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Effect of Row Spacing and Phosphorus Fertilizer Rates on Yield and Yield Related Traits of Mung Bean (*Vigna radiata* L.) at Fedis, Eastern Ethiopia

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Abstract: Determination of appropriate row spacing and phosphorus rate of mung bean can increase its productivity. Therefore, a field experiment was conducted at Fedis Agricultural Research Center during main growing season to evaluate the effect of phosphorus rate and row spacing on yield and yield related traits of mung bean. Factorial combinations of four phosphorus rate (0, 23, 46, 69 kg P_2O_5 ha^{-1}) and three row spacing (20, 30, and 40 cm) laid out in RCBD with three replications. A total of 12 treatments and Borda variety was used for the experiment. The results revealed that there were significant ($P<0.05$) differences for plant height, total and effective number of nodule $plant^{-1}$, pod $plant^{-1}$, thousand grain weight, dry biomass yield and grain yield due to phosphorus application. Branch per plant, pod per plant, pod length and dry biomass yield were significantly ($P<0.05$) affected due to row spacing. The highest Thousand Grain Weight (30.18 g) was obtained from the application of 46 kg P_2O_5 ha^{-1} while the lowest (28.27 g) was obtained from 0 kg P_2O_5 ha^{-1}. The highest grain yield (961.6 kg ha^{-1}) was achieved from 46 kg P_2O_5 ha^{-1} while the lowest (766.7 kg ha^{-1}) was from 0 P_2O_5. In conclusion, the application of 46 kg P_2O_5 ha^{-1} and 30 cm row spacing recorded highest grain yield with highest economic returns (14123.78 ETB ha^{-1}). Based on grain yield and economic return, combination of 46 kg P_2O_5 ha^{-1} and 30 cm row spacing was recommended for the study area and similar agro-ecology.

Keywords: Row Spacing, Mung Bean, Phosphorus, Yield

1. Introduction

Mung bean (*Vigna radiata* L.) also known as Green gram is a self-pollinated leguminous crop and is among the most important pulse crops of the world. It has great value as food, fodder and green manure. This crop can be successfully grown on marginal lands where other crops perform poorly [7]. It is a fast-growing, warm-season legume.

Optimum row spacing plays an important role in contributing to the high yield because thick plant population will not get proper light for photosynthesis and can easily be attacked by diseases. On the other hand, very small population will also reduce the yield [16]. Improper spacing reduces the yield of mung bean up to 20-40% [4] due to competition for light, space, water and nutrition. Optimum plant spacing and seed rate should be ensured for the plant to grow properly in order to give higher yield [15].

Research on crop nutrition has documented nitrogen and phosphorus as the most limiting nutrient elements for crop production [14]. However, P has been reported to be more limiting than N in tropical legumes [10]. Nodulation and N fixation for tropical legumes and survival of Rhizobia in soil are particularly affected under low P and acid soil conditions [8].

One of the major constraints that limit the production of mung bean is a lack of optimum plant populations and soil fertility status. As a number of factors such as fertility status of the soil, moisture availability, salinity stress, growth pattern of the variety and cultural practices influence optimum planting density and phosphorus rate should be determined to specific area and to specific mung bean variety through conducting location or agro-ecology based experiment [9]. The objectives of the study were to evaluate the effect of row spacing and phosphorus rate on yield and yield related traits of mung bean.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Fedis Agricultural Research Center, Boko experimental site in Fedis district, east Hararghe Zone of Oromia region. Boko experimental site is located at the latitude of 9° 07'N and longitude of 42° 04' East, in the middle and low land areas and at average altitude of 1702 meter above sea level, with a prevalence of low lands. The district receives average annual rain fall of 860.4 mm; the minimum and maximum air temperature of 20°C and 35°C, respectively.

2.2. Description of Experimental Materials

Improved variety of mung bean Borda (MH-97-6) was used as a test crop. It is drought tolerant, disease resistant and high yielding variety. It has 0.8 to 2.4 ton/ha yield potential and 60-70 days to maturity and well adapted and popularized around the study areas. Triple super phosphate (TSP) was drilled in the row as per the treatment and mixed with soil just at the time of planting.

2.3. Treatments and Experimental Design

The treatments consisted of factorial combination of four fertilizer rate (0, 23, 46 and 69 kg ha^{-1} of P_2O_5) as triple super phosphate (TSP) and three row spacing (20, 30 and 40cm). The experiment was laid out in Randomized Complete Block Design (RCBD) and replicated three times per treatment in factorial combination with a total of 12 treatments.

2.4. Experimental Procedures

The land was ploughed by tractor, disked, harrowed and finally all plots was manually leveled for precise planting. Starter fertilizer 20 kg ha^{-1} of urea was uniformly drilled in the row to all treatments and mixed with soil just at the time of planting. The plot size was 2.5m by 2.4m. The experiment consists of 6, 8 and 12 rows for 40, 30 and 20cm row spacing respectively. The spacing between blocks and plots was 1m and 0.6m respectively. The border row was used as destructive rows and the middle rows were used for data collection. Two seeds was per hill and then thinned to one plant three weeks after seedling emerge. All other management practices were given as per the recommendations.

2.5. Data Management and Analysis

2.5.1. Data Collected

Data collected were plant height, number of branch, number of nodules, effective nodule per plant, number of pod, pod length, number of seed per pod, hundred grain weights, biomass yield and grain yield.

2.5.2. Data Analysis

All the measured parameters were subjected to analysis of variance (ANOVA) appropriate to factorial experiment in RCBD according to the General Linear Model (GLM) of Gen Stat 15th edition (Gen Stat, 2015). LSD test at 5% probability level was used for mean comparison when the ANOVA showed significant differences.

3. Results and Discussion

3.1. Soil Physico-Chemical Properties of the Experimental Site

The analysis result of the collected soil sample from the experimental site (Table 1) indicated that the soil was clay with a particle size distribution of 23% sandy, 29% silt and 48% clay with pH value of 8.1 which is slightly alkaline. The soil was medium in total nitrogen (0.167%), had low available phosphorus (2.61 mg kg^{-1} soil), moderate organic matter (2.277) contents and low cation exchange capacity (7.13 cmol kg-1 soil) according to range [20].

Table 1. *Selected soil physico-chemical properties of the experimental site*

Parameter	pH	CEC	OC	Avail. P	TN	Texture
Value	8.1	23.304	1.268	2.61	0.167	Clay

3.2. Plant Height

Analysis of variance showed that plant height was significantly ($P<0.05$) influenced by the main effect of phosphorus. However, the main effect of row spacing and their interactions were not significant. The tallest plant height (29.93cm) was recorded from application of 69 kg P_2O_5 ha^{-1}, which was statistically similar with 46 kg P_2O_5 ha^{-1} while the shortest plant height (26.96 cm) was obtained when the plants were not treated with P_2O_5 (Table 2).

The result is in line with Imran, Asad, Inamullah, and Fayaz [11] who reported Plots treated with 60 kg P ha^{-1} produced taller plants height, being at par with 80 and 100 kg P ha^{-1} while shorter plants height was recorded in control plots. Similarly Kumar, Singh, Singh, Latare, Mishra and Supriya [13] reported Plant height increased continuously and significantly with increasing levels of phosphorus up to 45 kg P_2O_5 ha^{-1} at all stages of crop growth.

3.3. Number of Branches per Plant

There was significant ($P<0.05$) difference in number of branches per plant due to the main effect of row spacing while, the main effect of phosphorus and their interaction had no significant effect. The highest number of branch per plant (4.767) was obtained from the row spacing of 40 cm which was statistically similar with 30 cm and the lowest number of branch per plant (4.125) was obtained from 20 cm (Table 2).

The finding is in agreement with Gebrelibanos Gebremariam and Fiseha Baraki [6] who reported the highest numbers of branches per plant were recorded from 30 cm and 40 cm inter-row spacing whereas the lowest was obtained from 20 cm inter-row spacing.

3.4. Number of Nodules and Effective Nodule per Plant

The main effects of phosphorus application significantly (P<0.05) affected the total number of nodules per plant, however, the main effect of row spacing and their interaction had no significant effect. The highest total number of nodule per plant (3.83) was obtained from plants grown under P rate of 69 and 46 kg P_2O_5 ha^{-1}, while, the lowest (2.44) was observed under control treatment (Table 2). The improvement in nodule number due to P fertilizer could be associated with its stimulating effect on growth [19].

The analysis of variance revealed that the main effects of phosphorus application significantly (P<0.05) affected the effective number of nodule per plant, while, the main effect of row spacing and their interaction had no significant effect. The highest effective number of nodule $plant^{-1}$ (3.28) was obtained from plants grown under P rate of 69 kg P_2O_5 ha^{-1}, while the lowest (1.94) was observed under control treatment (Table 2).

In addition to the nodule formation, deficiency of phosphorus in legume also markedly reduced the development of effective nodules and the nodule leghaemoglobin content which is responsible for the formation of dark pink or red centers inside nodules [18].

Table 2. *The means of plant height, branches per plant, nodule per plant and effective nodule per plant as influenced by the main effect of phosphorus and row spacing.*

P_2O_5 (kg ha^{-1})	Plant Height	branch $Plant^{-1}$	nodule $Plant^{-1}$	Effective nodule $plant^{-1}$
0	26.96^{c}	4.411	2.44^{a}	1.94^{a}
23	27.34^{bc}	4.5	2.61^{a}	2.17^{a}
46	29.53^{ab}	4.478	3.83^{b}	3.11^{b}
69	29.93^{a}	4.533	3.83^{b}	3.28^{b}
LSD (5%)	2.331	NS	0.82	0.49
row spacing (cm)				
20	28.74	4.125^{b}	3.17	2.58
30	28.54	4.55^{ab}	3.08	2.5
40	28.05	4.767^{a}	3.29	2.79
LSD (5%)	NS	0.4496	NS	NS
CV (%)	12.2	17.3	38.7	27.8

Means followed by the same letter (s) are not significantly different at 5% level of significance for each treatments; LSD = Least Significant difference; CV= Coefficient of Variation.

3.5. Number of Pods per Plant

The analysis of variance revealed that main effect of row spacing and phosphorus rate were significant (P<0.05) on the number of pod $plant^{-1}$. However, the interaction effect was not significant. The highest Number of pod per plant (19.27) was obtained from row spacing of 40 cm which was statistically similar with 30 cm while the lowest (15.32) was obtained from 20 cm row spacing and the highest number of pod per plant (18.93) was obtained from 46 kg P_2O_5 ha^{-1} and the lowest (15.71) was from when there was no P_2O_5 application (Table 3).

The current result is in line with Ajio, Talwana and Kagoda [2] who reported plants sown at a spacing of 40 x 10 cm had the highest average number of pods (16.18).

3.6. Pod Length and Number of Seed per Pod

The analysis of variance showed significance differences (P<0.05) as affected by row spacing while, the main effects of phosphorus and their interaction were not significant. The highest pod length (7.742 cm) was recorded in 30 cm inter row spacing while the lowest pod length (7.162 cm) was from 20 cm (Table 3).

The present finding consisted with Foysalkabir, Quamruzzaman, Mohammed, Rashid, Yeasmin and Islam [5] who reported the maximum pod length (10.18 cm) was obtained from 30 cm × 10 cm spacing whereas, the minimum (6.38 cm) was observed from 20 cm × 10 cm spacing.

Analysis of variance showed that the main effect and their interaction effect on number of seed per pod were not significant (Table 3). Fertilizer application and wider plant spacing increased the number of seeds pod^{-1}, but the variation was not up to the mark statistically.

3.7. Thousand Grain Weight

The analysis of variance revealed application of phosphorus significantly (P<0.05) affected thousand grain weights. While, the main effect of row spacing and their interaction effect was not significantly influenced. The highest thousand grain weight (30.18 g) was obtained from the application of 46 kg P_2O_5 ha^{-1} while the lowest (28.27 g) was obtained from the control plot (Table 3). The current result is in line with Khan, Singh and Kumar [12] reported maximum test weight was recorded with 45 kg P_2O_5 ha^{-1} followed with 30 kg P_2O_5 ha^{-1}, whereas, the minimum remained with 0 kg P_2O_5 ha^{-1}.

Table 3. *The means of pod per plant, Pod length, seed per pod and thousand grain weight as influenced by the main effect of phosphorus and row spacing*

P_2O_5 (kg ha^{-1})	Pod $plant^{-1}$	Pod length	Seed pod^{-1}	1000 grain weight
0	15.71^b	7.278	11.19	28.27^b
23	17.72^{ab}	7.361	11.28	28.32^b
46	18.93^a	7.583	11.2	30.18^a
69	18.68^a	7.633	11.74	29.06^{ab}
LSD (5%)	2.285	NS	NS	1.147
row spacing (cm)				
20	15.32^b	7.162^b	10.99	28.3
30	18.69^a	7.742^a	11.48	29.25
40	19.27^a	7.487^{ab}	11.58	29.33
LSD (5%)	1.979	0.393	NS	NS
CV (%)	19.2	9.1	9.3	5.9

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance; LSD=Least Significant difference; NS=Not significant; CV= Coefficient of Variation.

3.8. Above Ground Dry Biomass

Above ground dry biomass was significantly ($P<0.05$) influenced by the main effect of row spacing and phosphorus application. While, there was no significant effect of their interactions. The highest above ground dry biomass (2556 kg ha^{-1}) was achieved under the application of 46 kg P_2O_5 ha^{-1}. The treatment without P_2O_5 application resulted in the lowest above ground dry biomass (2023 kg ha^{-1}). The highest and lowest above ground dry biomass (2424 kg ha^{-1}) and (2103 kg ha^{-1}) was also obtained under 20 cm and 40 cm row spacing respectively (Table 4).

This result is agreement with Amanullah, Majidullah, Muhammad, Nawab and Ali [3] who reported Phosphorus levels had significant impact on biomass yield of mung bean under dry land condition. Similarly, Kumar, Singh, Singh, Latare, Mishra and Supriya [13] reported there was rise in straw yield with increasing doses of phosphorus.

In the case of row spacing Rasul, Cheema, Sattar, Saleem, and Wahid [17] reported that the row spacing of 30 cm and 45 cm produced dry biomass of 4131 kg ha^{-1} and 4003.5 kg ha^{-1} while, the wider spacing of 60 cm resulted in minimum dry biomass (3328.9 kg ha^{-1}).

3.9. Grain Yield

The analysis of variance revealed the main effect of phosphorus application was significant difference ($P<0.05$). However, the main effect of row spacing and their interaction were not significant difference. The highest grain yield (961.6 kg ha^{-1}) was achieved from 46 kg P_2O_5 ha^{-1} while the lowest grain yield (766.7 kg ha^{-1}) was obtained from control treatment (Table 4).

Table 4. *The means of dry biomass and grain yield as influenced by the main effect of phosphorus and row spacing.*

P_2O_5 (kg ha^{-1})	Dry biomass yield	Grain Yield (kg/ha)
0	2023^c	766.7^c
23	2184^{bc}	$822.1b^c$
46	2556^a	961.6^a
69	2396^{ab}	911.5^{ab}
LSD (5%)	270.715	97.9
Inter row (cm)		
20	2424^a	904
30	2341^a	886
40	2103^b	807
LSD (5%)	234.446	NS
CV (%)	17.6	16.9

Means followed by the same letter (s) are not significantly different at 5% level of significance for each treatments; LSD = Least Significant difference; CV= Coefficient of Variation.

The result is in line with Kumar, Singh, Singh, Latare, Mishra and Supriya [13] Maximum value of 10.78 q ha^{-1} grain yield was recorded at 45 kg P_2O_5 ha^{-1} and minimum value of 7.32 q ha^{-1} grain yield was recorded at 0 kg P_2O_5 ha^{-1}. Similarly Ahmad, Khan, Ali, Imran and Habibullah [1] reported mean value of phosphorus levels indicated that plots treated with 80 kg P ha^{-1} produced maximum grain yield (1139 kg ha^{-1}) being at par with 100 kg P ha^{-1}, while minimum grain yield (617 kg ha^{-1}) was recorded in control plots.

3.10. Partial Budget Analysis

Application of phosphorus rate at 46 kg ha^{-1} and row spacing of 30 cm recorded maximum net benefit with acceptable marginal rate of returns followed by combination of 69 kg ha^{-1} and 20 cm from mung bean production. The lowest net returns were obtained at 0 P_2O_5 kg ha^{-1} in all treatment combinations.

Table 5. *Summary of economic analysis of the effects of phosphorus rates and row spacing.*

Treatments P_2O_5 (kg ha^{-1})	row spacing	UGY (kg ha^{-1})	AGY (kg ha^{-1})	GFB (ETB ha^{-1})	TVC (ETBha^{-1})	NB (ETB ha^{-1})	MRR (%)
0	40	601.85	541.665	10833.3	640	10193.3	
0	30	673.81	606.429	12128.58	925	11203.58	354.4842
0	20	744.44	669.996	13399.92	1210	12189.92	346.0842
23	40	680.56	612.504	12250.08	1537	10713.08	D
23	30	864.29	777.861	15557.22	1822	13735.22	1060.4
23	20	857.64	771.876	15437.52	2107	13330.52	D
46	40	843.52	759.168	15183.36	2434	12749.36	D
46	30	935.71	842.139	16842.78	2719	14123.78	482.2526
46	20	949.31	854.379	17087.58	3004	14083.58	D
69	40	865.74	779.166	15583.32	3331	12252.32	D
69	30	829.37	746.433	14928.66	3616	11312.66	D
69	20	996.53	896.877	17937.54	3901	14036.54	955.7474

Where, P=Phosphorus (P_2O_5) rate (kg ha^{-1}); R = row spacing (cm); UGY = Unadjusted grain yield; AGY = adjusted grain yield; GFB = gross field benefit; TVC= total variable cost; NB = net benefit, MRR = marginal rate of return; D = dominated treatments.

4. Conclusion

The experiment was conducted to determine the effect of row spacing and phosphorus fertilizer rate on mung bean yield and yield parameters. The results indicated that there were significant effects among treatments for plant height, total and effective number of nodule plant^{-1}, pod plant^{-1}, thousand grain weight, dry biomass yield and grain yield due to the application of phosphorus. Branch per plant, pod per plant, pod length and dry biomass yield were significantly ($P< 0.05$) affected due to row spacing. The highest grain yield (961.6 kg ha^{-1}) was achieved from 46 kg P_2O_5 ha^{-1} while the lowest (766.7 kg ha^{-1}) was from 0 P_2O_5 kg ha^{-1}. In conclusion, the application of 46 kg P_2O_5 ha^{-1} and 30 cm row spacing recorded highest grain yield with highest economic returns (14123.78ETB ha^{-1}). Based on grain yield and economic return, combination of 46 kg P_2O_5 ha^{-1} and 30 cm row spacing was recommended for the study area and similar agro-ecology.

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