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Research article

Exploring farmer perceptions and evaluating the performance of mung bean (*Vigna radiata* L) varieties in Amhara region, Ethiopia

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ABSTRACT

The experiment is designed to evaluate the yield performance and profitability of mung bean varieties and to survey the innovation inclination of the farmers in the study area. The experiment was carried out in the potential environments of the North Shewa zone for two years during the main growing period. As experimental treatments, four mung bean cultivars of Rasa, NLV-1, Arkebe, and local varieties were used and evaluated across the four environments (two farmers' fields per each environment). The experimental plots were arranged in a simple random block design. The result of the combined analysis of variance revealed that there was highly significant variation ($p < 0.01$) of grain yield among the genotypes while the environments and genotype by environment interaction are found insignificant. The highest mean grain yield of 1430.6 kg ha^{-1} was obtained from the improved variety Rasa, which was selected first by the farmers followed by the variety NVL-1. The results also confirmed the existence of a strong and statistically significant association between the actual values rank and the farmers' preference rank for both grain and biomass yields ($R = .80$, $p < .001$). Also, the variety Rasa provides the highest (686.6%) marginal rate of return on investment. Therefore, by considering the results of the grain yield performance, farmers' selection, and the result of the partial budget analysis the variety Rasa was recommended for the study areas.

1. Introduction

Legumes play a significant role in the transformation of the global food system as they provide a plant-based source of dietary proteins and other essential micronutrients. Furthermore, legumes' capacity to fix atmospheric nitrogen is crucial for the sustainability of agriculture (Ali and Gupta 2012). Legumes are of crucial importance for rural households in Ethiopia as they cover almost thirteen percent of the cultivated area (Rashid et al., 2010; CSA 2016). Legumes are an essential facet of Ethiopian subsistence farming serving as a source of protein and cash income (Rashid et al., 2010). The most common pulses produced in Ethiopia include faba bean, haricot bean, grass pea, field pea, chickpea, lentils, and mung bean.

Mung bean *(Vigna radiata* L.*)* which is an annual herb of the legume family (MoA 2011) is one of the most important legume crops in Asia and is gaining popularity in other continents. Currently, mung bean is cultivated on more than 7.3 million hectares worldwide and global annual production is approximately 5.3 million tones (Nair et al., 2022). India and Myanmar are the greatest mung bean producer countries in the globe each supplying approximately 30%, followed by China (16%), and Indonesia (5%) (Nair et al., 2022). The report also revealed that mung bean grain yields are quite low on a global scale, averaging 0.73 t ha^{-1}, and there is great potential to develop better -performing varieties. In East and Southeast Asia, mung bean is commonly used to produce bean sprouts as well as to produce transparent noodles and mung bean paste, while in East Africa, it is more commonly consumed as a bean stew (Nair and Schreinemachers 2020). The crop is ascribed to a high nutritional value of 20.9–31.3 percent protein content (Anwar et al., 2007; Ali and Gupta 2012; Umata 2018) and the ability to fix nitrogen (Keatinge et al., 2011).

In Ethiopia, more than 327,788 smallholders have been involved in growing the crop (CSA, 2018). Mung bean is mostly grown in the Amhara region, especially in North Shewa and South Wollo zones. Amhara region particularly the North Shewa zone alone accounted for 48% of the national area coverage of the crop and 53.1% of the total volume of production in 2015/2016 (CSA 2016). The crop is also grown in some parts of Oromia, Southern Nations Nationalities, Peoples Region, and Benishangul Gumuz areas of the country. In the country, mung bean is less used

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domestically and is mainly grown by farmers for generating cash income. It plays a key role in the country as a source of foreign currency. Mung bean exports from Ethiopia have subsequently increased, owing to the Ethiopian Commodity Exchange's installation of mung beans as the sixth commodity since 2014 which in turn, has inspired many farmers to start producing the crop. Also, it serves as a rotational crop in the lowlands which have limited access to proper crop rotation on cereal crops (Hussain et al., 2012).

Despite efforts to improve the productivity of mung bean cultivars, the crop's yield remains low. Various biotic and abiotic variables could account for this. The most important determinants were the use of local low-yielding varieties and the lack of modern high-yielding cultivars (Alene et al., 2000; Dadi et al., 2005; Bishaw and Van Gastel 2008; Rashid et al., 2010), as well as the inadequate or non-application of inorganic fertilizers (Asfaw et al., 2011). The pod -boring weevil *Apion clavipes* Gerst is also economically an important pest of the mung beans, causing a yield loss of over 60 percent (Worku and Azerefegne 2019). The experiment is therefore intended to evaluate and analyze the productivity and profitability of the improved mung bean varieties, as well as to assess the variety preference characteristics of the farmers in the study area.

1.1. Conceptual framework

This experiment was carried out using Linn et al. (2010)'s scaling-up model, which had three main phases (Figure 1). The innovation phase is the first phase of the model and involves testing and verifying mung bean varieties. In the current study, the experiment, participatory evaluation of mung bean cultivars comprising of three cultivars namely, Rasa, Arkebe, NVL-1, and the local landrace as a control treatment falls under the innovation phase. During the learning phase, the experience with the design and implementation of the pilot is demonstrated and evaluated. The participating farmers learned from the researcher, through direct observation, and by evaluating the demonstration areas and each other as a group dynamic. Demonstration plots are a critical tool for extension promotion allowing the farmer to test and learn about the new technologies (Mbure and Clare 2017) and farmers tend to test the new technologies demonstrated in the demonstration sites that have better-expected benefits and a lower risk of failure (Pannell et al., 2006). In the scaling-up phase, the innovations or technologies demonstrated and tasted during the innovation and learning phases were brought to a large scaling-up. For the scaling-up phase, the selected improved Rasa variety with its recommended management practices was used for further scaling up on a wider scale. In turn, higher yield returns would improve farmers' thrust on the improved agricultural technologies and increase their investment in improved agricultural innovations. Higher-income households are better off investing in access to improved technologies.

Indeed, this experiment was conducted using the farmers' research and extension group (FREG) approach. FREG has several relative advantages, including enhancing the link between extension and research as a system, and increasing farmer capacity in technology testing (Zewdie 2008). FREG has also increased stakeholder participation and involvement in the technology review and dissemination process, paving the stage for the approach's institutionalization (Anandajayasekeram et al., 2008; Anchala 2008). Before implementing the experiment, farmers and experts were theoretically and practically trained in mung bean agronomy, seed production, post-harvest handling, and marketing. As the trial advanced, field days were organized and the farmers, development agents, professionals, and governmental authorities attended field days. Field days are significant in light of the fact that they give a gathering to communication between farmers and extension staff and among farmers themselves for sharing new information and experiences (Oswald 2005).

2. Methods

2.1. Characterization of the experimental sites

The experiment was conducted for two consecutive years, 2015 and 2016 in the lower parts of the North Shewa areas of Efratana Gidim, Kewot, Ensaro, and Merhabetie districts. The area is characterized by a unimodal rainfall pattern and receives an average annual rainfall ranging between 943 and 1199 mm while the annual average temperatures range between 17.6 and 23 °C. The altitude ranges between 1263 and 2164 meters above sea level. The production system in the study area is characterized as a mixed crop-livestock agricultural system. Sorghum, tef, and mung bean are among the major crops mostly grown in the area. Among pulse crops, land covered by mung beans is important. The crop is mainly grown for generating cash income. Cattle, sheep, and poultry are also important domestic animals kept by smallholder farmers and integrated with crop production.

2.2. Materials and research design

On-farm comparative evaluation of different improved mung bean varieties was done in the 2015 main growing season. The varieties used

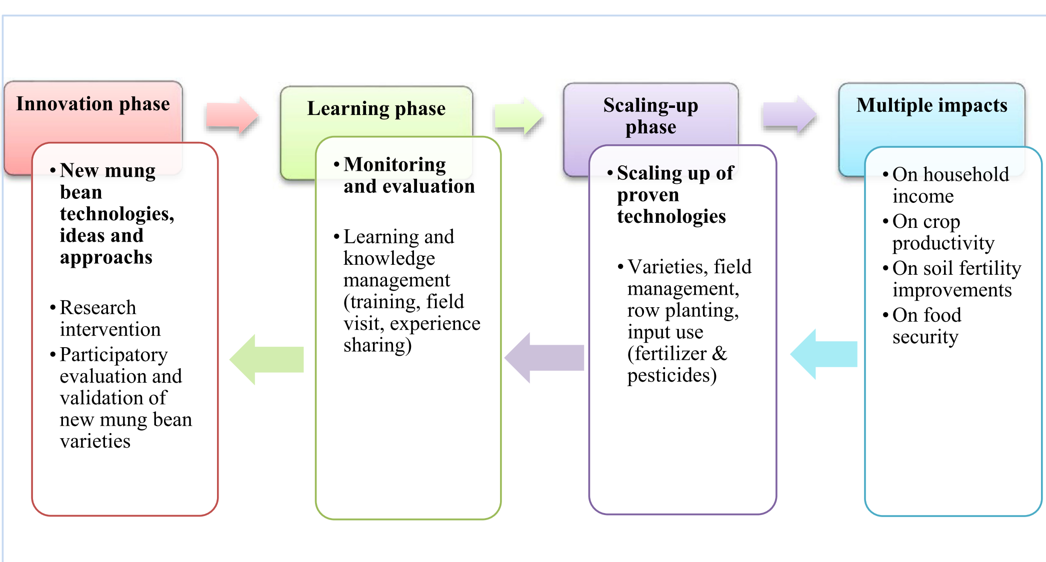

Figure 1. Conceptual framework of the experiment.

for this research during the first phase were Rasa, Arkebe, NVL-1, and the local landrace as a control treatment (Table 1). The experiment was set up in a simple random block design and evaluated across four environments (two farmers' fields per each environment). The plot area was 10 m by 10 m for each variety. The agronomic practices for the implementation of the research were using a spacing of 30 cm and 5 cm between rows and plants on the row, respectively. A seed rate of 38, 33.7, 24.7, and 25 kg ha^{-1} was applied for Rasa, NVL-1, Arkebe, and Shewa Robit local varieties, respectively, which were determined based on seed size. Phosphorous fertilizer was used at the rate of 46 kg P_2O_5 per hectare. The plantation was done from the third week of July to early August depending on the onset of rainfall.

During the second phase of the experiment, in 2016, the improved Rasa variety with its associated recommended agronomic management practices was used for wide-scale evaluation under farmers' conditions. The variety was selected based on farmers' preferences and yield performance during the first phase of the experiment. The required amount of seed was delivered to participant farmers free of payment. During the implementation period, approximately 2.2 tons of improved seed of the variety Rasa were delivered and more than 54 ha of land was covered. About 203 farmers were addressed directly through the dissemination of the improved mung bean seed. In this scaling-up phase, farmers were selected purposively based on farmland clustering and their interest in receiving the new technologies.

2.3. Data collection and analysis

Agronomic data such as yield and other parameters of the variables were collected on both a plant and plot basis to assess the performance of the varieties. Yield, morphological, and yield component data such as plant height, number of pods per plant, pod length, and biomass yield were collected both on a plant and plot basis. To estimate the yield data, five quadrants each having a 1 m by 1 m area were collected from each variety. Ten plants were selected at random from each variety at harvest, and the plant height, the number of pods per plant, and the pod length were measured and counted.

Farmer's research extension groups (FREGs) were formed to collect farmers' perceptions and preferences regarding the introduced improved mung bean varieties. About 94 farmers took part in this experiment evaluation during the first stage of the experiment. Before evaluating the experimental sites, the participant farmers were first to identify and prioritize their variety of selection traits. Finally, the farmers were asked to rank each of the cultivars as per their preference based on the individual assessment criteria. Farmers' choice of a particular mung bean variety was influenced by several attributes like its inherent resistance to disease, grain and biomass yield, number of pods, physiological maturity, and seed size. Also, during the first phase of the experiment, the participant farmers were interviewed to identify and prioritize mung bean production constraints in the study area. The result was analyzed using simple descriptive statistics of frequency and presented in a bar chart.

Descriptive statistical methods were then used to analyze the agronomic data. Linear mixed effect models (LMMs) were used to estimate the mean differences in yield and yield-related attributes among the varieties. Linear mixed models are an extension of simple linear models that can take into account both fixed and random effects. LMMs are especially useful when there is non-independence in the data, such as that caused by a hierarchical structure (West et al., 2007). A fixed effect does not change. Random effects, on the other hand, are parameters that are themselves random variables. In the current study, the tested varieties were considered the fixed factor, while the environment (farmers' fields and districts) was considered the random factor or blocks because the farmer's soil properties, cultural practices, and even the previous crop may differ from farmer to farmer.

A combined analysis of variance was performed from the mean data of all environments to detect the presence of GEI and to partition the variation due to genotype, environment, and genotype × environment interaction. The R statistical software version 4.2.0 was used to analyze the combined mean of the different agronomic traits of the mung bean genotypes and AMMI analysis (R Core Team, 2022).

Furthermore, the Kruskal-Wallis test was used to test the mean rank difference assigned by the farmers. The analysis of variance was performed according to the standard method of Gomez and Gomez (1984).

To analyze farmers' preferences and the rank assigned for each of the tested varieties, the Rank Based Quotient (RBQ) analysis was employed (Sabarathnam 1988). The RBQ was calculated using the following mathematical formula (Eq. (1)).

$$RBQ = \frac{\sum fi\,(n+1-i)}{N^{*}n}{*}100 \tag{1}$$

Where,

fi = Frequency of farmers for the ith rank of the attribute,
N = No. of farmers contacted for factor identification,
n = Maximum no. of ranks given for various factors.
i = Rank of the attributes.

To see the degree of associations between the actual values of measured variety attributes and varieties' rank given by the farmers' Spearman's rank correlation was used per the following equation (Eq. (2))

$$r_s = 1 - \frac{6\sum d^2}{n(n^2-1)} \tag{2}$$

Where r_s = Spearman's rank correlation coefficient; d = difference in the ranks assigned to the same individual or phenomenon and n = number of individuals or phenomena ranked.

A partial budget analysis was used to determine the financial gains and economic viability of using improved crop varieties. The analysis was done using the market prices for inputs at sowing and outputs at harvest. The average grain yield and straw yield were reduced by 10 percent to represent yield under operational conditions and to avoid unexpected yield losses. The marginal rate of return (MRR) was determined using Eq. (3) to estimate the increased net return resulting from a change in unit cost.

Table 1. Description of the varieties used for the experiment.

Variety	Year released	Research Center	Altitude (m asl)	Rainfall (mm)	Plant height (cm)	Growth habit	Seed color	Days to maturity	Crop disease reaction	Yield (kg ha^{-1})
NVL-1	2014	Melkasa	450–1670	300–750	40–50	Determinate	Shiny green	60–70	Resistant/tolerant to major disease	750–1500
Arkebe	2014	Humera	600–1000	400–800	38–58	Erect	Green	60–68	—	1955–2526
Rasa	2011	Melkasa	900–1670	350–550	33	Determinate bush	Green	65–80	Resistant/tolerant to major disease	800–1500
Shewarobit local	—	—	—	—	—	—	—	—	—	—

Source: (MoA 2011; MoA 2014)

$$MRR = \frac{\Delta NB}{\Delta TVC} \times 100 \quad (3)$$

Where ΔNB is changing in net benefit compared with the unsprayed farmers' practice and.

ΔTVC is a change in variable input cost compared with control.

Besides, technological gaps, extension gaps, and the technological index between the farmer practice and the improved technologies were calculated using the following formulas (from Eqs. (4) and (5), in its order) as suggested by Samui et al. (2000).

$$TG = Y_i - Y_j \quad (4)$$

$$EG = PY_i - Y_i \quad (5)$$

$$TI = \frac{TG}{PY_i} \times 100 \quad (6)$$

Where: Y_i: current average yield of the improved Rasa variety under farmers' condition, Y_j: average yield of the local variety, TG: technological gap, EG: extension gap, PY_i: potential yield of the improved technology (researcher managed fields)[1], TI: technological index.

3. Results

3.1. Yield and yield component parameters

The combined mean values of the tested varieties across all the environments were summarized in Figure 2. The variety Rasa had the highest combined mean seed yield with 1430.6 kg ha^{-1}, followed by the local variety (1256.5 kg ha^{-1}) and this variation might be due to the genetic potential of the genotypes (Figure 2e). The varieties Arkebe and NVL-1, on the other hand, had the lowest mean seed yield. The results showed that the Rasa variety had a yield advantage of up to 13.9% over the local variety, though this difference was not statistically significant. The Rasa variety yielded significantly higher and nearly twice as much as the NVL-1 and Arkebe varieties. The result of the linear mixed effect model revealed that the introduced varieties varied significantly for seed yield at $p < 0.001$ (Table 2). The coefficients for the varieties local, NVL-1, and Rasa were 572.46, 210.42, and 746.57, respectively, indicating that the average seed yield of the varieties local, NVL-1, and Rasa were 572.46, 210.42, and 746.57 higher than the mean grain yield of the variety Arkebe. The 'lmer' function automatically coded the variety Arkebe as the reference category because, like most R functions, the category with the lower numeric value (or alphabetically first letter) is coded as the reference category. The current result was found consistent with Rasul et al. (2012), Adhiena et al. (2015), Umata (2018), and Kassa et al. (2018) who reported that mung bean cultivars had a significant effect on seed yield.

The genotypes examined showed a highly significant variation in the biomass yield at the $p < 0.01$ probability level (Table 2). As presented in Figure 2(e) the higher biomass yield (approximately 4215 kg ha^{-1}) was achieved from the improved Rasa variety, followed by the local variety (4094 kg ha^{-1}). The correspondingly lower biomass yields (3007 and 3333 kg ha^{-1}, respectively), however, were obtained by the Arkebe and NVL-1 varieties. The coefficients for the varieties local, NVL-1, and Rasa were 1086.88, 881.52, and 1207.933, respectively, indicating that the mean biomass yield of the varieties local, NVL-1, and Rasa were 1086.88, 881.52, and 1207.933 higher than the mean biomass yield of the Arkebe variety. Similarly, Adhiena et al. (2015) found that mung bean cultivars had a significant influence on the average biomass yield.

Pod length and hundred seed weight are important morphological traits that positively contribute to seed and biomass yields in leguminous plants. The linear mixed effect model result in Table 2 revealed that genotypes showed a significant difference in pod length, and hundred seed weight at $p < 0.001$. The mean value of genotypes in pod length ranged from 7.71 cm to 9.99 cm (Figure 2c). Significantly, the longest pod length was recorded from the variety NVL-1 which, however, did not statistically different from the Rasa variety; whereas, the lowest pod length of 7.71 cm was shown by the local variety. The highest hundred seed weight of 5.23 g was gained from the variety of Rasa followed by the NVL_1 variety with an average hundred seed weight of 4.97 g (Figure 2d).

On the other hand, the numbers of pods and plant height (presented in Figures 2a and 2b) showed statistically a non-significant difference at any acceptable probability level (Table 2). Contrary to this result, the findings of Ahmad et al. (2015), Gereziher et al. (2017), and Rasul et al. (2012) reported that mung bean cultivars had a significant influence on the number of pods and pod length.

3.2. AMMI model analysis

Table 3 shows the additive main effects and multiplicative interaction analysis (AMMI) for yield and yield-related traits of the four mung bean genotypes tested across four environments (two farmers' fields per district). The genotypes (G) were significant ($P < 0.01$) for pod length, hundred seed weight, and seed yield, while, significant ($p < 0.05$) for biomass yield. Similarly, the environment (E) had a significant ($p < 0.01$) effect on the number of seeds, while it affects the number of pods, pod length, and hundred seed weight at the $p < 0.05$ probability level. Similar findings were reported by Asfaw et al. (2012); Baraki et al. (2020); and Yoseph et al. (2022), who found that genotype had a significant ($P < 0.01$) effect on seed yield of mung bean genotypes. On the other hand, The AMMI analysis of variance for all measured traits showed that the genotype-by-environment interaction (GEI) effect was non-significant which revealed the variation of the mung bean mean seed yield was affected by the inherent variability of the genotypes. This indicated that the ranking of the genotypes was not changing from environment to environment confirming the existence of stable genotypes over all environments in this experiment. In contrast to the current study, Asfaw et al. (2012); Baraki et al. (2020); and Yoseph et al. (2022) reported a significant environment and genotype by environment interaction in grain yield of mung bean genotypes evaluated in different environments.

3.3. Farmer preference and selection of varieties

To gain a better understanding of farmers' desires for numerous mung bean traits, they were asked to rank some traits of varieties based on their perceptions, as shown in Figure 3. Disease resistance which scored 100 percent was the most preferred trait as perceived by the farmers, while yield-related attributes of seed size, pod length, and the number of pods per plant were ranked second, third and fourth in its order. Resistance to diseases is among the most essential criteria for farmers to consider when evaluating varieties. Seed size was the second main aspect for farmers when selecting mung bean cultivars, as it was strongly related to market price. Because the crop is an export product, cultivars with a larger grain size range were indeed widely preferred and received a higher price. Similarly, physiological maturity and residual straw yields were key attributes considered by farmers when selecting mung bean varieties. Farmers favored an early maturing, drought-tolerant variety because the study locations were lowlands that typically experience moisture stress during the onset and post-flowering crop growth stages.

The comparison result thus revealed that under all viewpoints the variety Rasa was selected first followed by the variety NVL-1 (Figure 4). The participant farmers agreed that the variety Rasa was performed well,

[1] Improved technologies in the current study refers to the varieties in combination with the recommended agronomic management practices such as, row planting, spacing, timely sowing, using the recommended amount of inorganic fertilizer and seed.

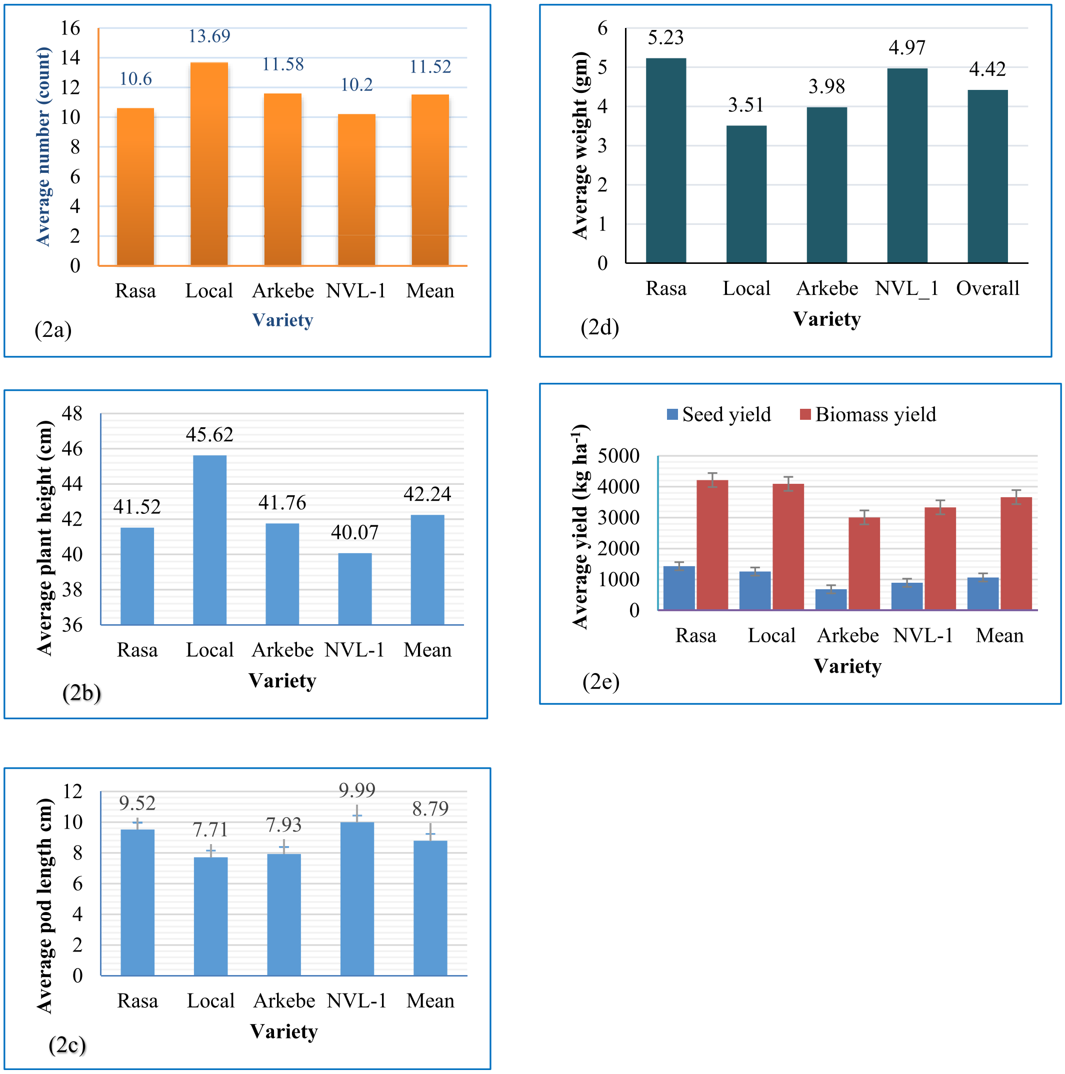

Figure 2. The combined mean values of different morphological, yield, and yield-related parameters across all the tested environments (2a) the average number of pods per plant (count); (2b) the average plant height measured in cm; (2c) the average pod length measured in cm; (2d) average weight of the tested varieties across all the environment measured in gm; (2e) the combined average seed and biomass yield measured in kg ha^{-1}.

adapted to the area; relatively early matured; moderately resistant to disease; had a higher number of pods and longer pods; larger in grain size, and is, a high yielder variety compared to the other varieties. The varieties, NVL-1, and the local cultivar hold the second and third positions, respectively. According to the farmer's evaluation, the Kruskal-Wallis Test in Table 4 showed that the tested varieties were highly significantly ($p < .001$) varied in terms of disease resistance, number of pods, pod length, seed size, physiological maturity, and straw yield. This result appears to corroborate the findings of (Kassa et al., 2018), who found that the Rasa variety was chosen first by farmers in the same locality. Similarly, Umata (2018) found that the Rasa cultivar was resistant to Cercospora leaf spot disease.

3.4. The correlation coefficient between farmers' selection and the actual value of measured agronomic attributes

Spearman's rank-order correlation was used to determine the correlation between farmers' preference rating and the actual value of the agronomic parameters of the introduced varieties. The findings revealed a significant and positive relationship between farmers' preference rank and the actual value of measured grain and biomass yield of the varieties. Farmers' selection rank and actual value rating for grain and biomass yield were statistically significant ($rs = .80$, p.001) (Table 5). According to this finding, farmer involvement mostly in the development process of new agricultural technologies was essential for enhancing technology adoption and diffusion. The result is in line with the reports from Fentie and Jemberu (2012); Zerihun et al. (2012); Ferede and Demsie (2020); Mihiretu and Abebaw (2020).

3.5. Economic feasibility of the tested varieties

According to the results of the present experiment's economic analysis, the variety Rasa provided the highest net benefit (Table 6). The Rasa variety had the highest net benefit (29395.5 ETB ha^{-1}) followed by the local variety with a net benefit of 26271.5 ETB ha^{-1}. On the other hand, both the varieties, Arkebe and NVL-1 returned the lowest gross field return. The result from the dominance analysis revealed that the varieties of Arkebe and NVL-1 were found dominated (assigned “D”) by the other two varieties, hence, are eliminated from further steps of the economic analysis. The result showed that only the variety Rasa had an acceptable MRR value of greater than 100%. For each additional 1 ETB investment for the variety of Rasa, the farmers can expect 1 ETB and obtain an

Table 2. The Linear mixed effect model results in the mean differences of the agronomic data.

	Estimate values of the agronomic and morphological traits						
	No. of pods per plant	No. of seed per pod	Plant height (cm)	Pod length (cm)	Hundred seed weight (gm)	Grain Yield (kg ha^{-1})	Biomass yield (kg ha^{-1})
Fixed effects (Variety): Estimate							
Local	2.11 (1.14)	0.11 (0.54)	3.87 (3.46)	-0.22 (0.37)	-0.47 (0.17)**	572.46 (106.54)***	1086.88 (376.24)**
NVL-1	-1.38 (1.14)	0.6 (0.54)	-5.02 (3.46)	2.07 (0.37)***	0.99 (0.17)***	210.42 (106.54)*	881.52 (376.24)*
Rasa	-0.98 (1.14)	0.18 (0.54)	-0.23 (3.46)	1.59 (0.37)***	1.26 (0.17)***	746.57 (106.54)***	1207.933 (376.24)**
Intercept	11.55 (1.27)***	10.27 (0.92)***	41.45 (3.09)***	7.91 (0.50)***	3.99 (0.17)***	683.92 (113.55)***	3059.42 (591.29)***
Random effects (environment and farmers' fields nested within each environment): Variance							
Farmers' fields: Environment (Intercept)	1.048	0.188	0.00	0.087	0.003	27139	0.000
Environment (Intercept)	3.334	2.6937	14.23	0.686	0.058	16516	1113307
Residual	5.891	1.303	53.83	0.603	0.128	51081	637000
Observations	36	36	36	36	36	36	36
Log Likelihood	-82.37	-59.65	-115.379	-46.53	-19.59	-228.792	-267.829
Akaike Inf. Crit.	178.75	133.30	244.758	107.06	53.18	471.584	549.657
Bayesian Inf. Crit.	189.83	144.38	255.843	118.15	64.26	482.669	560.742

Note: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$ and the values in the parenthesis indicate the standard error.

Table 3. Analysis of variance table for Additive main effects and multiplicative interaction (using AMMI model) for yield and yield -related traits of mung bean varieties across four environments (districts).

Sources of variation	DF	Mean square						
		No. of pods per plant	No. of seed per pod	Plant height (cm)	Pod length (cm)	Hundred seed weight (gm)	Grain Yield (kg ha^{-1})	Biomass yield (kg ha^{-1})
Total	31	10.42	3.6	77.8	2.04	0.68	182671	1707642
Genotype (G)	3	14 ^{ns}	5.7^{ns}	116^{ns}	8.9**	5.21**	1067755**	2828455*
Environment (E)	3	37*	0.25**	190^{ns}	6.5*	0.59*	332466^{ns}	9193488**
Interactions (GEI)	9	6.8^{ns}	1.3^{ns}	78^{ns}	0.61^{ns}	0.17^{ns}	47224^{ns}	862218^{ns}
IPCA1	5	7.8^{ns}	1.9^{ns}	138^{ns}	0.68^{ns}	0.20^{ns}	80381^{ns}	1320499^{ns}
IPCA2	3	21^{ns}	0.57^{ns}	4.6^{ns}	0.63^{ns}	0.19^{ns}	7388^{ns}	385278^{ns}
Residuals	1	1	0.56	0.95	0.19	0.0001	948	1628
Error	12	5.4	1.5	47	0.6	0.11	46116	598828

Note: ns, *, **, = Non-significant, significant at $p \leq 0.05$ and significant at $P \leq 0.01$ respectively, DF = Degree of freedom, GEI = Genotype by Environment Interaction, IPCA = Principal Component Axis for Interaction.

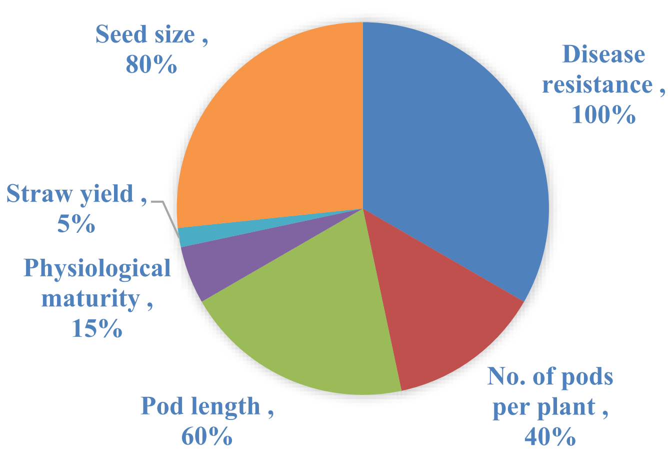

Figure 3. Farmers' preferred traits and their degree of contribution to mung bean variety selection.

additional return of approximately 6.9 ETB. When there are two or more treatments, the treatments with MRR greater than 100% are chosen for recommendation (CIMMYT 1988).

3.6. The yield performance, technological gap, extension gap, and technological index under farmers' condition

Under farmer's conditions, in the 2016 growing season, the average yield obtained from the improved Rasa variety and farmers' local cultivars was 1370.8 and 1007.3 kg ha^{-1}, respectively (Table 7). In comparison to the local variety, the improved Rasa variety exhibited a yield advantage of 36.1 percent. The improved variety was highly demanded by farmers in the areas because of its higher biomass and grain yield and its larger seed size than the local variety. The result seems consistent with the results of the experiment conducted in the preceding year.

Table 7 depicts data on the technology gap, extension gap, and technological index. The technological gap is the difference between the

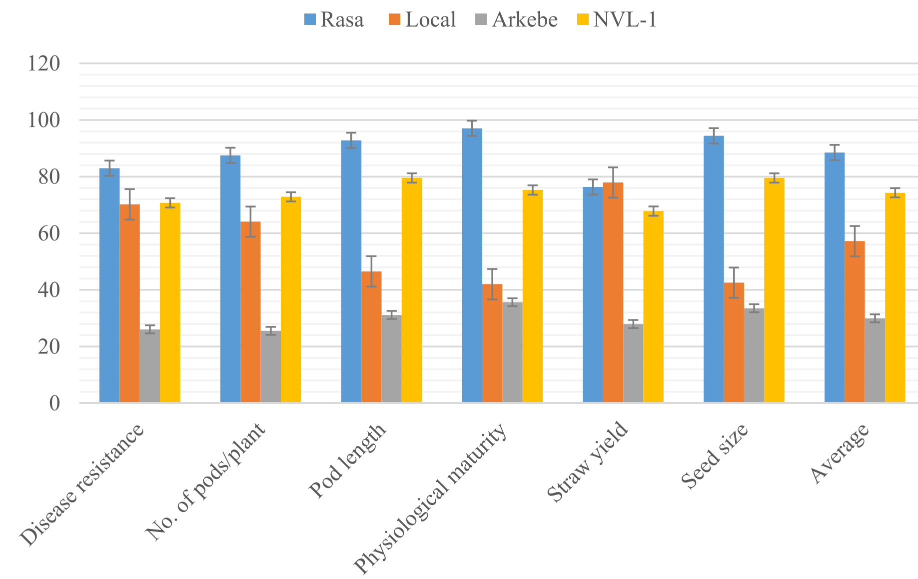

Figure 4. Summary of farmers' preference ranking of the varieties (RBQ value in %).

Table 4. The Kruskal-Wallis Test of the selected farmer's evaluation variety attributes.

Farmer's variety selection parameters	Variety	Mean Rank	Chi-Square	Asymp. Sig.
Disease resistance	Rasa	265.5	224.932***	.0001
	Local	217.5		
	Arkebe	51.5		
	NVL-1	219.5		
Number of pods per plant	Rasa	282.5	252.213***	.0001
	Local	194.5		
	Arkebe	49.5		
	NVL-1	227.5		
Pod length	Rasa	302.5	294.822***	.0001
	Local	129.5		
	Arkebe	69.5		
	NVL-1	252.5		
Physiological maturity (earliness)	Rasa	248.5	228.652***	.0001
	Local	83.5		
	Arkebe	74.5		
	NVL-1	187.5		
Straw yield	Rasa	243.5	207.769***	.0001
	Local	246.5		
	Arkebe	55.5		
	NLV1	208.5		
Seed size (largeness)	Rasa	308.5	305.585***	.0001
	Local	113.5		
	Arkebe	79.5		
	NVL-1	252.5		

***The mean difference is significant at the 0.001 level.

improved variety's potential yield and demonstration yield when using the recommended management practices. According to the findings, the technological gap in the research area was found to be 363.5 kg ha^{-1}. Consistent with this the technology gap was found to be 367.8 kg ha^{-1} when estimated using the national average productivity of mung beans during that same period. The extension gap, which was determined as the difference between the yield of improved production technologies and the farmer's yield, on the other hand, was 129.2 kg ha^{-1}. The level of feasibility of the demonstrated innovation in the farmer's field is indicated by the technology index. The lower the value of the technology index, the more the technology is feasible. The research area had a relatively high technology index of 24.2 percent in mung bean production. Similar results were reported by Mihiretu and Abebaw (2020).

Table 5. Spearman's Rank Correlation coefficient between the actual measured yield parameters and farmers' rank.

Ranking parameters	The correlation coefficient (rs)	Sig.
Actual grain yield rank-Rank is given by farmers	0.8***	0.000
Actual biomass yield rank-Rank is given by farmers	0.8***	0.000

***Correlation is significant at the 0.01 level (2-tailed).

3.7. Constraints of mung bean production in the study areas

Mung bean is mainly grown by farmers because the crop holds the key as a potential rotational crop, has high market value, easily grows with a few available soil moistures with little or no land competing in the bulge[2], has a short maturity period, is an alternative option of animal feed and can be easily grown with a minimum labor requirement. Although mung bean is a cash crop in the study areas, its production is confronted with many constraints (Figure 5). A pest infestation, inaccessibility to pesticides, and improved seed were the most significant factors limiting mung bean production in the research region. More than 94 percent of the participants mentioned that pod -boring weevil *Apion clavipes* are the most important constraint of mung bean production in the study area. Besides that, over 80 percent of the participants reported a lack of access to high-quality pesticides at a reasonable cost also a significant challenge for farmers. About 62.3, 49.7, and 43.4 percent of the farmers have also suffered from a lack of availability to high-yielding varieties, a poor sale price during harvesting, price volatility along through buyers and time, and postharvest loss due to weevils, respectively.

[2] The *bulge* is the short rainy season, which extends from February to May. Adequate rains in March may have helped farmers to complete bulge (minor) season planting of short cycle crops, such as mung bean. In bulge dépendent areas particularly in the low lands of the study area farmers usually sow mung bean in May and harvested in June.

Table 6. The economic feasibility analysis of the demonstrated varieties.

Cost and benefit components	Varieties			
	Local	Rasa	Arkebe	NVL-1
Gross farm gate benefits				
Adjusted grain yield (kg ha^{-1})	1130.83	1287.55	615.64	804.99
Adjusted straw yield (kg ha^{-1})	2369.53	2316.29	1955.42	2344.77
Average grain selling price (ETB kg^{-1})	23.00	23.00	23.00	23.00
Average grain selling price (ETB kg^{-1})	0.48	0.48	0.48	0.48
Gross field benefit (ETB ha^{-1})	27146.46	30725.47	15098.32	19640.26
Seed cost (ETB ha^{-1})	875	1330	864.5	1179.5
Variable input cost				
Amount of seed used (kg ha^{-1})	25	38	24.7	33.7
Seed price (ETB kg^{-1})	35.00	35.00	35.00	35.00
Total costs that vary (ETB ha^{-1})	875	1330	864.5	1179.5
Net benefit (ETB ha^{-1})	26271.46	29395.47	14233.82	18460.76
MRR (%)	-	686.6	D	D

Table 7. Effect of improved Rasa variety on the technology gap, extension gap, and technology index.

Variety	Average grain yield kg ha^{-1}	Technological gap (kg ha^{-1})	Extension gap (kg ha^{-1})	Technological index (%)
Rasa	1370.8	363.5	129.2	24.23
Local	1007.3			
Rasa[a]	1500.0	367.8	129.2	24.52
National average productivity	1003.0[b]			

[a] The maximum potential yield (PYi) of the improved Rasa variety under research field was 1500 kg ha^{-1} (MoA, 2011).

[b] The national average productivity of mung bean during the same growing season was 1003.0 kg ha^{-1} (CSA 2016).

4. Discussions

The issue of farmers engaging in agricultural research has recently received a great deal of attention. One of the arguments is that a participatory approach started with existing local indigenous knowledge and skills and therefore is founded around a system that allows farmers to manage and control research fields (Suvedi et al., 2017; Abbeam et al., 2018). Farmers' participation would significantly raise the relevance of research findings as well as the acceptability of the technology developed. Agricultural innovation systems necessitate a strong link between research and extension organizations, as well as the numerous actors involved in the agricultural sector as a whole (Teklewold and Gulti 2016). Several studies show that farmers that participate in on-farm demonstrations, farmer research groups, and field day gatherings seem to be more probably adopting improved agricultural technologies than those who do not (Dadi et al., 2005; Asfaw et al., 2011; Krishnan and Patnam 2014; Verkaart et al., 2017; Chandio and Yuansheng 2018).

The result from the estimation of the extension gap, the technological gap, and the technology index showed that using the variety Rasa in combination with the recommended agronomic practices resulted in a higher technology gap, higher extension gap, and also higher technological index. The result appears to be consistent with the reports of Alemu and Bishaw's (2019) findings, which found that the estimated national average yield gap is greater than 49.2%. These yield gap figures signify the capacity of bridging the yield gaps through improved access to varieties and quality seeds along with associated recommended agronomic practices and extension services on availing the required information. The technology gap could be narrowed down through the application of improved mung bean technologies as per the recommendation. The farmers' decisions to adopt new agricultural technologies were influenced by the dynamic interplay between traits of the technology and a range of circumstances (Loevinsohn et al., 2012; Biagini et al., 2014), as well as largely relies on the accessibility of improved seeds (Abera 2008; ICARDA 2008; Asfaw et al., 2012). To a large extent, the quality of the seeds used determines the responses of most other factors of production. Improved seed is amongst the most crucial innovation (Messrs et al. 2007), and has contributed to a 50% improvement in crop productivity (ATA 2011). Besides that, intense measures are necessary to educate and encourage producers to increase the application of modern production technologies to narrow down technological and extension gaps. According to Chandio and Yuansheng (2018), Krishnan and Patnam (2014), and Verkaart et al. (2017), the technology transfer initiatives delivered by extension agents help to pass on important information to farmers. In Ethiopia, currently, about 41,633.20 hectares of land were covered by mung beans and about 325,788 farmers were engaged in growing the crop in the 2017/18 growing season (CSA, 2018). Consider reducing technological extension gaps by 50 percent by improving access to improved technologies and providing proper advisory services to determine the national implications. The result calculated using the average technological gap showed that the 50 percent increase in mung bean production in the target study areas should result

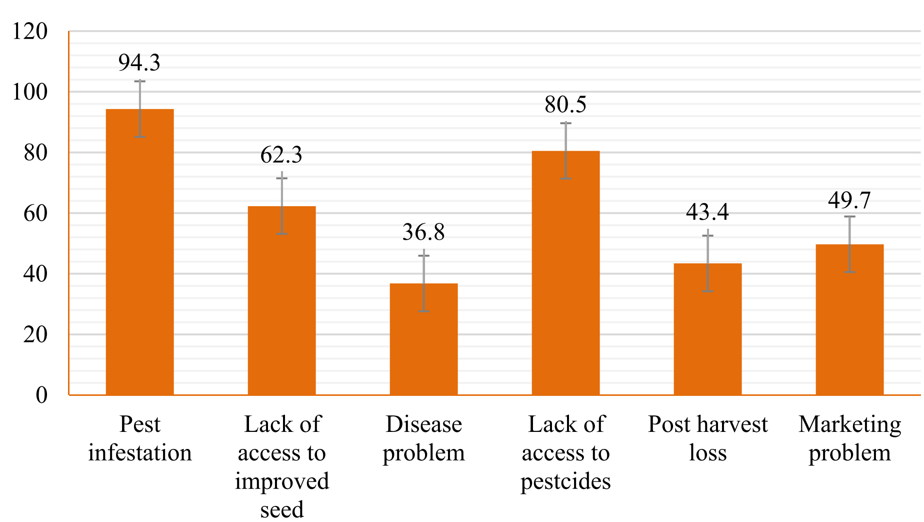

Figure 5. Major constraints of mung bean production in the study area (%).

in an estimated increase of 181.8 kg ha^{-1} and 14.7% of the national volume of mung bean production. This result did appear to corroborate Benson et al. (2018)'s findings.

Several biotic and abiotic issues impacted mung bean productive capacity in the region. The pod -boring weevil *Apion clavipes* are an economically significant pest in the study area. Worku and Azerefegne (2019) reported that it can cause a yield loss of over 60 percent. What's more, farmers are oblivious to how much and what pesticides should indeed be applied. They were purchased at a high price from Agro-chemical traders, but they have no notion which pesticide is appropriate. However, previous studies have indicated that Deltamethrin and Lambda-cyhalothrin are perhaps the most efficacious insecticides for reducing the pest's impact to a minimal level (Worku and Azerefegne 2019). After the pod boring weevil *Apion clavipes*, important diseases including yellow mosaic virus, dry root rot, Cercospora leaf spot (CLS), and anthracnose continue to be a significant bottleneck of green gram production in the globe and notably in the study region (Umata, 2018; Nair et al., 2019). According to Singh (1980), yield reductions in mung beans owing to yellow mosaic virus disease ranged from 76 to 100 percent. There has also been a shortage of access to improved seeds, low prices for harvest, marketing problems with low levels of local demand, inadequate market chain, insufficient marketing information, pricing impulsive behavior, and weevil after a damaged harvest (Mohammed et al., 2017).

5. Conclusions

Mung bean is among the important pulses cultivated in different agroecological zones of the world and Ethiopia. However, the crop's productivity is constrained by a lack of adaptable varieties as well as biotic and abiotic factors. This field trial was conducted to evaluate the yield performance and profitability of improved mung bean varieties. The result from the combined analysis of variance shows that only genotypes were significant while, the environment and their interaction were nonsignificant for seed yield, confirming the existence of stable genotypes across environments in this experiment. The highest average seed yield of 1430.6 kg ha^{-1} was obtained from the Rasa variety. When compared to the local variety, the variety had a yield privilege of approximately 36.1 percent.

Farmers demonstrated a multifaceted preference for variety-specific attributes. Grain yield, disease resistance, larger seed size, pod length, number of pods, and early maturity were the most farmer-preferred traits. The results of the farmer ranks revealed that the Rasa variety was chosen first followed by NVL-1. The Spearman correlation results also confirmed strong, positive, and significant correlations between farmers' preference rating and the true value of recorded grain and biomass yield of the varieties. Furthermore, the highest marginal rate of return (686.6 percent) had also been derived from the same cultivar.

Therefore, by considering the findings of the average seed yield, farmer selection, the economic feasibility analysis, and the AMMI analysis result, the variety Rasa was recommended for the tested environments. The results of the present study also suggested that farmers' perceptions of variety needs and requirements, should be considered as a preliminary guide in the breeding of mung beans to boost the adoption of new varieties and the production potential of the crop.

Declarations

Author contribution statement

Yehuala Kassa, MSc: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper. Amsalu Abie, MSc (Candidate); Dejene Mamo, MSc; Teklemariam Ayele, BSc: Performed the experiments.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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