

Research Article

Effects of Organic Nutrient Sources and NPS Fertilizer on the Agronomic and Economic Performance of Haricot Bean (*Phaseolus vulgaris* L.) in Southern Ethiopia

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Despite the fact that mineral fertilizers are widely considered as a major option for addressing the crisis of nutrient depletion, their use among smallholder farmers is not adequate due to an escalating cost. Alternatively, nutrient-rich organic sources that are easily available to farmers are not widely promoted. Thus, this study was carried out in the research field of Wolaita Sodo University, Southern Ethiopia, to evaluate the effects of locally available organic nutrient sources and nitrogen (N) phosphorus (P) sulfur (S) fertilizer (19N-46P₂O₅-7S) on the productivity and economic performance of common bean. The organic materials used were *Croton* (*Croton macrostachyus*) and *Erythrina* (*Erythrina brucei*) at 2:1 ratio, respectively. The experiment was laid out in a randomized complete block design with three replications. Treatments for organic fertilizer (OF) were 0, 2.5, and 5 t·ha⁻¹ and for NPS fertilizer were 0, 50, 100, and 150 kg·ha⁻¹. Chemical composition analysis of organic materials showed high nutrient content where the amount varied from 4.7%–5.2% N, 11.07–18.6 mg/kg P, and 2.12%–3.07% K. Results on agronomic parameters revealed that the leaf area index, grain weight, number of pods per plant, dry matter per plant, and grain yield of haricot bean were significantly affected by both main and combined effects of NPS and OF fertilizers. The grain yield under integrated application of 150 kg NPS/ha and 2.5 t-OF/ha (4.16 t/ha) was significantly higher than that obtained from unfertilized crop (1.01 t/ha) by 312%. Additionally, it resulted in 34%, 31%, and 79% yield increment over the blanket dose (100 kg-NPS·ha⁻¹), 2.5 t/ha and 5 t/ha, respectively. It was also noted that resource-poor farmers, compared to unfertilized crop, can get grain yield superior by 130% and 214% using sole OF at 2.5 and 5 t·ha⁻¹, respectively. Furthermore, the highest economic benefit (27, 179.5EtB) was recorded from 150 kg NPS/ha + 2.5 t-OF/ha. The finding suggested that locally available organic materials of plant origin alone/integrated with NPS fertilizer are helpful for increased yield of haricot bean.

1. Introduction

Agriculture, a soil-based industry, is supporting the livelihood for over 80% of the Ethiopian population that is estimated 114 million in 2020 [1]. In order to feed the growing population in the country, the need to produce more per unit area is increasing ever so rapidly. Meanwhile, an increase in productivity is likely attained through adequate and balanced supply of nutrients. Yet, declining soil fertility is a serious problem to crop production and food security that has long gone unsolved.

Emerging research outcomes from various parts of Ethiopia demonstrated alarmingly low soil organic matter (SOM) and deficiencies of essential nutrients such as nitrogen (N), phosphorus (P), potassium (K), sulfur (S), boron (B), and copper (Cu) as the main causes of crop yield decline and nonsustainable agricultural production [2–5]. The problems are attributed to continuous cropping of the same land year after year, inadequate replenishment of the lost nutrients, complete residue removal from the field, and soil erosion [6]. In order to curb the soil nutrient depletion, fertilizers, namely,

organic, inorganic, or their integration are used as the source of essential plant nutrients.

Mineral fertilizers are widely considered as a major option for addressing the crisis of nutrient depletion and sustaining food production. In Ethiopia, application of inorganic fertilizer containing N and P in the form of urea (46N-0-0) and diammonium phosphate (DAP) (18N-46P₂O₅) has long been started some 50 years ago after realizing that both nutrients are a widespread problem. However, crop yield gain from both fertilizers is gradually declining over time despite steady increases in fertilizer consumption in the country [7, 8]. Insufficient and long-term application of the soil using N and P fertilizers has aggravated the depletion of macro- and micronutrients from inherent nutrient stacks [8–10] and resulted in variable yield even within the same field receiving the same input and management [11]. As a way out strategy, the government of Ethiopia following the EthioSIS (Ethiopian Soil Information System) recommendation has introduced new compound (e.g., NPS (19N-46P₂O₅-7S)) and blended fertilizers containing micronutrients [2, 3]. Yet, subsistence farmers reasoning the high pricing of fertilizers apply far below the blanket rate [9]. Apart from this, mineral fertilizers are also blamed for the harmful effects on soil microorganisms and the environment.

The use of organic nutrient sources derived either from livestock or plants has been receiving worldwide support as they are the store house and source of several essential plant nutrients [12, 13]. They are also used to correct the marginal deficiencies of secondary and micronutrients which are, in most cases, not addressed by mineral fertilizers. Furthermore, organic fertilizing sources influence soil physical properties as well as soil microbial activity [14], and subsequently improve crop productivity [15]. Despite the positive impacts, locally available materials of plant origin, particularly biomass transfer from agroforestry leaves, which are easily available to farmers are not being fully utilized and not widely appreciated as resources. Moreover, the large amount of organic material required to meet crop nutrient demand makes it challenging for wider use [15, 16].

According to Alhrouf et al. [17], neither organic nor mineral fertilizers can stand on their own to solve soil fertility depletion problems. Thus, integrated use of organic and mineral fertilizers is suggested as it overcomes the limitations that both fertilizers are encountering. Particularly, under nutrient limiting soils, the practice stimulated the activity of microorganisms, enhanced decomposition of organic residues and release of essential nutrients, and subsequently, improved grain yield [13, 18–22]. In addition, integrated nutrient management has helped to reduce the cost of mineral fertilizer up to 50% [23] or more [15]. However, information on the effects of locally available organic materials of plant origin and the recently introduced NPS (19N-46P₂O₅-7S) fertilizer under nutrient poor soils of Southern Ethiopia has been lacking. Thus, the aim of this experiment was to evaluate the effects of organic nutrient sources, mineral fertilizer, and their combination on the agronomic and economic performance of haricot bean (*Phaseolus vulgaris* L.).

2. Methodology

2.1. Location. The study was carried out in 2017 at the Wolaita Sodo University (WSU) research and practical farm in Sodo Zuria district, Southern Ethiopia. Geographically, it is located in 06°50'00"N latitude and 37°45'07"E longitude with an altitude of 1882 m above the mean sea level. The annual average rainfall was 1212 mm and characterized by having a bimodal rainfall pattern that forms two cropping seasons, namely, *Belg* (February-May) and *meher* (June-September). Farmers cultivate different crops during the two seasons.

Nitisol is the dominant soil type which occurs in the experimental location and district. The site has clay textural class. In terms of chemical properties, the experimental site had slightly acidic reaction (pH = 5.9) with low content of organic carbon (OC) (0.17%), total nitrogen (0.01), and available P (5.4 mg/kg) [24]. The low OC could be explained by the lack of addition of organic resources. Major annual crops growing in the area include haricot bean (*Phaseolus vulgaris* L.), wheat (*Triticum aestivum* L.), and maize (*Zea mays* L.).

2.2. Treatments, Research Design, and the Experimental Procedure. A factorial experiment consisting of three levels of organic fertilizer (0, 2.5 and 5 t·ha⁻¹) and four levels of NPS fertilizer (0, 50, 100 and 150 kg·ha⁻¹) was arranged in a Randomized Complete Block Design (RCBD) with three replications. Nutrients from organic sources were obtained from two agroforestry tree leaves, namely, *Croton* (*Croton macrostachyus*) and *Erythrina* (*Erythrina brucei*). These trees are growing in crops fields and/or farm boundaries; and farmers prune the tree branches and mulch the green leaves to enhance soil fertility. Each experimental unit had 2.40 m length × 1 m width (2.4 m²) in which the length was divided into six rows at 40 cm intervals. Each row was opened at 20 cm depth (i.e., average plough layer), and the whole doses of organic and inorganic fertilizers as per the treatment were applied into the soil two weeks prior to sowing of the test crop variety Nasir.

Two seeds per hill were planted in rows 40 cm apart and, with 10 cm between seeds. A distance of 0.5 m × 1 m was left between plots and blocks, respectively. Thinning was performed after full emergence of the crop by leaving one seedling per hill. Each plot had six rows and a total of 60 plants per plot. Weeding and other necessary agronomic management practices were carried out properly. These procedures were repeated on each of crop-growing seasons.

2.3. Chemical Composition of Organic Residues. Organic materials collected from the tree leaves were chopped, dried in shade, and then, oven dried at 70°C until constant weight. The leave litters were ground and used for characterization of chemical composition. The chemical composition, namely, N, P, K, and OC, and C:N contents of organic materials were determined according to the work of Sahlemedhin and Taye [25]. The samples were analyzed at the JIJE Analytical Testing Service Laboratory,

Addis Ababa, Ethiopia. This procedure was completed prior to planting of the crop.

2.4. Crop Data Collection. Data on the plant height, leaf area index (LAI), and dry matter per plant were recorded from five randomly selected plants of internal rows. The plant height was measured from the base of the plant to the apical bud of plant and expressed in centimeters. The leaf area index (LAI) was calculated as the ratio of total leaf area to ground area occupied by the plant using a pictorial method [26]. Dry matter per plant was measured after oven drying of the sample plants to constant weight at 70°C for 48 hours.

Yield components, namely, numbers of branches per plant, numbers of pods per plant, and numbers of seeds per pods, and 1000 seeds weights were also recorded from randomly selected five plants at two central rows of the plot. Grain yield was collected on a plot bases and after 10% moisture adjustment, it was converted to ton/ha.

2.5. Economic Analysis. The partial budget analysis was carried out using the methodology described in CIMMYT [27]. Grain yield data was used for the analysis. The price of 1 kg of haricot bean grain at local market near the experimental site was taken as 8.0 Ethiopian Birr (ETB). The price of NPS fertilizer was 15.15 kg⁻¹ ETB. The average labor cost incurred for incorporating 1.0 t·ha⁻¹ of *E. brucei* biomass was 200 ETB. Then, the total variable cost (TVC) was calculated as the sum of all costs that are variable or specific to a treatment against an unfertilized plot. The gross benefit (GB) was calculated as average adjusted grain yield (kg·ha⁻¹) × grain price. Adjusted Yield (AY) refers to 90% of the total grain yield that was adjusted downward by a certain percentage to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment. Net benefit was calculated by subtracting TVC from the GB. The marginal rate of return (MRR) was calculated as the ratio of differences between net benefits of successive treatments to the difference between TVC of successive treatments. The minimum acceptable MRR is 100%.

2.6. Statistical Analysis. All data obtained from experiments were subjected to analysis of variance (ANOVA) using SAS [28]. When effects were significant, means were compared using least significant difference (LSD) at a probability level of 5%. Pearson's correlation and simple regression analysis were performed to evaluate relationships among selected parameters.

3. Result and Discussion

3.1. Chemical Composition of Organic Nutrient Sources. The chemical composition of *Croton* (*Croton macrostachyus*) and *Erythrina* (*Erythrina brucei*) used for the study is presented in Table 1. The organic carbon content of *Croton* and *Erythrina* ranged from 50.8 to 51.8%, respectively. *Croton* has higher N (5.2%) than 4.7% on *Erythrina*. The N

TABLE 1: Chemical characteristics of organic nutrient sources.

Leave litters	OC %	N %	P mg/kg	K %	C:N -
<i>Croton</i>	50.83	5.2	11.07	3.07	10
<i>Erythrina</i>	51.83	4.7	18.59	2.12	11

content of both nutrient sources was above 2.5%, which is the threshold value indicating the quality of organic material and implying that, in short term, it would result in N mineralization in soil [29]. Phosphorus contents (mg/kg) were 11.07 in *Croton* and 18.6 in *Erythrina*. The potassium (K) content also varied from 2.12% (*Erythrina*) to 3.07% (*Croton*). Furthermore, the C : N ratio also varied between 10 and 11 which denotes higher decomposition probably due to the presence of less resistant structures and organic compounds. This would result in a faster rate of decomposition and release of essential nutrients to the crop. In agreement, Gindaba et al. [30] on green leaves of *Croton* and Wassie [15] on *Erythrina* found C : N ratio less than 20 and higher N content (4.83%), respectively. Overall, the chemical characteristics of organic nutrient sources were found to be high and encouraging to use as soil amendment.

3.2. Growth and Yield of Common Bean

3.2.1. Plant Height. The plant height of haricot bean plants was significantly ($p < 0.001$) increased with successive increase of NPS and organic fertilizer (OF) but not by their interaction (Table 2). Application of 150 kg·NPS/ha had resulted in 48% taller plants compared to non-fertilized plants. On the other hand, application of organic fertilizer at 5 ton/ha recorded 23% taller plants over the control. However, it was at par with 2.5 ton/ha. The plant height exhibited progressive increment with increasing rates of either NPS or OF fertilizer. The taller plants at higher doses of both fertilizer types can be associated with the complementary effects of N, P, and S and other nutrients released from organic matter decomposition. In line with this, the maximum plant height at increasing rate of NPS [31] and NPKSB [32] on haricot bean was reported.

3.2.2. Leaf Area Index. The leaf area index (LAI) of haricot bean was significantly influenced by the combined effects of NPS and OF application (Table 3). The maximum (4.49) and minimum (1.35) LAI were attained from 150 kg·NPS/ha + 5 ton/ha and the nonfertilized plot, respectively (Table 3). The treatment with a maximum LAI has resulted in 233% more LAI compared to unfertilized treatment. Integrating NPS along with other nutrients provided by OF at increasing rate had shown an increase in the LAI which was attributed to supplying of balanced nutrients (Figure 1). N resulted in more foliage and promoted photosynthetic action, P has a role in the synthesis of cellulose and hemicelluloses, which is leading to the expansion of individual leaves, and K and S encourage vegetative growth of common bean [26, 33].

TABLE 2: Plant height, branches per plant, and seeds per pods affected by NPS and organic fertilizer.

	Plant height (cm)	Branch plant ⁻¹ (No.)	Seed pod ⁻¹ (No.)
NPS (kg/ha)			
0	57.972d	3.4444d	2.8622c
50	69.906c	4.4778c	4.0889b
100	77.339b	4.9889b	4.5478a
150	85.856a	5.6778a	4.9033a
LSD _{0.05}	6.9859	0.3890	0.4191
OF (t/ha)			
0	64.279b	4.0167b	3.6075c
2.5	75.050a	4.8250a	4.1192 b
5	78.975a	5.100a	4.5750a
LSD _{0.05}	6.0500	0.3369	0.3629
CV (%)	9.82	8.56	10.45

Nutrient sources of organic and inorganic when combined create a synergistic effect to increase the leaf area and LAI. In line to this, Zahida et al. [21] also reported that integrated fertilizer application results in a significantly higher LAI of common bean over sole and nonfertilized plots. Similarly, Nasim et al. [34] on maize also reported a maximum LAI in plot fertilized with a combination of poultry manure and N fertilizer.

In our study, a faster daily decay rate (k) and decomposition were recorded when organic nutrient sources are treated with 150 kg-NPS/ha. This implies that mineralization and release of nutrients to the crop were started since the early crop growth period. The correlation analysis further indicated that the LAI has a significant ($p < 0.01$) relationship with k ($r = 0.63$), NPS ($r = 0.73$), and OF ($r = 0.38$). This could contribute to increased synchrony between nutrient demand and supply that resulted to more number of leaves per plant and higher LAI of plants.

3.2.3. Yield Attributes. The number of branches per plant and seeds per pod were significantly ($p < 0.01$) affected by the main effects of NPS and OF application (Table 2), whereas their interaction affected pods per plant and thousand seed weight (Table 3). NPS at 150 kg/ha and OF at 5 t/ha have resulted in 67% and 28% more branches per plant than by unfertilized treatment. Moreover, the earlier NPS and OF treatments in their order have also resulted in 69% and 28% higher seeds per pod than control. Generally, branches per plant and seeds per pod of haricot bean have shown an increasing trend with an increasing rate of either fertilizer sources.

Integrated application of 150 kg NPS/ha + 2.5 t/ha OF significantly enhanced the pod number per plant by 227% over unfertilized plots (Figure 2). The advantage in yield attributes was probably caused by greater availability and uptake of macro- and micronutrients that might have resulted in higher photosynthesis, tissue differentiation, and assimilation of translocation and, in turn, leading to better vegetative growth (e.g., LAI and higher total dry matter production) and yield attributes (branches and pods/plant). The Pearson correlation matrix (Table 4) also indicated that

the number of pods per plant was significantly associated with the NPS ($r = 0.73$), OF ($r = 0.38$), LAI ($r = 0.86$), dry matter production ($r = 0.8$), and number of branches per plant ($r = 0.744$).

The results regarding yield attributes are in accordance with the findings of Zahida et al. [21] who reported the highest branches/plant in plots treated with NPK and poultry manure or farm yard manure. Furthermore, similar results on chickpea were also reported by Sohu et al. [19]. According to Ahmad and Abdin [35], applications of N and S fertilizers enhance the net photosynthetic rate in crop plants, which in turn, increases dry matter, yield attributes, and grain yield. The effect would become better when organic fertilizer is mixed together. This is due to the fact that organic fertilizer would have provided the micronutrients in addition to macronutrients [12, 13].

3.2.4. Biomass per Plant and Grain Yield. Interactive effects of NPS and OF significantly ($p < 0.05$) influenced the biomass yield of haricot bean (Table 3). Application of 150 kg NPS/ha and 5 t/ha recorded the highest dry biomass per plant (45.2 g) compared to the minimum (12.2 g) from unfertilized crop. Biomass production has shown an increasing trend with an increasing rate of NPS + OF fertilizers. The better performance under integrated nutrient application was closely associated with improvement in the LAI and yield attributes. This is supported by a significant and positive association with the NPS ($r = 0.64$), OF ($r = 0.53$), LAI ($r = 0.78$), plant height ($r = 0.84$), pods per plant ($r = 0.8$), and seeds per pod ($r = 0.86$) (Table 4). For instance, the higher LAI of plants enabled plants to intercept more of the available radiation for the production of assimilates. This was, in turn, dependent upon nutrient availability. Ashenafi [26] had also reported increased biomass yield of common bean cultivars with an increase in the rate of NPS. The author associated to enhanced availability and uptake of N, P, and S nutrients that significantly improved the plant height, number of branches, and number of pods per plant that contributed to higher above ground dry biomass yield.

Data regarding grain yield indicated that application of 150 kg NPS/ha and 2.5 t-OF/ha significantly resulted the highest grain yield (4.16 t/ha) which was a 312% increase over unfertilized crop (1.01 t/ha) (Figure 3, Table 3). In addition, it also recorded 31%, 79%, and 34% yield increment over sole application of organic fertilizer at 2.5 t/ha, 5 t/ha, and 100 kg-NPS/ha (i.e., blanket dose), respectively. Abdou et al. [36] reported that combined application of organic and inorganic nutrient sources resulted in synergistic effects and improved synchronization of nutrient release and uptake by plants leading to higher yields. In addition, mixing the organic nutrient sources with mineral fertilizer enhanced decomposition and mineralization [12, 13] and consequently improved nutrient release and uptake leading to higher yield [12, 22]. In the present study, enhanced decomposition at an increasing rate of NPS, and a significant ($p < 0.01$)

TABLE 3: LAI, pods per plant, 1000 seed weight, biomass per plant, and grain yields of haricot bean affected by organic and NPS fertilizer.

LR	LAI			Pods per plant (PPPL)			1000 seeds wt.			Dry matter plant ⁻¹			Grain yield (ton/ha)		
	0 t/ha	2.5 t/ha	5 t/ha	0 t/ha	2.5 t/ha	5 t/ha	0 t/ha	2.5 t/ha	5 t/ha	0 t/ha	2.5 t/ha	5 t/ha	0 t/ha	2.5 t/ha	5 t/ha
0	1.35d	2.41c	3.59b	7.8 g	14.7f	19.9cde	198.5b	246.5a	248.0a	12.2 g	27.9ef	29.6ef	1.01 g	2.32f	3.17de
50	2.54c	3.61b	3.96ab	17.0ef	19.2de	21.6bcd	235.3a	238.5a	234.9a	25.9f	32.6cde	37.8bc	2.08f	3.18de	3.27cde
100	4.01ab	4.39a	3.94ab	21.7bcd	22.3bcd	23.0abc	235.0a	241.1a	247.9a	31.6def	32.6cde	40.1ab	3.10e	3.81abc	3.43bcde
150	4.35a	4.23ab	4.49a	23.2 ab	25.5a	24.1ab	238.9a	241.9a	245.1a	36.6bcd	36.4bcd	45.2a	3.73abcd	4.16a	3.93ab
LSD_{0.05}	0.65			3.23			14.127			5.91			0.5804		
CV (%)	10.82			9.54			3.51			10.78			11.06		

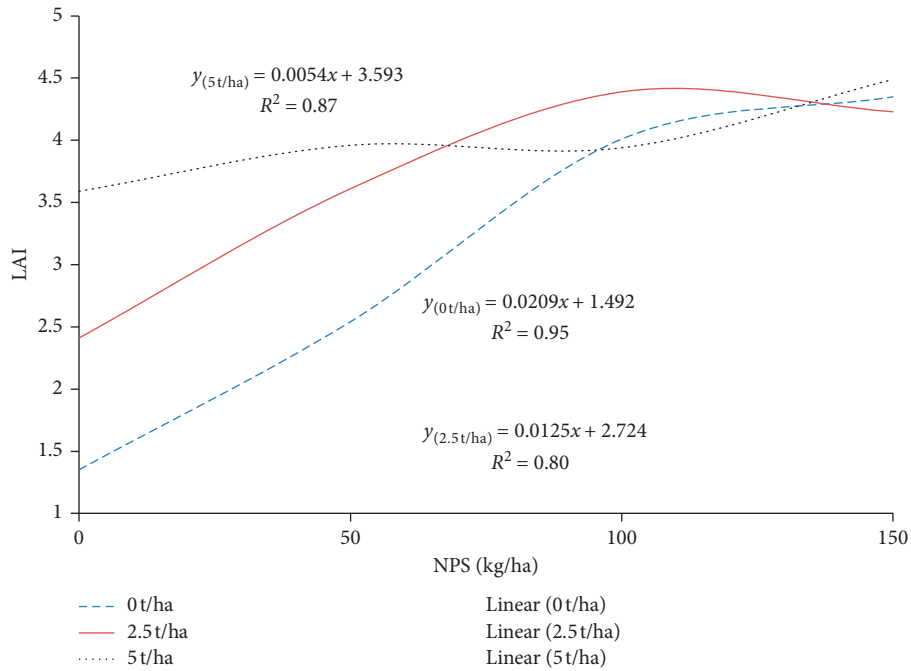


FIGURE 1: Leaf area index of haricot bean as affected by interaction effects of NPS and organic fertilizer.

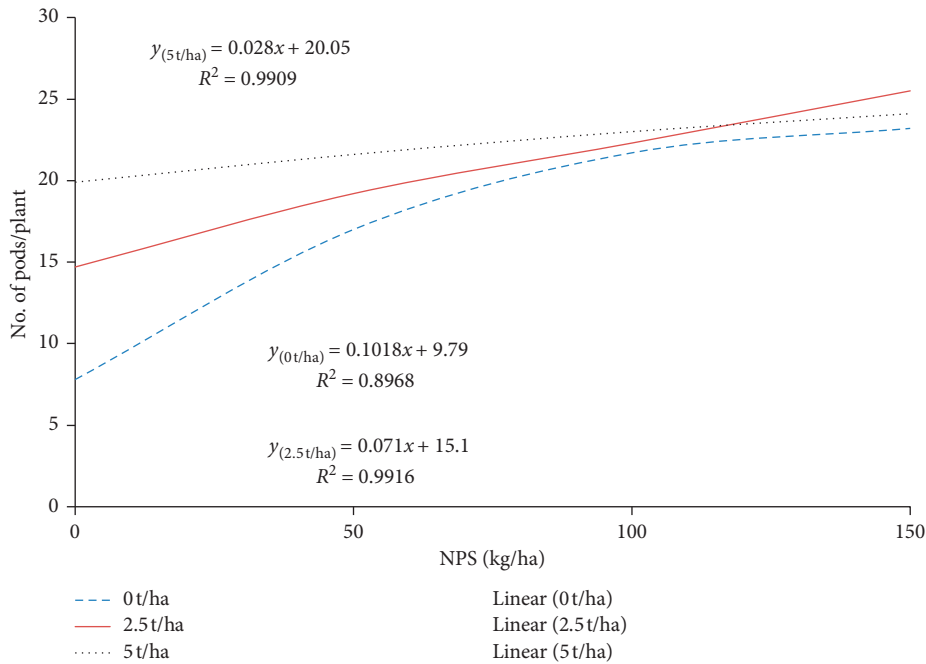


FIGURE 2: Number of pods/plant of haricot bean as affected by interaction effects of NPS and organic fertilizer.

relationship between grain yield and daily decay rate (k) ($r=0.67$) were recorded. All these processes have been a good reason for vigorous vegetative growth, higher dry matter accumulation, increased yield attributes, and the resultant effect on grain yield of bean. Earlier studies have also reported that combined application of mineral and organic fertilizer resulted in higher grain yield [13, 22, 37, 38].

3.3. Economic Analyses. The result revealed that the application of 150 kg-NPS/ha + 2.5 t-OF/ha recorded the highest net benefit (27179.5 birr) with acceptable MRR (>100%) (Figure 4, Table 5). It was followed by net benefit (25417.0 ETB) at 100 kg NPS/ha and 2.5 t-OF/ha. The finding also demonstrated that resource-poor farmers can get reasonable benefit ranging from 16204.0 to 21824.0 ETB by sole application of organic nutrients at 2.5 t-OF/ha and 5 t-OF/ha, respectively.

TABLE 4: Pearson correlation matrix of applied fertilizers and agronomic parameters.

	NPS	OF	LA	LAI	PHT	BPL	PODPT	SEDPOD	TSW	BIOMP
LA	0.768***	0.434**								
LAI	0.730***	0.384*	0.862***							
PHT	0.735***	0.433**	0.845***	0.834***						
BPL	0.753***	0.412*	0.835***	0.803***	0.843***					
PODPT	0.727***	0.375*	0.801***	0.863***	0.834***	0.744***				
SEDPOD	0.779***	0.418*	0.836***	0.808***	0.810***	0.850***	0.758***			
TSW	0.274 ^{ns}	0.448**	0.556***	0.565***	0.564***	0.442**	0.695***	0.382*		
BIOMP	0.639***	0.528***	0.804***	0.777***	0.836***	0.836***	0.800***	0.861***	0.584***	
GY	0.696***	0.414*	0.834***	0.862***	0.765***	0.705***	0.873***	0.642***	0.638***	0.626***

***, ***, and ^{ns} refer to $p < 0.05$, 0.01, 0.001, and not significant, respectively. LA = leaf area, LAI = leaf area index, PHT = plant height, BPL = no of branches per plant, PODPT = no of pods per plant, SEDPOD = no of seeds per pod, TSW = thousand seed weight, BIOMP = biomass per plant, GY = grain yield.

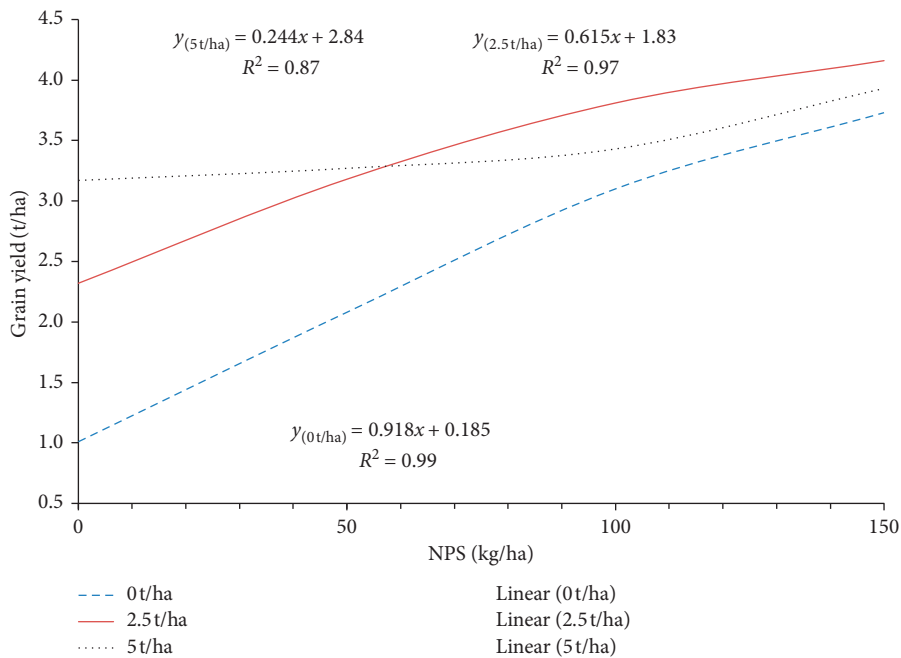


FIGURE 3: Grain yield of haricot bean as affected by interaction effects of NPS and organic fertilizer.

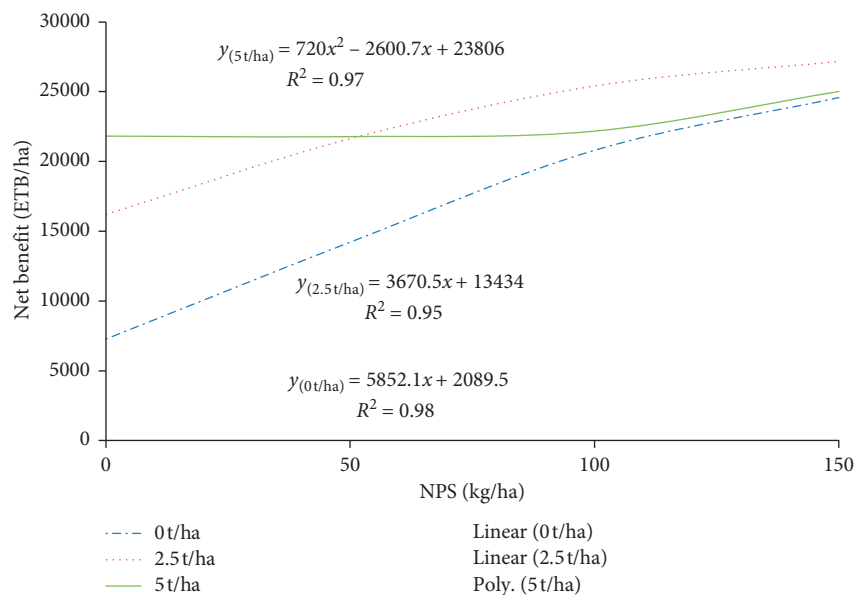


FIGURE 4: Net return of haricot bean as affected by interaction effects of NPS and organic fertilizer.

TABLE 5: Profitability as affected by NPS and OF fertilizer rates.

OF (tha ⁻¹)	NPS (kg·ha ⁻¹)	GY (tha ⁻¹)	Adj.GY (tha ⁻¹)	GB (ETB)	TVC (ETB)	Net benefit (ETB)	MRR (%)
0	0	1.01	0.91	7272	0.0	7272.0	—
0	50	2.08	1.87	14976	757.5	14218.5	917.0
0	100	3.1	2.79	22320	1515.0	20805.0	869.5
0	150	3.73	3.36	26856	2272.5	24583.5	498.8
2.5	0	2.32	2.09	16704	500.0	16204.0	—
2.5	50	3.18	2.86	22896	1257.5	21638.5	717.4
2.5	100	3.81	3.43	27432	2015.0	25417.0	498.8
2.5	150	4.16	3.74	29952	2772.5	27179.5	232.7
5	0	3.17	2.85	22824	1000.0	21824.0	—
5	50	3.27	2.94	23544	1757.5	21786.5	D
5	100	3.43	3.09	24696	2515.0	22181.0	52.1
5	150	3.93	3.54	28296	3272.5	25023.5	375.2

Unit cost of NPS = 15.15 ETB/Kg, application cost of organic fertilizer = 20 ETB/Qt = 200 ETB/ton, MRR (%) = marginal rate of return, D = dominant OF = organic fertilizer, GY = grain yield, Adj.GY = adjusted grain yield, GB = gross benefit, TVC = total variable cost.

4. Conclusions

This study demonstrated that an integrated application of 150 kg-NPS/ha and 2.5 t-OF/ha resulted in faster decomposition and the highest growth, yield component, and grain yield over unfertilized crop. The effect on grain yield was triple (312%) that of unfertilized crop. Additionally, 31% and 79% yield increment compared with sole OF application at 2.5 t/ha and 5 t/ha, respectively, were recorded. Economic analysis has further confirmed the highest net benefit from the combined application of 150 kg-NPS/ha and 2.5 t-OF/ha. Therefore, under low input cropping systems such as the study area, integrated use of mineral fertilizer with locally available organic nutrient sources are suggested to enhance soil quality and crop productivity. Resource-poor farmers are advised to use sole OF at 5 t/ha as it recorded superior yield and economic advantage over unfertilized to 100 kg-NPS/ha.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Authors' Contributions

The authors collected, analyzed, interpreted, and prepared the manuscript.

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