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Efficiency of Indigenous Soil Rhizobia on Growth Performance of the Common Bean (*Phaseolus vulgaris* L.)

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ABSTRACT

Phaseolus vulgaris L (Common bean) is an essential pulse crop for smallholder farmers in sub-Saharan African countries like Ethiopia. However, crop growth, development, and production are limited by poor soil fertility due to poor soil management practices. Our study evaluated the effect of indigenous rhizobia inoculants on common bean root nodulation, and growth on the *Gofta*, a local common bean variety (G-2816) in Fedis District, Eastern Oromia Region in Ethiopia. The study, conducted at Haramaya University, isolated and characterised the rhizobia from the root nodule of a common bean. A total of five bacterial isolates were isolated from the root nodules of the Gofta on YEMA media after four days of incubation. All five isolates were identified as rhizobia based on authentication tests (Congo red test and catalase test). Based on morphological properties, all the isolates were round and slimy white with raised elevation and smooth surfaces indicating rhizobia. All the isolates were pink in colour in Gram's reaction and were rod-shaped indicating gram-negative bacteria. The ability of isolates to utilize alternative sources of carbon was assessed. Mannitol was found to be the best source followed by maltose, with sucrose being the least favoured for the selected isolates. Different tolerance levels were noticed for stress conditions: high or low pH; salt concentration; and temperature above ideal levels. The five isolates were able to grow in acidic media of pH 5.5, while three isolates (HURFB1, HURFN2, and HURFM3) showed weak growth in alkaline conditions of pH 9.5. However, all five isolates were able to grow well at salt concentrations of 2% and 3% NaCl, but reduced growth was noted for 3%; only one isolate (HURFB1) was tolerant to 5% salt concentration. At 45 °C temperature, only 20% of the isolates experienced good growth. The isolates were assessed for symbiotic effectiveness (SE) through greenhouse experiments. All isolates were symbiotically effective(SE) with 80% of the isolates recording a SE of >80% with the remaining 20% exhibiting a SE of 51 to 80%. They produced root nodules and the effects on nitrogen fixation were noticed by changes in growth and development features which revealed efficiency of rhizobia isolated. Common beans inoculated by native rhizobia exhibited better performance than those fed with nitrogen fertilizer. Among the selected five isolates, HURFM3 isolate showed highest symbiotic efficiency (187%) when compared with the nitrogen fed plants. In conclusion, this study confirmed the presence of indigenous rhizobia in Ethiopian soil, especially in the study site, which have the ability to nodulate the common bean more effectively and enhance crop growth and development.

Key words: **indigenous rhizobia, common bean, symbiotic efficiency**

INTRODUCTION

Rhizobium inoculation is an ecological and economical bio-based technology to improve soil fertility through the accumulation of nitrogen by the biological fixation process. The *Rhizobium* also improves legume plant growth and development. Conversely, rhizobia inoculants, especially some of the commercial rhizobial strains are unsuccessful in responding to agro-environmental conditions different from their original habitat. In line with this, Argaw and Tsigie (2015) studied the ability of the indigenous rhizobial isolates to begin optimistic interactions with other microorganisms and their eco-friendly conditions over the commercial isolates.

In their study, Eliah-Malugu (2021) found indigenous rhizobial strains to show a positive effect on diverse leguminous crop plants including cowpeas, common beans, and soybeans which supplement grain production in their country. They found them to be interconnected to the indigenous growth-promoting rhizobia qualities,were well-adapted to soil and actively associated with specific crop plants. Plant genotype also has an influence on the efficacy of nitrogen fixation in rhizobia. The harmonious relationship between the *Rhizobium* and the host plant is very significant as it has a role in evasion of the negative or neutral effects of plant and microbial collaboration (Yadav and Verma 2014). Hence, the practice of a well-matched plant rhizobia relationship may lead to superior host plant nutrition, important to plant growth, development, and yield. Hence the need for this study to explore rhizobia isolates and their responses to the association with the host plant in relation to growth and yield, predominantly in adverse environmental conditions.

The common bean is one of the important cereal crops in Ethiopiathat has has been cultivated by indigenous farmers for years (Argaw and Tsigie 2015). This leguminous plant is important in terms of providing soil nutrition as well assuring the safety of food. However, in Ethiopia, this crop production is correspondingly less compared to other African countries (Mabhaudhi *et al*. 2017). In emerging countries like Ethiopia, agricultural strategies have been inspired by cultivating the production of crops that have an economic status in domestic and global markets. There is therefore a need to discover sustainable ways and commercial practices for the production of bio-fertilizers through indigenous rhizobacterial inoculants. Enrichment of soil nutrition is a dynamic feature of increasing production to meet increasing food demand. In Ethiopia, the growth of the common bean depends on the biological nitrogen fixation process to provide soil nutrition (Augusto *et al*. 2013). The practice of indigenous *Rhizobium* stimulating an active relationship symbiotically with their host plant is a prospective ecological practice to improve its production in a developing country like Ethiopia. Therefore, this research assumes that indigenous rhizobia inhabiting the smallholder farms of Ethiopia have capabilities to fix nitrogen, and inoculation of indigenous rhizobia in the common bean that would increase growth and production. Hence, this investigation aimed to explore active indigenous *Rhizobium* isolates and identify their consequence on the nodulation, growth and yield of the common bean.

MATERIALS AND METHODS

Collection of soil samples

Five kilograms of the soil samples were collected from five villages namely Bunicch, Nunnu, Meeta, Hasswn, and Genne in the Fedis district in Eastern Oromia region, Ethiopia. The fields selected were from established farms where the common bean was grown for a minimum of three to four successive seasons. With the help of a scoop, soils were taken at 0 to 20 cm depth from five different localities in the selected fields to make a combined soil sample and filled into a plastic container. The soil samples were labeled and transferred to Haramaya University, Ethiopia.

TABLE 1

Sample site location in the study areas

District	Village	Altitude	Latitude	Longitude
Fedis	Bunicch	1586	0179155	1008025
	Nunnu	1589	0179647	1008077
	Meeta	1600	0180363	1007735
	Hassena	1599	0179444	1007248
	Genna	1600	0179032	1007723

Analysis of soil samples

The collected soil samples were shifted to the Haramaya University laboratory for the examination of selected soil chemical properties. Regular methods were followed to identify soil pH while total nitrogen was analysed by the Kjeldahl method. Available soil phosphorus was identified using the Bray-1 method. The interchangeable cations in organic matter of the soils including magnesium (Mg^{2+}), potassium (K^{+}), calcium (Ca^{2+}), and sodium ions (Na^{+}) were also examined (Anderson and Ingram 1993).

Collection of rhizobia

The collected soil samples were allocated into selected pots to grow common beans in the greenhouse for the isolation of *Rhizobium*. The common bean *Gofta* (G-2816) seed variety was obtained from Haramaya University and used for this experimental study. Forty days after planting, initial flowering was noticed. The plants were then subjected to observation for root nodules with a reddish pink color. The fully developed root nodules were separated from the roots, preserved in plastic bags, and stored in a deep freezer for isolation of rhizobia.

Media preparation

For rhizobia isolation, Yeast Extract Mannitol Agar (YEMA) was used (Vincent, 1970) with pH was set at 6.8 ± 0.2. The agar was sautoclaved for 15 minat 121 °C and left to cool before it was poured into sterile Petri dishes (Somasegaran and Hoben 1985**).**

***Rhizobia* isolation from root nodules**

The nodules from the freezer were moved into falcon tubes with sterilized distilled water and kept overnight at 4°C for imbibition. Subsequently, the root nodules were disinfected for 10 sec by submerging in ethanol 95%, transferred to sodium hypochlorite 3.5% for two min, and cleaned approximately six times by changing the sterile distilled water. Using a clean petri dish with a drop of sterilized disinfected water, 4 to 6 root nodules were crushed by disinfected forceps and the milky fluid solution was collected. The loopful of suspension was streaked with the help of a disinfected inoculation loop onto Petri dishes with YEMA medium. After inoculation, the cultures were kept at room temperature for 4 to 7 days. (Woomer *et al*. 2011). Each isolate was labelled as HURF (Haramaya University *Rhizobium* Fedis district followed by the first letter of the village name).

Presumptive tests for cultures purity

Rhizobia colonies from well-developed cultures were additionally sub-cultured and streaked using a disinfected inoculation loop into fresh YEMA to produce a secondary culture. The presumptive examination for purity of the isolates was done by streaking the secondary culture into YEMA with Congo red, and into glucose peptone agar media under identical situations to detect Congo red absorption and growth (Woomer *et al*. 2011). Lastly, the agar slants of

YEMA were organised by using sterile 50 mL sized falcon tubes.The slants were used to raise the required quantity of pure culture which after 4 to 7 days of growth were maintained in a freezer for future use.

Morphological and biochemical characterisation

Morphological characteristics of the colonies were observed after 4 to 7 days of incubation of pure culture. Cell shape and motility were also observed under the microscope as explained by Howieson and Dilworth (2016). The morphological observations were type of growth, colony form, colony colour, elevation, margins, texture, and colony size. One ml of 30% hydrogen peroxide was spread on Petri dishes with isolates for analysis of catalase activity and observed for oxygen bubble formation as suggested by Hamza and Alebejo (2017).

Physiological characterisation

The selected *Rhizobium* isolates were tested for their carbon source using substitute sugars. In this study, the sugars used were maltose and sucrose, which were substituted with mannitol in YEMA. The isolates were allowed to grow in selective media with glucose peptone agar and growth features were observed as suggested by Somasegaran and Hoben (1985). Different pH levels such as 5.5, 6.5, 7.5, 8.5, and 9.5 were used to test for pH tolerance of isolates. Salt tolerance was tested by using YEMA with different salinity levels (2%, 3%, 4%, and 5% NaCl), while growth features of isolates were observed under different temperature levels (35 °C, 40 °C, 45 °C and 50 °C) as suggested by Legesse (2016). The growth responses of isolates under different physiological tests were rated as described by Kucuk *et a*l. (2006).

Multiplication of rhizobia cells

Sixty ml of Yeast Mannitol Broth (YMB) medium was prepared and poured into 250 mL conical flasks and sterilized for 15 min at 121°C. The identical volume of the corresponding rhizobia colony was added to YMB (Olsen *et al*. 1996).

Soil and seed preparation

Soil samples which were saline free and not water stagnant with a pH 7±2, were collected, sterilized, and cooled aseptically. The soil wasfilled into sterilized pots of 2 L size. The common bean *Gofta* (G-2816) seed variety was subjected to surface sterilization with the sterilized seeds being kept in a beaker with sterilized distilled water to imbibe before planting (Woomer *et al*. 2011).

Planting and treatment application

Five clean and disinfected seeds *Phaseolus vulgaris* were selected and transferred into each pot with disinfected soil using sterile forceps. Ten mL of rhizobia isolates and their inoculum volume of 1x108 cells/mL in broth cultures were inoculated (Somasegaran and Hoben 1985). The experimental arrangement in the greenhouse was a randomized complete block design with three replications. As controls, each block contained two pots, negative control with no chemical fertilizer and no inoculum (Con-) and positive control with chemical fertilizer (Con+) and no inoculum. The pots were irrigated on the day of planting and three weeks after planting with a nitrogen-free nutrient solution. To 10 L of sterile distilled water, 5 mL of each stock solution was added to form a nitrogen-free nutrient solution which was used to provide nutrients to the potted plants (Broughton and Dilworth 1971) The plants were thinned to two after seed germination, and the two plants were left to grow for six weeks after which the they were harvested for determination of rhizobia effectiveness. The relative symbiotic efficiency of isolates (SEi) was calculated according to the method of Somasegaran and Hoben (1985).

RESULTS AND DISCUSSION

Analysis of soil in the study area

Soil analysis data showed most soils to have a pH in the range of 7 to 7.21, which is normally suitable for the growth of *Rhizobium*. Nitrogen content of the soil samples was less (<0.1%) with a maximum of 0.08% compared tothe standard level of 0.25%. Accessible phosphorus was less than 20 ppm of critical value with 80% of the soils having an acceptable range, while, 20% had a less phosphorus content. Likewise, 80% of the soils indicated sufficient organic matter content and only 20% having organic matter less than the critical level of 4 mg/kg. The data for the interchangeable cations (me/100 g soil) for K^+, Mg^{2+}, and Ca^{2+} were greater than critical levels (0.22, 2, and 4 meq/100g respectively), while for Na+, the values were within the critical range (less than 1 me/100 g soil).

TABLE 2
Selected chemical properties of the soil samples

District	Village	Total N (%)	P (ppm)	OM (mg/kg)	Interchangeable cation (meq/100g Soil)				pH (H_2O) 1:2.5
					K^+	Ca^{2+}	Mg^{2+}	Na^+	
Fedis	Bunicch	0.06	13.85	0.87	0.91	6.48	6.26	0.25	7.01
	Nunnu	0.08	14.74	1.26	0.88	4.42	4.29	0.17	7.00
	Meeta	0.05	13.48	4.57	0.37	6.32	3.50	0.60	7.21
	Hassena	0.03	15.21	4.27	1.26	15.44	8.28	0.49	7.10
	Genna	0.05	15.58	4.66	1.09	9.05	3.22	0.38	7.21

Note: N – Nitrogen; P – Phosphorus;K-Potassium; Ca-Calcium;Mg-Magnesium ;Na- Sodium; OM- organic matter

In relation to the chemical properties of the tested soil samples, the soils were found to have less nitrogen and phosphate with the pH being nearly acidic. Further, the nitrogen and phosphate content in the selected soil samples may be less due to the effect of low pH which leads to the leaching of nitrogen and phosphate adsorption resulting in nutrient deficiency (Mowo *et al,* 2006). In this study, most of the soil samples showed pH values ranging between 7.0 to 7.21. According to Onyango *et al*. (2015), the range of soil pH values of this study is best for agriculture activities, is favorable for the growth of rhizobia bacteria and positive towards the root nodulation process in legumes. In Ethiopia, most of the soil samples have low nitrogen and phosphate to sustain suitable soil productivity and support plant growth even though the presence of replaceable cations K^+, Ca^{2+}, Mg^{2+}, and Na+ are within the recognized critical levels. A critical range of nutrients is desirable for successful plant growth and for an effective increase in root nodule rhizobacteria (Valverde *et al*. 2002)

Morphological Characteristics of Rhizobia Isolates

Our study results showed a discrepancy in growth of isolates and colony appearance (Table 3). After 5 to 7 days of cultivation, isolates exhibited diverse colony forms. The colonies of isolates HURFB1, HURFN2, HURFM3, and HURFG5 appeared to be circular in form.The colony of the remaining isolate (HURFH4) showed an oval form which was creamy white. The colonies had irregular and regular margins with smooth exteriors but a cloudy appearance was detected. The production of mucus was noticed in all the rhizobia isolates, particularly high in the HURFG5 isolate and moderate in all other isolates. The isolates appeared to be rod and coccus in shape but all were motile. In this study, all the isolates did not absorb the colour and remained as white-pink colonies when grown in Congo red. The formation of a bubble in the catalase test for all isolates was considered as catalase positive for the test. All the selected isolates

exhibited healthy growth in mannitol, 20% of isolates experienced medium growth in maltose and weak growth in sucrose when used as a sole source of carbon.

In this study, the isolates were creamy white and did not absorb Congo red and according to Somasegaran and Hoben (1985), their incapability to absorb Congo red dye is one of the distinguishing features of rhizobia. All five *Rhizobium* isolates were catalase positive in the test as indicated by bubble formation (Wadhwa *et al*. 2017). This study found that mannitol was the best source for carbon among the selected sugars, for rhizobia culturing. The deficiency or absence of growth of rhizobia in sucrose and maltose may be due to the incompetent uptake of disaccharides by these rhizobia (Dekak *et al*. 2018).

TABLE 3
Colony morphology of rhizobia isolated from root nodules of the *common* bean

Isolates	Form	Margin	Colour	Surface	Viscosity	Cell shape	Motility	Biochemical Congo red	Catalase activity
HURFB1	Circular	Regular	Creamy-white	Smooth	Mucoid	Rod	Motile	Not absorbed	Positive
HURFN2	Circular	Regular	Creamy-white	Smooth	Mucoid	Rod	Motile	Not absorbed	Positive
HURFM3	Circular	Regular	Milky-white	Smooth	Mucoid	Rod	Motile	Not absorbed	Positive
HURFH4	Oval	Irregular	Creamy-white	Smooth	Mucoid	Coccus	Motile	Not absorbed	Positive
HURFG5	Circular	Regular	Creamy-white	Smooth	Highly Mucoid	Rod	Motile	Not absorbed	Positive

TABLE 4

Growth responses of rhizobia isolated from the common bean under different carbon sources

Isolates	Growth media with different carbon sources			
	Mannitol	Maltose	Sucrose	Glucose peptone agar
HURFB1	***	***	***	-
HURFN2	***	***	***	-
HURFM3	**	***	***	-
HURFH4	***	**	*	-
HURFG5	***	**	*	*

Note: - (No growth); * (Weak growth); ** (Medium growth); *** (strong growth)

Effect of Different Physiological Stress on Growth of Rhizobia

At pH 5.5 and 6.5, all selected isolates showed strong growth (100%)(Table 5); three isolates (HURFM3, HURFH4, and HURFG5) exhibited medium growth at 7.5. pH, while at 9.5 pH most of the isolates showed weak growth and two isolates (HURFH4, and HURFG5) were not able to grow at all. In this study, 2% and 3% NaCl levels did not affect the growth of isolates, but at higher salt concentrations, growth was extremely affected. Temperature also influenced growth of rhizobia with all isolates being highly susceptible to high temperatures (50˚C). However, rhizobial isolate HURFB1 was capable of strong growth up to 45˚C, with HURFN2 and HURFM3 exhibiting medium growth and HURFH4 and HURFG5 showing less or weak growth.

The strong growth of rhizobia in lower salt levels was probably due to minor saline effects in media and the physiological growth of the rhizobia itself. Reduced growth was noticed in 4%

and 5% salt concentration(Table 5). The increased salt level in growth media may affect the physiological activities and stimulate osmotic stress which suppresses rhizobia growth (Zahran 1999). Despite the toxicity in high-level salt concentrations, a slow-growing isolate such HURFM3 and HURFH4 and a fast-growing isolate of HURFB1 tolerated the salinity and grew even at 5% NaCl levels. These are considered as salt tolerant isolates. Similar findings for *Rhizobium,* and *Brady Rhizobium* growing at 4% salt concentration were reported by Laurette *et al*. (2015). The tolerance to high salt concentration is a significant feature of rhizobia effectiveness in high salt rhizosphere.

TABLE 5

Effect of different physiological stresses on growth of rhizobia isolated from root nodules of the common bean

Isolates	Physiological conditions												
	Temperature level				Salt concentration(NaCl)				pH level				
	35˚C	40˚C	45˚C	50˚C	2%	3%	4%	5%	5.5	6.5	7.5	8.5	9.5
HURFB1	***	***	***	-	***	***	***	***	***	***	***	***	*
HURFN2	***	***	**	-	***	***	**	*	***	***	***	**	*
HURFM3	***	***	**	-	***	***	**	*	***	***	**	*	*
HURFH4	***	**	*	-	***	***	*	*	***	***	**	*	-
HURFG5	***	**	*	-	***	***	*	-	***	***	**	-	-

Note: - No growth; * Weak growth; ** Medium growth;*** strong growth

Temperature also has an important consequence on growth and physiological activities of rhizobia (Simon *et al*. 2014). In this study, the optimum temperature for the growth of the isolates was perceived to be 35°C. In line with this, Benselama *et al*. (2013) reported a similar temperature as optimum for rhizobia. Isolates such as HURFB1, HURFN2, and HURFM3 were more temperature tolerant than others, growing strongly up to 45°C. These results are optimistic since the use of these isolates can support root nodulation and nitrogen fixation, and improve plant growth in high-temperature soil regions.

Assessment of symbiotic effectiveness of the wild rhizobia of the bommon Bean

This experimental analysis revealed that all common bean plants inoculated with rhizobia isolates were able to produce nodules in the root. The substantial change in nodulation among the isolates was significant at $p<0.05$ (Table 6). The isolate HURFM3 displayed a maximum number of root nodules with 86±13.1 nodules per plant, followed by HURFB1 (82±18.6 nodules/plant). However, HURFH4 isolate had the minimum number of nodules with 39±11.9 nodules/plant. Finally, no nodules were found in un-inoculated and nitrogen-fed plants. The dry weight of the nodules was statistically significant at $p<0.05$ between the isolates (Table 6). It was maximum at 0.280± 0.010 gram/plant in isolate HURFM3 with the minimum being 0.046 ± 0.002 gram/plant in HURFH4. Isolates HURFB1 (82±18.6 gram/plant), and HURFN2 (76±1 gram/plant) performed equitably in this study.

TABLE 6
Evaluation of symbiotic effectiveness of the wild rhizobia of the common bean

Isolates	Root nodule number/ plant	Root nodule dry weight/plant(gm)	Shoot dry weight/plant(gm)	Symbiotic effectiveness (%)	Symbiotic Effectiveness(Level)
HURFB1	82±18.6^{cf}	0.250±0.010^{b}	1.652±0.002^{b}	172	Highly effective
HURFN2	76±1^{ps}	0.174±0.002^{eg}	1.332±0.002^{c}	139	Highly effective
HURFM3	86±13.1^{bd}	0.280± 0.010^{a}	1.800±0.001^{a}	187	Highly effective
HURFH4	39±11.9^{os}	0.046± 0.002^{nq}	0.833±0.001^{hn}	87	Highly effective
HURFG5	56±12.9^{io}	0.145± 0.001^{d}	0.723±0.001^{lq}	75	Effective
Control(-)	0.00	0.00	0.412±0.002st	43	Lowly effective
Control(+)	0.00	0.00	0.959±0.001^{ek}	100	Highly effective

Note: % SEHighly effective - >80%; Effective- 51 -80%; Lowly effective-35-50%; Ineffective - < 35% Numbers in the same column followed by the same letters are not significantly different at p<0.05(Fisher's LSD).

The shoot dry weights of the common bean were affected by rhizobia inoculation and was significantly different between treatments at $p < 0.05$. As seen in Table 6, the dry weight of the shoot ranged from a maximum of 1.800±0.001 g/plant for HURFM3 isolate, followed by 1.652±0.002 g/plant (HURFB1), 1.332±0.002 g/plant (HURFN2), and 0.833±0.001 g/plant (HURFH4). The least dry weight of the shoot was observed in HURFG5 with 0.723±0.0011 g/plant. The N-fed plants had a reduced amount of shoot dry weight with 0.959±0.001g/plant associated with isolates like HURFB1, HURFN2, and HURFM3. In negative control, shoot dry weight was much less compared to all other treatments, with 0.412±0.002g/plant.

This study found reasonable changes in the relative symbiotic efficiency (Table 6). Among the selected isolates, HURFM3 recorded the highest effectiveness 187%, followed by HURFB1 (172%) and HURFN2 (139%). The least symbiotic effectiveness was found in isolate HURFG5 (75%). Our greenhouse experiment established four indigenous isolates as highly effective as they showed relative symbiotic efficiency of above 100% while HURFG5 isolate is also considered effective as it had 75% relative symbiotic effectiveness.

The analysis of thegreenhouse experiment found that inoculation with indigenous isolates substantially improved root nodulation and shoot dry weight compared to the control plants. The symbiotic relations in legume crops is dependent on the efficiency of the rhizobia to fix nitrogen. The good symbiotic relationship between the host plant and the rhizobia is mostly reflected in higher biomass production (Gyogluu *et al*. 2018). Most of the indigenous isolates showed better performance in root nodulation, shoot dry weight, and symbiotic efficiency.

The effectiveness of the rhizobia strains has been exploited through its application as a bio-fertilizer for the legumes. This is a sustainable practice to enhance legume production (Julian and Ezekiel 2020). This experiment shows that good rhizobia strains do occur in the domestic soil, and this could lead to exploring further low-cost inoculants to progress common bean production.

In relation to the negative control, inoculation of common bean with indigenous rhizobia improved the shoot dry weight. The better shoot growth in legumes resulting from inoculation with indigenous rhizobia was reflected in enhanced plant growth resulting in better biomass production (Matse *et al*. 2020). The high shoot dry weight of indigenous rhizobia-treated plants could be due to the synthesis of plant growth hormone (IAA) by the indigenous isolates (Mabrouk *et al*. 2018). However, no root nodules were produced in negative controls which were not innoculated with rhizobia. Hence the absence of nitrogen fixation contributed to

limited biomass formation and this reduced the shoot dry weight in the negative control (Muleta *et al*. 2017). The better growth of common bean inoculated with indigenous isolates compared to positive and negative control indicates that the indigenous isolates are good bio-fertilzers and, offer the potential for exploitation as rhizobia inoculants to enhance common bean production.

CONCLUSION

This study validated the presence of active indigenous rhizobia isolates in smallholder farms with abundant potential to enhance common bean growth. Remarkably, most of the inoculants improved nodulation, nodulation dry weight, and shoot dry weight. Among the selected five isolates HURFM3 isolate exhibited the highest symbiotic efficiency (187%) compared to nitrogen-fed plants. This study has confirmed the presence of indigenous rhizobia in Ethiopian soil, especially in the study site, which has the ability to nodulate common bean more effectively and enhance crop growth and development. Finally, this research recommends further extensive field studies be carried out to test native isolates to identify the "finest" isolates for the development of inexpensive and active bio-fertilizers that will enhance sustainable common bean production.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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