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Evaluation of the Agronomic Traits and Grain Yield of Mung bean (Vigna radiata L.) by Different Levels of Phosphorus Fertilizer with Row Spacings at Abine Germama Kebele in Adamitulu Jido kombolcha Wereda

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Abstract
Mung bean is among the most important pulses crop cultivated from low to midland agro-ecological zones of the world including Ethiopia. The study was conducted at Abine Germama Kebele in 2020/21 cropping season (*rainy*) on Adamitulu Jido Kombolcha Wereda. We used mung bean variety the so called Arkebe for this experiment. The trial was also 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 Phosphorus for Mung bean production. The soil was medium in total nitrogen (0.143%), had low available phosphorus (2.42 mg kg^{-1} soil), moderate organic matter (2.252) contents and low cation exchange capacity (6.15 cmol kg^{-1} soil). The highest number of seeds per plant (12.37) was counted from the interaction effects of 40kg/ha phosphorus and 15cm row spacing. The highest above ground biomass yield (8064.48 kg ha^{-1}) and grain yield (2493.83 kg ha^{-1}) of mung bean was obtained from the interaction effects of 60kg/ha Phosphorus and 10cm intra row spacing. The highest (0.25) value of harvest index of mung bean was calculated from the interaction effect of 60kg P_2O_5 ha^{-1} with 40cm x 10cm row spacing. The maximum net benefit (86772.51 ETB ha^{-1}) was obtained from 40cm x 10cm row spacing and 60kg P_2O_5 ha^{-1}. The highest marginal rate of return per unit production cost was recorded when mung bean planted on 40cm x 10cm row spacing with 60kg P_2O_5 ha^{-1} application (MRR = 942%). we advised to farmers 60 kg P_2O_5 ha^{-1} with 40cm x 10cm row spacing was the best for mung bean production, but since 60 kg P_2O_5 ha^{-1} was the maximum level Phosphorus among the treatments so, this needs to add the levels of Phosphorus beyond 60kg P_2O_5 ha^{-1} for future study.
Keywords: Grain yield, Net benefit, Marginal rate of return, Phosphorus and Row spacing
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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 (Mesele *et al*., 2015). According to the nutritionists, pulses are an excellent source of dietary proteins and can play an important role in fulfilling food requirements of rapidly increasing population (FAO, 2004). 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 (Degefa, 2016). Mung bean is an essential short duration, self-pollinated diploid legume crop with high nutritive values and nitrogen fixing ability (Teame *et al*., 2017). It is an eco-friendly food grain leguminous crop of dry land agriculture with rich source of proteins, vitamins, and minerals. Besides, being a rich source of protein, it maintains soil fertility through biological nitrogen fixation in soil and thus plays a vital role in furthering sustainable agriculture (Muhammad *et al*., 2004). The crop is a short duration crop therefore has less water requirement as compared to summer crops. Moreover, it is drought resistant that can withstand adverse environmental conditions, and hence successfully be grown in rain fed areas (Anjum *et al*., 2006). 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 (Anonymous, 1997). 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. (1993) 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. 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. 2000). Lateef *et al*. (1998) 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*. (2002) 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 (Gill *et al*., 1985), and also for nodulation and nitrogen fixation (Olofintoye, 1986). 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 (Ogata *et al*., 1988). 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 [Cheng and Cao,1996; Hussain, *et al.,* 2019; Khan *et al*.,1999; Ikraam, 2002; Oad *et al.,* 2003]. 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 [Jian *et al.*, 2014; Zafar and Athar 2013]. According to Sageghipour *et al*. (2010) 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 (Rafiei, 2009). The significance of using optimum inter and intra row spacings has been recognized by several researchers. Kabir and Sarkar (2008) 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 (Singh et al., 2011). The results of Ahmadi (2016) 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 (Jahan and Hamid 2004). These authors also reported a decline in seed yield as the density of plants increased to 60 plants m^{-2} Nawale (2001) 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 Ziway (Batu) areas, the effect of different agronomic practices including inter and intra-row spacing are 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 evaluate the effects of phosphorus fertilizer rate and row spacing for better grain yield production of mung bean on the study area. 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 Phosphorus for Mung bean production.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted at Adamitulu Jido Kombolcha wereda Abine Germama Kebele and Sankura wereda Jejebicho Kebele in 2020/21 cropping season on farmer's field. The area has a soil type of sandy clay soil. Adamitulu Jido Kombolcha wereda Abine Germama Kebele was located in Eastern Shewa zone and it takes **163km** from our capital city Addis Ababa, Ethiopia. Abine Germama kebele is located about 2km distance to Ziway city. Batu or Ziway, is a town and district on the road connecting Addis Ababa to Nairobi in the East Shewa Zone of the Oromia Region of Ethiopia. It has a latitude and longitude of 7°56′N 38°43′E respectively with an elevation of 1643 meters above sea level.

Description of the Experimental Materials

We already used Arkebe variety for this study**.** The available released variety of mung bean which it was released in 2008 by Humera Agricultural Research Center /HARC'. It matures in 90-120 days. It is 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 kg P_2O_5 ha^{-1}) and three inter row spacing (5cm, 10cm and 15cm). Totally by combining the factors twelve treatments for this experiment was used. The source of phosphorus was triple super phosphate (TSP).

Land preparation, field layout and sowing
The seed of mung bean was sown on the experimental field at the end of June 2020 and 2021. The experimental field was ploughed and harrowed by a tractor to get a fine field. It was levelled 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.

Table 1 Details of the treatment's description given below

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

Where, Trts= Treatments

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.

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, $Y_{ijk} = \mu + \alpha_i + \beta_j + \Upsilon_k + \alpha\Upsilon_{ik} + \varepsilon_{ijk}$. Where, Y_{ijk} = the value of the response variable; μ = Common mean effect; α_i = Effect of row spacing; β_j = Effect of block; Υ_k = Effect of phosphorus fertilizers $\alpha\Upsilon_{ik}$ = Interaction effect of row spacing & fertilizer levels; and ε_{ijk} = Experiment error.

RESULTS AND DISCSTION

The Weather data, temperature (°C) and rain fall(mm.) on 2020 and 2021 cropping season at Abine Germama kebele (Ziway)

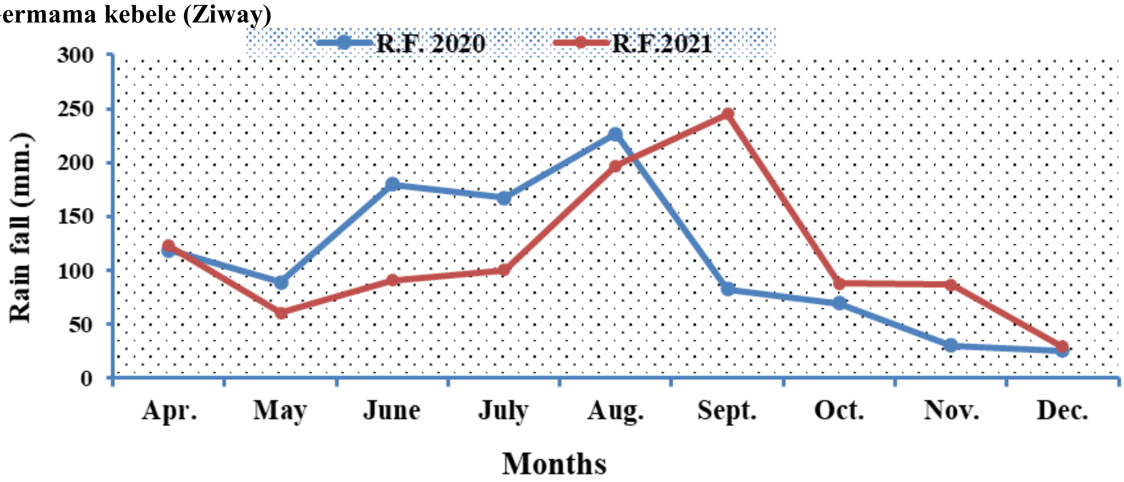

Figure 1.the total mean monthly rain falls at Abine Germama Kebele (Ziway) during 2020 and 2021 cropping seasons

Table 2. the mean monthly maximum and minimum temperature on 2020 and 2021 Cropping Season at Abine Germama Kebele of Adamitulu Jido Kombolcha Wereda in 2020 and 2021 Cropping season

	2020 Cropping season		2021 Cropping season	
Month	Maxi.T^{O}C	Mini.T^{O}C	Maxi.T^{O}C	Mini.T^{O}C
April	34.62	17.89	36.26	17.87
May	36.96	18.59	33.6	18.41
June	38.95	18.83	36.23	19.11
July	36.97	19.83	36.83	18.71
August	35.52	18.20	36.65	18.07
September	32.9	18.38	31.87	17.31
October	30.73	14.47	32.9	15.39
November	31.60	14.92	32.8	13.81
December	29.85	13.44	32.19	13.44

Maxi.T^{O}C= maximum temperature (^{O}C) and Mini.T^{O}C=minimum temperature (^{O}C)

Soil Physico-Chemical Properties of Abine Germama Kebele

The analysis result of the collected soil sample from experimental site (Table 2) indicated that the soil was clay with a particle size distribution of 28% sandy, 30% silt and 42% clay with pH value of 7.5 which is slightly alkaline. The soil was medium in total nitrogen (0.143%), had low available phosphorus (2.42 mg kg^{-1} soil), moderate organic matter (2.252) contents and low cation exchange capacity (6.15 cmol kg^{-1} soil) (Tekalign, 1991).

Table 3. the mean results of Soil physico-Chemical Properties on Abine germama kebele

Soil physico-Chemical Properties	Results
pH	**7.5**
CEC	**6.15 cmol kg^{-1}**
OC	**2.252**
Av. P.	**2.42 mg kg^{-1}**
Tot. N	**0.147%**
Textural class	**28% sandy, 30% silt and 42% clay**

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

Effect of Phosphorus fertilizer rate and Row spacing on the Growth, Yield components and Yield of Mung bean at Abine germama kebele in Adamitulu Jido Kombolcha Wereda

The analysis of data showed that both plant height (cm) and branch number per plant of mung bean was significantly affected by the interaction effects of both phosphorus fertilizer and row spacing (Table 5).

Plant height: the tallest plant (58.95cm) was measured from the interaction effect of 60kg P_2O_5 ha^{-1} and 5cm intra row spacing. However, the shortest plant (46.76cm) was measured from 20kg ha^{-1} of phosphorus and

15cm intra row spacing at Abine germama kebele (Table 5). The plant height increased with the increase in phosphorus levels. This may be due to increase in plant height (cm) was due to increasing rate of Phosphorus with increasing trend with wider crop geometry level could be noticed. The probable reason for tallest plant at 40cm x 15cm spacing could be more utilization of energy properly in branching because there was most competition of light due to there was insufficient utilization of light energy by the plant and due to the inter plant shading along the row finally leads to efficient utilization of resources than others, while in case of 40cm x 5cm and 40cm x10cm spacing is not. This may might be reducing 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. Application of optimum phosphorous fertilizer which indirectly helps in providing nitrogen supply and its availability helped the plants to attain more vigour in terms of plant height (Khan *et al*., 2017). This study was supported by the results of Erman *et al*. (2009), they reported that Phosphorus application had a significant effect on the plant height. This result was also in lined with the experimental results of Ahmed *et al.* (2013) who reported that Phosphorus application had a significant effect on the Plant height. The highest Plant height was recorded where Phosphorus was applied at the rate of 85 kg $ha^{-}1$ followed by 60 kg ha^{-1}, while control plots produced significantly lower Plant height

Branch number: the statistical analysis data showed that rate of Phosphorus and row spacing significantly affected branch number per plant and number of pods per plant of mung bean on both cropping seasons. The number of pods/plants was also significantly affected by intra row spacing of mung bean. The highest branch number per plant was counted from (7.09 and 5.25) from 60kg ha^{-1} of Phosphorus fertilizer rate from 2020 and 2021 cropping season respectively (Table 4). The study was supported by the experimental results of Lake and Jemaludin, (2018); Arega and Zenebe (2019); Kawte *et al*. (2020); Deresa *et al.* (2018) 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. This experimental result was disagreed with the founding of Gezu *et al*. (2021) reported that different rates of phosphorus was non significantly affected number of branches per plant.

The interaction effects of both Phosphorus and row spacing significantly affected branch number per plant. The highest number of branch per plant (6.50) of mung bean was counted at the interaction effects of 60kg/ha of phosphorus and 15cm intra row spacing (Table 5). Increased plant height might have been due to the adequate availability of plant nutrient through appropriate nutrient supply and sunlight to each plant required for its growth and development. Similar findings were also reported by Siddaraju *et al*., (2010), and significantly maximum number of branches per plant (6.67) recorded at harvest in those plots which are treated with row spacing 40×10 cm2 with spacing 40 kg ha-1 Phosphorus fertilizer rate on number of branches. This study was also supported, by experimental results of Khan et al.(2017); Mathur et al. (2007) they reported the maximum grain yield was obtained from 45kgha-1 P2O5 with 10cm row spacing that Khan et al. (1999); Shabbir (1982); Kalita (1989), concluded that application of 60 kg P2O5, 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.

Number of pod plant-1: branch number plant-1 increased with increased application of Phosphorus. The highest number of pods per plant (26.04 and 22.11) was counted from 60kgha-1 on 2020 and 2021 cropping season respectively (Table 4). The highest number of pods per plant (19.96) was counted from 15cm intra row spacing on 2021 cropping season, but both 10cm and 15cm intra row spacing statistically at par (Table 4). This might be also owing due to better utilization of available growth resources viz., nutrient, moisture and solar radiation to a greater extent and accumulation of photosynthates. This is in lined with the experimental result of Biranu et al. (2018); Malek et al. (2013) which revealed that the highest number of pods per plant was obtained from 15cm intra row spacing. In the overall mean the highest of branch number per plant and number of pod per plant was counted from 60ka/ha phosphorus and 10cm intra row spacing at Ziway Abine germama kebele. This may due to the presence highest rate phosphorus as compared to other treatments. The statistical data analysis showed that number of pod per plant of mung bean was significantly affected by the interaction effects of phosphorus fertilizer and row spacing. The data pertaining to the number of pods plant-1 are affected by phosphorus levels and intra row spacings presented in Table (6). Which reveal that both phosphorus levels and intra row spacings had significantly affected on number of pods plant-1. The highest number of pods Plant-1 (27.02) was recorded from the plot on which fertilizer was applied at the rate of 60 kg ha-1 and 15cm row spacing (Table 6). While significantly least number of pods Plant-1 (14.10) was counted from the interaction effects of nil P2O5 (control) and 5cm intra row spacing. These results confirm the finding of Malik et al., (2003), who reported that application of P2O5 increased the number of pods plant-1 in Mung bean. it was also in lined with Ahmad et al (2015) also observed maximum number of pods Plant-1 where phosphorus was applied 75 kg ha-1 over control.

Number of seed per pod: the highest number of seeds per plant (12.37) was counted from the interaction effects of 40kg/ha phosphorus and 15cm row spacing (Table 6). This may be at highest rate phosphorus enable to sprouting the more branch number with 10cm spacing. Phosphorus fertilizer 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 highest number of seeds pods-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). The result is similar to Veeresh (2003), Shubhashree (2007), Meseret and Amin (2014) they reported that applications of different rates of phosphorus fertilizer influence number of seed per pod. They also stated that a greater number of seeds per pods of common bean at application rate of 75 kg P2O5 ha-1. The experimental results of Singh and Singh (2000) was also supported who reported that significant increase in number of seeds per pods, due to increased P fertilization and spacings levels. 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.

Table 4. the phosphorus fertilizer rate and row spacing on the growth of mung bean on 2020 and 2021 cropping season at Ziway Abine germama kebele

	2020	2021		2020	2021	
PR (kgha^{-1})	**BN**	**BN**	**Mean**	**NPP**	**NPP**	**Mean**
0	5.38b	3.88b	4.63b	21.94ab	17.21b	19.58b
20	5.23b	4.03b	4.63b	20.37c	15.70b	18.04b
40	5.81b	4.07b	4.94b	22.92ab	17.88b	20.40ab
60	7.09a	5.25a	6.17a	26.04a	22.11a	24.08a
LSD	1.21	0.75	0.93	4.87	3.73	3.81
RS (cm)						
5	5.92	4.03	4.98	21.48	16.51b	18.99b
10	5.63	4.29	4.96	21.87	18.21ab	20.04ab
15	6.08	4.60	5.35	25.11	19.96a	22.54a
LSD.p0.05	1.05	0.65	0.81	4.22	3.23	3.30
CV (%)	21.14	17.76	18.76	21.82	20.93	19.01

Where, mean followed by the same letter with the same column are statistically non-significant at p<0.05 according to the least significant difference (LSD) test at P<0.05; PR= phosphorus rate, RS=row spacing, BN= branch number and NPP=number of pods plant^{-1}, CV= Coefficient of variance.

Table 5. the interaction effects of phosphorus fertilizer and row spacing on plant height and branch number per plant of Mung bean at Ziway Abine germama kebele

	Plant height (cm)			Branch number		
	Row spacing (cm)			Row spacing (cm)		
P. rate	**5cm**	**10cm**	**15cm**	**5cm**	**10cm**	**15cm**
0	50.85bc	50.31bc	48.61bc	4.74c	4.55c	4.61c
20kha^{-1}	48.13bc	54.15ab	46.76c	4.06c	4.86bc	4.98abc
40kgha^{-1}	52.75ab	52.21abc	54.99ab	4.73c	4.78bc	5.30abc
60kgha^{-1}	58.95a	50.24bc	51.05bc	6.37ab	5.65abc	6.50a
LSD	7.06			1.62		
CV (%)	8.09			18.76		

Table 6. the interaction effects of phosphorus fertilizer and row spacing on number of pods per plant and number seed per pod of Mung bean at Ziway Abine germama kebele

	Number of pods/plant			Number of seeds/pod		
	Row spacing (cm)			Row spacing (cm)		
P. rate	**5cm**	**10cm**	**15cm**	**5cm**	**10cm**	**15cm**
0	14.10c	19.00bc	21.13ab	8.90b	9.87b	9.57b
20kha^{-1}	18.61bc	20.36bc	19.65bc	10.27ab	9.30b	10.67ab
40kgha^{-1}	21.18ab	17.67bc	22.35ab	9.13b	9.90ab	12.37a
60kgha^{-1}	22.08ab	23.13ab	27.02a	9.13b	10.93ab	8.77b
LSD	6.61			2.47		
CV (%)	19.01			14.74		

Effects of different Phosphorus fertilizer rates and row spacings on Above ground biomass and Grain yield of mung bean on both 2020 and 2021 cropping seasons

Above ground biomass: the statistical analysis data showed that rate of phosphorus and row spacing and their interaction effects were significantly affected above ground biomass yield (kg/ha) and grain yield (kg/ha) of mung bean on both cropping seasons. The highest above ground biomass yield (8124.48 kg/ha and 6195.66 kg ha^{-1}) was obtained from 60kg P_2O_5 ha^{-1} on both 2020 and 2021 main cropping seasons (Table 8). This indicates that both biomass and grain yield of mung bean increased with the increased amount of phosphorus fertilizer from 0 to 60kg P_2O_5 ha^{-1}. The highest values of the parameters at 60 kg P_2O_5 ha^{-1} might due to the primary role of Phosphorus in photosynthesis by way of rapid energy transfer and thereby increased photosynthetic efficiency and thus increased the availability of photosynthesis. This resulted in increase in the total biomass production and their translocation in plant parts. The analysis data also showed that both above ground biomass yield and grain yield of mung bean significantly affected by row spacing on 2020 and 2021 cropping seasons. The highest biomass yield (6998.91kg ha^{-1}, 5792.38kg ha^{-1}) was also obtained from 40cm x 10cm and 40cm x 15cm row spacings for 2020 and 2021 cropping seasons respectively (Table 8). The pooled mean analysis was also showed that the highest biomass yield (6395.65kg ha^{-1}) obtained from 40cm x10cm row spacing. However, the lowest biomass yield (6038.83kg ha^{-1} and 4803.12kg ha^{-1}) was from 40cm x 5cm row spacing on 2020 and 2021 cropping seasons respectively (Table 8). This is in lined with the experimental results of Solomon (2003); Biranu *et al*. (2018) 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*. (2012), who reported that more biomass was produced at narrow row spacing than wider spacing. The highest above ground biomass yield (8064.48 kg ha^{-1}) of mung bean was obtained from the interaction effects of 60kg/ha Phosphorus and 10cm intra row spacing (Table 8). However, the lowest biomass (4652.01kg/ha) of mung bean was obtained at the interaction effects of 0kg ha^{-1} of Phosphorus and 5cm intra row spacing (Table 8). This might be due to the presence of higher amount of Phosphorus and absence of Phosphorus fertilizer. This might be due to the optimum intra row spacing is 10cm, which means not as narrow as 5cm or as wide as 15cm spacing for mung bean production. The founding's of Meseret and Mohammed (2014), revealed that the maximum biomass yield and grain yield were recorded at application of 60 kg P_2O_5 ha^{-1} with optimum row spacing of mung bean, whereas the minimum grain yield was recorded on control with narrow row spacing. This result was similar to Shubhashree (2007), 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 (Veeresh, 2003). 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 P fertilizer might be due to the adequate supply of P_2O_5 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.

Grain yield: the highest grain yield (2285.38kg/ha and 1187.11 kg/ha) was obtained from 60kg/ha of phosphorus on 2020 and 2021 main cropping seasons respectively (Table 7). In the overall mean the highest grain yield was also obtained from 60kg P_2O_5 ha^{-1} of phosphorus. The highest grain yield (2058.26kg ha^{-1} and 1018.24kg ha^{-1}) was obtained from 10cm intra row spacing as compared to other row spacings on 2020 and 2021 cropping seasons respectively (Table 7). However, the lowest grain yield (1426.98kg ha^{-1} and 625.86kg ha^{-1}) was obtained from 40cm x 5cm row spacing on 2020 and 2021 cropping seasons respectively at Ziway Abine germama kebele (Table 7). The experimental results of Khan *et al*. (1999); Rao *et al*. (1993); Dwangan *et al*. (1992) concluded the **grain yield** increased with the rate of P application, while, minimum **grain yield** recorded in control. They were also found that water use efficiency was also increase with phosphorus application. This study was disagreed with experimental results of Kadam and Khanvilkar (2015) which revealed that grain yield of mung bean was increased with increased rate of mung bean up to 40kg/ha 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 a*l. (2018); Abuzar *et al*. (2011) the highest grain was obtained from 40cm x 10cm row spacing as compared ow spacing of mung bean and common bean respectively.

Interaction effects of both Phosphorus and row spacing were significantly affected grain yield of mung bean. The maximum grain yield (2493.83 kg ha^{-1}) was obtained from the interaction effects of 60kg P_2O_5 ha^{-1} with 40cm x 10cm intra row spacing (Table 8). This result is in line with Kumar *et al*. (2012) who reported that the highest grain yield was recorded at the highest levels of P_2O_5 ha^{-1} with 10cm intra row spacing, and minimum grain yield was recorded at no (0 kg P_2O_5) with maximum intra row spacing. This study was also agreed with Gezu *et al* (2021); Ahmad, *et al*. (2015), they were reported mean value of phosphorus levels indicated that plots treated with 80kg P_2O_5 ha^{-1} with 10cm intra row spacing, produced maximum grain yield, while the minimum grain yield was recorded in control plots. The highest grain yield at 60kg P_2O_5 kg ha^{-1} with 40cm x 10cm spacing resulted mainly due to higher number of branches plant^{-1}, number of pods plant^{-1} and number of seeds pod^{-1}. Similar findings were also observed by Rasul *et al.* (2012); Yadav (2004) and Hangsing *et al.* (2019), they reported that the highest grain yield was obtained from 40kg P_2O_5 ha^{-1} with 40cm x 10cm row spacing.

Table 7. Effects of phosphorus fertilizer rate and row spacing on the above ground biomass yield and grain yield of mung bean on 2020 and 2021 cropping seasons at Ziway Abine germama kebele

	2020	2021		2020	2021	
PR (kgha^{-1})	**AGB**	**AGB**	**Mean**	**GY**	**GY**	**Mean**
0	5451.26c	4587.50c	5019.15c	1238.79c	592.39c	915.59d
20	5782.92c	4825.50c	5304.21c	1441.34c	708.54bc	1074.94c
40	6797.78b	5376.5b	6086.97b	1815.38b	824.03bc	1319.59b
60	8124.48a	6195.66a	7160.07a	2285.38a	1187.11a	1736.24a
LSD	490.31	344.02	357.09	215.71	125.98	151.03
RS (cm)						
5	6038.83b	4803.12c	5420.97c	1426.98c	625.86c	1026.42c
10	6998.91a	5142.76b	6395.65a	2058.26a	1018.24a	1538.25a
15	6579.60a	5792.38a	5861.18b	1685.99b	839.96b	1220.10b
LSD.p0.05	424.62	297.93	309.25	186.81	109.1	130.79
CV (%)	7.67	6.70	6.20	13.02	15.56	12.25

Table 8. the interaction effects of Phosphorus fertilizer and row spacing on above ground biomass and grain yield of Mung bean at Ziway Abine germama kebele

	Above ground biomass (kgha^{-1})			**Grain yield (kgha^{-1})**		
	Row spacing (cm)			**Row spacing (cm)**		
P. rate	**5cm**	**10cm**	**15cm**	**5cm**	**10cm**	**15cm**
0	4652.01f	5122.11ef	5283.34de	771.82g	1013.76efg	961.fg
20kha^{-1}	5142.18def	5501.81de	5268.63de	991.86fg	1126.07def	1106.89def
40kgha^{-1}	5621.14de	6894.18b	5745.58cd	1084.32ef	1519.34b	1355.10bcd
60kgha^{-1}	6268.56c	8064.48a	7147.16b	1257.68cde	2493.83a	1457.22ab
LSD	618.49			261.59		
CV (%)	6.20			12.25		

Harvest index: the statistical analysis data showed that rate of phosphorus and row spacing significantly affected harvest index of mung bean on both cropping seasons. The highest harvest index value was obtained from 60kg P_2O_5 ha^{-1} (0.28, 0.19) and 10cm intra row spacing (0.29, 0.17) on both 2020 and 2021 cropping seasons (Table 9). This showed that both biomass and grain yield of mung bean was increased with the increased rate of Phosphorus from 0-60 kg ha^{-1}. The application of Phosphorus with different intra row spacings were significantly influence the harvest index value of mung bean at Ziway on both cropping seasons. The above results, it was apparent that growth, yield and yield attributes of mung bean were increased with the application of phosphate fertilizer up the maximum level for this experiment (60 kg P_2O_5 ha^{-1}) and it was also differed among the mung bean spacing's. the study was in lined with the experimental results of Khan *et al.* (2017) reported that harvest index was significantly affected by different levels of Phosphorus and row spacing, the maximum harvest index value was recorded from the highest rate of 45 kg P_2O_5 ha^{-1}.

Interaction effects of both Phosphorus and row spacing were significantly affected harvest index. The interaction effects of both phosphorus fertilizer and row spacing were significantly affected harvest index of mung bean. The highest (0.25) and lowest (0.11) value of harvest index of mung bean was calculated from the interaction effect of 60kg P_2O_5 ha^{-1} with 40cm x 10cm row spacing and 0kg ha^{-1} of Phosphorus with 40cm x 5cm row spacing respectively at Ziway, Abine germama kebele (Table 10). This may directly relate to above ground biomass and grain yield of mung mentioned in table 10. The increased harvest index with an increase P_2O_5 rates of fertilizer is in agreement with the findings of Chiezey *et al.* (1992); Kawte *et al.* (2020) related to lower value of harvest index at low level of phosphorus application with wider spacing leads to poor development of plants at different growth stages of soybean. Similarly, Singh *et al.* (2015); (Fageria *et al.* (2010) they reported that the highest harvest index of common bean and lentil was obtained when 45 kg P_2O_5 ha^{-1} with 10cm intra row spacing respectively.

Table 9. the phosphorus fertilizer rate and row spacing on yield and yield components of mung bean on 2020 and 2021 cropping seasons at Ziway Abine germama kebele

	2020	2021	
Phosphorus rate (kgha^{-1})	**Harvest index**	**Harvest index**	**Mean**
0	0.23b	0.13b	0.18cd
20	0.25ab	0.15b	0.20bcd
40	0.27a	0.15b	0.21bc
60	0.28a	0.19a	0.24a
LSD (P= 0.05)	0.03	0.03	0.02
Row Spacings (cm)			
5	0.23b	0.13b	0.18c
10	0.29a	0.17a	0.23a
15	0.25b	0.16a	0.21ab
LSD (P=0.05)	0.03	0.03	0.02
CV (%)	13.69	19.45	19.45

Table 10. the interaction effects of phosphorus fertilizer and row spacing harvest index of Mung bean at Ziway Abine germama kebele

	Harvest index		
	Row spacing (cm)		
Phosphorus rate	**5cm**	**10cm**	**15cm**
0	0.11d	0.14cd	0.14cd
20kha^{-1}	0.14cd	0.14cd	0.16bc
40kgha^{-1}	0.12cd	0.15bcd	0.19ab
60kgha^{-1}	0.14cd	0.25a	0.17bc
LSD	0.06		
CV (%)	19.45		

Partial Budget Analysis

The economic analysis for mung bean production at Abine Germama kebele during the 2020/2021 cropping seasons calculated with partial budget as suggested by CIMMYT (1988) is presented in Table 11. The interaction of row spacings and Phosphorus fertilizer rates was significantly influence on grain yield and hence partial budget analysis was carried out for 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 and row spacing treated plots. It is clear that 40cm x 15cm row spacing without P_2O_5 application plot had considerably reduced costs of labor, transportation, fertilizer and mung bean seed as compared to others. The results revealed that the maximum net benefit (86772.51 ETB ha^{-1}) was obtained from 40cm x 10cm row spacing and 60kg P_2O_5 ha^{-1} (Table 11). The results show a general increase in benefit-cost ratio with an increase in the level of Phosphorus fertilizers. The analysis of marginal rate of return (MRR) revealed that all un dominated treatments recorded above 100% return per unit production cost. The highest marginal rate of return per unit production cost was recorded from mung bean planted with 40cm x 10cm row spacing and 60kg P_2O_5 ha^{-1} application (MRR = 942%) (Table 11). Producing mung bean with 40cm x 10cm row spacing and 60kg P_2O_5 ha^{-1} expect to recover 1 Ethiopian Birr and obtain an additional 9.42 Ethiopian Birr return for 1 invested Birr during the production time. Even if the variable cost of mung bean planted with 40cm x 5cm and 40cm x 10cm row spacing with the application of 60 P_2O_5 kg ha^{-1} were almost the same, the marginal rate of return of 40cm x 10cm row spacing had 11.36% higher than 40cm x 5cm row spacing mung bean. It was advisable application of 60 kg P_2O_5 ha^{-1} with 40cm x 10cm row spacing for this specific area. However, since 60 kg P_2O_5 ha^{-1} was the maximum level of Phosphorus among the treatments so this needs to increase the levels of Phosphorus for future study.

Table 11. Marginal analysis to establish the profitability of mung bean production as affected by phosphorus fertilizer and row spacing at Abine Germama Kebele, Ziway.

Treatments	Average yield(kg)	Adjusted yield (kg)	GFB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)
0kg + 40cm x 15cm	961.20	939.64	37585.78	2595.87	34989.91	-
0kg + 40cm x 10cm	1013.76	990.48	39619.11	3170.57	36448.55	D
20kg +40cm x 15cm	1106.89	1065.80	42632.13	3753.53	38878.60	336
0kg + 40cm x 5cm	771.82	743.35	29733.96	4207.01	25526.95	D
20kg +40cm x 10cm	1126.07	1077.97	43118.72	4239.08	38879.64	237
40kg + 40cm x 15cm	1355.10	1324.50	52979.99	5202.33	47777.66	491
20kg + 40cm x 5cm	991.86	952.32	38092.94	5548.92	32544.02	D
40kg + 40cm x 10cm	1519.34	1461.91	58476.55	5838.63	52637.92	544
60kg + 40cm x 15cm	1457.22	1452.70	58108.05	6466.98	51641.07	430
40kg + 40cm x 5cm	1084.31	1035.41	41416.25	7040.86	34375.38	D
60kg + 40cm x 10cm	2493.83	2371.65	94866.02	8093.51	86772.51	942
60kg + 40cm x 5cm	1257.68	1224.55	48981.90	8103.69	40878.21	107

ETB = Ethiopian Birr; GFB = Gross field benefit; MRR = Marginal rate of return; NB = Net benefit; TVC = Total variable cost and D= Dominated.

CONCLUSION AND RECOMMENDATION

Mung bean is amongst the important pulses cultivated in different agro-ecological zones of the world. The soil was medium in total nitrogen (0.143%), had low available phosphorus (2.42 mg kg-1 soil), moderate organic matter (2.252) contents and low cation exchange capacity (6.15 cmol kg-1 soil). 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. In addition to fertilizer application using proper agronomic practices are the best ways to increase yield of any crops, among the agronomic practices, optimum plant population or row spacing is a prerequisite for obtaining higher productivity of mung bean. The highest above ground biomass yield (8064 kg ha-1) was obtained from 40cm x 10cm row spacing and 60kg P_2O_5 ha−1. Similarly, the highest grain yield (2493.83 kg ha-1) was obtained from 40cm x 10cm row spacing and 60kg P_2O_5 ha−1. The results of this study revealed that the maximum net benefit (86772.51 ETB ha-1) was obtained from 40cm x 10cm row spacing and 60kg P_2O_5 ha−1. The highest marginal rate of return per unit production cost was recorded from mung bean planted with 40cm x 10cm row spacing and 60kg P_2O_5 ha-1 application (MRR = 942%). It was advisable application of 60 kg P_2O_5 ha-1 with 40cm x 10cm row spacing for this specific area. However, since 60 kg P_2O_5 ha-1 was the maximum level Phosphorus among the treatments so this needs to increase the levels of Phosphorus for future study.

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