On-Farm Verification of Different Phosphorus Levels for Cotton Production in West Gondar Zone Amhara Region

Tamrat Worku*, Melkamu Adane, Baye Ayalew, Ayalew Addis

Gondar Agricultural Research Center, Soil and water management research directorate, Gondar, Ethiopia.
*Corresponding author email: *tamratworku59@gmail.com*

Abstract

The government has launched the 'EthioSIS' project to develop soil fertility maps and generate soil fertility map-based balanced fertilizer recommendations in the country. The map shows deficiencies of seven nutrients (N, P, K, S, B, Zn, and Cu) in many soils of cultivated and cultivable lands of the Amhara region. A field experiment was carried out during the 2018 cropping season at the Metema and Tach Armacheho district, West Gondar zone, ANRS, to verify the effects of different phosphorus (P) levels on seed yield of cotton and validating the soil fertility map of the lowland areas of Amhara region. 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 (46 N kg ha^{-1}) and four levels of phosphorus fertilizer (20, 28.26, 36.52, and 44.78 kg ha^{-1}). The application of different rates of

$^{-1}$)

and lowest (1910.6 kg ha^{-1}) seed yields were obtained from the application of 44.78 kg P ha-1 and the control plots (46 kg N ha^{-1}), respectively at Metema sites. At Tach Armacheho sites, the highest and lowest seed yields of 3190.7 and 2149.7 kg ha^{-1}were recorded for plots received treatment 5 (44.78 kg P ha^{-1}) and control plots (46 N ha^{-1}), respectively. The highest lint yield of cotton (1729.9.kg ha^{-1}) was obtained from treatment 5(44.78 kg P ha^{-1}), while the least lint yield (972.2kg ha^{-1}) was recorded from treatment 1(46 kg N ha^{-1}) at Metema sites. Phosphorus applied at the rate of 44.78 kg P ha^{-1} produced maximum lint yield (1303 kg ha^{-1}) while lower lint yield (855.3 kg ha^{-1}) was recorded for the control (46 kg N ha^{-1}) treatment 1 at Tach Armacheho sites. The application of fertilizer rates 20 kg P ha^{-1} and 64 kg Urea ha^{-1} for Metema and Tach Armacheho, are economically optimum and acceptable rates for cotton production based on the partial budget analysis result of the experiment.

Keywords: Cottonseed yield, Lint yield, Phosphorus, Soil fertility map

Introduction

Cotton (Gossypium spp.) is grown in about 76 countries, covering more than 32 million ha, under different environmental conditions worldwide and world cotton commerce is about US$20 billion annually (Saranga *et al*., 2001). Cotton plays a considerable role in economic development worldwide and an important source of fiber, oil, and animal feed (Dai and Dong, 2014). China leads the world cotton production with India and the U.S. at second and third, respectively (Darren *et al*, 2009). Cotton growth, development, and maturity are greatly influenced by NPK nutrients application which increases yield and yield components and fiber quality (Xia *et al*., 2011; Adnan *et al*., 2017 and Wajid *et al*., 2017). The NPK are key nutrients required in large quantities by all crop plants and classed as major nutrient elements

Phosphorus is the second most limiting nutrient in crop production after nitrogen. Phosphorus deficiency has a large and rapid negative effect on the growth of a range of crops (Singh *et al.*, 2000). It does not occur as abundantly in the soil as N and K. The total concentration of P in surface soil varies between about 0.01 and 0.02%. Unfortunately, the measure of total P in soil has little or no relationship to the availability of P to plants (Tisdale, 2002). In a cotton crop, the critical-P concentration ranges from 0.20 to 0.31% (Crozier *et al*., 2004). Adequate phosphorus nutrition enhances many aspects of plant physiology, including the fundamental processes of photosynthesis, root growth particularly the development of lateral roots and fibrous rootlets (Brady and Weil, 2002).

Chemical fertilizers in Ethiopia have contributed to increasing crop growth and yields to date, although there is potential for further improvement. Ethiopia's Growth and Transformation Plan (GTP) recognizes the importance of fertilizer for maintaining soil fertility and maximizing the agricultural productivity of 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 the 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 (MoANR and ATA, 2016). Therefore, this research aimed to verify the response of cotton to P application and validating the soil fertility map of Metema and Tach Armacheho districts in the lowlands of the Amhara region.

Materials and Methods

Description of the Study Area

The experiment was conducted on the farmers' field in Metema and Tach Aremacheho Districts in the West Gondar administrative zone in the Amhara National Regional State, Ethiopia. The experimental areas are located at 35.51-37.24 and 12.25-13.14 and 36.62-37.59 and 12.78-13.29 14 longitude and latitude in Metema and Tach Armacheho respectively (Figure 1). The altitude of the areas ranges from as low as 550 to 1608 meter a.s.l.

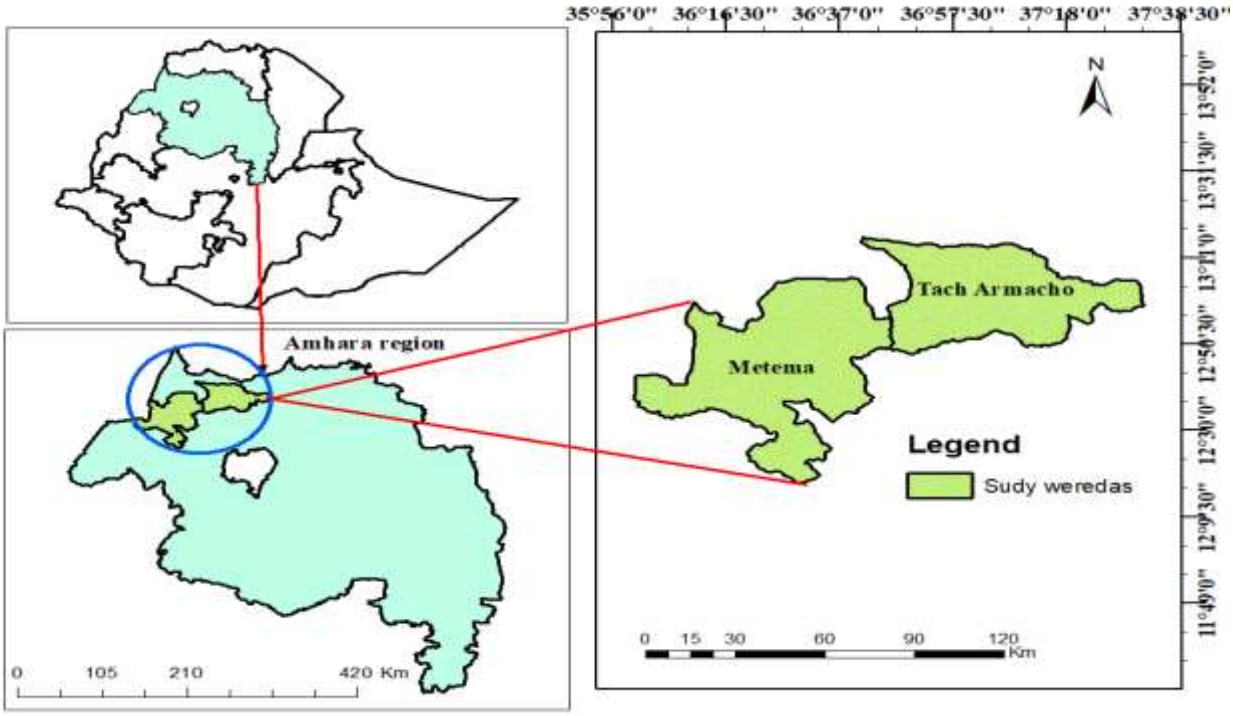

Figure 1. Map of the study areas.

Nearly all the land in the area is in the lowlands except some mountain tops which fall outside. The mean annual temperature ranges between 22 and 28 ^{0}C. Daily temperature becomes very high from March to May, where it may get to as high as 43 ^{0}C in Metema district. 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 rain falls during July and August.

Experimental Design and Treatments

The experiment was laid out using a Randomized Complete Block Design. The treatments were recommended nitrogen alone (46 kg N ha^{-1}), 20, 28.26, 36.52, and 44.78 kg P ha^{-1}. The old recommendation for fertilizer use is 100 kg DAP and 100 kg Urea ha^{-1}. The plot size was 5.4 m *5 m for cotton. There were 1 m, 1.5 m, 45 cm, and 20 cm between plots, replications, rows, and plants, respectively.

Soil Sampling Technique Sample Preparation and Analysis

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 soil total nitrogen, available phosphorous, pH, OC, CEC before sowing. The texture of the soil was determined by the hydrometer method according to (Bouyoucos, 1962). Total soil 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 (FAO, 2008). Organic carbon content was determined by Walkley and Black method (Walkley and Black, 1934). The available soil 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) of the soil was determined following the 1N ammonium acetate extraction (pH7) method.

Land Preparation and Sowing

The experimental field was prepared based on 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 where the plots in the blocks were 1m apart from each other. Each plot consisted of 12 rows of 5 m in length and spaced 0.45 m apart. The selected cotton variety (Delta pine 90) seeds were sown manually at the equal spacing between plants and rows with a seed rate of 20 kg/ha 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 the split. A 1/3 urea (i.e., as per treatment) was applied uniformly in rows at planting. The remaining 2/3 of nitrogen fertilizer was side-dressed after 45 days from sowing. The weeds 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 get the recommended stand population. All other typical agronomic practices of the area were performed uniformly to all plots. Meanwhile, during this study some of the data collected were days to maturity, seed yield, and lint yield,

Statistical Analysis

Plant data were recorded on a plot base 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 Test (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:

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

Net profit = 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 = change in NB/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 Discussions

Selected soil physical and chemical properties before planting

The pH of the soil is one of the most important properties influencing plant growth and production as it affects ion exchange capacity and nutrient availability. The pH values of the composite surface (0-20 cm) soil samples were ranged from 6.4-7.0 at Metema, which was slightly acidic to neutral in reaction. At Tach Armacheho pH of the soil samples was also ranged from 6.7-7.3 (Table 1), which was moderately alkaline in reaction. The textural class of the soil was clay. The organic carbon content of the soils of the study area was classified as low to very low (London, 1991). 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. Moreover, there is no practice of applying organic fertilizers, such as farmyard manure and green manure that would have contributed to the soil OM pool. Ertebo and Sertsu (2002) also indicate that the organic carbon content and nutrient supplying power of most cultivated soils in Ethiopia are low. The available P content of the composite surface soil sample of the experimental sites was low. Generally, the existence of low contents of available P is a common characteristic of most soils of Ethiopia (Tekalign and Haque, 1991; Yihenew, 2002) and 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. Selected physical and chemical properties of the soil.

Location	Parameters					
Metema	PH (H_2O)	OC	Ava. P (p/ppm)	CEC (cmol/k	Exch.k^+ (cmol/kg)	Textural class
Site 1	6.7	1.3	3.8	69.8	0.7	Clay
Site 2	7	1.5	3.7	63.1	0.6	Clay
Site 3	6.4	1.5	1.9	70.2	0.4	Clay
Armacheho						
Site 1	7.2	1.3	3.9	74.9	1.5	Clay
Site 2	7.3	1.6	3.2	44.1	0.7	Sandy clay
Site 3	6.9	1.5	3.5	58.9	0.9	Clay
Site 4	6.7	1.4	4.5	74.2	0.9	Clay
Site 5	6.9	1.4	2.5	62.6	0.7	Silt clay

Yield and Yield-Related Parameters

Days to maturity

Cotton plants grown on plots received treatment 1 (46 kg N ha^{-1}) showed a delay in maturity (155.3 days) and shorter maturity duration (124.9 days) was recorded for plants grown on plots received treatment 5 (44.78 P ha^{-1}) relative to plants grown on plots treated with other treatments at Metema (Table 2). Therefore, the application of phosphorus fertilizer has influenced (P<0.05) days to maturity of cotton at Metema sites, but at Tach Armacheho sites does not affect.

Cotton-seed yield

Cotton-seed yield is a very complex attribute. It is a product of several components. The

-seed yield. The

highest (3226.2 kg ha^{-1}) and lowest (1910.6 kg ha^{-1}) mean cotton-seed yield was obtained from the application of 44.78 kg P ha^{-1} and the control plots, respectively in Metema. There was also a significant effect between treatments in Tach Armacheho district. The yield of 3190.7 (44.78 kg P ha^{-1}) and 2149.7 (46 N ha^{-1}) kg/ha has the highest and lowest cottonseed yield, respectively. It did not show a consistent trend with increasing levels of phosphorus in the two districts. Increased cottonseed yield per hectare, as well as earliness in cotton, were achieved with increasing phosphorus levels. Sawan *et al*. (2008) also reported increased cottonseed yield per hectare with the application of increased P levels. However, the increase was non-significant between P levels.

Table 2. Effects of phosphorus levels on days to maturity, seed & lint yields of cotton in Metema and Tach Armacheho districts.

	155.29^{a}	**1910.6^{c}**	**972.7^{c}**	**2149.7^{b}**
		3226.2^{a}	**1729.9^{a}**	**3190.7^{a}**

*NB: DTM=Days to maturity, CSY= Cotton-seed yield, LY= Lint yield, CV= Coefficient of variance, LSD= Least significance difference, and *=Significant*

Lint yield

Analysis of variance of the results revealed that the effect of P levels was significant ($p<0.05$) on the lint yield of cotton. The highest lint yield of cotton (1729.9 kg ha^{-1}) was obtained from plots received treatment 5 (44.78 kg P ha^{-1}), while the lowest lint yield (972.2 kg ha^{-1}) was recorded from plots treated with treatment 1 (46 kg N ha^{-1}) in Metema district sites. In Tach Armacheho district experiment sites, phosphorus applied at the rate of 44.78 kg P ha^{-1} produced higher lint yield (1303 kg ha^{-1}) while lower lint yield (855.3 kg ha^{-1}) was recorded from the control plot with (46 kg N ha^{-1}), treatment 1. According to Aslam *et al*., (2009), increased lint yield of cotton per hectare was achieved with increasing phosphorus levels.

Partial budget analysis

The result of the partial budget analysis revealed that the economically most fertilizer application rate varies. Since cottonseed yield is the major worry of this experiment, the economic application rates within the acceptable level of cotton seed yield. Tables 3 and 4 showed an economically feasible application rate at 20 kg P ha^{-1}. It has a 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 (761 and 522 Birr) was obtained from 20 kg P ha^{-1} resulting in a yield of 2788.8 kg and 2814.4 cotton seeds ha^{-1} (Table 3 & 4) in Metema and Tach Armacheho districts, respectively. This indicates that farmers can obtain 761 & 522 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 phosphorus fertilizer for cotton production in Metema district

No.	Treatment (TSP)	Total Revenue	TVC

Table 4. Partial budget analysis of phosphorus fertilizer for cotton production in Tache Armacheho district.

No.	Treatment (TSP)	Total Revenue	TVC	Net Revenue	MRR (%)
	(kg)	(birr)	(birr)	(birr)	(birr)
1	0	34825.1	0	34825.1	_
2	**20**	**45596.5**	**1652**	**43944.5**	**552**
3	28..3	48830.0	2334	46496	109
4	36.5	47506.5	3017	44489.5	-66
5	44.8	51689.3	3899	47790.3	84

No.=serial number, TVC=Total vary cost, MRR=Marginal rate of return

Conclusions

There were significant effects of P levels on some cotton parameters such as on cotton-seed yield and lint yield in both districts. The rest parameters have no significant difference. This is not mean that no response of cotton in terms of those parameters to applying different amounts of phosphorus. The result indicated that there was a 68.8 % and 48.4 % yield advantage over the unfertilized plot on Metema and Tach Armacheho respectively. The application of fertilizer rates 20 kg P ha^{-1} and 64 kg Urea ha^{-1} for Metema and Tach Armacheho, are economically optimum and acceptable rates for cotton production based on the partial budget analysis result of the experiment.

Acknowledgments

We thank Agricultural Growth Program II for funding this research. We also like to acknowledge Gondar Agricultural Research Center for facilitating and supplying every necessary materials at the right time to implementing this research.

References

Adnan NS, Javaid I, Mohsin T, Guozheng Y, Waseem H, et al. (2017) Nitrogen fertilization and conservation tillage: a review on growth, yield, and greenhouse gas emissions in cotton. *Environmental Science Pollution Research* 24: 2261-72.

Aslam, M., M.Y. Memon, P. Khan, M. Imtiaz, and Nizamuddin. 2009. Performance of fertigation technique for phosphorus application in cotton. *Soil & Environment* 28: 45-48.

Berhanu Debele, 1980. The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land Use Planning and Regulatory Department, Ministry of Agriculture, Addis Ababa, Ethiopia.

Brady, N.C., and R.R. Weil (2002). The Nature and Properties of Soils (13th ed). Pearson Education Ltd., USA.960p.

Bouyoucos, J. 1962. Hydrometer method improved for making particle size analysis of soil. *Agronomy Journal*, 54: 464-465.

CIMMYT. From Agronomic Data to Farmer Recommendations: *An Economics Training Manual*; CIMMYT: El Batán, Mexico, 1988; Volume 27.

Crozier, C.R., B. Walls, D.H. Hardy, and J.S. Barnes. 2004. The response of cotton to P and K soil fertility gradients in North Carolina. *Journal of Cotton Science* 8: 130-141.

Dai J, Dong H (2014) Intensive cotton farming technologies in China: achievements, challenges, and countermeasures. *Field Crop Research* 155: 99-110.

Darren Hudson, Suwen Pan, Maria Mutuc, Samantha Yates, 2009.*Global cotton baseline* 2008/09-2018/19.Cotton Economics Research Institute. Department of Agricultural and Applied Economics at Texas Tech University.

Ertebo, T, and Sertsu S. (2002). Influence of crop residues on nitrogen mineralisation in an acidic nitosol. *Ethiopian Journal of Natural Resources.*

FAO (Food and Agriculture Organization of the United Nations). 2008. Fertilizer and plant nutrition bulletin: *Guide to laboratory establishment for plant nutrient analysis*. FAO, Rome, Italy, 203 p.

Jackson, M. 1962. *Soil chemical analysis*. New Delhi, Prentice-Hall of India Pvt. Ltd, 498.

Landon, JR (eds). 1991. Booker tropical soil manual: *a handbook for soil survey and agricultural land evaluation in the tropics and subtropics.* John Wiley & Sons Inc., NewYork.

Ministry of Agriculture and Natural Resource and Agricultural Transformation Agency of Ethiopia,2016.*Soil Fertility Status and Fertilizer Recommendation Atlas of Amhara National Regional State*, Ethiopia.

Murphy, H. 2007. A report on fertility status and other data on some soils of Ethiopia. Collage of Agriculture HSIU. Experimental Station Bulletin No. 44, Collage of Agriculture: p 551.

Olsen S.R., V.Cole, F.S. Watenable and L.A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Cir. No. 939.

Sahlemedhin S. and Taye B., 2000. *Procedures for Soil and Plant Analysis*. National Soil testing center, Addis Ababa, Ethiopia.

Saranga, Y., M. Menz, C.X. Jiang, J.W. Robert, D. Yakir, and H.P. Andrew. 2001. Genomic dissection of genotype X environment interactions conferring adaptation of cotton to arid conditions. *Genome Research* 11: 1988 1995.

Sawan, Z.M., M.H. Mahmoud, and A.H. El-Guibali. 2008. Influence of potassium fertilization and foliar application of zinc and phosphorus on growth, yield, and fiber properties of Egyptian cotton (Gossypium barbadense L.). *Journal of Plant Ecology* 1(4): 259-270

Singh, D.K., P.W.G. Sale, C.K. Pallaghy, and V. Singh. 2000. Role of proline and leaf expansion rate in the recovery of stressed white clover leaves with increased phosphorus concentration. *New Phytology* 146: 261 269.

Tekalign Mamo and I Haque. 1991. Phosphorus status of some Ethiopian soils, II. Forms and distribution of inorganic phosphates and their relation to available phosphorus. *Tropical Agriculture* 68: 1: 2-8.

Tisdale, L.S., L.W. Nelson, D.J. Beaton, and J.L. Haulin, (2002). *Soil Fertility and Fertilizers*, 633 p. Macmillan publishing company. NewYork, Toronto, Oxford, and Singapore.

Wajid A, Ahmad A, Awais M, Habib-ur-Rahman M, Sammar A, et al. (2017) Nitrogen requirements of promising cotton cultivars in the arid climate of Multan. *Sarhad J Agri* 33: 397-405.

Walkley, A. and Black, C.A. 1934. An examination of the Degtjareff method for determining soil organic matter and the proposed modification of the chromic acid titration method. *Journal of Soil Science*, 37: 29-38.

Xia Y, Jiang CC, Chen F, Lu JW, Wang YH (2011) Differences in growth and potassium-use efficiency of two cotton genotypes. *Commu Soil Analysis* 42: 132-143.

Yihenew Gebreselassie. 2002. Selected chemical and physical characteristics of soils of the Adet Research Centre and its testing sites in Northwestern Ethiopia. *Ethiopian Journal of Natural Resources* 4 (2): 199-215.