On-farm verification of different phosphorus levels for mungbean production in West Gondar Zone Amhara Region.

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Abstract

A field experiment was carried out during the 2018 cropping season at the Metema and Tach Armacheho district, West Gondar zone, Amhara National Regional State (ANRS), to verify the effects of different phosphorus (P) level on the yield and yield-related components of mungbean and validating soil fertility map of lowland areas of the region. The Ethiopian government has -

based balanced fertilizer recommendations in the country. The map indicates a multi-nutrient deficiency in addition to the conventional N and P nutrients. The map shows seven nutrients (N, P, K, S, B, Zn, and Cu) deficiencies in many cultivated and cultivable areas of Amhara region. *Phosphorus is an essential plant nutrient which involves in all physiological activities of the crop production. The experiment was laid out in a randomized complete block design (RCBD) with three replications and the treatment consisted of one rate of N fertilizer (23 N kgha^{-1}) and four levels of phosphorus fertilizer (20, 28.26, 36.52, and 44.78 kgha^{-1}). The application of different rates of P was significant ($P<0.05$) for grain yield. The highest (1658.1 kg ha $^{-1}$) and lowest (864.7 kg ha^{-1}) mean grain yield was obtained from the application of 36.52 kg P ha $^{-1}$ and the control plots (23 kg N ha $^{-1}$), respectively in Metema. The maximum grain yield (1510.4 kg ha^{-1}) was obtained from the application of 28.26 kg Pha^{-1} (trt 3) while the minimum grain yield (1094.8 kg ha $^{-1}$) of mungbean was recorded from the control plots (23 kg N ha^{-1}) on Tache Armacheho.*

Keywords: Metema, Phosphorus, Soil fertility map, Tache Armacheho

Introduction

Mungbean is a rich source of vegetable protein. It is considered a poor man's meat containing almost triple the amount of protein as compared to rice (ref). It contains 1-3% fat, 50.4% carbohydrates, 3.5-4.5% fibers, and 4.5-5.5% ash, while calcium and phosphorus are 132 and 367 mg per 100 grams of seed, respectively (Frauque, A., *et al*,2000). It is an economically and nutritionally important food and feed legume crop. An important feature of the mungbean crop is its ability to establish a symbiotic partnership with specific bacteria, setting up the biological N_2-fixation in root nodules that supply the plant's needs for N_2 (Mahmood and Athar, 2008; Mandal *et al*., 2009). Mungbean being drought tolerant and short duration can grow well under varied conditions (irrigated and rain-fed). Mungbean has the potential of producing higher seed yield from 1295 to 2961 kg ha^{-1} depending on the genotypes studied (Ullah et al., 2011; Bilal, 1994).

Phosphorus is one of the important plant macronutrients, making up about 0.2% of a plant's dry weight. It is an important component of key molecules such as nucleic acids, phospholipids, and ATP, and consequently, plants cannot grow without a reliable supply of this nutrient. P is also involved in controlling key enzyme reactions and in the regulation of metabolic pathways (Theodorou and Plaxton, 1993). Phosphorus is present in seed and fruit in large quantities and is essential for seed formation. It is known to stimulate root growth and is associated with the early maturity of crops. It not only improves the quality of fruits, forages, vegetables, and grains but also plays a role in disease resistance of plants. (Brady and Weil, 1999). Phosphorus plays a remarkable role in plant physiological processes. Phosphorus is a key constituent of ATP and it plays a significant role in the energy transformation in plants and also essential for energy storage and release in living cells (Sangakara *et a*l, 2001). Legumes require relatively high amounts of phosphorus for nodulation, yield, and high-quality seeds (Ugese and Avan, 2005). Chemical fertilizers in Ethiopia have contributed to crop yield growth to date, although there is still potential for further improvement. Ethiopia's Growth and Transformation Plan (GTP) recognizes the importance of fertilizer for maintaining soil fertility and maximizing agricultural growth in the country.

However, due to the diverse agro-ecologies (soil and climate) in the country, site-specific and soil-test based fertilizer recommendations are indispensable. Accordingly, the MoANR and ATA have recently completed a detailed soil fertility map for the country. The map shows seven nutrients (N, P, K, S, B, Zn, and Cu) deficiencies in many cultivated and cultivable areas of Amhara region. The new soil fertility map of the Amhara region shows that P is highly deficient (almost 100%) in the soils of the region (ATA and MoANR, 2016). Based on the above facts the present study was aimed to verify the response of mungbean to P application and validating soil fertility map on Metema and Tach Armacheho districts in the lowland areas of Amhara Region

Materials and Methods

Description of Study Area

The experiment was conducted on the farmers' field in Metema and Tache Aremacheho districts in the North Gondar administrative zone in the Amhara National Regional State, Ethiopia. The experimental areas are located at 35.51-37.24 longitude and 12.25-13.14 latitude in metema and 36.62-37.59 and 12.78-13.29 14 longitude and latitude in Tache Armacheho.

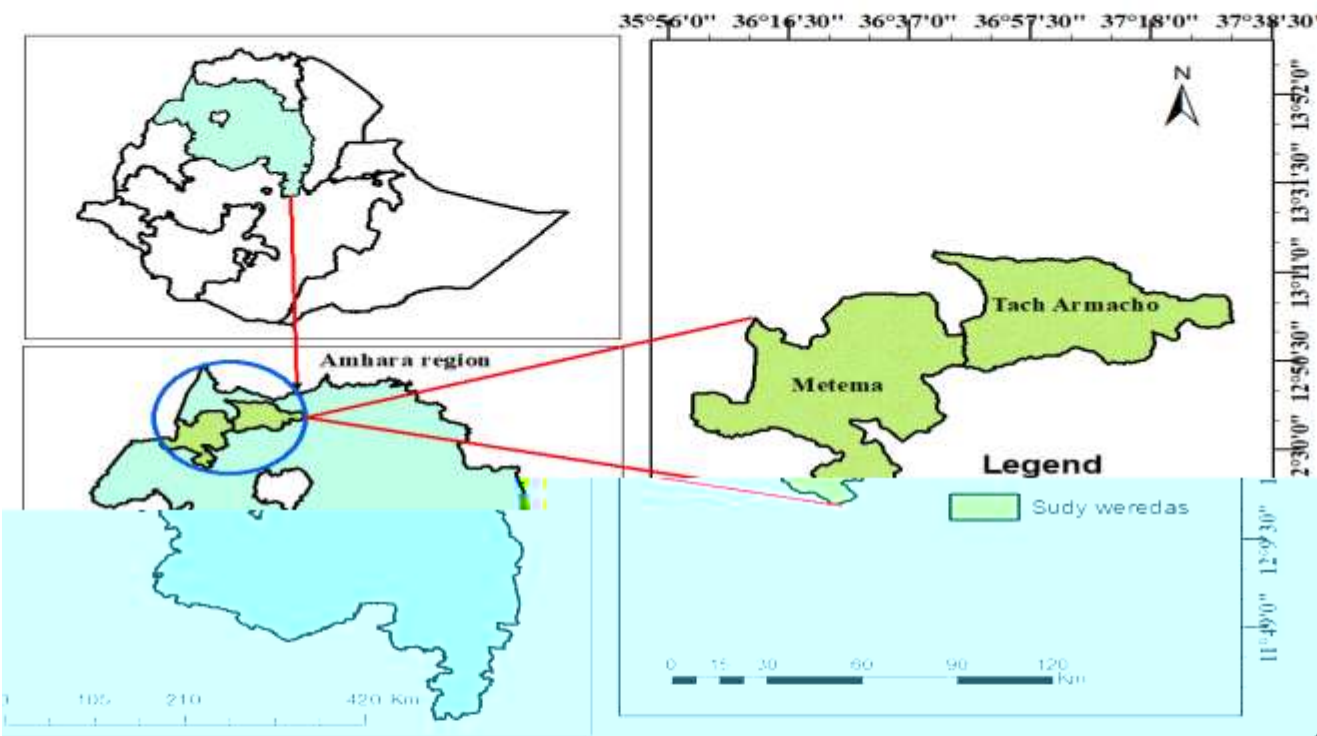

Figure 1. Map of the study areas.

The altitude of the areas ranges from as low as 550 to 1608 m.a.s.l while the minimum annual temperature ranged between 22 ^{0}C and 28 ^{0}C. Daily temperature becomes very high from March to May, where it may get to as high as 43 ^{0}C. Nearly all of the land in the area is in the lowlands except some mountain tops which fall outside. According to the available digital data, the mean annual rainfall for the area ranges from about 850 to around 1100 mm. Based on this digital data, about 90% of the area receives a mean annual rainfall of between 850 and 1000 mm. The rainy months extend from June until the end of September. However, most of the rainfall is received during July and August.

Experimental Research Design and Treatments

The experiment contains five treatments in Randomized Complete Block Design with three replications. The treatments were recommended nitrogen alone (23 kg N ha^{-1}), 20 , 28.26 , 36.52 , and 44.78 kg P ha^{-1} by adjusting the recommendation of N and P of the experimental sites. The old recommendation of fertilizer used 100 kg Dap ha^{-1}. The plot size was 5 m *5 m wide and length. There were 1m, 1.5 m, 40 cm, and 5 cm between plots, replications, rows, and plants respectively.

Soil sampling and preparation

Soil samples were randomly collected in a diagonal pattern before sowing from a depth of 0-20 cm. The soil samples were air-dried and passed through a 2 mm sieve for physicochemical analysis. The soil was analyzed for texture and total nitrogen, available phosphorous, pH, OC, and CEC before sowing. The texture of the soil was determined by the hydrometer method according to (Bouyoucos, 1962). Total N was analyzed by the Kjeldahl digestion method with sulphuric acid (Jackson, 1962). Soil pH was determined from the filtered suspension of 1:2.5 soil to water ratio using a glass electrode attached to a digital pH meter, a potentiometer (FAO, 2008). Organic carbon content was determined by the volumetric method (Walkley and Black, 1934). The available phosphorus was determined by the Olsen method (Olsen *et al*; 1954). Exchangeable potassium was extracted by ammonium acetate at pH 7 (Sahalmedhin and Taye, 2000) and determined by an Atomic absorption spectrometer. The cations exchange capacity (CEC) was determined following the 1N ammonium acetate extraction (pH7) method.

Land preparation and sowing

The experimental field was prepared following the conventional tillage practice of the area. It was manually leveled and then divided into blocks and plots; the blocks were separated by a 1.5 meter-wide open space whereas the plots in the block were 1m apart from each other. Each plot consisted of 12 rows of 5 m in length and spaced 0.4 m apart. The selected mungbean variety (Rassa) seeds were sown manually at equal spacing between plants and rows with a seed rate of 20 $kgha^{-1}$ and depth (3-5 cm) mid-way on the row and slightly covered by soil.

Fertilizer use, thinning and weeding.

The full dose of TSP fertilizer was applied during sowing, while urea was applied in split as a 1/3 urea (i.e. as per treatment) was applied uniformly in rows at planting. The remaining 2/3 of each nitrogen fertilizer treatment was side dressed after 45 days from sowing. The weeds observed in the plots were controlled manually at the same time for all treatments. Thinning of seedlings was done three weeks after sowing and the second thinning was also done a week after the first thinning to have 20 cm spacing between plants as recommended and practiced in the area to obtain the recommended stand population. All other typical agronomic practices of the area were performed uniformly to all plots

Statistical analysis

Plant data was recorded on a plot basis and extrapolated on a hectare basis. All parameters were determined and calculated from the middle rows. Analysis of variance and treatment means comparisons for the different measured parameters were carried out using SAS software window 9.0. Mean separation for the recorded plant parameters was made using the Least Significance Difference (at 0.05 significance level).

Economic analysis

Economic analysis was conducted using partial budget analysis as described by CIMMYT (1988) to find the best treatment which has an economic benefit. The following equations were used:

$$\text{Gross benefit} = \text{economical yield return} * \text{price (birr } kg^{-1})$$

$$\text{Net profit} = \text{gross benefit - total cost that varies.}$$

To identify the best treatments from the experiment the dominance analysis was used. The marginal rate of return (MRR) was calculated by considering a pair of non-dominated treatments listed. MRR denotes the return per unit of investment for the different managements tested in the field. Following the analysis, treatments with the highest MRR were recommended to farmers.

$$MRR = \text{change in NB}/\text{change in TCV}$$

Where MRR is the marginal rate of return, NB is net benefit ha^{-1} for each treatment, and TCV is the total variable costs ha^{-1} for each treatment.

Results and Discussion

Selected physical and chemical properties of soils before planting

The PH value ranged from 6.4-7.3 which indicated that slightly acidic to neutral. As per the classification set by London (1991), the organic contents of all the study sites rated under very low. The reasons for the very low content of OC could be intensive cultivation of the land and the total removal of crop residues for animal feed and source of energy. Moreover, there is no practice of the addition of organic fertilizers, such as farmyard manure and green manure that would have contributed to the soil OC pool in the study area. The available P content of the composite surface soil sample of the experimental sites could be rated as low. Generally, the existence of low contents of available P is a common characteristic of most soils in Ethiopia (Tekalign and Haque, 1991; Yihenew, 2002 ;). The exchangeable potassium of the soil was optimum (Berhanu Debele, 2008). According to Murphy (2007) the cation exchange capacity of the soil was very high.

Table 1. Physical and chemical properties of soil used on Metema and Tache armacheho district.

Site	Parameters					
Metema	PH (H_2O)	OC	Ava. P (p/ppm)	CEC (cmol/k)	Exch.k^+ (cmol/kg)	Textural class
	6.7	1.3	3.8	69.8	0.7	Clay
	7	1.5	3.7	63.1	0.6	Clay
	6.4	1.5	1.9	70.2	0.4	Clay
Tach-Armacheho						
	7.2	1.3	3.9	74.9	1.5	Clay
	7.3	1.6	3.2	44.1	0.7	Sandy clay
	6.9	1.5	3.5	58.9	0.9	Clay
	6.7	1.4	4.5	74.2	0.9	Clay
	6.9	1.4	2.5	62.6	0.7	Silt clay

Yield and yield-related components

The responses of plant height, hundred seed weight, and number of pod per plant, number of seed per pod, grain yield, and straw yield of mungbean to phosphorus fertilization of the combined data of over three Metema experiment sites are demonstrated in Table 2. The effect of applied fertilizers on plant height was found significant ($P < 0.05$). As indicated in Table 2 the minimum (49.0 cm) and maximum (61.5 cm) plant height were obtained from the application of no phosphorus and 36.52 kg P ha^{-1} respectively. These results showed that, plant height was gradually increased due to the increase in phosphorus doses up to 36.52 kg P $ha^{-1,}$ and thereafter it was decreased. Almost similar results were found by Rahman *et al*. (2008), Bhuiyan *et al*. (2004) and Akter et al, (2019).

Similarly, the number of pod per plant was significantly affected ($P \leq 0.05$) by phosphorus application. The maximum number of pod per plant (9.1) was obtained from the application of 36.52 kg P ha^{-1}, while the lowest (7.6) from the control treatment 23 kg N ha^{-1} alone Muhammad et al (2017), reported that the maximum and minimum number of pods per plant was recorded in 39-52 kg P ha^{-1} and the control plots where no phosphorus was applied respectively.

The application of different rates of phosphorus fertilizer show a significant ($P > 0.05$) effect on a hundred seed weight at both experimental sites. The maximum (5.1 gm) and minimum (4.7 gm) hundred seed weight was recorded on treatment 4 (36.52 kg P ha^{-1}) and treatment 1 (23 kg N ha-^{1}) respectively. On Tache Armacheho the highest (5.6 gm) hundred seed weight was obtained on treatment 3 (28.26 kg P ha^{-1}).

Table 2. Effects of phosphorus levels on yield and yield components of mungbean

	Metema					Tache Armacheho	
Treatments	PH (cm)	NPP (No.)	HSW (gm)	GY (kg)	STR	HSW (gm)	GY (kg)
23 N	49.0[b]	7.6[b]	4.7[b]	864.7[b]	911.4[b]	5.3[b]	1094.8[b]
20 P	58.2[a]	9.1[a]	4.9[ab]	1617.2[a]	1560.0[a]	5.4[b]	1402.6[a]
28.26 P	59.4[a]	9.0[a]	5.0[ab]	1553.2[a]	1528.6[a]	5.6[a]	1510.4[a]
36.52 P	*61.5*[a]	9.1[a]	5.1[a]	1658.1[a]	1447.6[a]	5.3[b]	1422.7[a]
44.78 P	58.4[a]	9.0[a]	4.9[ab]	1581.3[a]	1402.6[a]	5.3[b]	1436.6[a]
CV (%)	6.7	14.2	4.6	16.9	21.7	4.5	13.0
LSD (5%)	7.1	1.4	0.3	342.5	325.4	0.2	148.9

*NB: Plant height(PH),No. of pod/plant(NPP),No. seed/pod(NSP) , 100 seed weight(TSW), Grain yield(GY),and Straw yield(STR). * Significant*

The application of different rates of P was significant ($P<0.05$) for grain yield. As shown in Table 2 the highest (1658.1 kg ha $^{-1}$) and lowest (864.7 kg ha^{-1}) mean grain yield was obtained from the application of 36.52 kg P ha $^{-1}$ and the control plots (23 kg N ha $^{-1}$) on Metema respectively. Ali et al., 2010 reported that all the levels of phosphatic fertilizer showed a significant impact on the mungbean crop compared to the control plotseventhough the treatment of phosphatic fertilizer with the rate of 84 P_2O_5kg ha-1 out yielded the rest of the treatments In Pakistan. Similar results obtained by Emsley. (2000), showed that phosphatic fertilization has an increasing influence on growth and yield. Also on Tache Armacheho the maximum (1510.4 kg ha^{-1}) and minimum (1094.8 kg ha $^{-1}$) grain yield of mungbean was obtained from the application of 28.26 kg P ha^{-} and the control plots (23 kg N ha^{-1}) respectively. According to Rahman *et al* (2015), the minimum significant seed yield (1.11 t ha^{-1}) was obtained with the treatment 0 kg P ha^{-1} which was in line with our research finding.

The highest (1560 kg ha $^{-1}$) and the lowest (911.4 kg ha $^{-1}$) straw yield was obtained from the application of 20 kg P ha^{-1}and 0 kg P ha^{-1} respectively. As phosphorus rate increased, straw yield also correspondingly increased up to 28.26 kg ha^{-1} P levels and then declined. This result was in conformity with Hamaz et al, (2016), who reported highest stover yield (2.86 t ha^{-1}) using 40 kg

P_2O_5 ha^{-1} which was statistically similar to 60 kg P_2O_5 ha^{-1}. Straw yield of mungbean increased with an increase rate of phosphorus fertilizer

Partial budget analysis

The result of the partial budget analysis revealed that the economically feasible fertilizer application rate varies. Since mung bean yield is the major worry of this experiment, the economic application rates within the acceptable level of mung bean yield was necessary. Tables 3 & 4 showed an economically feasible application rate at 20 kg P ha^{-1} due to its high marginal rate of return. The other treatments were eliminated by the concept of dominance analysis since the net benefit incurred decreased as the cost increased. The highest MRR (514 and 151 birr) was obtained from 20 kg P ha^{-1} resulting in a yield of 1617.2 and 1402.6 kg grain yield ha^{-1} (Table 3 & 4) on Metema and Tache Armacheho respectively. This indicates that farmers can obtain 514 & 151 birr extra by investing one birr buying fertilizer to apply 20 kg P ha^{-1}. The farmers should apply 100 kg DAP to obtain 20 kg P ha^{-1}. The application of phosphorus fertilizer above 20 kg P ha^{-1} is not economically beneficial for both districts

Table 3. Partial budget analysis of mungbean produced by applying phosphorus (Metema).

No.	Treatment (TSP)	Total Revenue	TVC	Net Revenue	MRR (%)
	(kg)	(birr)	(birr)	(birr)	(birr)
1	0	11673.45	0	11673.45	_
2	20	21832.2	1652	20180.2	514.9
3	28..3	20968.2	2334	18634.2	-66.2
4	36.5	22384.35	3017	19367.35	24.3
5	44.8	21347.55	3899	17448.55	-49.2

TVC; Total vary cost, MRR; Marginal rate of return

Table 4. Partial budget analysis of mungbean produced by applying phosphorus (Tache Armacheho).

No.	Treatment (TSP)	Total Revenue	TVC	Net Revenue	MRR (%)
	(kg)	(birr)	(birr)	(birr)	(birr)
1	0	14780	0	14780	_
2	**20**	18935.1	1652	17283.1	151.5
3	28..3	20390.4	2334	18056.4	33.1
4	36.5	19206.5	3017	16189.5	-61.8
5	44.8	19394.1	3899	15495.1	-17.8

TVC; Total vary cost, MRR; Marginal rate of return

Conclusion and Recommendation

The result obtained from this study showed that different applications rates of phosphorus fertilizers significantly improved mungbean growth and yield as compared to the control. It can be observed that the number of pods and seeds per plant tended to increase as the phosphorus rate increased in all Metema experimental sites. The maximum plant height were produced with the application rate of 23 kg N ha^{-1} + 36.52 kg P ha^{-1} in both districts. This can be attributed to the promoted vegetative growth of mungbean due to phosphorus fertilizer. There was an increase in hundred seed weight, grain yield, and straw yield with an increasing rate of phosphorus fertilizer. Fertilizer rate of 23 kg N ha^{-1} + 36.52 kg Pha^{-1} and 23 kg Nha^{-1} + 28.26 kg Pha^{-1} also appeared to give a higher grain yield compared to the rest of the treatments in Metema and Tach Armacheho respectively. The lowest yield was obtained on 23 kg N ha^{-1} alone on both districts. This might be due to a limitation or low amount of available phosphorus in the soil. Based on the partial budget analysis result of the experiment, it is possible to recommend the application of fertilizer with rates of 20 kg P and 23 kg N ha^{-1} for both Metema and Tache Armacheho because of economically optimum and acceptable rates for mungbean production.

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