On-Farm Verification of Different Levels of Phosphorus for Sesame Yield and Yield-Related Components at West Gondar Zone, Northwestern Ethiopia

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Abstract

Sesame is considered one of the most important oil crops ("Queen of oil seeds") in the world because its seed has high contents of oil and protein. A field experiment was carried out during the 2019 cropping season at the metema and tacharmacheho district, West Gondar zone, to verify the effects of phosphorus (P) fertilizer level on the yield and yield-related components of sesame and validate soil fertility maps of the lowland areas of the Amhara region. 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 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 (46 N kg ha-1) and four levels of phosphorus fertilizer (8.3, 16.6, 24.9, and 33.3 kg ha^{-1}). Phosphorus application had a significant effect on 100 seed-weight. The highest thousand seeds weight was recorded on 46 kg P_2O_5 ha^{-1} (Trt 4) while the control plot (0 kg P_2O_5 ha^{-1}) had the lowest thousand seeds weight. The highest grains yield (936.6 kg ha^{-1}) was recorded in 46 kg P_2O_5 ha^{-1}and the lowest grain yield (678.6 kg ha^{-1}) was recorded in the control plot. Application of different rates of P fertilizer provided a statistically significant difference in grain yield of sesame.

Keywords*:* *Metema, Phosphorus, Sesame, Soil map, Tach armacheh*

Introduction

world because its seed has high contents of oil and protein (Berhanu *et al*., 2016). World production of sesame seed gradually increased from 5.2 million tons year^{-1} in the 2011s to 6.1 million tons year^{-1} in 2014, due to increasing demand for sesame oil worldwide (FAOSTAT, 2016). According to the FAO, in 2016, the reserved area for sesame planting in the world was 11.06 million hectares with a production rate of 6.08 million tons year-1 and an average yield of 1.11 t ha^{-1}. In Africa, Ethiopia stands fifth in the area after Sudan, Tanzania, Nigeria, and Burkina Faso, however, in productivity, Ethiopia stands eighth after the Central African Republic, Egypt, Somalia, Benin, Nigeria, Cameroon, and Morocco (FAOSTAT, 2016). The major sesame seed-producing regions are situated in the North West and South West Ethiopia in Humera, Gondar, Wollega, and Metekel (Dawit and Meijerink, 2010; CSA, 2011).

In Ethiopia oil seeds added 6.68% (about 846,493.53 hectares) of the grain crop area and 2.79% (about 8,550,738.16 quintals) of the production to the national grain total. Neug, sesame, and linseed covered 2.29% (about 290,494.94 hectares), 2.92% (about 370,141.06 hectares) and 0.62% (about 79,044.51 hectares) of the grain crop area and 1.06% (about 3,233,448.82 quintals), 0.84% (about 2,559,034.30 quintals) and 0.29% (about 882,096.51 quintals) of the grain production, respectively (CSA,2018).

Nitrogen, phosphorus, and potassium are often called primary macronutrients because of the large quantities taken up from the soil relative to other essential nutrients. The need for phosphorus is critical during the early stage of growth when normal meristem development and rapid shoot growth are necessary for high yield. Plants use about 1/10 as much phosphorus as nitrogen. It is part of plant nucleoprotein and hence important in plant heredity. Phosphorus also plays a role in energy transfer reactions, metabolic processes, cell division, stimulates fruit setting, and seed production (Miller and Donahue, 1995; Tisdale *et al*., 1995). The physical and chemical properties of soil were reported to influence the solubility of phosphorus and its absorption reaction in soils. These include the nature and amount of soil mineral, soil pH, cation effect, anion effect, extent of P saturation, and fertilizer management (Tisdale *et al*., 1995). Lack of improved varieties, moisture stress, poor crop management practices, and the growing of sesame on the same land for a long time without crop rotation are considered as some of the reasons for the reduction of the yield in Ethiopia (Berhanu et al., 2016). Therefore, this research aimed to verify the response of sesame to different phosphorus levels application and validate soil fertility maps on metema and tach armacheho districts in the lowlands of the Amhara region.

Materials and Methods

Description of Study Area:

and Aftit kebeles in Metema and Sanja and Fendeqa kebeles in Tache armacheho districts in the West and Central Gondar administrative zone respectively in the Amhara region, Ethiopia. The experimental areas are located 35.51^{0}-37.24^{0} and 12.25^{0}-13.14^{0} and 36.62^{0}-37.59^{0} and 12.78^{0}-13.29 14^{0} longitudes and latitude of Metema and Tache armacheho respectively. Vertisols are the dominant soil type and sesame, sorghum, soybean, mungbean, and cotton were the main crops growing in the study areas. The study areas has mixed crop-livestock farming system.

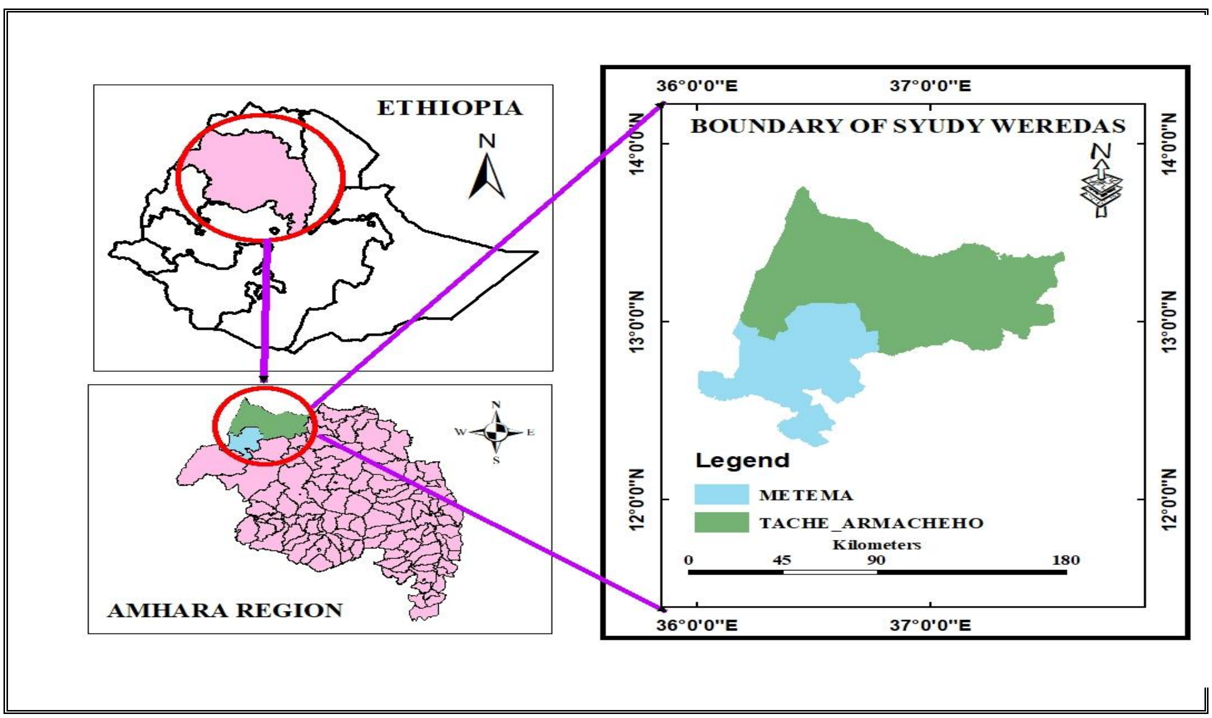

Figure 1. Map of the study areas

The altitude of the areas ranges from as low as 550 to 1608 masl while the mean annual temperature ranged 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 the Metema district. Nearly all 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 (NMSA, 1985).

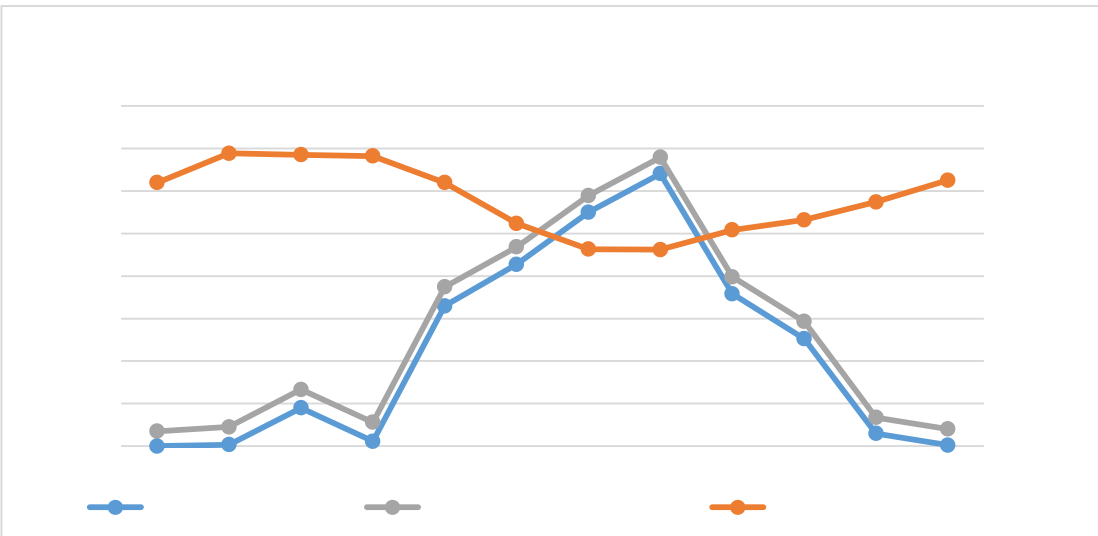

Figure 2. Annual rainfall (mm) and Minimum and Maximum Temperatures at Metema district (2011 E.C)

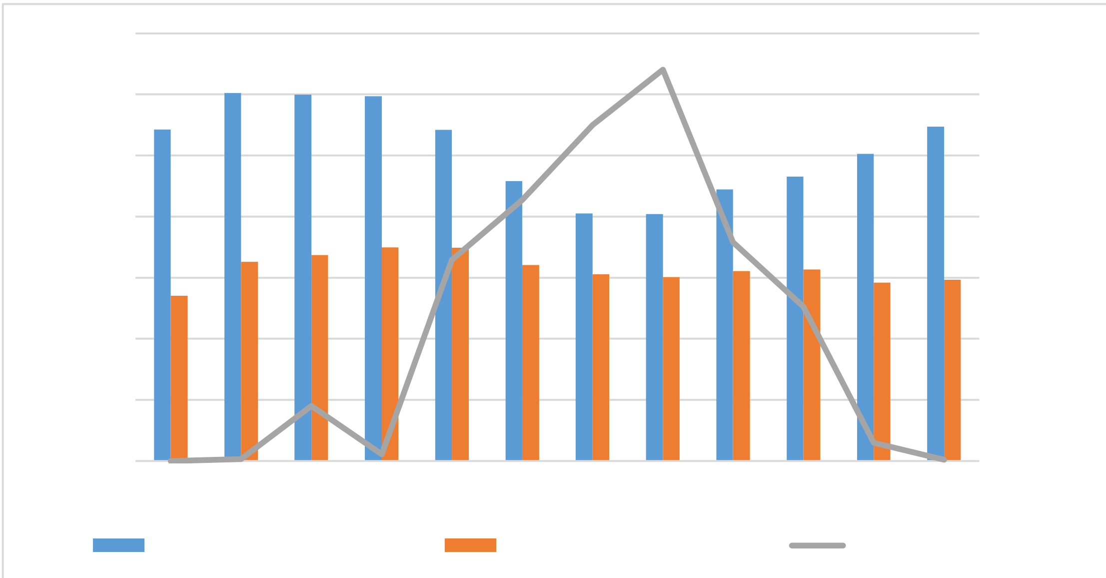

Figure 3. Annual rainfall (mm) and Minimum and Maximum Temperatures (^{0}C) at Tache armacheho (2011 E.C)

Experimental Research Design and Treatments

The experiment was laid out on a randomized complete block design and the treatments were; 0 P_2O_5, 19 P_2O_5, 38 P_2O_5, 46 P_2O_5, and 57 kg P_2O_5 ha^{-1}. The recommendation of fertilizer used for sesame was 65 kg Urea ha^{-1}. The plot size was 4.8 m * 5 m wide and length. There were 1m, 1.5 m, 40 cm, and 10 cm between plots, replications, rows, and plants respectively.

Soil Sampling Technique and Analysis

Eighteen soil samples were randomly collected in a diagonal pattern before sowing from a depth of 0-20cm on each experimental site and taken one composite sample. The composite soil sample was air-dried and passed through a 2 mm sieve for physicochemical analysis. The soil was analyzed for texture, soil 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 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 soils to water ratio using a glass electrode attached to a digital pH meter, a potentiometer (FAO, 2008). Organic carbon, was determined by oxidizing carbon with potassium dichromate in sulfuric acid solution following the 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 for 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 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 sesame variety (Abasyena) seeds were sown manually at the equal spacing between plants and rows with a seed rate of 4 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 the 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 10 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.

Data Collected: Plant height; the mean height of ten randomly selected plants at physiological maturity, measured from the base to the tip. Number of branch per plant: at maturity, ten plants from central rows were chosen at random and their branch was counted from each plant. Number of pod per plant is recorded as the mean of ten randomly selected plants at physiological maturity. Seeds per pod was counted on ten randomly selected pods at physiological maturity and recorded the mean value. Thousand seed weight; the weight

Table 1. Physico-chemical properties of the experimental sites

Parameters	Metema		Tach armacheho	
	Site 1	Site 2	Site 1	Site 2
Soil pH (H_2O)	6.18	6.37	6.42	6.48
Organic Carbon (%)	1.14	0.99	0.73	0.99
Total N (%)	0.17	0.17	0.18	0.20
Available P (mg kg^{-1})	4.6	3.06	4.6	3.12
CE.C (cmol kg^{-1})	45.90	46.72	49.90	50.20
Exch. K+ (cmol kg^{-1})	0.06	0.10	0.14	0.17
Sand (%)	16.72	18.72	16.72	18.72
Silt (%)	21.28	27.82	23.28	25.28
Clay (%)	62	54	60	56
Textural class	Heavy clay	Clay	Clay	Clay

Growth Character: Plant height: The application of phosphorus shows a significant effect on plant height of sesame. The highest (144cm) and lowest (137cm) were recorded on treatment 4 (46 kg P_2O_5 ha^{-1}) and treatment 1(Control) respectively. A similar result was found from the findings of Nushrat *et al*., (2019) they stated that the highest plant height of sesame was recorded from 46 kg P_2O_5 ha^{-1}. However, the longest plant height was obtained on treatment (4) there was a significant effect on the other treatments (2, 3, & 5) except the control plot. These results might be due to the stimulating effect of phosphorus on metabolic activity, cell division and expansion, leading to higher plants (Marschner, 1986).

Table 2. Effect of phosphorus on growth and yield parameters of sesame

Treatment (P_2O_5 kgha^{-1})	pH*	NPP	TSW	GY
0 (Control)	137^{b}	25^{c}	2.6^{b}	678.6^{c}
19	142^{ab}	32^{ab}	2.6^{b}	829.5^{b}
38	143^{ab}	33^{ab}	2.6^{b}	879.8^{ab}
46	144^{a}	36^{a}	2.7^{a}	936.3^{a}
57	140^{ab}	31^{ab}	2.6^{b}	828^{ab}
Mean	141	31	2.7	830.4
CV (%)	4.1	18.8	5.1	7.6
LSD (Sig)	*	*	*	*

* Plant height (PH), Number of pod per plant (NPP), 1000 seed-weight (TSW), Grain yield (GY kg ha^{-1}), Coefficient of variance (CV), Least significance difference (LSD) and * significant at 5 % level.

Yield Contributing Characters

*Number of Pods/Plant***:** Analysis of variance showed that the number of pods/plant was much affected by different levels of phosphorus. The phosphorus application at increasing levels showed significant effect on number of pods per plant up to 46 kg P_2O_5 ha^{-1} then reduced. The greatest numbers of pods/plant (36) and the smallest number of pods/plant (25) were recorded on 46 kg P_2O_5 ha^{-1} (Trt 4) and control, respectively. Similarly, this finding agreed with the report of Habte Berhanu and Adugna Hunduma,2017 they indicate that the highest pods per plant (68.67) was recorded from the application of 40 kg P_2O_5 ha^{-1} and the lowest pods per plant (48.52) was recorded from zero levels of phosphorus fertilizer (control).

1000 Seed Weight: Phosphorus application had a significant effect on 100 seed-weight. The highest thousand seeds weight was recorded on 46 kg P_2O_5 ha^{-1} (Trt 4) while the control plot (0 P_2O_5 ha^{-1}) had the lowest thousand seeds weight. Increasing phosphorus fertilizer rate up to 95 kg P_2O_5 ha^{-1} significantly increased the 1000-seed weight of sesame (Hafiz and El-Bramawy, 2012). According to Ali *et al*. (2002), 1000-seed weight was influenced significantly by the application of phosphorus. The present finding agrees with Nushrat *et al*, 2019.

Grain Yield: The highest grains yield (936.6 kg ha^{-1}) was recorded in 46 kg P_2O_5 ha^{-1} and the lowest grain yield (678.6 kg ha^{-1}) was recorded in the control plot. Nushrat *et al*. (2019) showed that the highest seed yield of sesame was recorded from 46 kg P_2O_5 ha^{-1} but the lowest seed yield of sesame was recorded from control (0 kg P_2O_5 ha^{-1}). The result is supported by the findings of (Shehu, E.H.*et al*, 2010 and Haruna, M. 2011) who reported that increasing phosphorus levels has significantly increase grain yield. Hafiz and El-Bramawy (2012) found that increasing phosphorus fertilizer rate up to 95 kg P_2O_5 ha^{-1} significantly increased the seed yield of sesame.

Conclusion and Recommendation

The present study indicates that different levels of phosphorus showed a significant effect on growth and yield of sesame. The result of the experiment showed the application of different rates of P fertilizer provided a statistically significant difference in grain yield of sesame; and adding P fertilizer could increase the grain yield of sesame when compare to unfertilized plot (0 P). Therefore, further research on the factorial combination of various P and N fertilizer rates should be done to recommend the optimum rate of NP fertilizer for sesame in the lowland areas of the west Gondar zone.

Acknowledgements

The authors would like to thank GARC (Gondar Agricultural Research Center) and ARARI for their financial support and also the authors are grateful to GARC soil fertility case team for their valuable involvement to the achievement of the study.

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