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(RESEARCH ARTICLE)

Yield response of common bean to different types and rates of blended fertilizers in Hawassa Zuria Woreda, Southern Ethiopia

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Abstract

Despite the importance of common bean to farmers and its contribution to the national economy, limited information is available on the use of inorganic fertilizers containing macro and micro nutrients for its production in Hawassa area. A trial was conduct to evaluate different fertilizer types containing macro and micro nutrients and to determine their optimum rates for common bean production in Hawassa zuria woreda during the main cropping seasons of 2016 and 2017.Three fertilizer types (NPS, NPSB and NPSBCu) were arranged in different levels and tested on two farms. The experiment consisted of a total of ten treatments: control (no fertilizer) and three levels of each NPS, NPSB and NPSBCu. The treatments were laid out in a randomized complete block design replicated three times. Besides crop parameters, economic analysis was also performed to investigate feasibility of the fertilizers for common bean production. In general, it was observed that application of inorganic fertilizers increased grain yield, where economically feasible treatments improved yield by 34% to 36% over the control plot. The highest net benefit was obtained from NPS at nutrient ratio of 23: 16.5: 7kg/ha with acceptable marginal rate of return of 120%, even under the projected input price, which was sufficient to justify the additional investment needed for this treatment. Similarly, NPSB with 23 kg N + 15.7 kg P + 6.7 kg S + 0.71 kg B/ha also gave the required economic return. Therefore, both treatments could be recommended for common bean production in Hawassa area.

Keywords: Economy feasibility; Grain yield; Soil nutrients, Blended fertilizers

1. Introduction

Common bean (*Phaseolus vulgaris* L.) is grown and consumed throughout the world. Most of theproduction takes place in developing countries (Hillocks *et al*., 2006). It plays an important role inthe nutrition of low-income people especially in developing countries, where it is often the most important source of protein, carbohydrate, dietary fiber and minerals (Tharanathan and Mahadevamma, 2003) and is also a primary and least expensive source of calories and vitamins (Guzman-Maldonado *et al*., 2000; Hillocks *et al*., 2006). It complements cereals and other carbohydrate rich foods in providing near perfect nutrition to people of all ages and helps to lowercholesterol and cancer risks (Singh, 1999). Common bean is high in starch (49%), protein (21.4%)and dietary fiber (22.9%) and is also a good source of minerals and vitamins, including iron, potassium, selenium, molybdenum, thiamine, vitamin B6, and folic acid (Ferris andKaganzi, 2008). It is also an important cash crop and export commodity that generates foreign currency forEthiopia (Abebe, 2009).

Despite the importance of the crop to farmers and its importance for the national economy, averageyields obtained by farmers in Ethiopia are very low. The national average yield of common bean (white and red type) calculated for Meher and Belg seasons of 2015/16 was 1208 kg/ha, while theregional average yield of Belg season in the southern part was 880 kg/ha (CSA, 2018). The low yield may be attributed to combinations of several production constraints, among

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which imbalanced soil nutrient, moisture stress, diseases and insect pests, weeds and untimely field operations play a major role (Kidane and Amare, 1990).

Particularly, nutrient mining due to sub-optimal fertilizer use, in one hand, and unbalanced fertilizer (only N and P) uses, on the other hand, is the main production constraint of the crop in the country. This situation has favored the occurrence of multi-nutrient deficiency in Ethiopian soils (Abyie *et al*., 2003; Wassie and Shiferaw, 2011). Based on the soil fertility map produced byAgricultural Transformation Agency (ATA) (2016), N, P, K, S, B, Zn and Cu are deficient in the soils and, thus, fertilizers containing these nutrients in different mix formsare recommended for the southern region of Ethiopia. Similarly, based on the deficient nutrients indicated in the fertilitymap, NPS, NPSB and NPSBCu fertilizers are recommended for the study area (Hawassa zuria woreda). Therefore, this work was initiated to identify best fertilizer types and determinedoptimum rates that would enhance common bean production and productivity in the area.

2. Material and methods

Field experiment was conducted to evaluate different blended fertilizers for common bean production in Hawassa zuria woreda of the Southern Nations, Nationalities and Peoples Regional State (SNNPRS) in the main cropping seasons of 2016 and 2017. The experimental site was located at 07.0038 N latitude and 038.2255 E longitudes at an altitude of 1705 m above sea level. Treatments were arranged based on nutrient deficiency of the area, which is indicated in the soil fertility map of (ATA, 2016). Accordingly, three types of fertilizers (NPS, NPSB and NPSBCu) were used in different rates. The experiment consisted of ten treatments: (1) no fertilizer (control), (2) NPS: 23 kg N + 16.5 kg P + 7 kg S/ha, (3) NPS: 46 kg N + 23.5 kg P + 10 kg S/ha, (4) NPS: 69 kg N + 31 kg P + 13 kg S/ha, (5) NPSB: 23 kg N + 15.7 kg P + 6.7 kg S + 0.71 kg B/ha, (6) NPSB: 46 kg N + 31 kg P + 13 kg S + 1.07 kg B/ha, (7) NPSB: 69 kg N + 39 kg P + 17 kg S + 1.7 kg B /ha, (8) NPSBCu: 23 kg N + 15.7 kg P + 6.7 kg S + 0.71 kg B + 0.625 kg Cu/ha, (9) NPSBCu: 46 kg N +31 kg P + 13 kg S + 1.07 kg B + 0.625 kg Cu/haand (10) NPSBCu: 69 kg N +39 kg P + 17 kg S + 1.7 kg B + 0.625 kg Cu/ha.

Experimental layout: The experiment was conducted on two farms in a randomized complete block design using 4 m by 4 m plot size and replicated three times. To avoid mixing up of treatments, the plots were separated by 1.00m with a spacing of 1.50 m between blocks. All doses of NPS and NPSBwere applied at planting time and urea was top dressed 45 days after planting. Foliar application was used for copper sulfate. An improved common bean variety, Hawassa Dume, was planted in rows and all other field management practices were applied as recommended for the crop.

Agronomic and economic analysis: Agronomic data for common bean, including plant height, number of pod/plant, number of seed/pod, 1000 seed weight, above ground total fresh biomass yield and grain yield, were measured. Analysis of variance for all data was done using Proc GLM procedures of SAS version 5 (SAS Institute Inc., 2008). Least significant difference (LSD) at 5% probability level was used to separate treatment means. Economic analysis was carried out to investigate feasibility of the fertilizer types and rates for common bean production in the area. Partial budget and dominance analysis were done andmarginal rate of return was calculated. For partial budget analysis, averages yield that was adjusted downwards by 10% was used, assuming that farmers would get about 10% less yield than is achieved on an experimental site. The average open market price for common bean (8.0 Ethiopian Birr (ETB)/kg) and the official prices for NPS (10.94 ETB/kg), NPSB (10.28 ETB/kg), N as Urea (8.76 ETB/kg) and copper sulfate (1000 ETB/kg) were used for the analysis of total variable costs (TVC). All other costs including those of management practices were assumed to be uniform for all the treatments. For a treatment to be considered a worthwhile option for farmers, the minimum acceptable marginal rate of return should be over 50% (CIMMYT, 1988). However, Gorfuet al. (1991) suggested a minimum acceptable rate of return should be 100%. Therefore, the minimum acceptable marginal rate of return considered in this study was 100%.

3. Results and discussion

It was observed that all the fertilizer treatments significantly ($P < 0.05$) increased grain yield of common bean compared to the control. However, the difference between the fertilized plots was not significant. Similarly, treatment 6 (NPSB: 46+31+13+1.07kg/ha) and 8 (NPSBCu: 23+15.7+6.7+0.71+0.625kg/ha) did not differ from the control plot for yield (Table 1). The yield advantage of economically feasible treatments, 2 (NPS: 23+16.5+7kg/ha) and 5(NPSB: 23+15.7+6.7+0.71kg/ha) (Table 4), were 35.6% and 33.8%, respectively, compared to the control (no input). Similarly, the yield incrementfor treatment 2 and 5 were 51%and 49% over the national average and 107% and 104% over the regional average, respectively (CSA, 2018). In line with the present study, Lake and Jemaludin (2018) reported that blended fertilizer increased common bean grain yield with high net benefit and acceptable returns, where100 kg/ha 0f NPSZnB fertilizer with the ratio of 16.9: 33.8: 7.3: 2.23: 0.67 was recommended for farmers around Meskan woreda.

Besides grain yield, all other crop parameters, except number of seeds/pod and 1000 seed weight, were significantly affectedby fertilizer treatments. Accordingly, significantly lowest values of above ground total fresh biomass yield, plant height and number of pods/plant were recorded for the control plot compared to the fertilized treatments (Table 1). According to Landon (1991), plant growth and development may be retarded if any of nutrient elements is less than its threshold value in the soil or not adequately balanced with other nutrient elements. Therefore, the higher vegetative growth and yield obtained from thetreated plots might be due to relatively balanced and adequate supply of nutrients from the soil to the plants.

Table 1 Yield and yield components of common bean as influenced by different blended fertilizer rates inHawassa zuria woreda

	Treatments	**Plant height (cm)**	**No of pod/plant**	**No of seed/pod**	**1000 seed weight (gm)**	**Biomass yield (t/ha)**	**Grain yield kg/ha**
1.	No fertilizer	52.9d	13.9e	5.3	197.7	2.34c	1344.8b
2.	NPS:23 + 16.5 +7 kg/ha	66.2bc	17.6d	5.6	194.1	3.36ab	1824.2 a
3.	NPS:46 + 23.5 + 10 kg/ha	69.4ab	20.7c	5.8	191.8	3.29ab	1838.8 a
4.	NPS: 69 + 31 + 13 kg/ha	71.8a	23.8ab	5.8	189.3	3.53a	1964.4 a
5.	NPSB: 23 + 15.7 + 6.7 + 0.71 kg/ha	65.2c	19.6cd	5.7	198.2	3.06b	1799.9 a
6.	NPSB: 46 +31 +13 + 1.07 kg/ha	68.3abc	20.4c	5.7	195.3	3.20ab	1676.5 ab
7.	NPSB: 69 +39 + 17 + 1.7 kg/ha	70.7a	23.8ab	5.8	199.9	3.57a	1958.7 a
8.	NPSBCu: 23 + 15.7 + 6.7 + 0.71 + 0.625 kg/ha	65.7bc	19.4cd	5.7	191.8	3.08b	1668.8 ab
9.	NPSBCu: 46 + 31 + 13 + 1.07 + 0.625kg/ha	68.7abc	21.3bc	5.6	192.6	3.18ab	1729.8 a
10.	10. NPSBCu: 69 + 39 + 17 + 1.7 + 0.625 kg/ha	72.0a	24.4a	5.8	198.3	3.58a	1985.5 a
11.	LSD at 0.05	3.87	2.60	NS	NS	0.42	343.71
	CV (%)	9.47	15.21	4.86	6.2	16.8	16.93

Figures followed by the same letter(s) with in a column are not significantly different at $P < 0.05$.

3.1. Economic analysis

The dominance analysis (Table 2) showed that, except treatment 2 (NPS: 23+16.5+7kg/ha) and 5 (NPSB: 23+15.7+6.7+0.71kg/ha), all other treatments were dominated by the treatment with lower variable cost and higher net benefit. Treatment 2 and 5 had the lower total variable costs and higher net benefits than did treatments 3, 4, 6, 7, 8, 9 and 10. Based on the dominance analysis, treatment 2 and 5 were potential options for farmers (Table 2). Therefore, treatments 3, 4, 6, 7, 8, 9 and 10 were eliminated and only the dominant treatments were considered for further partial budget analysis. The partial budget analysis (Table 3) showed that the treatment with the highest net benefit (11,944 ETB/ha) and acceptable marginal rate of return (164%) was treatment 2, while treatment 5 resulted in 11,835ETB/ha net benefit. However, the marginal rate of return for treatment 5 was191%. This means that for each 1 ETB investment, the producer can get more than 100% in both cases. Since the minimum acceptable rate of return assumed in this experiment was 100%, both treatments gave an acceptable marginal rate of return for the extra investment. Therefore, treatment 2 and 5could be accepted as the potential options for common bean producers in the area.

Table 2 Economic (partial budget and dominance) analysis of fertilizer rates for common bean production in Hawassa zuria woreda

Treat	NPSB (kg/ha)	NPS (kg/ha)	Cu (kg/ha)	N kg/ha	Av. yield	Adj.yield	TVC (EB/ha)	Revenue (EB/ha)	NB (EB/ha)	MRR(%)
1	0	0	0	0	1344.8	1210.3	0.0	9682.6	9682.6	
5	100	0	0	11	1799.9	1619.9	1124.5	12959.3	11834.8	
2	0	100	0	11	1824.2	1641.8	1190.7	13134.2	11943.5	
8	100	0	0.625	11	1668.8	1501.9	1624.5	12015.4	10390.9	D
6	150	0	0	42	1676.5	1508.9	1909.9	12070.8	10160.9	D
3	0	142	0	42	1838.8	1654.9	1921.8	13239.4	11317.5	D
9	150	0	0.625	42	1729.8	1556.8	2409.9	12454.6	10044.6	D
7	200	0	0	72	1958.7	1762.8	2686.7	14102.6	11416.0	D
4	0	189	0	72	1964.4	1768.0	2698.9	14143.7	11444.8	D
10	200	0	0.625	72	1985.5	1787.0	3186.7	14295.6	11108.9	D

Yield adjustment =10%, field price of common bean = 8.0 Ethiopian Birr/kg, official price for urea-N = 8.75 Ethiopian Birr/kg, NPS fertilizer = 10.9 Ethiopian Birr/kg, NPSB fertilizer = 10. 3 Ethiopian Birr/kg, copper sulfate-Cu = 1000 ETB/kg, TVC = total cost that varies, NB = net benefit, D indicates dominated treatments that were rejected, MRR = marginal rate of return, treat= treatment.

Table 3 Economic (partial budget and marginal rate of return) analysis of fertilizer treatmentsfor common bean production in Hawassa zuria woreda

	Treatment (kg/ha)	Av. Yield	Adj. yield	TVC (EB/ha)	Revenue (EB/ha)	NB (EB/ha)	MRR (%)
1.	No fertilizer	1344.8	1210.3	0.0	9682.6	9682.6	
5.	NPSB: 23,36,6.7, 0.71	1799.9	1619.9	1124.5	12959.3	11834.8	191
2.	NPS:23,38,7	1824.2	1641.8	1190.7	13134.2	11943.5	164

Yield adjustment =10%, field price of common bean = 8.0 Ethiopian Birr (ETB)/kg, official price for urea-N = 8.75 ETB/kg, NPS fertilizer = 10.9 ETB/kg, NPSB fertilizer = 10. 3 ETB/kg, TVC = total cost that varies, NB = net benefit, MRR = marginal rate of return.

3.2. Sensitivity analysis

Market prices for inputs and products are ever changing due to different reasons and, thus, recalculation of the partial budget considering future prices may be necessary to pin point treatments which can remain stable and sustain acceptable returns for farmers, despite input price fluctuations. In the present study, it was assumed that the official price of NPS, NPSB and Urea fertilizers will increase by 20%, mainly due to changes in the exchange rate and transport cost.

Table 4 Partial budget analysis with projected future prices of NPS, NPSB and urea fertilizers for common bean production in Hwassa Zuria Woreda

	Treatments (kg/ha)	Av. Yield	Adj. yield	TVC (EB/ha)	Revenue (EB/ha)	NB (EB/ha)	MRR (%)
1.	No fertilizer	1344.8	1210.3	0.0	9682.6	9682.6	
5.	NPSB: 23,36,6.7, 0.71	1799.9	1619.9	1349.3	12959.3	11609.9	143
2.	NPS:23,38,7	1824.2	1641.8	1428.9	13134.2	11705.4	120

Yield adjustment =10%, field price of common bean = 8.0 Ethiopian Birr (ETB)/kg, official price for urea-N = 8.75 ETB/kg, NPS fertilizer = 10.9 ETB/kg, NPSB fertilizer = 10. 3 ETB/kg, TVC = total cost that varies, NB = net benefit, MRR = marginal rate of return

Based on the sensitivity analysis (Table 4), treatments 2 (NPS: 23 kg N + 16.5 kg P + 7 kg S/ha) and 5 (NPSB: 23 kg N + 15.7 kg P + 6.7 kg S + 0.71 kg B/ha) would give an economic yield response and also sustain acceptable returns even under 20% increment in input price that farmers likely face in the future. Therefore, treatments 2 and 5can be accepted as the potential options for common bean producers in the area.

4. Conclusion

Results of the present study showed that, except treatment 6 and 8, all the other fertilizer treatmentgave significantly higher yields than did the control plot, but the difference between all the fertilized plots was not significant for grain yield of common bean. The dominance analysis indicated that, except treatment 2 and 5, all the other treatments were dominated by the treatmentwith lower total variable cost. The highest net benefit was obtained by applying NPS at nutrient ratio of 23: 16.5: 7 kg/ha with acceptable marginal rate of return (120%) even under the projectedinput price, which is sufficient to justify the additional investment needed for this treatment. However, treatment 5 containing NPSB (23 kg N + 15.7 kg P + 6.7 kg S + 0.71 kg B/ha) also gavethe required economic return. Therefore, both treatments could be recommended for common beanproduction in Hawassa zuria woreda and farmers in the area could choose either of the two fertilizer rates depending on their resource and availability of the fertilizers in the local market. Inthe present study, individual effect of nutrients and positive control (recommended NP rate) werenot considered, as NPS and NPSB fertilizers were used in compound form. Therefore, future fieldtrials should focus on evaluating the influence of individual nutrients and recommended NP ratesalong with their compound formulations (NPS and NPSB) on crop performance to avoid confounding effects.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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