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Agronomic and other Traits of Mung Bean (Vigna Radiata *L.*) Response to Different Levels of Phosphorus Fertilizer and Row Spacing for Better Grain Yield Production in Silte Southern Ethiopia

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Abstract

Mung bean is one of the important annual self-pollinated pulse crops. The study was conducted at Sankura wereda Jejebicho Kebele in 2020/21 main cropping season on Jejebicho research station of WGARC. We used mung bean variety called 'Arkebe'' released by HARC. This study was conducted to determine the optimum row spacing and phosphorus fertilizer rate for better grain yield of mung bean and to assess the economic value of using P for Mung bean production. The analysis data showed that, branch number per plant, number of pods per plant, number of seed per pod, above ground biomass yield, grain yield and harvest index of were significantly affected by due to the interaction effects of both Phosphorus fertilizer application and intra row spacing. The highest branch number per plant (8.55), number of pods per plant (31.17), number of seed per pod (13.45), above ground biomass yield (8901.5kg ha^{-1}), grain yield (2500.6 kg ha^{-1}) was obtained from the application of 60 kg P_2O_5 ha^{-1} and 10cm intra row spacing but, maximum harvest index was from the application of 40 kg P_2O_5 ha^{-1} and 15cm intra row spacing. that the highest mean net benefit (87307.56 ETB ha^{-1}) with acceptable MRR (720%) was obtained in the application of 60 kg P_2O_5 ha^{-1} with 40cm x10 cm row spacing. In contrast, the lowest mean net benefit (38,873.03 ETB ha^{-1}) was obtained from the control (unfertilized) plot 40cm x 5cm row spacing. So, application of 60 kg P_2O_5 ha-1 with 10 cm x 40cm row spacing is best and economical to mung production for farmers in the study area and similar agro-ecologies.

Keywords: Economic Analysis; Grain Yield; Phosphorus, Row spacing

Abbreviations: P: Phosphorus; KM: Kilo Meter; MASL: Meters Above Sea Level; HARC: Humera Agricultural Research Center; LSD: Least Significant Difference; TSP: Triple Super Phosphate.

Introduction

Mung bean (Vigna radiata) is one of the important annual pulse crops that belong to family fabacaae. It is originated from India and Expanded to East, South, Southeast Asia (China) and some countries in Africa [1]. It is a warm season annual grain legume the optimum temperature ranges from 27oc to 30°C it is requiring 90 to120 days of frost-free for maturity [2]. Mung bean is an essential short duration, self-pollinated diploid legume crop with high nutritive values and nitrogen fixing ability [3]. It is an eco-friendly food grain leguminous crop of dry land agriculture with rich source of proteins, vitamins, and minerals.

Mung bean by virtue of its richness in protein and essential amino acids play an important role in making up the protein deficiency for poor. Moreover, this crop plant being leguminous in nature, improve soil fertility by fixing atmospheric nitrogen to available form through bacterial symbiosis. In addition, it is a short duration pulse crop requiring low inputs and suitable for cultivation both under rain fed and irrigated conditions. It is grown in Pakistan on an area of 192.4 thousand hectare annually with a total production of 89.5 thousand tones and with an average yield of 465 kg ha^{-1} as against the inherent potential [4]. The advanced production technology stresses on the use of appropriate level of fertilizers which is a key input contributing about 30-70% increase in crop yield. Being a legume crop it requires less nitrogen but application of phosphorus and potassium plays a vital role in getting high yield per unit area. They concluded that number of pods per plant, number of seeds per pod and seed weight were the highest with the application of phosphorus fertilizer. Sandhu [5] also reported that application of phosphorus is essential to harvest good yield of mung bean on a sandy loam soil appeared to be the best level.

There are many factors and conditions that impact plant nutrient needs. The use of fertilizer is considered to be one of the most important factors to increase crop yield on per unit basis. The application of phosphorus to mung bean has been reported to increase dry matter at harvest, number of pods $plant^{-1}$, seeds pod^{-1}, 1000 grain weight, seed yield and total biomass Naeem, et al. Lateef, et al. [6,7] found that mung bean genotypes varied in yield as response to phosphorus application and mung bean genotypes differed significantly for plant height and number of branches $plant^{-1}$, and greatest number of pods. Similarly, Khan, et al. [8] obtained a linear increased trend in total biomass, straw yield and grain yield of mung bean with increasing the rates of phosphorous fertilizer. Legumes have a high phosphorus requirement for growth and also for nodulation and nitrogen fixation [9]. Phosphorus deficiency, common in tropical soils, is therefore a major factor contributing to poor nitrogen fixation and yield of legumes, and P fertilization results in improved growth [10]. Being a legume crop it requires less nitrogen but application of phosphorus plays a vital role in getting high yield per unit area.

Phosphorus (P), is essential and present in high levels in mung bean, and play important roles in its growth, development, high yield and significantly affect many mung bean traits [11-15]. Phosphorus fertilizer promotes root growth, disease resistance, drought tolerance, and enhances nutrient and water absorption in the seedlings after they have depleted their endosperm reserves [16,17]. According to Sadeghipour, et al. [18] revealed that the highest seed yield of mung bean was obtained at highest rate phosphorus fertilizer. Since mung bean is a new and very economical crop for our country, we have to develop appropriate agronomic package like fertilizer rate determination. But rate of fertilizer recommendation is affected by different factors like, soil type; available nutrient in the soil, climatic factors and other environmental factors.

Use of good yielding varieties and applying the best agronomic practices are the best ways to increase yield of any crops. Among the agronomic practices, optimum plant population is a prerequisite for obtaining higher productivity [19]. The significance of using optimum inter and intra row spacings has been recognized by several researchers. Kabir and Sarkar [20] reported that highest seed yield of mung bean was obtained maintaining 30 cm × 10 cm spacing between rows and plants, respectively. Plant density of 40 plants m^{-2} at 25 cm x10 cm planting was the optimum for achieving higher productivity [21]. The results of Ahmed [22] showed a seed rate of 25 kg ha^{-1} is optimum to obtain maximum mung bean yield. Seed yield of mung bean per unit area tended to increase up to 30 plants m^{-2} and further increase in density did not result any further in yield per unit area [23]. These authors also reported a decline in seed yield as the density of plants increased to 60 plants m^{-2} Nawale [24] concluded that the optimum plant population for mung bean was 666,667 plants per hectare obtained through the configuration of 30 cm and 10 cm between rows and plants within row, respectively. Since mung bean is recently introduced to our country as well as Silte zone Sankura wereda Jejebicho research station, the effect of different agronomic practices including inter and intra-row spacing were not well studied. Such studies have paramount importance for promotion of the crop in line with the country's effort to diversify agriculture for improved nutrition and food security. Therefore, there is need to determine optimum row spacing and phosphorus fertilizer rate for better grain yield production of mung bean at selected areas. So, this activity was conducted: to determine the optimum row spacing and phosphorus fertilizer rate for better grain yield of mung bean and to assess the economic value of using P for Mung bean production.

Materials and Methods

Description of the Study Area

The study was conducted at Sankura wereda Jejebicho Kebele in 2020/21 cropping season on research station. The area has a soil type of sandy clay loam soil. Sankura wereda was located in Silte zone of southern Ethiopia and it takes 214 kilo meter (km) from our capital city Addis Ababa and it takes also 40km from Worabe city of Silte Zone Southern Ethiopia. The geographical coordinate of the research site is 9°43'N and 39°78'E with an altitude of 1643 meters above sea level (m.a.s.l.).

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Description of the Experimental Materials

Mung bean: the available released variety of mung bean ‘’Arkebe’’ which was released in 2008 by Humera Agricultural Research Center (HARC). It matures in 90-120 days and it is also a warm season annual, highly branched and having trifoliate leaves like the other legumes. Both upright and vine types of growth habit occur in mung bean, with plants varying from one to five feet in length. The pale-yellow flowers are borne in clusters of 12-15 near the top of the plant. Mature pods are yellowish-brown in color, about five inches long, and contain 10 to 15 seeds. Self-pollination occurs so insect and wind are not required and mature seed colors can be yellow.

Treatments and Experimental Design

The experiment was consisting of two factors, four levels of phosphorus (0, 20, 40 and 60 kgha^{-1}) and three row spacing (5cm x 40cm, 10cm x 40cm and 15cm x 40cm). Totally by combining the factors twelve treatments for this experiment was used. The source of phosphorus was triple super phosphate (TSP) Table 1.

Trts code	Levels of P_2O_5 in kg/ha	Row spacing (cm)	Trts, combinations
1	0	5cm x 40cm	0 x 5cm x 40cm
2	0	10cm x 40cm	0 x 10cm x 40cm
3	0	15cm x 40cm	0 x 15cm x 40cm
4	20	5cm x 40cm	20kgha^{-1} x 5cm x 40cm
5	20	10cm x 40cm	20 kgha^{-1} x 10cm x 40cm
6	20	15cm x 40cm	20 kgha^{-1} x 15cm x 40cm
7	40	5cm x 40cm	40 kgha^{-1} x 5cm x 40cm
8	40	10cm x40cm	40 kgha^{-1} x 10cm x 40cm
9	40	15cm x 40cm	40 kgha^{-1} x 15cm x 40cm
10	60	5cm x 40cm	60 kgha^{-1} x 5cm x 40cm
11	60	10cm x 40cm	60 kgha^{-1} x 10cm x 40cm
12	60	15cm x 40cm	60 kgha^{-1} x 15cm x 40cm

Where, Trts= Treatments

Table 1: Detail of treatment description.

Land Preparation, Field Layout and Sowing

The seed of mung bean was sown on the experimental field at the end of June 2020. The experimental field was ploughed and harrowed by a tractor to get a fine field. It was leveled by manually before the field layout was made. The distance between plot and block was 0.5 m and 1 m respectively. Inter-row spacing of 40 cm was used for all treatments. The row length of the experiment was 1.5 m; therefore, the gross plot of was also 6m^2 (1.5 m x 4.5 m). Generally, a total of 23.5 m x 14 m (329 m^2) experimental field area was used for this particular study.

Soil Sampling and Analysis

A composite soil sample was taken from experimental field before sowing. The soil analysis was done for parameters of Soil textural class, Soil pH, Organic Carbon (%), Total nitrogen (%), Available P (ppm), CEC (meq/100g soil), the soil sample was taken before sowing mung bean.

Data to be Collected

At the time of data collection, the following data was taken: plant height (cm), number of branches per plant, number of pods per plant, number of seed per pod, above ground biomass yield (kgha^{-1}), grain yield (kgha^{-1}), harvest index (%), 1000 seed weight and economic analysis (partial budget analysis) were used as parameter for this study.

Harvesting Grain of Mung Bean

The grain of mung bean was harvested in mid of November 2020 and 2021. The Mature pods have a color (yellowish-brown to black), about five inches long. Mature seed colors can be yellow, brown, mottled black or green, depending upon variety.

Weather Data

The weather data like maximum and minimum temperature (T^{0}C) was recorded from the experimental site.

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The mean annual rainfall (mm) was also incorporated.

Data Analysis

All data was subjected to the analysis of variance (ANOVA) appropriate to the randomized complete block design using SAS (SAS, 2002). Least significant difference (LSD) test at 5% level of probability was used for mean separation as procedure described by Gomez and Gomez, (1984). We used the linear model of RCBD while analysed the data by SAS, Yijk =μ+ ai + bj + ¡k + α¡ik + eijk. Where, Yijk = the value of the response variable; = Common mean effect; ai = Effect of row spacing; bj = Effect of block; ¡k = Effect of phosphorus fertilizers, α¡ik = Interaction effect of row spacing & fertilizer levels; and eijk = Experiment error.

Results and Discussion

Soil Physico-Chemical Properties of Jejebicho Research Station

The analysis result of the collected soil sample from both experimental sites Tables 2 & 3 indicated in that the soil was clay with a particle size distribution of 21% sandy, 25% silt and 48% clay with pH value of 8.5 which is slightly alkaline. The soil was medium in total nitrogen (0.167%), had low available phosphorus (2.62 mg kg^{-1} soil), moderate organic matter (2.287) contents and low cation exchange capacity (7.15 cmol kg^{-1} soil) [25] Figure 1.

Soil physico-Chemical Properties	Results
pH	8.5
CEC	7.15 cmol kg^{-1}
OC	2.287
Av. P.	2.62 mg kg^{-1}
Tot. N	0.17%
Textural class	21% sandy, 25% silt and 48% clay

Note, OC= Organic carbon, Av. P.= Available phosphorus and Tot. N= Total nitrogen

Table 2: showed the average mean value of Soil physico-Chemical Properties at Sankura Wereda Jejebicho research station.

Month	2020 Cropping season		2021 Cropping season	
	Maxi.T°C	Mini.T°C	Maxi.T°C	Mini.T°C
April	31.25	14.08	32.06	14.8
May	32.43	15.13	26.93	13.64
June	29.87	14.2	25.75	13.22
July	26.21	14.25	23.89	13.26
August	25.59	13.26	23.71	12.76
September	24.52	12.98	23.98	13.38
October	25.16	8.8	24.83	9.02
November	26.76	10.46	26.63	7.9
December	24.49	9.2	27.55	7.46

Table 3: the mean monthly maximum and minimum temperature (maximum and minimum) data on 2020 and 2021 Cropping Season at Sankura Wereda Jejebicho Kebele.

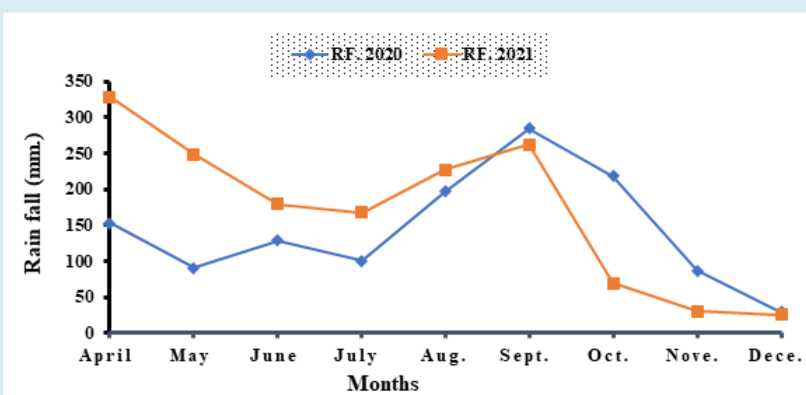

Figure 1: Mean monthly rainfall at Jejebicho Kebele of Sankura Wereda in 2020 and 2021 cropping season

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Effect of phosphorus fertilizer rate and row spacing on the growth, yield components and yield of mung bean at Jejebicho research station in Sankura Wereda.

Plant Height: application of phosphorus fertilizer significantly affected plant height of mung bean on both 2020 cropping season at Jejebicho research station. The tallest plant was measured from 60kg P ha^{-1} while the shortest plant was recoded from the control (nil) phosphorus Table 4. This might be due to the reason that soil had no enough P level and higher doses of P from 0-60kgha^{-1} was effective in increasing plant height. This may due to the competition between plants for sun light, water, nutrients and space at closer spacing which encouraged self-thinning of branches and enhanced vertical growth rather than horizontal growth. These results were in lined with Ahmed et al. [26], the highest plant height was recorded where P was applied at the rate of 60 kgha^{-1} over the control plots. This study was also supported by Ali, et al. [27] who observed significant higher plant height in mung bean crop when fertilized at the rate of 100 kg ha^{-1} phosphorus. Similarly supported by Bonepally, et al. Thavaprakaash & Siddaraju, et al. [28-30], they reported that the increased in plant height (cm) was due to increased trend with closer spacing or crop arrangements. This may due to the presence of higher intraspecific competition in closer intra-row spacing than other treatment.

Branches number per plant: numbers of branches per plant were significantly increased by fertilizer application over control for both cropping year Table 4. Maximum number of branches per plant (8.20) were recorded in plots where P fertilizers were applied at 60 kgha^{-1} each in 2020 cropping season over the control. Lowest number of branches per plant in control plots may be due to low nutrient supply that is not enough for a good sprouting of branches in such plants. However, the maximum branch number (8.74) was recorded from where plots receive 40kg of P ha^{-1} on 2021 cropping season. All other rates of P produced statistically same number of branches per plant (i.e., 7.87, 7.94 and 8.03) Table 4. Row spacing non-significantly affected both plant height and branch number. This may be due to spacing governed by fertilizer application to sprouting different number of branches across different level of phosphorus. These results were in full agreement with those obtained by Tariq, et al. Hussain, et al. Ahmed, et al. [26,31,32]; who reported that the number of pods bearing branches Plant^{-1} was significantly increased by potassium applications in mung bean. Increase number of branches plant^{-1} in mung bean was also reported by Akhtar, et al., Ali, et al. & Fatima, et al. [33-35], their findings were supported this research work. Similar finding was also reported by Siddaraju, et al. [30], revealed that the maximum number of branches per plant was recorded at harvest in those plots which are treated with 10 cm intra row spacing and 40kgha^{-1} phosphorus.

Branch Number Plant^{-1}: branch number was also significantly affected by the interaction effects of row spacing with different level of phosphorus fertilizer. The highest number of branches per plant (8.55) was counted from 40kg P ha^{-1} and 15cm intra row spacing Table 5. This study was supported, by experimental results of Khan, et al. & Mathur, et al. [36,37] they reported the maximum grain yield was obtained from 45kgha^{-1} P with 40cm x10cm row spacing that Khan, et al., Shabbir & Kalita [13,38,39], concluded that application of 60 kg P ha^{-1} significantly increased the number of branches per plant. The highest number of branch plant^{-1} might have been possible due to more vigor and strength attained by the plants as a result of better photosynthetic activities with sufficient availability of light, spacing between the plants and supply of nutrients in balanced quantity to the plants at growing stages.

	2020	2021		2020	2021	
PR (kgha^{-1})	PH	PH	Mean	BN	BN	Mean
0	42.53b	52.7	47.64	6.14c	7.87b	7.47
20	43.76ab	59	51.37	7.00bc	7.94b	7.58
40	43.66ab	56.2	49.94	7.56ab	8.74a	7.98
60	45.94a	54.6	50.29	8.20a	8.03b	7.76
LSD	3.36	NS	NS	1.12	0.67	NS
RS (cm)						
5	44.72	7.99	50.17	6.78	7.99	5.67
10	43.48	8.42	49.53	7.69	8.42	7.76
15	43.72	8.03	49.73	7.22	8.03	7.67
LSD.p0.05	NS	NS	NS	NS	NS	NS
CV (%)	7.82	15.2	10.54	15.86	8.36	9.5

Where, PR= phosphorus rate, RS= row spacing, PH= plant height (cm), BN= Branch number/plant

Table 4: The phosphorus fertilizer rate and row spacing on the growth, yield and yield components of mung bean on 2020 cropping season at Sankura wereda Jejebicho research Station.

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P_2O_5 rate	Branch number/plant			Number of pods/plants		
	Row spacing (cm)			Row spacing (cm)		
	5cm	10cm	15cm	5cm	10cm	15cm
0	7.80ab	7.55ab	7.07b	19.25e	19.47e	19.93de
20kha^{-1}	7.72ab	7.47ab	7.57ab	22.53cde	21.85cde	25.37bcd
40kgha^{-1}	7.43ab	7.97ab	8.55a	22.55cde	24.90cde	27.23abc
60kgha^{-1}	7.73ab	8.07a	7.48ab	30.90ab	31.17a	25.22bcd
LSD	1.24			5.69		
CV (%)	9.5			13.89		

Table 5: The interaction effects of phosphorus fertilizer and row spacing on growth of Mung bean at Sankura Jejebicho research station.

Number of pods per plant: application of Phosphorus fertilizer had significantly increased the number of pods per plant (Table 6). The highest number of pods per plant (22.46 and 35.73) were produced in plots were received 60kgha^{-1} P for both 2020 and 2021 cropping year respectively (Table 6). However, minimum numbers of pods per plant (17.16 and 21.94) were produced in control plots on 2020 and 2021 cropping season respectively (Table 6). The result is similar to Veeresh, Shubha Shree, Meseret and Amin [40-42] they reported that applications of different rates of phosphorus fertilizer influence number of pod per plant. They also stated that a greater number of pods per plant of common bean at application rate of 75 kg P ha^{-1}. The experimental results of Singh and Singh [43] was also supported who reported that significant increase in number of pods per plant, due to increased P fertilization. The increment of number of pods per plant may be due to application of P fertilizer confirms with P fertilizer promotes the formation of nodes and pods in legumes. These results agree with Ahmad et al., Malik et al. [44,45] who reported that P induced significant increase in pods plant^{-1}, they also reported that phosphorus up to 75 kgha^{-1} significantly increase number of pod plant^{-1}. The study was supported by the experimental results of Lake and Jemaludin, Arega and Zenebe, Deresa, et al. [46-48] they revealed that the increase in number of pods per plant with the increased NPS rates might possibly be due to adequate availability of N, P and S, nutrients which might have facilitated the production of more branches and canopy development, which might, in turn, have contributed for the production of higher number of total pods.

The productive capacity of mung bean plant is ultimately considered by the number of pods per plant. The interaction of row spacing with phosphorus rates resulted in a significant difference in the number of pods per plant. The highest number of pod plant^{-1} (31.17) was recorded from the interaction effects of 60kg ha^{-1} P and 40cm x 10cm intra row spacing (Table 5). This may be at highest rate phosphorus enable to sprouting the more branch number with 10cm spacing. Phosphorus fertilizer with optimum intra row spacing, which might have facilitated the production of more branches and canopy development, which might, in turn, have contributed for the production of higher number of total pods. The higher number of pods plant^{-1} might have been possible due to more vigour and strength attained by the plants as a result of better photosynthetic activities with sufficient availability of light, and supply of nutrients in balanced quantity of the plants at growing stages. This result was agreed with the experimental results of Ahmad, et al. [49], who reported that there is higher yield in close spaced compared to wide-spaced groundnut systems usually attributed to higher plant population densities that effectively utilize water, nutrient, and perhaps due to the presence of more important sunlight.

Number of seed per pod: phosphorus fertilizer application increased the number of seeds per pod over control. The highest number of seed per pod (11.36, 12.63) were counted where plots received 60kg/ha as compared to others on 2020 and 2021 cropping season respectively (Table 6). The control treatment and application of at 20kg P ha^{-1}, 40kg P ha^{-1} each produced statistically similar number of seeds per pod in both seasons. This tread similar with the overall mean of both parameters the maximum number of pod/plant and number of seed per pod were counted where plots received 60kg P ha^{-1}. The result of the present study was supported by the findings of Meseret and Mohammed, Shubha Shree [42,50], who reported that number of seeds per pod increased significantly to levels of phosphorus added. The increment of seeds per pod with increasing P fertilizer application up to maximum level might be P fertilizer for nodule formation, protein synthesis, fruiting and seed formation of haricot bean. Number of pods plant^{-1} was also significantly affected by row spacing on 2021 cropping season. The highest number of pod plant^{-1} (12.48) was counted from 10cm x 40cm row spacing as compared to others. This might be due to interception of sunlight for photosynthesis, which results in the production

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of more nutrients for partitioning toward the development of more branches and finally it leads to produce a greater number of pods per plant.

	2020	2021		2020	2021	
PR (kgha^{-1})	NPP	NPP	Mean	NSP	NSP	Mean
0	17.16c	21.94c	19.55c	9.93b	11.53b	10.73b
20	19.34bc	27.16bc	23.25b	10.10b	11.41b	10.76b
40	20.87ab	28.92bc	23.89b	10.32b	12.04ab	11.18b
60	22.46a	35.73a	29.09a	11.36a	12.63a	11.99a
LSD	2.56	6.29	3.29	0.81	0.94	0.68
RS (cm)						
5	19.58	28.03	23.8	10.69	11.57b	11.13ab
10	20.69	28	24.35	10.6	12.48a	11.54a
15	19.59	29.28	24.44	9.99	11.68ab	10.83b
LSD. (P0.05)	NS	NS	2.85	NS	0.81	0.59
CV (%)	2.56	22.61	13.89	7.99	8.06	6.22

Where, PR= phosphorus rates, RS=row spacing, NPP= Number of pod/plants, NSP= Number of Seed per pod.

Table 6: Phosphorus fertilizer rate and row spacing on yield components of mung bean on 2020 and 2021 cropping seasons at Sankura wereda Jejebicho research Station

The results revealed that two-way interaction effects of varieties with phosphorus fertilizer rates and intra row spacing had highly significant ($P \leq 0.01$) effect on number of seeds per pod. The 10cm intra row spacing, with 60 kg P ha^{-1}, produced significantly highest number of seeds per pod (13.45), while the other treatments showed statistical non-significant and similar number of seeds per pod was recorded (Table 7). The increment in number of seeds per pod with increasing P fertilizer application rates might be due to the fact that P is an essential component in seed formation. Furthermore, the supply of adequate nutrients might have facilitated the vegetative growth, which might, in turn, have contributed for the production of higher number of seed per pod. These results agree with those of Uddin, et al. [51] who reported difference in number of seeds pod^{-1} in between row spacing and phosphorus fertilizer rates might be due to the direct effects of plant population density of mung bean on nutrient uptake especially phosphorus. This is in lined with the experimental results of Solomon & Biranu, et al. [52,53] which revealed that biomass yield of haricot bean was significantly affected by row spacing (inter and intra row, spacing) they reported that the highest biomass yield was obtained from 40cm x10cm as compared to 40cm x 15cm intra row spacing. However, this is disagreed with the findings of Kazemi, et al. [54], who reported that more biomass was produced at narrow row spacing than wider spacing.

	Number of seed/pod			Above ground biomass (kg/ha)		
	Row spacing (cm)			Row spacing (cm)		
P2O5 rate	5cm	10cm	15cm	5cm	10cm	15cm
0	11.13b	10.48b	10.58b	6686.83e	7230.17d	7224.00d
20kha^{-1}	10.87b	10.83b	10.57b	7294.83d	7338.50d	7359.50d
40kgha^{-1}	11.13b	11.38b	11.03b	7362.17d	7761.50bc	7671.50c
60kgha^{-1}	13.38b	13.45a	11.15b	7719.67bc	8901.50a	7894.83b
LSD	1.17			212.02		
CV (%)	6.22			1.66		

Table 7: The interaction effects of phosphorus fertilizer and row spacing on the yield and yield components of Mung bean at Sankura Jejebicho research station.

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Above ground biomass: The application of P and different levels of intra-row spacing significantly affect the above ground biomass yield of mung bean in both cropping seasons. The maximum biomass yield (8275.58kg/ha, 8068.22kg/ha) where 60kg/ha P at jejebicho research station on both cropping seasons respectively (Table 8). The maximum biomass yield (7903.67kg/ha, 7712.17kg/ha) were also obtained from 10cm intra row spacing for both 2020 and 2021 cropping seasons respectively (Table 8). This might be due to the optimum row spacing is 40cm x 10cm, which means not as narrow as 40cm x 5cm or as wide as 40cm x 15cm spacing for mung bean production. The founding's of Meseret and Mohammed [50], the maximum biomass yield and grain yield were recorded at application of 60 kg P ha^{-1}, whereas the minimum grain yield was recorded on control. This result was similar to Shubha Shree [41], who reported dry matter accumulation increase with application of phosphorus rates. Similarly, significant and linear increase in total dry matter production of common bean plant was observed due to increased Phosphorus [40]. The Phosphorus concentration in the soil increased the whole plant dry matter accumulation and total leaf area. This increment in dry matter yield with application of Phosphorus fertilizer might be due to the adequate supply of Phosphorus could be attributed to an increase in number of branches per plant, and leaf area. This in turn increased photosynthetic area and number of pods per plant, which demonstrates a strong correlation with dry matter accumulation and yield.

	2020	2021		2020	2021	
PR (kgha^{-1})	AGB	AGB	Mean	GY	GY	Mean
0	6924.44d	7169.56c	7047.00d	1285.50c	1233.53c	1259.52b
20	7396.67c	7265.22c	733094c	1347.04c	1325.89c	1336.46ab
40	7717.56b	7479b	7598.39b	1541.79b	1541.67b	2163.96a
60	8275.58a	8068.22a	8172.00a	1880.76a	1917.84a	1899.30ab
LSD	186.27	168.51	122.41	119	100.7	889.79
RS (cm)						
5	7233.50C	7298.25c	7265.88c	1307.37c	1318.76c	1779.73
10	7903.67a	7712.17a	7807.92a	1744.56a	1715.94a	1730.25
15	7598.67b	7476.25b	7537.46b	1489.39b	1479.51b	1484.45
LSD.p0.05	161.32	145.93	106.01	103	87.21	770.58
CV (%)	2.51	2.3		8.04	6.85	24.67

Where, AGB=Above ground biomass (kgha^{-1}), GY=Grain yield (kgha^{-1})

Table 8: The effects phosphorus fertilizer rate and row spacing on yield and yield components of mung bean on 2020 cropping season at Sankura wereda Jejebicho research Station.

The productivity of a crop is largely determined by the biological yield. Production of large amount of biomass is among one of the attributes of seed yield. The results of this study showed that the two-way interaction effect of intra row spacing with and phosphorus fertilizer rate were significant effect for aboveground biomass. Accordingly, the highest above-ground biomass (8901.50kgha^{-1}) was recorded for 40cm x 10cm intra row spacing with 60 kg P ha^{-1}, while the lowest above-ground biomass (6686.83kgha^{-1}) was recorded for mung bean, grown on plots receiving nil P rate at row spacing of 40cm x 5cm (Table 9). This might be due to improved growth under 10cm intra- row spacing for better utilization of light and adequate supply of nutrients added from the applied higher fertilizer rate.

	Grain yield (kg/ha)			Harvest index		
	Row spacing (cm)			Row spacing (cm)		
P2O5 rate	5cm	10cm	15cm	5cm	10cm	15cm
0	1118.50e	1373.24cde	1286.81de	0.24de	0.25b-e	0.23e
20kha^{-1}	1331.73cde	1345.21cde	1332.45cde	0.34abc	0.34abc	0.26cde
40kgha^{-1}	1862.78b	1701.94bcd	1593.82bcd	0.33a-d	0.36a	0.25b-e
60kgha^{-1}	1472.58b-e	2500.60a	1724.72bc	0.35abc	0.29a-e	0.32d-e
LSD	435.9			0.1		
CV (%)	16.57			20.4		

Table 9: The interaction effects of phosphorus fertilizer and row spacing on grain yield and harvest index of Mung bean at Sankura Jejebicho research station.

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Grain yield: grain yield was significantly increased by the application of P fertilizer levels over control (639.78 $kgha^{-1}$) (Table 7). The highest (1880.76$kgha^{-1}$, 1917.84$kgha^{-1}$) grain yield of mung bean were obtained where plots received 60kg ha^{-1}, but the lowest grain yield were also obtained from the control (1285.50$kgha^{-1}$, 1233.53$kgha^{-1}$) on 2020 and 2021 cropping seasons respectively Table 7. Grain yield was also significantly different due to different level of intra row spacing. Similar, to above ground biomass yield, the highest grain yield (1744.56$kgha^{-1}$, 1715.94$kgha^{-1}$) were obtained from 40cm x 10cm row spacing on 2020 and 2021 cropping seasons respectively (Table 7). The result is in lined with Kumar, et al. (2012) who reported that the highest grain yield was recorded at the highest levels of P_2O_5 ha^{-1} and minimum grain yield was recorded at no (0 kg P_2O_5). This study was also agreed with Ahmad, et al. & Gezu, et al. [44,55], they were reported mean value of phosphorus levels indicated that plots treated with 80kg P ha^{-1} produced maximum grain yield, while the minimum grain yield was recorded in control plots. These results agree with those Hussain, et al. [32] who reported that increased in grain yield with increased in P level up to 75 $kgha^{-1}$ further increase in P level slight decrease recorded in grain yield. The increase in grain yield might be due to phosphorus application was attributed to profound branching, better fruiting, increased number of seeds pod^{-1} and heavier grains as a result grain yield increased as compared with control plots. Grain yield was also significantly affected by row spacing on 2021 cropping season. The highest grain yield (1715.94 $kgha^{-1}$) was obtained from 10cm x 40cm row spacing (Table 7). Grain yield and yield components of mung bean are markedly influenced by planting density. The farmers usually grow mung bean without maintaining proper planting density and spacing. They hesitate to grow mung bean in rows and optimum row spacing, although row planting facilitates easy intercultural operations resulting in higher yield [56].

The interaction effects of intra row spacing and phosphorus rate were significant on grain yield. Hence, the maximum grain yield (2500.60kg P ha^{-1}) was recorded for 60kg P ha^{-1} with 40cm x 10cm row spacing, while the lowest grain yield (1118.50kg P ha^{-1}) was recorded from the control combined with 5cm intra row spacing (Table 10). This might be due to the less intra row spacing increases competition in solar radiation that stunt growth of closer intra row plant in vegetative phase. This might be also attributed to higher growth and dry matter production due to applied P2 with optimum intra row spacing finally leads better grain yield production of mung bean.

Harvest Index: harvest indices were invariably affected by different P levels over the control Table 10. Plots receiving no fertilizer depicted the lowest harvest index as compared to other treatments. Different row spacing intervals was also significantly affected harvest index on both cropping seasons (Table 10). The highest harvest index (0.22, 0.24) was obtained from 60 kg P ha^{-1} levels in both seasons. Harvest indices was also significantly affected by row spacing in both seasons. The increased harvest index with an increase P rate of fertilizer is in agreement with the findings of Chiezey, et al. & Kawte, et al. [57,58] related to lower value of harvest index at low level of phosphorus application to poor development of plants at different growth stages of soybean. Similarly, Singh, et al. & Fageria, et al. [59,60] they reported that the highest harvest index of common bean and lentil was obtained when 45 kg P ha^{-1} was applied respectively. These results agree with the findings of Kumar, et al. [61] who reported that increasing rate of phosphorus application significantly increased harvest index over control plots. They also stated that with the increase of phosphorus level harvest index increasing significantly and plots treated with 80 kg P ha^{-1} produced the maximum harvest index, while the minimum harvest index was recorded in control plots.

The results revealed that the interaction effect of intra row spacing and phosphorus fertilizer rates showed a significant effect for harvest index. Accordingly, maximum harvest index (0.36) was recorded from 40cm x 10cm with 40 kg P ha^{-1}, while minimum (0.23) was recorded from 40cm x 5cm with control (Table 9). This might be due to the influence of increased rate of phosphorus rate on translocation of dry matter from vegetative part to economic yield. This study was in lined with the findings of Bonepally, et al., Sarkar, et al. & Balai, et al. [28,62,63] they reported that the increased in seed yield due to phosphorus application is attributed to source and sink relationship. This finally forced to appeared that greater translocation of photosynthates from source and sink might have increased seed yield. This study was disagreed with experimental results of Kadam and Khanvilkar [64] which revealed that grain yield of mung bean was increased with increased rate of mung bean up to 40kg P ha^{-1} of phosphorus. Similarly, the highest biomass and grain yield was also obtained from 10cm intra row spacing for both cropping seasons as compared to others. This study agreed with the results of Birhanu, et al. & Abuzar, et al. [53,65] the highest grain yield was obtained from 40cm x 10cm row spacing as compared ow spacing of mung bean and common bean respectively.

Harvest index was also influenced significantly affected due to the two-way interaction of Phosphorus fertilizer rates and intra row spacings. The maximum harvest index (0.36) was recorded from interaction effect of 40 kg P ha^{-1} fertilizer with 10cm row spacing (Table 9). The minimum harvest index (0.23) was obtained from no P fertilizer and 15cm row spacing (Table 10). The study in in lined with Malik, et al. [45] who reported that an increased in harvest index of mung bean with an increased rate of phosphorus.

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	2020	2021	
Phosphorus rates (kgha^{-1})	Harvest index	Harvest index	Mean
0	0.19bc	0.17c	0.24b
20	0.18c	0.18c	0.31a
40	0.20b	0.21b	0.30a
60	0.22a	0.24a	0.32a
LSD	0.02	0.01	0.06
Row Spacing (cm)			
5	0.18c	0.18c	0.31
10	0.22a	0.22a	0.31
15	0.20b	0.20b	0.27
LSD.p0.05	0.01	0.009	0.05
CV (%)	8.62	5.33	19.49

Table 10: Effects of phosphorus fertilizer rate and row spacing on yield and yield components of mung bean on both cropping seasons at Sankura wereda Jejebicho research Station.

Economic Analysis

The results of the partial budget analyses and the data used in the development of marginal rate of return are given in Table 11. The treatments ranked in order of increasing total variable cost (TVC) revealed that the treatment 15cm row spacing without p application costs less than from other P rates and row spacing treated plots. It is clear that 15cm row spacing without P application plot had considerably reduced costs of labour, transportation, fertilizer and purchasing mung bean seed cost as compared to others. So, production of mung bean by using intra row spacing and P fertilizer management involved different costs, which affected the total production cost that varied within each treatment (Table 11). It is quite evident from the data presented in table 10, that the highest mean net benefit (87307.56, Ethiopian birr (ETB) ha^{-1}) with acceptable MRR (720%) was obtained in the application of 60 kg P ha^{-1} with 40cm x 10 cm intra row spacing. In contrast, the lowest mean net benefit (38873.03 ETB ha^{-1}) was obtained from the control (unfertilized) plot 40cm x 5cm intra row spacing (Table 11). Therefore, on economic grounds, the application of 60 kg P ha^{-1} with 40cm x 10 cm intra row spacing would be the economical best reward for the production of mung bean around Sankura Woreda jejebicho Kebele.

Treatment	Average yield (kg)	Adjusted yield (kg)	GFB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)
0 -kgha^{-1}+ 15cmx40cm	1286.81	1155.42	50340.83	2595.87	47744.95	-
0 kgha^{-1} + 10cmx40cm	1373.24	1282.82	53697.69	3170.57	50527.13	484
20 kgha^{-1} + 15cmx40cm	1332.45	1603.16	51300.8	3753.53	47547.27	DD
0 kgha^{-1} + 5cmx40cm	1118.5	1243.91	43080.05	4207.01	38873.03	DD
20 kgha^{-1} + 10cmx40cm	1345.21	1490.5	51449.98	4239.08	47210.9	DD
40 kgha^{-1} + 15cmx40cm	1593.82	1947.07	62361.97	5202.33	57159.64	361
20 kgha^{-1} + 5cmx40cm	1331.73	1216.1	51087.31	5548.92	45538.38	DD
40 kgha^{-1} + 10cmx40cm	1701.94	1491.9	65541.33	5838.63	59702.71	369
60 kgha^{-1} + 15cmx40cm	1724.72	1871.27	69070.75	6466.98	62603.78	384
40 kgha^{-1} + 5cmx40cm	1862.78	1400.77	70940.96	7040.86	63900.1	363
60 kgha^{-1}+ 10cmx40cm	2500.6	1992.96	95401.07	8093.51	87307.56	720
60 kgha^{-1} + 5cmx40cm	1472.58	1345.3	57375.04	8103.69	49271.34	28

ETB=Ethiopian Birr; GFB=Gross field benefit; MRR= Marginal rate of return; NB=Net benefit; TVC=Total variable cost.
Table 11: Marginal and dominance analysis to establish the profitability of mung bean production as affected by phosphorus fertilizer and row spacing at Jejebicho kebele Sankura wereda.

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Conclusion and Recommendation

Phosphorus (P), is essential and present in high levels in mung bean, and play important roles in its growth, development, high yield and significantly affect many mung bean traits. Agronomic management has a great role for obtaining best grain yield of mung bean associated to soil nutrition and varietal type. The highest grain yield of mung bean was obtained from the maximum Phosphorus rate (60kg ha^{-1}) and 10cm intra row spacing at Jejebicho research station of Wondo Genet Agricultural Research Center (WGARC). Generally, from this the investigation it may be concluded that for obtaining optimum seed yield performance of mung bean under rainfed conditions, maintaining a wider spacing of (40×10) cm2 along with 60 kg P ha^{-1} is the best management practice to increase the availability and utilization of nutrients by mung bean. We recommend 60 kg P ha^{-1} with 40cm x 10cm row spacing is best and economical to mung production for farmers in the study area and similar agro-ecologies.

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