Optimization of P and K fertilizer recommendations for soybean in Ethiopia: the case of JabiTehnan District

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Abstract

*Ethiopian soils are reported to exhibit multi-nutrient deficiency addition to nitrogen (N) and phosphorus (P). Legume crops including soybean can satisfy their N demand through biological N fixation. However, P and potassium (K) nutrients should be supplied in optimal amount. Thus, taking the aforementioned premises in account, a study was conducted in Jabitehnan district of West Gojam Zone of Amhara region in 2015 and 2016 aimed at optimizing P and K fertilizer recommendations for soybean. Four levels of P (*0, 10, 20, 30 P kg ha^{-1}*) and four levels of K (0, 10, 20 and 30 K kg ha^{-1}) were combined in incomplete factorial arrangement with a diagnostic satellite treatment comprising S, Zn, Mg and B. The treatments were laid in RCBD with three replications. Phosphorus, K, S and Mg fertilizers were applied as basal application in the form of triple super phosphate (TSP), KCl, CaSO4 and MgO, respectively. While, the micronutrients Zn and B were applied as foliar application 45 days after planting. The agronomic data analysis results collected in both experimental years indicated that there was no significant yield response both to the application of P and K fertilizers and addition of other macro and micronutrients (S, Mg, Zn and B). However, it was observed that inoculation of soybean with TAL-379 gave a better yield return compared to the control (non-inoculated) treatment with a yield advantage of 39.6%. Therefore, it can be concluded that application of P and K did not significantly affect soybean yield in Jabi-Tehnan district. While, the strain TAL-379 can be used as an alternative rhizobia inoculant to improve yields of soybean in the mentioned district. However, further investigation on the status of P and K availability on the surface soil of the present study area and selection of the right source of P and K fertilizers need to be done to improve the productivity of soybean in the area.*

Keywords: Inoculation, nodule, rhizobia, strain, yield

Introduction

Soybean (*Glycine max* L.) is now produced in larger quantities than any other legume crop in the world and is certainly the most important source of vegetable oil, processed in a wide variety of ways to produce soya milk, bean curd, flour and fermented products. The seed (bean) contains about 18% oil and 38% protein and the extraction residue represents more than 40% of the utilization value of the plant (Asiedu, 1989). Soybean fixes up to 200 kg N ha^{-1} $year^{-1}$ when in symbiotic association with *Bradyrhizobium japonicum* (Zhange et al., 2002) reducing the need for potentially environmental damaging N fertilizer (Asiedu, 1989). Nitrogen and phosphorus have been the two major nutrients that largely limit plant growth in smallholder farms in Africa. However, nutrient mining due to sub optimal fertilizer use in one hand and unbalanced fertilizer uses on other have favored the emergence of multi nutrient deficiency in Ethiopian soils (Abyie *et al.,* 2003; Wassie *et al.*, 2011) that in part may contributed to fertilizer factor productivity decline experienced over recent past.

Different research reports indicate that nutrients like K, S, Ca, Mg and all micro-nutrients except Fe are becoming depleted and deficiency symptoms are being observed on major crops in different areas of the country (Wassie *et al.,* 2011; Asgelil *et al.*, 2009; Abyie *et al.*, 2003). Recently acquired detail soil survey data from EthioSIS (Ethiopian Soil Information System) revealed that in addition to nitrogen and phosphorus, K is reported to be deficient in most of the cultivated land in the country. Legume crops including soybean can satisfy their N demand through biological N fixation if there is effective indigenous rhizobia strain or artificially inoculated with effective rhizobia inoculants. However, P and K nutrients should be supplied optimal in the form of fertilizer to meet the crop demand. This research was therefore conducted with the objective of optimizing P and K fertilizer recommendations for soybean.

Materials and Methods

Study Site Description

This study was conducted in Jabi-Tehnan District of West Gojam Zone of Amhara region for three years from 2014 to 2016. The study district is geographically located at coordinates of 10^{o}40'41'' northern latitude and 37^{o}16'23'' eastern longitude with altitudinal ranges of 1500-2500 masl. The dominant soil type in the study site is Rhodic Nitisols. The mean annual rainfall and mean minimum and maximum temperatures of the study district are 1250 mm, 14 and 32 ^oC, respectively. The soil physico-chemical characteristics of surface soils of the study district are given below (Table 1).

Table 1. Some physico-chemical characteristics of surface soils of the study district

Soil parameter	Value
Organic carbon (%)	0.55-3.10
Total nitrogen (%)	0.044-0.136
Cation exchange capacity CEC (meq 100 gm^{-1})	14.8-22.6
Base saturation (%)	36-55
Texture	Clay

Experimental Procedure and Treatments

The field was ploughed and prepared with oxen-drawn traditional *Maresha*. The experimental field was then divided in to experimental plots which had an area of 3 m * 3 m. The space between each plot and block was 1 m. An improved variety of soybean *Gishama 335* was planted in a row with 40 cm and 10 cm spacing between rows and plants, respectively. Phosphorus, K, S and Mg fertilizers were all applied as basal application in the form of triple superphosphate (TSP), KCl, $CaSO_4$ and MgO, respectively. While, Zn and B were applied as foliar application 45 days after planting. Soybean seeds were moistened with water soaked with table sugar and inoculated with the strain under a shade immediately before planting. Composite surface (0-20 cm) soil samples were collected at planting for the determination of pH, texture, OC, TN and available P analysis.

Four levels of K (0, 10, 20 and 30 K kg ha^{-1}) and four levels of phosphorus (0, 10, 20 and 30 P kg ha^{-1}) were combined in incomplete factorial arrangement. There was also a diagnostic satellite treatment comprised of N, P, K, S, Mg, Zn and B (23N, 20P, 20K, 5S, 5Mg, 1Zn and 0.5B) in both experimental years. Except the control treatment (non-fertilized), all the rest treatments were inoculated with the rhizobia strain TAL-379. The treatments were laid in RCBD with three replications.

Data Collection and Analysis

The inner rows excluding the boarder were harvested at maturity and yield and yield related parameters were measured. The grain yield measured was adjusted to 14% moisture content. Composite surface soil (0-20 cm) samples were collected before planting for pH, OC, TN, available P and CEC analysis. The agronomic data collected were subjected to analysis of variance (ANOVA) using SAS statistical software version 9.0 (SAS, 2009). Mean separation was made by using Duncan's Multiple Range Test Method (DMRT) at 5% level.

Results and Discussion

Effect of P and K fertilizers on the yield of soybean

The data analysis in the first and second experimental years (Table 2, 3 and 4) indicated that except from the control treatment, there was no statistically significant grain and dry biomass yield differences among the other treatments. The lowest yield was obtained from the control treatment in both experimental years. The result revealed that inoculation of soybean with TAL-379 rhizobia strain gave significantly higher grain and biomass yields than the control treatment. This indicates the need for inoculation of soybean with effective commercial rhizobia strains for improved production. The result is supported by Tesfaye *et.al.* (2010), who reported indigenous rhizobia bacteria in the present study area were not found effective and competitive as compared to a commercial rhizobia strain like TAL 379 in increasing yield.

However, application of P and K were not found to have significant effect on the yield of soybean in the study. In contrast with this result, Isreal 1987 indicated that legume plants that depend on biological N-fixation require more P and other macro and micronutrients than plants receiving fertilizer N since the reduction of atmospheric N by the nitrogenous system is a very energy consuming process and more P and other nutrients are needed for symbiotic N-fixation than for general plant metabolism. But, other completed research on the effect of different rhizobia strains on the yield of soybean in the present study area revealed that inoculation alone without P fertilizer could give comparable yield with the treatments which received P fertilizer (Abebe et al. 2018, unpublished).

Table 2. Effect of P and K fertilizer application on the yield (kg ha^{-1}) of soybean at site 1 and site 2 in 2015

	Site 1		**Site 2**		**Combined**	
Treatment*	**Grain yield (kg ha^{-1})**	**Biomass (kg ha^{-1})**	**Grain yield (kg ha^{-1})**	**Biomass (kg ha^{-1})**	**Grain yield (kg ha^{-1})**	**Biomass (kg ha^{-1})**
1. Control	1954.0b	5072.9b	2509.9	5354.2	2232.0b	5213.5
2. Inoculation alone	2755.1a	6503.5a	2473.0	5222.2	2614.0a	5862.8
3. 10P + Inoc.	2854.3a	6534.7a	2863.4	5958.3	2858.9a	6246.5
4. 20P + Inoc	2804.3a	6465.3a	2735.9	5951.4	2770.1a	6208.3
5. 30P Inoc.	2935.5a	6566.0a	2627.0	5798.6	2781.3a	6182.3
6. 0P20K + Inoc.	2791.5a	6475.7a	2724.2	5725.7	2757.9a	6100.7
7. 10P20K + Inoc	2802.9a	6503.5a	2792.8	5607.6	2797.8a	6055.6
8. 20P20K + Inoc.	2723.2a	6295.1a	2885.6	5868.1	2804.4a	6081.6
9. 30P20K + Inoc.	2735.8a	6232.6a	2848.3	5916.7	2792.0a	6074.7
10. 20P10K + Inoc.	2830.7a	6503.5a	2942.1	6034.7	2886.4a	6269.1
11. 20P20K 5S 1Zn 0.5B + Inoc.	2752.1a	6291.7a	2572.2	5878.5	2662.2a	6085.1
12. 20P30K + Inoc.	2788.4a	6215.3a	2762.9	5885.4	2775.6a	6050.3
Mean	2727.3	6304.9	2728.1	5766.8	2727.7	6035.9
CV (%)	5.6	7.4	10.7	11.3	8.7	9.2

**Mean separation made by DMRT at 5% level. Means without a letter or followed by the same letter within a column are not significantly ($p \geq 0.05$) different.*

Table 3. Effect of P and K fertilizer application on the yield (kg ha^{-1}) of soybean at site 3 and site 4 in 2016

Treatment*	Site 3		Site 4		Comb	
	Grain yield	**Biomass yield**	**Grain yield**	**Biomass yield**	**Grain yield**	**Biomass yield**
1. Control	1236.6b	2810.2b	866.2b	2226.9b	1051.4c	2518.5b
2. Inoculation alone	2035.9a	4282.4a	1904.1a	4069.4a	1970.0ab	4175.9a
3. 10P + Inoc.	2201.7a	4444.4a	1561.9a	3268.5ab	1881.8ab	3856.5a
4. 20P + Inoc.	2379.6a	4745.4a	1976.3a	4194.4a	2178.0a	4469.9a
5. 30P + Inoc.	2271.4a	4833.3a	1483.0a	3314.8ab	1877.2ab	4074.1a
6. 0P20K + Inoc.	1920.8a	4037.0a	1491.7a	3324.1ab	1706.3b	3680.6a
7. 10P20K + Inoc.	2158.9a	4245.4a	1713.2a	3731.5a	1936.0ab	3988.4a
8. 20P20K + Inoc.	2094.3a	4384.3a	2043.0a	4421.3a	2068.7ab	4402.8a
9. 30P20K + Inoc.	2213.4a	4606.5a	1981.3a	3833.3a	2097.3ab	4219.9a
10. 20P10K + Inoc.	2306.1a	4763.9a	1849.5a	3884.3a	2077.8ab	4324.1a
11.20P20K5S1Zn 0.5B + Ino.	2275.5a	4768.5a	1695.5a	3736.1a	1985.5ab	4252.3a
12. 20P30K + Inoc.	2044.5a	4097.2a	1475.9a	3231.5ab	1760.2ab	3664.4a
Mean	2094.9	4334.9	1670.1	3603	1882.5	3968.9
CV (%)	14.5	13.2	19.4	17.7	16.8	15.2

**Mean separation made by DMRT at 5% level. Means without a letter or followed by the same letter within a column are not statistically significantly ($p \geq 0.05$) different.*

Table 4. Effect of P and K fertilizer application on the yield of soybean pooled over years and testing sites

Treatment*	Grain yield (kg ha^{-1})	Biomass (kg ha^{-1})	Plant height (cm)	Pod per plant
1. Control	1641.7b	3866.0b	70.8b	27.9
2. Inoculation alone	2292.0a	5019.4a	78.3a	30.4
3. 10P + Inoc.	2370.3a	5051.5a	81.0a	33.7
4. 20P + Inoc.	2474.0a	5339.1a	81.5a	33.6
5. 30P + Inoc.	2329.2a	5128.2a	77.8a	32.9
6. 0P20K + Inoc.	2232.1a	4890.6a	80.1a	33.3
7. 10P20K + Inoc.	2366.9a	5022.0a	78.9a	33.8
8. 20P20K + Inoc.	2436.5a	5242.2a	79.6a	33.2
9. 30P20K + Inoc.	2444.7a	5147.3a	80.3a	33.5
10. 20P10K + Inoc.	2482.1a	5296.6a	80.9a	32.5
11.20P20K5S1Zn0.5B + Inoc.	2323.8a	5168.7a	83.1a	32.7
12. 20P30K + Inoc.	2267.9a	4857.3a	79.4a	31.8
Mean	2305.1	5002.4	79.3	32.4
CV (%)	12.2	11.7	7.8	15.6

**Mean separation made by DMRT at 5% level. Means without a letter or followed by the same letter within a column are not statistically significantly ($p \geq 0.05$) different.*

Conclusion and Recommendation

The study results indicated that there was no significant difference between inoculation alone and inoculation with application of P and K fertilizers on the yield of Soybean. However, it was found that inoculation of soybean with the strain TAL-379 gave significantly higher yield than the control treatment. Therefore, the rhizobium inoculum TAL-379 can be used as alternative inoculants for soybean. However, further investigation on the status of P and K availability on the surface soil of the present study area and selection of the right source of P and K fertilizers need to be done to improve productivity soybean in the area.

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