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Original Research Article

Response of Soybean (*Glycine max* L.) Varieties to Different Rates of Phosphorus Fertilizer on Yield and Yield Components at Omo Kuraz, Southern Ethiopia

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Abstract: Soybean (Glycine max (L.) Merrill) is the most important source of protein, oil and also cash for poor farmers. Lack of improved variety and optimum phosphorus fertilizer rate are the most important limiting factor for the productivity of soybean. Therefore, an experiment was carried out at Omo Kuraz-1 Sugar Development Project during 2018 cropping season to determine the effect of phosphorus (P) fertilizer levels on yield and yield related traits of soybean varieties. Factorial combination of three soybean varieties (Nova, Awassa-04 and Gazolia) and four rates of P fertilizer (0, 23, 46 and 69 kg P_20_5/ha were laid out in a RCBD with three replications. Data were collected for yield and yield components and analyzed using Statistical analysis software (SAS and Genstat). The analyses of variance showed that there was significant difference ($p \leq 0.001$) among the varieties for the entire tested parameters, indicating the presence of ample genotypic variation among then Awassa-04 Variety produced significantly high grain yield (1183 Kg ha^{-1} as compared to Gazolia (950 Kg ha^{-1}) and Nova (566 Kg ha^{-1}). Interaction of variety Awassa-04 with 69 Kg P_20_5 ha^{-1} showed maximum grain yield (1352 Kg ha^{-1}) while the minimum value (403 Kg ha^{-1}) was recorded for interaction of Nova variety with 0 kg P_20_5 ha^{-1}. Based on the economic analysis phosphorus fertilizer application at rate of 69 Kg P_20_5 ha^{-1} resulted in highest marginal rate of return (350.9%). Therefore, it was conclude that phosphorus fertilizer application at rate of 69 Kg P_20_5 ha^{-1} can be recommended for the study area. However, further study should be done on different rate of phosphorous to come up with a more comprehensive recommendation.

Keywords: Omo Kuraz, phosphorus, soybean, variety and yield.

1. INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is a legume plant belonging to botanical family leguminasae. Soybean is grown in many parts of the world and is primary source of vegetable oil, protein for use in food, feed and industrial applications. It can substitute meat and to some extent milk. This is mainly because of its high grain nutritional value with 40% protein and 20% oil that makes it an important raw material for food and oil processing industries. It is also a very important crop for rotation with cereals like maize and sorghum because of its potential in biological nitrogen fixation that is important in improving soil fertility (Fekadu *et al*., 2009).

Soybean is contributes to increased soil organic N and carbon through its fallen senescent leaves and below ground parts. As a result, it has an additional advantage of reducing N fertilizer requirement for subsequent crops in a rotation (Bado *et al*., 2013).

In Ethiopia soybean is cultivated mainly in the southern and western parts of the country around Hawassa, Jimma, Bako, Pawe and Assosa (Aregu, 2012). According to CSA (2012), annual report, the current national production of the country is 19, 397 hectares with a total production of 35,880.29 t ha^{-} and the national average yield of soybean in Ethiopia is about 1.85t ha^{-}, which is lower than the national average for other countries, for instance 2.84 in Brazil. In spite of the great potentials of the crop, its production

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is still inadequate owing to low yields, resulting in a wide gap between what is currently produced and what is needed. As a way of improving the production level, one of the major areas to be considered is development of high yielding and disease and pest resistant varieties and development of improved cultural management practices (Mahamood, 2008).

It is believed that improved soil fertility management may play the greatest role in increasing soybean yields even with the existing varieties. It is common for growers to overlook or undervalue the importance of soil fertility management for soybean production. The intention of proper selection of a soybean variety and optimum in a management practice uses from the need to insure enhanced crop production. Selection and development of crop varieties that can efficiently utilize the soil P and perform well under low soil P conditions are considered as sustainable and economical approaches (Wang *et al*., 2010) to withstand the low P availability problem.

Based on the result of soil analysis the Experimental field, most soil fertility indicator parameters such as soil organic carbon were medium, while total nitrogen and available phosphorus were in the low range. This shows that fertilizer application is important for the enhancement of yield and productivity of soybean in the area. Especially, the recovery of P fertilizers by crop plants is usually very low due to soils high capacity to fix P to soil constituents and, this, little bioavailability (Manske *et al*., 2001; Lynch, 2007; Balemi and Negisho, 2012). To overcome such problem the research is needed to know optimum rate of phosphorus nutrition for soybean production in omo kuraz-1 sugar development project.

According to the Ethiopia Export Promotion Agency (EFPA), the country has untapped potential for expansion of soybean production to full fill the international market demand and it is the plan of the government to introduce it to lowland areas of the country. The communities living near by the project sites may improve their living condition by introducing and expanding early maturing soybean variety which are recommended for water stress areas.

Lack of improved variety and optimum phosphorus fertilizer rate are the most important limiting factors for the growth and productivity of soybean. Its cultivation is still not spread much and its average yield is very low as compared to other crops grown during the same season (CSA, 2014). Suchlow productivity of this crop could be due to various reasons, but, the major reason may be lack of improved varieties, limited knowledge on its potential as food, and difficulty in marketing the crop (Gebremedhin**,** 2008**)** Besides, no studies have also been carried out on the interaction between P fertilizer rate and different Soybean varieties under Omo Kuraz Sugar Project site. Therefore, the present investigation was conducted with the aim of identifying appropriate soybean varieties and optimum level of P fertilizer, for improved soybean production in Omo Kuraz area.

2. MATERIALS AND METHODS

2.1 Description of Experimental Site

The study was conducted at Omo Kuraz sugar project during cropping season of 2018 under irrigated conditions. The area is located between latitudes and altitudes ranging from 5o 8’ 18” to 6o 16’ 59” and 35o 43’ 37” to 36o 13’ 54”, respectively, in Southern part of Ethiopia about 918 kms of Addis Ababa with elevation ranging from 370 – 500 meters above sea level (Tadesse and Ambachew, 2009). The mean minimum and maximum air temperatures are 23.5 °C and 35.7 °C, respectively.

2.2 Experimental Materials and Design

Three soybean varieties (Nova, Awassa-04 and Gazolia) and four P levels (0, 23.46 and 69 Kg P ha^{-}) were used for the experiment. The experiment materials (varieties) used in this study were selected based on their yield potential. Their seeds were obtained from Arba Minch Agricultural Research Center (AARC). Factorial combination of three soybean varieties and four phosphorus fertilizer levels were laid out in randomized complete block design (RCBD) with three replications. Each experimental plot was 2.4 m x 3m (7.2 m^2). Spacing between blocks and plots was 1.5m and 1 m, respectively. The experiment consisted of 12 treatments with a total of 36 plots.

2.3 Data Collection

Data were recorded for yield and yield components such as Number of node, Number of pods per plant, Number of seeds per pod, Thousand seed weight (g), Grain yield (kg/ha), Above ground biomass yield (kg/ha), harvest index.

2.4 Statistical Analysis

Data were analyzed using the PROC GLM procedure using statistical analysis software version 9.0 (SAS, 2004). Comparisons among treatments for significant differences were done based on LSD (Least significance difference) test at 5% probability, and using Genstat (17th Edition) for parameters that showed treatment interactions.

2.5 Economic Analysis

Simple partial budget analysis was used for economic analysis of fertilizer application. The price of TSP fertilizer and the crop potential response towards the added fertilizer can determine the economic feasibility of fertilizer (CIMMYT, 1988). To estimate the total costs, mean market prices of soybean and TSP were taken from market assessment at the time of planting. The economic analysis was based on the formula developed by CIMMYT, (1988).

3. RESULTS AND DISCUSSION

3.1 Physico-Chemical Properties of Soils at Experimental Site

The physico-chemical properties of the soil were analyzed and presented in Table 1 Based on the soil textural class determination triangle, the soil texture of the experimental area is clay, containing 78% clay, 10% silt and 12% sand (Table 1).

Soil textures, or the relative amounts of sand, silt, and clay play a very important role in plant nutrition due to their effect on the ability to retain both water and nutrients and also determine water intake rate and the amount of aeration. Therefore, the clay soil texture of the study area was suitable for soybean production. The analysis result of the soils of the experimental field showed that Available phosphorus was low (6.610ppm) (Table 1). According to the rating of Cottenie (1980) stated that soil available phosphorus very low< 5ppm, low 5-9 ppm is low, 10-17 is medium, 18-25 is high, > 25 is very high. Generally, according to the laboratory results, the soil fertility indicator parameters such as soil organic matter and organic carbon were in the medium range. Similarly, total nitrogen and available phosphorus were low. This shows that fertilizer application is important for the enhancement of yield and productivity of soybean in the study area.

Table 1: Physico-Chemical properties of the soil at the experimental site

Soil properties	Mean Value
Sand (%)	12
Silt (%)	10
Clay (%)	78
Textural Class	Clay
pH (1: 2.5 H_2O)	8.56
EC (ds/m)	0.203
OC (%) OM (%)	1.69 2.91
Total N (%)	0.050
AvP (ppm)	6.610
CEC (meq/100g)	54.49

*EC = Electrical conductivity; OC = Organic carbon; AvP = Available phosphorous; CEC = Cation exchange capacity

3.2 Yield and Yield Related Parameters

The result revealed that varieties differed highly significantly ($P \leq 0.01$) for all Yield and Yield Related Parameters**,** while Phosphorous rate showed non significant difference for number of node per plant, Number of pods/plant and Grain yield (Table 2).

Number of Pods per Plant

Variety Awassa-04 produced the highest mean pod number per plant (39.57), which was significant ($P<0.05$) higher than that of Gazolia (28.26) and Nova (22.71) (Table 2). Genetic factors of the varieties might have contributed to the significant difference in pod yield, with Awassa-04 being the best performer and Nova the least. No significant ($P<0.05$) difference was observed among the P rates (Table 2). This result was in agreement with the findings of Alemu, (2018) have reported that the effects of the different rates of phosphorus were non-significant on number of pods per plant. Contrarily, Tekle (2014) has observed that phosphorous fertilization significantly affected number of pods per plant.

The interaction of variety with phosphorous rate for number of pod per plant showed significant difference ($p<0.05$) (Table 3). However, all rates of applied P produced higher number of pods/ plant^{-1} than that of the control, though the increment was statistically non-significant and inconsistent (Table 3). Though it was not significant difference for P application, the highest (42.2) number of pods per plant was recorded for variety Awassa-04 with P rate of 23 kg ha^{-1}.

Table 2: Main effects of varieties and phosphorus rates on yield and yield components of soybean

Treatments	Number of nodes	Number of pods/plant	Number of seeds/pod	Thousand seed weight (g)	Grain yield (Kg/ha)	Bio-mass yield (Kg/ha)	Harvest index
Nova	7.92b	22.71c	2.61a	143.23b	566c	1061b	0.55a
Awassa-04	9.91a	39.57a	2.69a	170.64a	1183a	2639a	0.46b
Gazolia	8.70b	28.26b	2.35b	144.65b	954b	2792a	0.40b
SE±	0.89	0.03	0.03	4.17	0.22	0.56	0.02
LSD(0.05)	1.04	2.77	0.10	11.66	0.66	1.83	0.06
P level							
0	8.53	30.53	2.57b	157.93a	907	1374c	0.64a

Treatments	Number of nodes	Number of pods/plant	Number of seeds/pod	Thousand seed weight (g)	Grain yield (Kg/ha)	Bio-mass yield (Kg/ha)	Harvest index
23	9.57	32.06	2.52b	141.13b	878	2279b	0.46b
46	8.92	28.52	2.38c	141.47b	861	2566a	0.37c
69	8.36b	29.62	2.72a	170.83a	959	2438ab	0.40bc
Mean	8.85	30.18	2.55	152.84	9.01	21.64	0.47
SE±	0.38	1.02	0.03	4.82	0.26	0.65	0.02
LSD(0.05)	Ns	Ns	0.12	13.46	Ns	2.11	0.07
CV (%)	13.93	10.87	4.93	9.01	8.69	9.98	16.67

Note: means with the same letters within the columns are not significantly different at P<0.05, SE = standard error; Ns= non-significant; LSD= least significant difference; CV= coefficient of variation.

The highest (42.2) and the lowest (19.57) number of pods per plant were recorded for variety Awassa-04 and Nova, respectively, with application of 69 kg P/ha^{-1} (Table 3). This shows that differences in pod number/plant due to their inherent genetic characteristics. Similarly, showed Subramanian and Radhak (1981), and Jayapaul and Ganesaraja (1990) have reported that application of 80-120 Kg P_2O_5 ha^{-} increased the number of pods per plant.

Table 3: Interaction of soybean variety and phosphorous rate in yield and yield components

Variety	Phosphorous (P) Rate (kg ha^{-1})	Number of pods/plant	Number of seeds/pod	Thousand seed weight (g)	Grain yield (Kg/ha)	Bio-mass yield (Kg/ha)	Harvest index
Nova	0	21.23c	2.6abc	140.0c	404h	818d	0.49bcd
	23	24.87bc	2.6abc	135.9c	683fg	995d	0.72ab
	46	25.20bc	2.56abc	148.2bc	528gh	1074d	0.50abcd
	69	19.57c	2.7abc	148.8bc	651fg	1359cd	0.48cd
Awassa-04	0	41.27a	2.83ab	188.6ab	1304ab	1899c	0.69abc
	23	42.2a	2.53abcd	145.4c	969cde	2670b	0.41b
	46	33.0ab	2.47bcd	137.5c	1110bc	2743b	0.35d
	69	41.80a	2.93a	211.1a	1352a	3247ab	0.42d
Gazolia	0	29.10bc	2.3cd	145.2c	1016cde	1406bcd	0.73a
	23	29.13bc	2.43bcd	142.1c	841ef	3173b	0.26d
	46	27.33bc	2.13d	138.7c	1088bcd	3882a	0.28d
	69	27.50bc	2.53abcd	152.6bc	874def	2709b	0.32d
SE±		2.67	0.10	11.25	0.64	1.76	0.06
LSD(0.05)		5.55	0.21	23.32	1.32	3.66	0.13
CV (%)		10.9	4.9	9.0	8.7	10.0	16.7

Number of Seeds per Pod

Variety Awassa-04 and Nova produced the highest number of seeds per- pod (2.69 and 2.61), respectively, while Gazolia had the lowest value (2.35) (Table 2). Interaction of soybean variety and phosphorus rate for number of seed per- pod is presented in Table 3. Number of seed per- pod was significantly ($P < 0.05$) affected by the interaction of variety with phosphorous rate (Table 3). Maximum number of seeds per pod (2.93) was recorded for variety Awassa-04 with 69 Kg P ha^{-1} while the minimum value (2.13) was for variety Gazolia with 46 Kg P ha^{-1}. This was probably due to more availability of nutrients by increasing the level of applied phosphorus. This result was in agreement with the findings of Khanam, (2016) who reported that the highest number of seeds per pod (2.98) was recorded with 175 Kg ha^{-1} of TSP. Similarly, Hernandez and Cueuas (2003) also reported that significantly higher number of seeds per pod was recorded when the highest rate (100 Kg) of P_2O_5 ha^{-1} was applied and the minimum value when no phosphorus was applied.

Thousands Seed Weight

The highest thousands seed weight of variety Awassa-04 could be due to its inherent genetic potential and also in response to the applied rate of phosphorus fertilizer. Maximum thousand seed weight (211.1 g) was observed for variety Awassa -04 with phosphorus level of 69 Kg P/ha. This variety also showed higher value (188.6 g) with 0 Kg P/ha. Whereas the minimum value (135.9) was recorded for variety Nova with P application of 23 Kg P/ha (Table 3). This result was in agreement with the findings of Devi *et al.* (2012) who found significant differences in weight of 1000 seeds with varying levels of P fertilizer applied to soybean. Furthermore, Khanam (2016), Reported that the highest soybean seed yield (3.01 t ha^{-1}) was produced when the crop was fertilized with the maximum (175 Kg ha^{-1}) of TSP application.

Grain Yield

Grain yield of soybean was significantly ($P < 0.001$) affected by variety and its interaction with P application rate. Variety Awassa-04 produced the highest mean grain yield of (1184 Kg ha^{-1}), followed by Gazolia and Nova with 955 Kg ha^{-1} and 567Kg ha^{-1}, respectively (Table 3). The results showed that the existence of varietal differences among the soybean varieties in response to the applied rate of phosphorus fertilizer and also due to the difference in their genetic makeup and. This result was in agreement with Mahmoodi *et al.*,(2013) have reported significant positive response of soybean varieties in terms of yield components to phosphorus fertilizer application only at higher levels of P greater than 60 Kg P/ha. This might be due to adequate supply of phosphorus resulting in increased photosynthetic rate, growth and grain yield of soybean.

Above ground bio-mass Yield

Biomass yield was very highly significantly influenced both by variety and phosphorus level and as well as their interaction ($P < 0.001$) (Table 2, Table 3). Results of mean comparison for biomass yield revealed that, variety Gazolia (3882 Kg ha^{-1}) with 46 kg P ha^{-1} gave highest biomass yield though statically at par with variety Awassa-04 (3247 Kg ha^{-1}) with 69 kg ha^{-1} and these treatment combinations showed an increment of 276 % and 171 %, respectively, over the control, while the lowest value was obtained for variety Nova (818 Kg ha^{-1}) with no P application (Table 3). Generally, biological yield increased with increasing does of P fertilizer application. This result was in agreement with Donald S. (2016) had reported that P application increased soybean biomass by 24%. This result showed higher positive influences of fertilizer application were observed in fertilized soybean varieties over the unfertilized soybean varieties.In line with the current result, Khanam (2016) has reported that the highest biological yield (7.69 t ha^{-1}) was recorded for application of 175 Kg TSP ha^{-1}.

Harvest Index

It was observed that there were highly significant ($P < 0.001$) differences among soybean varieties and P rates and in their interaction for harvest index (HI) (Table 2, Table 3). This result was in agreement with the findings of Alemu, (2018) have reported that harvest index was highly significantly influenced by the main effect of variety, phosphorus rates as well as the interaction effect of variety and phosphorus rates. The highest harvest index (0.55) was recorded for soybean variety Nova and the lowest harvest index was for variety Gazolia (0.40), which was not significant different from the value for variety Awassa-04 (0.46) (Table 2). The difference between varieties for harvest index might be due to their genetic difference. In line with this, Udealor (2002) and Ano (2005) have reported that differences in harvest index might be due to the inherent varietal characteristics, environmental factors and other cultural practices.

Significantly higher harvest indices were recorded for variety Gazolia (0.73) and Nova (0.72) with phosphorous level of 0 kg ha^{-1} and 23 kg ha^{-1} respectively (Table 7). Similarly, Malik *et al.* (2006) have reported significant effect of phosphorus rates on harvest index of soybean. Significantly higher harvest indices were recorded for variety Gazolia (0.73) and Nova (0.72) with phosphorous level of 0 kg ha^{-1} and 23 kg ha^{-1} respectively (Table 2). This result indicated that harvest index was higher than expected for such a climate that is warmer (Tropical). In line with the present finding, Beukema and van der Zaag (1990) have indicated that in temperate zone harvest indices of 0.75-0.85 are quite common but in warmer climates, the harvest index tend to be lower and often a wider variation is also observed between cultivars or growing conditions.

Increasing the rate of application of P from 0 to 69 Kg ha^{-1}generally decreased harvest index in almost all varieties. The reduction in harvest index with increasing P rates was not related to yield reduction rather lower harvest index was resulted from higher grain yield of soybean. The reason for this was the rate of increment in biological yield was more than the increment in economic yield in response to P. Therefore, even though harvest index is commonly used as one of plant parameters, it may not be directly correlated with high yield (Gawronska *et al.*, 1984).

3.3 Economic Analysis

Result of the economic analysis of the present experiment, the highest marginal net benefit (2717.5 ETB/ha) which was extremely above the minimum acceptable rate of return (100%) was obtained from application of 69 Kg P ha^{-1} (Table 3). the marginal rate of return or changing from no P fertilizer application to 69 Kg P ha^{-1} was 350.9% (Table 4). This means that for every ETB a farmer invests he or she earns 3.51 ETB. Hence it could be suggested that it is advisable to use on phosphorus fertilization at 69 Kg P ha^{-1}.This result in agreement with the finding of Tekle, (2014) have reported that the highest net benefit of (5993.32 ETB ha^{-}) was obtained from application of 25Kg P ha^{-1} while the least net benefit (4450.41 ETB ha^{-}) was from no P fertilizer application. Therefore, phosphorus fertilization at the rate of 69 Kg P ha^{-1} was economically the most achievable options for soybean production in Omo Kuraz sugar.

Table 4: Partial budget analysis for the variety and P rate on soybean

Treatment	Average grain yield (Kg ha^{-1})	Adjusted grain yield (Kg ha^{-1})	Gross Field benefit (ETB/ha)	App. cost for fertilizer (ETB/ha)	Fertilizer cost (ETB/ha)	Total variable cost (ETB/ha)	Marginal cost (ETB/ha)	Net benefit (ETB /ha)	Marginal net benefit (MNB) (ETB/ha)	Marginal rate of Return (%) (MRR)
P Rate (Kg P/ha)										
0	9.08	8.172	32688	0	0	0		32688		
23	8.78	7.902	31608	150	724.5	874.5	874.5	30733.5	-1954.5	D
46	8.62	7.758	31032	200	1449	1649	774.5	29383	-1350.5	D
69	9.59	8.631	34524	250	2173.5	2423.5	774.5	32100.5	2717.5	350.9

Note: 'D' represents dominance, MNB indicates marginal net benefit, MRR indicates marginal rate of return and 'ETB' Ethiopian Birr

4. CONCLUSIONS AND RECOMMENDATIONS

Soybean is an economically important leguminous crop worldwide. Lack of improved variety and optimum phosphorus fertilizer rate are the most important limiting factor for the growth and productivity of soybean. Therefore, this investigation was conducted with the aim of identifying appropriate soybean varieties and their optimum requirement of P fertilizer, for enhanced production of the crop at Omo Kuraz project site, Southern Ethiopia.

It was observed that interaction of Variety with phosphorous rate was significant for growth, yield and yield components of soybean. Variety Awassa-04 gave the highest grain yield (1352 Kg ha^{-1}) with application of 69 Kg P ha^{-1}. Hence, Maximum rate of application of phosphorus (69 kg ha^{-1}) resulted in maximum yield of soybean variety Awassa-04. Mean grain yield of variety Awassa-04 was the highest (1183 Kg ha^{-1}), followed by Gazolia and Nova with 954 Kg ha^{-1} and 566 Kg ha^{-1}, respectively.

Based on the response of soybean varieties to phosphorus levels, the following recommendations were drawn:-

- Variety Awassa-04 is recommended for maximum yield and yield related traits.
- Interaction of variety Awassa-04 with phosphorus level of 69 Kg P ha^{-1} is recommended for maximum grain yield.
- In general, it is also suggested that conducting the same study at different locations and seasons with in different rates of phosphorous would help to come with a more comprehensive conclusion and recommendation for optimum production of soybean in Omo Kuraz area.

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