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Co-inoculation of *Rhizobium* sp and Rhizobacteria for growth promotion of mungbean (*Vigna radiata* L.)

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Abstract

Legume inoculation has been carried out to favour nitrogen fixation before the onset of green revolution. *Rhizobium* species have outstanding ability to colonize roots of legumes to promote nitrogen fixation and ultimately yields of legumes. Isolates of *Rhizobium* sp and Rhizobacteria (five of each type) have been characterized for the biosynthesis of IAA, P-solubilization, exopolysaccharide, siderophore production and other biochemical tests. Isolates showed higher values of IAA equivalents, solubilization index, siderophore unit and on the basis of other biochemical tests were selected for enhancing nodulation, growth parameters of mung bean in a field study at graded N levels i.e., 12 and 25 kg ha^{-1}. Results clearly demonstrated the effect of bacterial inoculation at both N levels as compared to uninoculated ones. Co-inoculation effect on yield and nodulation parameters was significantly higher the separate application of isolates. Co-inoculation improved the grain and biomass yield of mung bean i.e., 984 and 2049 kg ha^{-1}, respectively. Co-inoculation also enhanced nodule number and mass (45 and 0.080 g plant^{-1}) as compared to the rest of inoculation levels and control at 25 kg N ha^{-1}. Similarly, co-inoculation also enhanced the grain and plant NP content in comparison to remaining treatments. Moreover, soil analysis at harvest also showed higher soil N and available P i.e., 0.053% and 10.15 mg kg^{-1}, respectively at higher N level. This field study suggested that interactive effect of symbiont and rhizobacteria could be used after thorough screening and valuable approach as compared to their individual application. However, there should be comprehensive strategy to use free living microbes in combination with their symbionts to promote quality foods and efficient nitrogen utilization in agricultural systems and exploring the hidden potential of rhizobacteria in field studies.

Keywords: Co-inoculation, N Levels, Mungbean, *Rhizobium* sp, Rhizobacteria

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Introduction

Legumes have remarkable role to produce quality foods through nitrogen utilization in the prevailing agricultural systems and to fulfil the human protein needs. Legumes are also involved in increasing in soil natural organic matter content and limit the agro-chemicals use thus providing eco-friendly agricultural/ farming systems (Lupwayi et al., 2011). Legume cultivation in rotation with other field crops restores the soil fertility status and lessen the threat of synthetic chemicals to environment. Legumes favours nitrogen fixation process through *Rhizobium*-legume symbiotic relationships which is the most sustainable and environment friendly way to produce the high protein content food with low cost of nitrogenous fertilizer (Vargas et al., 2017; Lin et al., 2019; Vocciante et al., 2022). The members of family Fabaceae are group of flowering plants enable to fix to nitrogen organically, and produce healthy cropping systems. Legumes form symbiotic relationships with rhizobium species and fix nitrogen by forming specialized cells in the root zones i.e., nodules (Berger et al., 2013; Liu et al., 2022). The symbiotic association with legumes is mainly dependent on specific microsymbionts and their specificity is the prime feature of *Rhizobium* species except the presence of some cross inoculation groups. The legume rhizosphere is the ultimate region for symbiosis, bacterial multiplication, rushing towards roots, formation of infection thread and curling of root hairs and up to the nodulation (Parthiban et al., 2016; Przygocka-Cyna & Grzebisz, 2018).

The increasing prices of mineral fertilizers in intensive cropping systems pretends hazardous to the natural ecosystems and also suffer the humans. The high intensity usage of mineral fertilizers affects the sustainable yields and results in deterioration of soil quality. The use of biological alternatives is the dire need of farmers to produce cost effective yields and to improve the soil quality. The microbial inoculants or biofertilizers are living microbes either carrier or liquid based to supplement the inorganic fertilizers and to sustain crop yields (Gouda et al., 2017). Legume inoculation with specific bacteria is an old practice to favour nitrogen fixation and thus producing low-cost system of crop production. *Rhizobium* species are the highest explored microorganisms and have the capability to form nodules on members of family Fabaceae (Gouda et al., 2017). Although, nitrogen covers the major portion of atmosphere in an unavailable form i.e.,79%. The triple bond of N_2 can be broken down by the microbes in the presence of nitrogenase enzyme complex in nodules and have the potential to provide N biologically and can compensate the mineral fertilizers (Gopalakrishnan et al., 2015). Introduction of specific microbes in high numbers to compete the native population and affecting the roots by producing physical changes to form nodules on roots (Hemissi et al., 2011; Pacheco-Villalobos et al., 2016; Vocciante et al., 2022).

Co-inoculation of nodule forming microbes and free living rhizobacteria have a pronounced effect than their separate application. The combined application with legume specific *Rhizobium* specie with rhizobacteria is more effective approach for favouring nodule formation by producing more chemical signals and ultimately more balanced plant nutrition (Gouda et al., 2017; Lin et al., 2019; Benjelloun et al., 2021). The rhizobacteria stimulated the plant growth by various means by viz. producing phytohormones, antibiotics or siderophores, solubilizing or mobilizing insoluble nutrients, improving nutrient uptake, inducing systemic resistance, biocontrol agents and ultimately boosting N fixation (Korir et al., 2017; Qureshi et al., 2022). The rhizobacterial inoculation in the pulse's rhizosphere employed positive effect on the plant health and yields through the above-mentioned mechanisms. In recent years, co-inoculation of pulses with *Rhizobium* species and free-living microbes has acquired the great attention. The rhizobacteria promoted the root system architecture by more producing more roots, lateral roots, rooting density and results in more sites for attachment of rhizobia and ultimately improves the nitrogen fixation potential (Vejan et al., 2016; Pacheco-Villalobos et al., 2016; Przygocka-Cyna and Grzebisz, 2018; Abd El-Mageed et al., 2022). The study was framed to evaluate the co-inoculation effect of *Rhizobium* sp and rhizobacteria at graded N levels on mung growth and yield parameters.

Materials and Methods

Isolation of *Rhizobiu*m and Rhizobacteria

The plants of mung bean growing at Pulses Research Institute, Faisalabad were removed and washed with water, separated the nodules and placed in the laminar flow cabinets in the container. The nodule surface sterilization was carried out with 95% ethanol and 0.2% $HgCl_2$ and washings many times with autoclaved distilled water (Russell et al., 1982). Then the nodules were pressed in autoclaved glass slides and obtained suspension was placed in sterilized distilled water to formulate a suspension. The nodule sap so obtained was streaked on yeast extract mannitol agar medium (YEM) (Vincent, 1970). The petri dishes were incubated at 28 ± 2 ºC for 48 hours and obtained growth was purified on the same medium frequently to get the pure cultures. The pure cultures were preserved at 5 ± 1 ºC on eppendorf tubes having 0.2 mL glycerol for further screening. The rhizosphere soil of mung bean was collected from the Pulses Research Institute, Faisalabad to isolate rhizobacteria. The serial dilutions were prepared, purified and screened on Jensen agar medium (Jensen, 1953) and then incubated at 28 ± 2 ºC for 48 hours. The obtained growth was purified on the same medium frequently to get pure cultures. The biochemical screening (Chrome azurole S (CAS) assay, Siderophore unit%, IAA equivalents, solubilization index (SI), Exopolysaccharide (EPS) production qualitatively, congo red etc) of both type of isolates were carried out by following the methods outlined in the Bergey's Manual of Systematic Bacteriology (Krieg & Holt, 1984).

Determination of auxin biosynthesis

The screening of isolates of *Rhizobium* sp of Mung bean and Rhizobcateria (five of each) labelled as (Mb_1, Mb_2, Mb_3, Mb_4 & Mb_5) and (Rh_1, Rh_2, Rh_3, Rh_4 & Rh_5) for the auxin biosynthesis potential with and without L-tryptophan was carried out. Each isolate was maintained in 100mL broth culture (LB broth) after inoculation for 72 hours. The IAA equivalents was determined as auxin biosynthesis potential by Salkowski's reagent (Sarwar et al., 1992). Isolates having higher IAA values were multiplied in broth for field testing. Isolates of rhizobacteria and *Rhizobium* sp (Rh_2 & Mb_3) were tested biochemically and exhibiting higher IAA equivalents, siderophore unit, solubilization index and other tests were used in field study (Table 1).

Inoculum preparation

On the basis of biochemical screening, the broth culture of selected isolates was prepared in culture bottles. The culture bottles containing isolates were incubated and placed on shaker to obtain the sufficient growth (0.5 optical density at 535 nm) for 72 hours. The seeds of mung bean were coated with slurry of respective culture according to respective treatments. The control was treated with sterilized carried and water and in co-inoculation, slurry was mixed by combing broth and carrier in 1: 1 ratio.

Field experiment

Field demonstration was carried out to assess interactive effect of (co-inoculation) *Rhizobium* sp and rhizobacteria at varied N levels on mung bean growth and yield Pulses Research Institute, Faisalabad. The physico-chemical characteristics in the pre-sowing soil samples revealed that sandy clay loam soil having pH: 8.20; EC_e: 1.40 dS m^{-1}; organic matter: 0.58%; soil N: 0.030% and available P: 6.67 mg kg^{-1}. All the treatments were tested at two fertilizer levels i.e., 12-60 and 25-60 kg NP ha^{-1} and laid out in randomized complete block design (RCBD). All N & P to the respective treatments were applied as basal. There were eight treatments viz. T_1: Control, T_2: Rhizobacteria inoculation (Rh_2), T_3: *Rhizobium* inoculation (Mb_3), T_4: Co-inoculation tested at two N levels i.e., 12 & 25 kg N ha^{-1}. The tube well water was used for irrigation accomplishing the quality criteria for crops (Ayers & Westcot, 1985). When the crop was at flowering stage, two plants from each plot removed to check the nodulation. Data regarding biomass, grain yield, plant and grains N & P-content, soil N and available P at harvest were recorded. The nitrogen and phosphorus were determined using Kjeldhal method and modified Olsen method, respectively (Bremner & Mulvany, 1982; Olsen & Sommers, 1982).

Statistical analysis

The data were analysed statistically by analysis of variance test following RCBD (Steel et al., 1997). The difference among treatment means were evaluated by Duncan's multiple range tests (Duncan, 1955).

Results

Lab screening of isolates

Isolates of *Rhizobium* sp of mung bean and Rhizobacteria (five of each) mentioned as (Mb_1, Mb_2, Mb_3, Mb_4 & Mb_5) and (Rh_1, Rh_2, Rh_3, Rh_4 & Rh_5) were screened for IAA content in the with/without L-TRP. Different biochemical tests (qualitative & quantitative) viz. IAA equivalents, solubilization index, siderophore unit, CAS assay, Exopolysaccharide production, congo rest were carried out. Results presented in Table 1 clearly demonstrated that isolates of each type yielded IAA content without L-TRP and the effect was more with L-TRP (Table 1). The *Rhizobium* sp and Rhizobacteria isolates produced IAA equivalents i.e., 2.35-2.90 and 2.10-3.25 µg mL^{-1} without L-TRP and higher values were obtained with L-TRP i.e., 3.35-4.45 and 3.25-4.30 µg mL^{-1}, respectively. The highest IAA equivalents were produced with Rh_2 and Mb_3 i.e., 4.30 and 4.45 µg mL^{-1}, respectively. The Rh_2 and Mb_3 isolates were subjected to solubilization index (2.48 & 2.50) and siderophore unit (36.5 & 39.0), respectively. The remaining isolates also showed promising results in biochemical screening and mentioned in Table 1.

Table 1 Some important stats of isolates during biochemical screening

Isolates	IAA equivalents (µg mL^{-1}) L-TRP [-]	IAA equivalents (µg mL^{-1}) L-TRP [+]	Congo red test	Solubilization index (SI)	Siderophore unit (%)	*CAS-assay	EPS production
Mb_1	2.70	3.50	+	2.21	28.5	+	++
Mb_2	2.30	3.90	+	2.38	24.5	++	++
Mb_3	3.25	4.45	+	2.50	39.0	+++	++
Mb_4	2.10	3.35	+	2.31	31.5	+	+
Mb_5	2.15	3.60	+	2.32	26.5	+	++
Rh_1	2.50	3.55	-	2.34	22.5	+	++
Rh_2	2.75	4.30	-	2.48	36.5	+++	++
Rh_3	2.35	4.10	-	2.16	36.0	++	++
Rh_4	2.50	3.25	-	2.76	22.0	++	++
Rh_5	2.90	3.95	-	2.42	25.0	+++	+

*L-TRP [-]: without L-tryptophan; L-TRP [+]: with L-tryptophan; CAS: Chrome Azurole S

Co-inoculation effect on yield components

Inoculation of *Rhizobium* sp (Mb_3) and rhizobacteria (Rh_2) significantly affect the yield components of mung bean (Table 2) and the effect was more promising when they are applied as co-inoculation at both N levels i.e., 12 & 25 kg N ha^{-1} in comparison to uninoculated ones. The highest grain yield of mung bean was produced by co-inoculation i.e., 984 followed by *Rhizobium* inoculation i.e., 936 kg ha^{-1} against the control i.e., 809 kg ha^{-1} at 25 kg N ha^{-1}. Similarly, co-inoculation (Mb_3 & Rh_2) produced higher biomass (2049) followed by *Rhizobium* inoculation (1968) against the control (1691 kg ha^{-1}) at 25 kg N ha^{-1}. Co-inoculation improved the grains and biomass yield at both N levels by 36, 29.7% and 21.6, 21.2% at both N levels, respectively.

Co-inoculation effect on the nodulation

Results presented in Table 2 for nodulation revealed that bacterial inoculation improved the nodulation i.e., number of nodules and nodular mass and the effect of co-inoculation is significant as compared to separate inoculation at both N levels. Co-inoculation produced the maximum nodule number and mass (g $plant^{-1}$) i.e., 45, 0.080 followed by *Rhizobium* inoculation i.e., 39, 0.070 as compared to control i.e., 17, 0.050 at higher level of N, respectively.

Table 2 Inoculation effect of the yield components of mung bean (Average of 3 repeats)

Treatments	Grain yield (kg ha^{-1})		Biomass yield (kg ha^{-1})		Nodule no. $plant^{-1}$		Nodular mass (g $plant^{-1}$)	
	12 kg N ha^{-1}	25 kg N ha^{-1}	12 kg N ha^{-1}	25 kg N ha^{-1}	12 kg N ha^{-1}	25 kg N ha^{-1}	12 kg N ha^{-1}	25 kg N ha^{-1}
Control	666^{c}	809^{abc}	1464^{c}	1691^{bc}	15.0^{f}	17.0^{f}	0.040^{c}	0.050^{c}
Rhizobacteria inoculation	744^{bc}	873^{ab}	1831^{ab}	1825^{ab}	21.0^{e}	27.0^{d}	0.063^{b}	0.067^{b}
Rhizobial inoculation	854^{ab}	936^{a}	1866^{ab}	1968^{a}	36.0^{c}	39.0^{b}	0.063^{b}	0.070^{ab}
Co-inoculation	906^{ab}	984^{a}	1898^{ab}	2049^{a}	41.0^{b}	45.0^{a}	0.073^{ab}	0.080^{a}
LSD	184.7		253.8		2.2568		0.0106	

Co-inoculation effect on N&P content

Results for grain/plant N & P content of mung bean are presented in Table 3. Co-inoculation improved the grain N and P content followed by *Rhizobium* sp inoculation and minimum values are obtained in uninoculated ones. Co-inoculation produced the highest grain N and P content i.e., 3.23, 0.333% followed by *Rhizobium* inoculation i.e., 3.21 and 0.323% against the control i.e., 3.12 and 0.280%, respectively at 25 kg N ha^{-1}. The percent increase in grain N and P was also higher in co-inoculation than the separate bacterial inoculation. Co-inoculation produced the highest plant N&P-content i.e., 1.223, 0.180% followed by *Rhizobium* inoculation i.e., 1.197 and 0.163% against the control i.e., 1.110 and 0.133%, respectively at higher level. The *Rhizobium* (Mb_3) or rhizobacteria (Rh_2) separate application or in combined form improved the plant and grain N & P-content in comparison to un-inoculated ones at both N levels and the result was more prominent at higher N level.

Table 3 Inoculation effect on plant & grain analysis of mung bean (Average of 3 repeats)

Treatments	Grain N (%)		Grain P (%)		Plant N (%)		Plant P (%)	
	12 kg N ha^{-1}	25 kg N ha^{-1}	12 kg N ha^{-1}	25 kg N ha^{-1}	12 kg N ha^{-1}	25 kg N ha^{-1}	12 kg N ha^{-1}	25 kg N ha^{-1}
Control	3.08^{g}	3.12^{f}	0.267^{f}	0.280^{e}	1.077^{f}	1.110^{e}	0.123^{e}	0.133^{de}
Rhizobacteria inoculation	3.14^{e}	3.16^{d}	0.287^{de}	0.293^{d}	1.117^{e}	1.150^{d}	0.143^{cd}	0.153^{bc}
Rhizobial inoculation	3.19^{c}	3.21^{b}	0.307^{c}	0.323^{ab}	1.177^{c}	1.197^{bc}	0.153^{bc}	0.163^{ab}
Co-inoculation	3.22^{ab}	3.23^{a}	0.313^{bc}	0.333^{a}	1.210^{ab}	1.223^{a}	0.167^{ab}	0.180^{a}
LSD	0.015		0.0125		0.0246		0.0176	

Co-inoculation effect on post-harvest soil N and Available P

Results regarding soil N & available P clearly demonstrated the effect of bacterial inoculation and the effect was more prominent with co-inoculation and presented in Fig. 1 & 2. Co-inoculation effect produced the maximum soil N i.e., 0.053 followed by *Rhizobium* inoculation i.e., 0.050 against the control i.e., 0.046% at 25 kg N ha^{-1}. Increase in soil N due to co-inoculation was 19 and 15%, followed by *Rhizobium* inoculation i.e., 11.9 and 8.7%, respectively at both N levels. Slight increase in soil N values due to Rhizobacteria inoculation was also observed. Likewise, co-inoculation also improved the available P values i.e., 9.17 and 10.15 mg kg^{-1} followed by *Rhizobium* inoculation i.e., 7.70 and 9.18 mg kg^{-1} and minimum were obtained with control i.e., 5.25 and 7.20 mg kg^{-1} at both levels of N, respectively. Highest percent increase in available P was also found with co-inoculation.

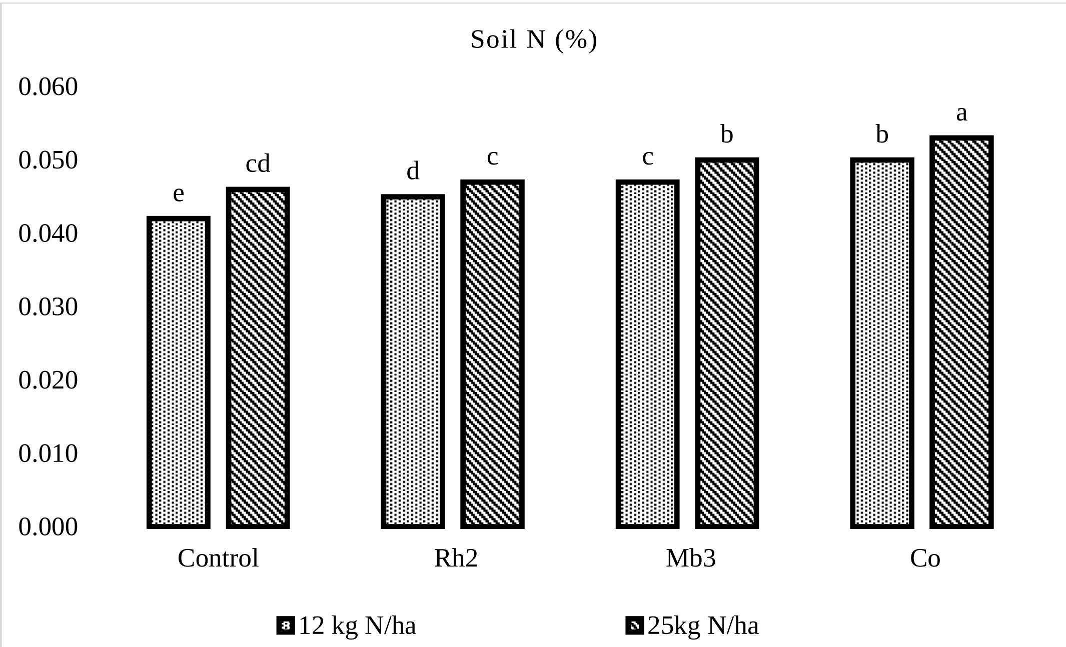

Fig. 1 Co-inculation effect on soil N content at harvest

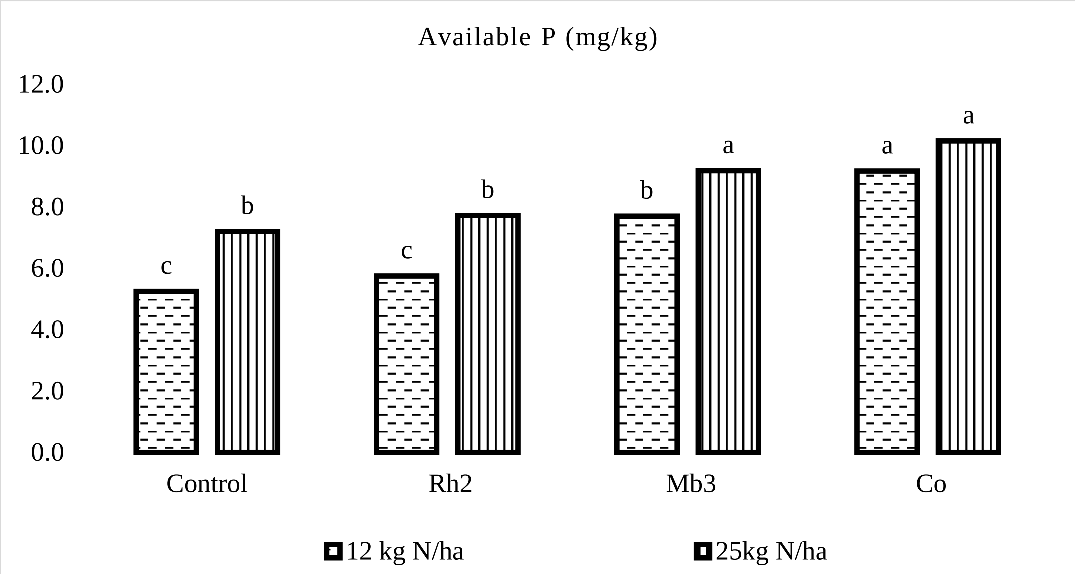

Fig. 2 Co-inculation effect on available P content at harvest

Discussion

Rhizobium species are familiar for its symbiotic association with legumes and can compensate its nitrogen requirements through biological nitrogen fixation. *Rhizobium* sp are also reported in literature for its ability to produce growth hormones, solubilize insoluble form of nutrients, and may be considered an efficient mean in improving crops yields (Govindarajan et al., 2008; Mehboob et al., 2011). Co-inoculation of symbionts with free living diazotrophs i.e., rhizobacteria having characteristic feature of producing biological active substances, solubilizing/mobilizing nutrients is an outstanding strategy for legume yield enhancement (Ibiene et al., 2012; Parthiban et al., 2016). The bacterial inoculants involved in growth promoting activities by various means i.e., fixing nitrogen, solubilizing/mobilizing insoluble nutrients, regulating hormonal balance, better nutrient uptake and stress relief (Korir et al., 2017; Benjelloun et al., 2021).

Rhizobium sp and rhizobacteria were characterized for their potential to form IAA contents, solubilization of insoluble form of nutrients, production of siderophores via quantitatively and qualitatively with CAS assay, and siderophore unit and exopolysaccharides producing behaviour and other biochemical tests like congo rest were carried out. The isolates under screening produced IAA equivalents to varying degree and effect was more prominent with L-TRP and presented in Table 1. Literature confirmed the evidences for the microbial role in producing bacterial volatiles and ultimately the crop yields (Akhtar et al., 2013; Gopalakrishnan et al., 2015; Dumsane et al., 2020). In present study, the *Rhizobium* sp (Mb_3) and Rhizobacteria (Rh_2) produced IAA equivalents (2.10-4.45; 2.35-4.30 µg mL^{-1}), solubilization index (2.21-2.50, 2.16-2.48), siderophore unit (26.5-39, 22-36.5%), respectively and reported by numerous researchers (Zahir et al., 2010; Pacheco-Villalobos et al., 2016; Parthiban et al., 2016; Abd El-Mageed et al., 2022).

In the present study, isolates of *Rhizobium* sp (Mb_3) and Rhizobacteria (Rh_2) producing higher values in biochemical screening were tested in field study of mung bean with two N levels i.e., 12 & 25 kg N ha^{-1}, and uniform dose of P (60 kg ha^{-1}). The bacterial inoculation either applied as single inoculant or in combined form (co-inoculation) improved the nodulation checked at flowering stage of the crop and higher values was obtained in co-inoculation in comparison to uninoculated ones. The improvement in nodule number and mass with co-inoculation owed to better root proliferations, formation of greater number of lateral roots, thus more niches to attack by the symbionts and hence more nodulation (Naher et al., 2009; Korir et al., 2017; Liu et al., 2022).

The bacterial application as separate or in combined form improved the bacterial stimulants, results in more curling of root hairs and infection threads that are main steps to form nodules. The introduction of rhizobacteria with *Rhizobium* sp improved the rooting density and altered the root system architecture results in more surface area and more active sites for the microbes (Ibiene et al., 2012; Gopalakrishnan et al., 2015; Dumsane et al., 2020). Increase in root volume/area served for improved nutrient acquisition. The improvement in nodules/root parameters by microbe application have been reported by many workers (Fatnassi et al., 2015; Verbon & Liberman, 2016; Gouda et al., 2017). The inoculation of rhizobacteria with legume specific symbionts either applied single or in combined form improved the crop yield reported by Akhtar et al. (2013); Korir et al. (2017). Results revealed that alone application of *Rhizobium* sp and Rhizobacteria enhanced the yield contributing factor of legumes and response was more with *Rhizobium* sp than Rhizobacteria. Results demonstrated that bacterial inoculation enhanced the yield parameters of mung bean against the un-inoculated control. The bacterial response was prominent at both N levels and suggested that bacterial performance was fertilizer dependent. Our findings are in accordance with the findings of number of researchers who confirmed the role of microbes in improvement of legume yields (Gopalakrishnan et al., 2015; Korir et al., 2017; Dumsane et al., 2020; Benjelloun et al., 2021).

Results in Table 3 disclosed that bacterial inoculation also improved the grain and plant N-P content as compared to uninoculated ones and effect was more prominent with co-inoculation. Inoculation of *Rhizobium* sp and Rhizobacteria in combined form having characteristic feature of producing hormones, solubilizing phosphorus results in more nutrient uptake (N&P) due to better root system development (Vargas et al., 2017; Lin et al., 2019). Improvement in nutrient content in plant/grains owed to more bioavailability of nutrients in the rhizosphere (Parthiban et al., 2016; Przygocka-Cyna & Grzebisz, 2018). The combined inoculation improved the N&P content in root zones/rhizosphere owed to more root hairs and lateral hairs, better root system, thus fixing more N and solubilizing more phosphorus. The bacterial fixing of nitrogen, solubilizing of phosphates and producing hormones and other secondary metabolites results in more nutrient availability to plant and better growth that ultimately enhanced yield of crops (Przygocka-Cyna & Grzebisz, 2018; Dumsane et al., 2020). The bacterial production of growth stimulants might be responsible for root cell division and results in better plant root/shoot growth (Zahir et al., 2010; Datta & Chakrabartty, 2014; Vocciante et al., 2022).

The introduction of microbes having potential of fixing/solubilizing nutrients, producing IAA, siderophores and EPS influenced that growth of test crop i.e., mung bean and improved better nutrient acquisition and effectiveness of *Rhizobium* sp reported by many researchers (Fatnassi et al., 2015; Mukhongo et al., 2017; Dumsane et al., 2020). The synergistic association of *Rhizobium* sp and Rhizobacteria improved the nutrient concentrations, plant vigour, and ultimately enhanced crop yields (Bhat et al., 2019; Dumsane et al., 2020). The bacterial interaction in combined form produced more organic acids that results in decrease in soil pH and involvement of phosphatase enzyme resultantly increased the P content and ultimately boosted crop yields (Datta & Chakrabartty, 2014; Fatnassi et al., 2015; Qureshi et al., 2022). The application of Rhizobacteria improved more chemical signals and more association of *Rhizobium* sp with legume-roots resultantly better crop yields. Results presented in tables/graphs revealed that co-inoculation enhanced the yield contributing factors of mung bean and are validated by many researchers (Zahir et al., 2010; Vejan et al., 2016; Bhat et al., 2019; Dumsane et al., 2020).

Conclusion

The results of present findings clearly showed that co-inoculation of significantly affected the yield parameters of mung bean. Inoculation of *Rhizobium* sp and Rhizobacteria employed more assenting effect on mung bean and acted quite miraculously. Study results clearly suggested that inoculation with microbe either applied singly or in combined form displayed positive response on yield attributes and plant/grain N&P content of mung bean.

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