protein content (%)	Protein yield (kg/ha)
Levels of Phosphorus (kg/ha)							
Control	61.49 c	1.54 c	21.98	7.56 c	13.71 c	22.50 c	170.07 c
20 kg P_2O_5/ha	73.71 b	1.64 b	22.25	9.84 b	16.79 b	23.25 b	228.81 b
40 kg P_2O_5/ha	77.71 a	1.68ab	22.33	11.07 a	18.21 a	23.91ab	264.81 a
60 kg P_2O_5/ha	79.79 a	1.74 a	22.39	11.51 a	18.36 a	24.19 a	278.51 a
SEd(±)	1.26	0.04	0.63	0.22	0.53	0.36	7.15
CD (P=0.05)	2.62	0.09	NS	0.45	1.10	0.74	14.84
Varieties							
PL 4	70.65 b	1.68 a	18.01 c	9.42 b	16.14 b	23.42	221.45 b
HUL 57	76.70 a	1.71 a	19.50 b	10.45 a	17.35 a	23.44	246.22 a
DPL 62	72.18 b	1.55 b	29.20 a	10.11 a	16.81b	23.52	238.98 a
SE d (±)	1.09	0.04	0.55	0.19	0.46	0.31	6.20
CD (P=0.05)	2.27	0.08	1.13	0.39	0.96	NS	12.85
Interaction P×V							
SEd(±)	2.18	0.07	1.09	0.37	0.92	0.62	12.39
CD (P=0.05)	4.53	NS	NS	0.77	NS	NS	NS

In a column figures having same letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly.

The maximum stover yield was recorded in HUL 57 (17.35 q/ha) and it remained significantly higher than PL 4 and DPL 62. However, PL 4 (16.14 q/ha) did not differ significantly with DPL 62 (16.81 q/ha).

The variation in seed and stover yield might be due to difference in growth characters like plant height, number of branches per plant and dry matter accumulation and also in yield attributing characters like number of pods per plant, seeds per pod and test weight among the varieties which is influenced by the genetic-make up. These results are in conformity with Sen *et al.,* (2016), Yadav *et al.,* (2016) and Iliger *et al.,* (2017) in lentil.

Varieties could not bring significant influence in crude protein content in seed (Table 2). However, the highest crude protein content was recorded in DPL 62. Crude protein yield was significantly influenced by different varieties. The maximum crude protein yield was recorded in HUL 57 (246.22 kg/ha) and it was at par with DPL 62 (238.98 kg/ha) but significantly higher than PL 4 (221.45 kg/ha). The differences in crude protein yield among the varieties might be contributed by seed yield and protein content. These findings were in agreement with Tomar *et al.,* (2000) in lentil.

Based on the results of the present study, it can be concluded that application of phosphorus at 40 kg/ha was found to be the optimum dose and HUL 57 and DPL 62 were found to be the best suited varieties for obtaining higher yield of lentil in Manipur.

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