

Effect of Biological and Chemical Fertilizers Combination on Yield of Mung Bean (*Vigna radiata* L. Wilczek) at Hawassa Southern Ethiopia

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Abstract: An integrated use of biological and chemical fertilizers is beneficial in achieving sustainable crop yield improvement during the era of climate change. At the same time, dependency on chemical fertilizer is not recommendable particularly for small-scale farmers who have options of using organic sources of fertilizer, due to its unaffordable cost for small-scale farmers, and contribution for climate change. Optimizing combined use of biological and chemical fertilizers could be a better option to improve crop productivity, minimize their effect on environmental and economic sustainability. Field experiment was conducted in 2019/20 to determine the combined effects of biological and chemical fertilizer sources on the yields of mung bean. The factorial combinations of four bio-slurry levels (control, 50, 100 and 150%) and four sources of nitrogen treatments (control, 23kg N ha⁻¹, Rhizobium strain MB-001 and 23kg ha⁻¹ N + strain MB-001) were laid out in a randomized complete blocks design with four replications. The phenology and yield parameters of mung bean were significantly affected by bio-slurry and N fertilizer. Hundred seed weight, above ground biological, grain, and straw yields were all improved by the combined application of bio-slurry and N fertilizer. Application of 150% bio-slurry with 23kg N ha⁻¹ resulted in highest biological and straw yield, whereas; application of 100% bio-slurry with Rhizobium strain MB-001 resulted in marked increase of grain yield. Pod number per plant and hundred seed weight were highest in the application of 100% bio-slurry with nil N fertilizers. The highest net benefit with highest marginal rate of return was obtained from combined application of 50% bio-slurry with 23kg ha⁻¹ N fertilizer followed by 50% bio-slurry with strain MB-001 inoculation. Integrated application of 50% bio-slurry ha⁻¹ with 23kg ha⁻¹ N may be recommended for smallholder mung bean producers in the experiment area and other areas having similar agro-ecology and socio-economic status.

Keywords: Bio-Slurry, Mung Bean, Nitrogen, Rhizobium Inoculation, Yield

1. Introduction

Mung bean (*Vigna radiata* L. Wilczek) is a short duration, self-pollinated diploid legume crop which belongs to the *Fabaceae* family. It is one of the most important crop grown in different tropical and sub-tropical parts of the world [1, 2]. It has been domesticated in India and most of world's mung bean production comes from Asia [3]. It is an important wide spreading, herbaceous and annual legume pulse crop cultivated mostly by traditional famers [4]. Mung bean is an

interesting crop from the point of view of the consumer, farmer and processor. For the consumer, mung bean is noted for its protein and rich in essential amino acids especially lysine, which supplements cereal based diets [5]. The seeds, sprouts and young pods are all consumed and provide a rich source of amino acids, vitamins and minerals [6]. The grain contains 24.2% protein, 1.3% fat and 60.4% carbohydrate [7]. It improves a farmers' field by fixing atmospheric N through symbiosis with bacteria and its green plants used as a source of animal feed. It has also a special importance in intensive

crop production system because of its short growing period. For the processor, mung bean provides many possibilities such as canned or frozen seeds and pods [8].

Mung bean is grown in drier marginal environments by the smallholder farmers in Ethiopia. Farmers cultivate it twice in a year covering 27,085.92 ha and production level of 27,898.5 t ha⁻¹ with an average yield of 0.75 t ha⁻¹ as reported in central statistics agency 2016/17, which is much lower than that of average national yield 4.61 t ha⁻¹ reported elsewhere [9]. According to a number of studies, Ethiopia has an extremely poor mung bean production when compared to other nations. This is partially caused by inadequate soil fertility, which is mostly attributable to the insufficient number of soil amendment options that are available [10, 11]. Therefore, there is potential to increase the production potential of this crop using integrated fertilizer use options, such as the application of bio-slurry and Rhizobium inoculation.

The fermented slurry, called bio-slurry, as a product of anaerobic fermentation of animal excrement in the biogas digester is an excellent organic fertilizer, that improve soil fertility and crop yields. The wet and dry bio-slurry is reported to contain around 1.6% and <0.5% N as the readily available form of ammonia [12, 13] Bio-slurry is potentially a 100% organic fertilizer suitable for natural farming systems and may qualify for organic farming. It is the by-product of methane and heat production coming from organic wastes and it has the ability to deliver nutrients especially N to crops. It is the most essential element of plants since it is taken up by plants in significant amount. As a result, when used to its full potential, the plant's fruit and blossom production improve. However, the source, soil type, and environmental factors that affect N availability to plants can all have an impact on crop performance. Therefore, the N supply of a crop should be coordinated with its demand. Every type of soil experiences N losses, so controlling these losses should always be the primary focus when examining how much N crops receive [14].

The dependency on inorganic fertilizer should be minimized due to high cost, release of greenhouse gases and loss due to ineffective application. Hence, it is not recommended particularly for small scale farmers who have options of using organic sources of fertilizer [15, 16]. When organic wastes and chemical fertilizers are used together, sandy loam soil's crop production, pH, organic carbon content, and available N, P, and K are all improved [17]. Furthermore, optimizing combined use of inorganic and organic fertilizers could be a better option to balance high productivity, and environmental as well as economic sustainability.

The symbiosis between rhizobial bacteria and legumes is a less expensive and typically more successful agronomic strategy for guaranteeing an adequate supply of N for the development of pasture and crops based on legumes. Rhizobium bacteria may fix nitrogen from the air while living in symbiosis with legumes (N₂). The vast natural source of N from the air can therefore be absorbed through

the symbiotic relationship, which results in a reduction or lack of N mineral fertilizer application in the field [18, 19].

So far, several studies have been carried out dealing with the response of mung bean to chemical fertilizer application. However, the response of the crop either to singular or combined application of bio- and chemical fertilizers and, its advantage for economic and environmental sustainability is scanty. Even for those farmers using the bio-chemical fertilize combinations, a research recommended rate for the combined use is lacking for the study area. Therefore, this research is initiated to evaluate the effects of integrated nutrient application on the yield of mung bean at Hawassa in southern Ethiopia.

2. Material and Methods

2.1. Description of the Experimental Site

The experiment was conducted at the experimental field of Hawassa University, Hawassa, Ethiopia. The site is situated 270 kilometers south of Addis Abeba, the country's capital. The region's coordinates are 7°03' 05.7" N and 38°30' 21.1" E, and its average elevation is 1712 meters above sea level. The mean minimum and maximum temperatures are 12.1 and 26.7°C, respectively, with a mean annual rainfall of 952 mm [20].

2.2. Physico-Chemical Characteristics of the Experimental Soil and Bio-Slurry

Before planting soil samples were taken randomly from the experimental fields at 0 – 20 cm depth to determine initial fertility status of the experimental soils using augur. The sample were thoroughly mixed and one composite representative sample was taken for analysis of physical (texture, total porosity and moisture content) and chemical (pH, total N, available P, exchangeable K, organic carbon (OC), C:N ratio and cation exchanging capacity (CEC) properties of the soil. The composite soil and bio-slurry samples were sent to Debrezeit Horticoop Ethiopia (horticulture) soil and water analysis laboratory and analysis was done based on the standard procedure of each sample.

The nutrient constituents of bio-slurry were also determined before its application as a treatment. To do this, a stick was used to stir the liquid bio-slurry in the bio-tank digester's in a circular motion. The precaution was taken to prevent scraping of the tank's bottom and corners. Then, using a 2 L sampling container, five representative liquid bio slurry samples were taken. Then mixed in the plastic container and 1 L representative sample was oven dried and subjected for analysis to determine water content, pH, CEC, organic carbon, EC, OC, total N, available P, available K, and exchangeable bases. Bio-slurry was obtained from private hotel (Gebrekiristos Hotel) Hawassa, Ethiopia. The oven dried 1kg bio-slurry sample was digested instead of 1 kg soil sample for manure analysis. The phosphorus, potassium, pH, OM content and CEC were determined by using the procedures stated for soil analysis in above section.

Analysis was done in Hawassa University, college of Agriculture soil analysis laboratory.

2.3. Treatments and Experimental Design

The experiment was arranged in factorial combination of four rates of bio-slurry (0, 50, 100 and 150%) and four sources of N fertilizer including the control (0, 23 kg ha⁻¹, *Rhizobium strain* MB-001, 23 kg N ha⁻¹ + *strain* MB-001). The total number of treatments were 16 replicated four times with the total of 64 plots. Each experimental plot have an area of 1.8 m x 1.5 m (2.7m²), total area of 326.7m² with a spacing of 0.5m and 1m between plots and blocks, respectively. The treatments were randomly assigned to each plot. Planting was

done on August 2019 with the spacing 0.3m x 0.1m between rows and plants, respectively and covered slightly with soil at the depth of 3 – 5 cm. There were six rows in each plot and data was collected from plants of middle four rows of plot, excluding plants in the two border rows as well as those at both ends of each row to avoid border effects.

The rate of bio-slurry was adjusted based on the recommended rate of inorganic N for mung bean, respective to its N content. Urea was used as the source of N and 23kg ha⁻¹ of national recommendation for legumes was used. Commercial *Rhizobium strain* (MB-001) was obtained from Private Menagesha Biotech, Company and applied as per the company's recommended rate 500 g ha⁻¹.

Table 1. The physicochemical properties of the experimental soil and bio-slurry.

Description of soil		Description of bio-slurry	
Profile code	Concentration	Profile code	concentration
Sand (%)	40	Water (%)	93.93
Clay (%)	32	Dry matter (%)	6.07
Silt (%)	28	Organic matter (%)	30.6
Textural class	Clay loam	Organic carbon (%)	17.7
pH	7.17	pH-H ₂ O (1:2.5)	7.33
Ava. P (mg/kg)	51.73	Total nitrogen (%)	1.53
Exch. K ⁺ (mg/kg)	946.85	Available P (mg P ₂ O ₅ kg ⁻¹ bio-slurry)	301.4
Exch. Ca ²⁺ (mg/kg)	2,641.79	Available K (mg K ₂ O kg ⁻¹ bio-slurry)	715.25
Exch. Mg ²⁺ (mg/kg)	320.30	Exch. Ca ²⁺ (cmol (+) kg ⁻¹ bio-slurry)	114.4
Exch. Na ⁺	222.73	Exch. Na (cmol (+) kg ⁻¹ bio-slurry)	33.2
S (mg/kg)	16.54	Exch. K ⁺ (cmol (+) kg ⁻¹ bio-slurry)	28.6
OC (%)	1.69	Exch. Mg ²⁺ (cmol (+) kg ⁻¹ bio-slurry)	17.4
Total N (%)	0.15	CEC (cmol (+) kg ⁻¹ bio-slurry)	64
C/N (%)	11.27		
CEC (Meq/100g soil)	22.79		

2.4. Management of Experiment

The experimental field was prepared using traditional tillage techniques, which include three plowing cycles prior to mung bean sowing. A field layout was created in accordance with the design's parameters; the ground was then cleared, leveled, and prepared for crop establishment. A week before planting, bio-slurry was applied to the prepared plots to reduce the burning effects on crop. At the time of planting, *Rhizobium strain* was mixed with a sugar solution in which the seed is soaked. The sugar solution ensures the strain adheres to the coating of the seed and that the *Rhizobia* quickly colonize the interior of the plant after germination.

2.5. Data Collection

2.5.1. Phenological Parameters

Days to 50% flowering was recorded by counting the number of days that takes from emergency to about 50% of the plants in the plot reached flowering and days to 90% physiological maturity was recorded when 90% of the pods in plots were changed from green to yellowish color.

2.5.2. Yield and Yield Components

Number of pods per plant was determined from randomly selected five plants from central rows of each plot and the

average was taken as number of pods plant⁻¹. Hundred seeds weight was determined by weighing randomly sampled 100 seeds threshed for seeds per pod from each plot.

Plants harvested from the three central rows of each plot after sun drying for four days was measured for its biological yield. Then it was threshed and adjusted at 10% moisture level to determine grain yield. Straw yield was calculated by subtracting grain yield from the corresponding total above ground biomass yield.

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Above ground dry biomass}} \times 100$$

2.5.3. Economic Analysis

The economic analysis was based on the formula developed by CIMMYT (1988) and given as follows: Adjusted yield: is the average yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers. Adjusted yield= gross average yield- (gross average yield* 0.1). Gross field benefit: was computed by multiplying field/farm gate price that farmers receive for the crop when they sale it as adjusted yield. Gross field benefit= adjusted yield* field/farm gate price of a crop. Total cost: mean current prices of urea (20 birr kg⁻¹), bio-slurry compost (0.4 birr l⁻¹), wage for bio-slurry application and urea application were considered 37 birr of area. Net benefit: was calculated by subtracting the total costs from the gross

field benefit for each treatment. Marginal rate of return = (marginal return/ marginal cost)*100.

2.5.4. Statistical Analysis

The data was subjected to analysis of variance (ANOVA) using a General Linear Model in SAS software version 9.0 and mean separation was made based on LSD at 5% ($P < 0.05$) level of significance (SAS institute, 2002).

3. Results and Discussion

3.1. Effect of Bio-Slurry and Nitrogen Sources on Phenological and Yield Components

3.1.1. Phenological Parameters

The analysis of variance revealed that the interaction effect of bio-slurry and N sources significantly ($P < 0.05$) affected phenological parameters. Combined application of 150% bio slurry and 23kg N ha⁻¹ delayed both flowering and maturity as compared to the control (Table 2). The shortest day required for 50% flowering was 38 which is 7.5 days earlier to set flower compared to the longest days. Increasing the levels of bio-slurry in combination with N resulted in proportional delay of maturity that the higher the rate of N the more maturity was delayed whereas; early flowering and maturity were observed on the control.

Such delay in both flowering and maturity due to the applied treatments might be due to the fact that N from liquid bio-slurry and urea favor vegetative growth by its role in physiological and metabolic function in the plant cells. Early maturity and flowering in the control treatment may be due to the fact that plants under shortage or stress condition forced to complete their life at instant period of time in order to survive or complete their life cycle. This result is in line with

[21] who stated that cabbage planted in a combined lowest rate of bio-slurry 10 m³ with recommended N and P fertilizers at the rate of 0 and 25% ha⁻¹ matured earlier, while the plants treated with 70 m³ bio-slurry ha⁻¹ and RNP rates of 25, 50, 75 and 100% ha⁻¹ matured late. In addition, another study elsewhere revealed that application of dry bio-slurry and chemical fertilizers on tomato caused delay in flowering and days to maturity compared to the control [22]. Delay on phenological parameters due to application of organic and inorganic fertilizers were reported previously [23, 24]. Moreover, the N taken up by plant roots in the form of nitrate from the root nodule could be used for an increased cell division and synthesis of carbohydrate, resulting in plants with a luxurious foliage growth [25].

3.1.2. Yield and Yield Components

The analysis of variance regarding the interaction between bio-slurry and N fertilizer treatments had significant ($p < 0.05$) effect on the 100 seed weight, biological yield, grain yield and straw yield of mung bean. The result revealed that heavier seed weight (5.1g) from application of 100% bio-slurry with 0 kg N ha⁻¹, followed by treatments received 100% bio-slurry with 23 kg N ha⁻¹ compared to control treatment (3.1 g). The increment in seed weight might be due to highest P content in bio-slurry increased seed weight of mung bean. According to [26] application of bio-slurry with mineral N increased seed weight of soya bean compared to other treatments. Also [27] stated that maximum 1000 grains weight was recorded under NPK with vermin compost which proved significantly superior over the control and other treatments. Another finding reported [28] that maximum seed weight was attained due to application of recommended dose of fertilizer NPK with 4t ha⁻¹ farmyard manure compared to control treatment.

Table 2. Effect of bio-slurry and N combination on phenological parameters of mung bean.

Treatments		Phenological parameters	
Rate of BS (%)	N fertilizer sources	Days to 50% flowering	Days to 90% maturity
0	0	38 ^e	65 ^e
	23	40 ^{cd}	67 ^d
	<i>Rhizobium</i>	38.25 ^e	65.2 ^e
	23+ <i>Rhizobium</i>	39 ^{de}	65 ^e
50	0	40 ^{cd}	67 ^d
	23	43 ^b	70 ^c
	<i>Rhizobium</i>	43 ^c	70 ^c
	23+ <i>Rhizobium</i>	40.5 ^c	67.5 ^d
100	0	42 ^b	69 ^c
	23	42.25 ^b	69.2 ^c
	<i>Rhizobium</i>	42.25 ^b	69.2 ^c
	23+ <i>Rhizobium</i>	42.5 ^b	69.5 ^c
150	0	45.25 ^a	73.2 ^{ab}
	23	45.5 ^a	74 ^a
	<i>Rhizobium</i>	44.5 ^a	72.5 ^b
	23+ <i>Rhizobium</i>	45 ^a	73.5 ^{ab}
CV% LSD (5%)		2	1.39
		1.21	1.37

Means followed by the same letter (s) within the column are not significantly different at ($P \leq 0.05$). BS = bio-slurry

The result clearly indicated that the highest biological yield was produced from application of 150% bio-slurry with

23 kg N ha⁻¹ whereas the lowest record was obtained from control treatment (Table 3). The increased amount of N from

both organic and inorganic sources attributed to above ground biomass accumulation. The result is in line with [28], maximum biological yield was estimated in recommended dose of fertilizer inorganic NPK with organic farmyard manure over remaining treatment.

Mung bean yield (number of pods, grain and biological yield) increased by the addition of compost, mineral N and *Rhizobium* inoculation [28]. The increment in biological yield might be due to the increased nitrogen results in more vegetative growth of the plant and higher availability of nutrients in organic fertilizer was the main factor contributing to higher biomass of plants [29]. The availability of other macro- and micronutrients as well as soil nitrogen is likely to have increased with an increase in bio-slurry nitrogen, which could have aided in meristematic growth and boosted biological production. Nitrogen is a crucial plant nutrient involved in the creation of proteins and enzymes. Enzymes regulate every metabolic activity in plants.

In addition, nitrogen is a crucial part of chlorophyll, the main molecule responsible for absorbing the light energy required for photosynthesis. The observed increase in biological yield in response to bio-slurry nitrogen may have been caused by its favorable impact on cell elongation, cell division, nucleotide and coenzyme formation in meristematic activity, and increasing photosynthetic surface, which led to more production and accumulation of photosynthetic compounds. The high P content of the bio-slurry may have helped to increase the biomass output of mung bean. Phosphate molecules serve as a plant's primary source of energy and are crucial for photosynthesis and the metabolism of carbohydrates. They are also saved for later growth and reproduction processes. The highest grain yield was obtained from the application of 100% bio-slurry with *Rhizobium* inoculation compared to control treatment (Table 3). The highest grain yield might be attributed to the influence of bio-slurry and *Rhizobium* inoculation improved net photosynthesis which resulted in maximum net grain product. It was reported that grain yield of mung bean was significantly enhanced by combined application of compost, *Rhizobium* and 75% recommended dose of N fertilizer [29]. According to [31] grain yield of barley was significantly affected by the combined application of organic FYM and

inorganic NP. In addition, indicated that combined treatment of NPK with vermicomposting recorded the maximum grain yield [27].

The result indicated that interaction of liquid bio slurry with N fertilizer had significant ($p < 0.05$) effect on straw yield of mung bean. The maximum straw yield was produced from the combined application of 150% bio-slurry with 23 kg N ha⁻¹ compared to the control treatment (Table 3). The significant interactive effect as a consequence of bio-slurry and N fertilizer application is attributed to the favorable nutritional status of the soil resulting into increased biomass production of the crop and resulted in higher straw yield. This result is in agreement with the data reported by [28] who revealed treatment NPK with vermin compost brought about significant improvement in straw yield followed by with farm yard manure and increase in the straw yield was up to 30-40 percent in comparison to the control treatment.

The highest mean pod number (22.9) was resulted from the sole application of 100% bio slurry compared to control treatment (17.5) Table 4. The increased pod number might be due to the fact that availability of N in bio-slurry and its enough releasing makes easily uptake and enhances pod formation of plants. Thus N is essential component of protoplasm, chlorophyll molecules, amino acids and photosynthesis that make enhancement of pod filling by insuring more survival of flowers under the supply of liquid bio-slurry. Similar results were reported by [32] who found that an addition of 5 and 10% w/w biochart each alone gives the highest 34.3 and 39 number of pods per plant and green bean respectively as compare to the lowest value (29) on control treatment.

The data clearly depicted that only main effects of bio-slurry was significantly affected the harvest index ($P < 0.05$), whereas the main effect of N and interaction effect had not significantly affected the harvest index. Maximum harvest index was observed from 50% bio-slurry was applied (Table 4). Bio-slurry is known to have the ability to supply both macro and micro nutrients required for crop growth, development and final economic yield [33]. It indicates that the physiological ability of a crop to convert proportion of dry matter in to economic yield.

Table 3. Combined effects of bio-slurry and N sources on yield of Mung bean.

Treatments			Yield parameters		
Rate of BS (%)	N fertilizer sources	100 seed weight (g)	Biological yield (t ha ⁻¹)	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)
0	0	3.1 ^d	1.90 ^e	0.70 ^f	1.20 ^d
	23	4.6abc	2.62 ^{cde}	0.80 ^{ef}	1.82 ^{cd}
	<i>Rhizobium</i>	4.4 ^{bc}	3.41 ^{bc}	0.86 ^{de}	2.55 ^{bc}
	23+ <i>Rhizobium</i>	4.3 ^{bc}	3.27 ^{bcd}	0.82 ^{def}	2.45 ^{bc}
50	0	4.3 ^{bc}	2.36 ^e	0.83 ^{def}	1.52 ^d
	23	4.8 ^{ab}	2.63 ^{cde}	1.15 ^{ab}	1.47 ^d
	<i>Rhizobium</i>	4c	2.35 ^e	1.03 ^{bc}	1.31 ^d
	23+ <i>Rhizobium</i>	4.6abc	2.59 ^{de}	0.95 ^{cd}	1.64 ^d
100	0	5.1 ^a	3.65 ^b	1.16 ^{ab}	2.49 ^{bc}
	23	4.6 ^{ab}	3.85 ^b	0.93 ^{cde}	2.91 ^b
	<i>Rhizobium</i>	4.3 ^{bc}	3.76 ^b	1.20 ^a	2.55 ^{bc}
	23+ <i>Rhizobium</i>	4.4 ^{bc}	3.96 ^b	0.91 ^{cde}	3.04 ^b
150	0	4.4 ^{bc}	3.52 ^b	0.81 ^{def}	2.71 ^b

Treatments		Yield parameters			
Rate of BS (%)	N fertilizer sources	100 seed weight (g)	Biological yield (t ha ⁻¹)	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)
	23	4.6 ^{ab}	5.24 ^a	1.05 ^{bc}	4.18 ^a
	<i>Rhizobium</i>	4.3 ^{bc}	3.84 ^b	0.88 ^{de}	2.96 ^b
	23+ <i>Rhizobium</i>	4.5 ^{bc}	3.85 ^b	0.88 ^{de}	2.97 ^b
CV% LSD (5%)		9.3	17	10.46	23
		0.5	0.80	0.13	0.77

Means followed by the same letter (s) within the column are not significantly different at ($P \leq 0.05$). BS = bio-slurry

Table 4. Main effects of bio-slurry and nitrogen fertilizer sources on yield parameters of mung bean.

Treatments		Yield parameters	
Rate of BS (%)		Number of pods plant ⁻¹	Harvest index (%)
0		17.5 ^b	30.8 ^b
50		20.6 ^{ab}	40 ^a
100		22.9 ^a	26.6 ^{bc}
150		20.5 ^{ab}	21.9 ^c
N fertilizer sources			
0		20.1 ^a	30.3 ^a
23		19.8 ^a	29.7 ^a
<i>Rhizobium</i>		20.9 ^a	31.9 ^a
23+ <i>Rhizobium</i>		20.7 ^a	27.5 ^a
CV% LSD (5%)		25.8	23.5
		3.7	5

Means followed by the same letter (s) within the column are not significantly different at ($P \leq 0.05$). BS = bio-slurry

Table 5. Partial budget analysis.

Treatments		Parameters of economic analysis			
BS%	N sources	ADMY kg ha ⁻¹	TVC	NB ETB ha ⁻¹	MRR%
0	0	630.54	0	25221.6	
0	23	721.8	1000	26672	65.9
0	<i>Rhizobium</i>	774.09	1360	29603.6D	
0	23+ <i>Rhizobium</i>	743.76	2360	27390.4D	
50	0	755.28	6130	24081.2D	
50	23	1043.19	7130	34597.6	1051.6
50	<i>Rhizobium</i>	933.12	6290	31034.8	424.1
50	23+ <i>Rhizobium</i>	858.06	7290	27032.4D	
100	0	1046.25	11060	30790	99.6
100	23	842.76	12060	21650.4D	
100	<i>Rhizobium</i>	1087.83	11220	32293.2D	
100	23+ <i>Rhizobium</i>	825.21	12220	20788.4D	
150	0	735.21	15990	13418.4D	
150	23	946.8	16990	20882	746.3
150	<i>Rhizobium</i>	792.36	16150	15544.4	635.4
150	23+ <i>Rhizobium</i>	791.19	17150	14497.6D	

BS= percent of bio-slurry; N= nitrogen fertilizer sources; ADMY= Adjusted marketable yield; TVC=Total variable cost, NB = net benefit; D= dominated and MRR=Marginal rate of return

3.2. Partial Budget Analysis

The highest net benefit was achieved on plots that received a combined application of 50% ha⁻¹ bio slurry and 23kg ha⁻¹ N fertilizer, followed by 50% ha⁻¹ bio slurry with *Rhizobium* inoculation, which had the highest marginal rate of return of 1051.5%. (Table 5). Most treatments were un-dominated and could be acceptable for mung bean producers or small scale farmers in the study area except the dominated one's. Moreover, the highest net benefit of 34597.6 Birr ha⁻¹ was obtained from treatment of 50% ha⁻¹ bio-slurry with 23kg ha⁻¹ N fertilizer, followed by treatment 50% ha⁻¹ bio-slurry with *Rhizobium* inoculation recorded the second most promising result 31034.8 Birr ha⁻¹ net benefit. Therefore, the most

economical rate for producers with low cost and higher benefit was combined application of 50% ha⁻¹ bio-slurry with 23kg ha⁻¹ N fertilizer and/or bio-slurry with *Rhizobium* inoculation was next most economically feasible treatment.

4. Conclusion

The result of the present study was revealed that application of bio-slurry in combination with N fertilizers had significantly ($p < 0.05$) influenced phenological traits and yield of mung bean. Similar to this, applying bio-slurry caused a noticeable improvement in harvest index and pod number. 100 seed weight, above ground biological, grain, and straw yields were all positively impacted by the combined application of bio-slurry and N fertilizer.

For instance, application of 150% bio-slurry with 23kg N resulted in highest biological and straw yield whereas application of 100% bio-slurry with *Rhizobium* inoculation resulted in marked improvement of grain yield. The study also revealed that 50% bio-slurry applied in combination with 23 kg ha⁻¹ of N fertilizer had the highest net benefit and marginal rate of return. This was followed by 50% bio-slurry applied in combination with rhizobium inoculation.

Based on the results of a study, smallholder mung bean growers in the Hawassa area and other areas with similar agroecologies and socioeconomic conditions may benefit from using 50% bio slurry ha⁻¹ in addition to 23kg ha⁻¹ N fertilizer. However, verification of the result on farmers' field across season and areas could be required before wide use of this study to put the recommendation in firm ground.

Competing Interests

Authors have declared that no competing interests exist.

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