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Evaluation of Multi-functional *Rhizobium* sp. Isolates of Urdbean (*Vigna mungo* L.) as Bio-inoculant for Enhancing Productivity and Soil Health

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Eighteen *Rhizobium* sp. isolates from diverse soils of Uttarakhand were characterized for plant growth promoting (PGP) traits and evaluated for nodulation, growth and yield of urdbean (*Vigna mungo* L.) and soil properties in a field trial. The isolates differed in sole carbon (C) source utilization profile and grew well at 28±2 ^{o}C. Among these, 11 isolates grew at 35±2 °C and 6 isolates at 40±2 °C. Isolates P-2, P-5, P-7, A-3, A-6, A-7, A-11, K-6 and C-1 solubilized P, isolates P-7, P-8, A-3, A-6, A-7, A-15 and K-6 secreted indole acetic acid (IAA) while P-2, P-7, P-8, A-3, A-6, A-7, A-9, A-18, K-12, C-1 and D-1 produced siderophores in *in vitro* conditions. Seed inoculation of rhizobial isolates significantly increased the nodule number from 18.1 to 45.2 per cent and nodule dry weight from 12.2 to 45.5 per cent over the uninoculated control at 45 days after sowing (DAS). The plant dry weight due to different isolates was significantly higher by 25.0 to 70.8 per cent at 30 DAS and 24.8 to 71.4 per cent at 45 DAS over the uninoculated control, respectively. Different isolates did not enhance the grain and straw yields significantly; nevertheless A-7 (isolated from VPKAS, Almora) produced 28.2 and 15.2 per cent more grain and straw yields over the uninoculated control, respectively. Inoculation of the isolates also significantly increased the grain N uptake by 23.9 to 86.9 per cent, straw N uptake by 21.9 to 108.7 per cent, grain P uptake by 20.2 to 72.4 per cent and straw P uptake, by 15.0 to 87.2 per cent over the uninoculated control. Different *Rhizobium* sp. isolates significantly improved the microbial biomass C from 32.5 to 255.3 per cent, organic C from 5.1 to 96.6 per cent, available N from 16.4 to 71.8 per cent and available P from 20.5 to 88.6 per cent over uninoculated control in the post-harvest soil. Isolate A-7 was found superior to others followed by C-1, P-7, and A-3 in beneficial effects on urdbean yield and soil properties.

Key words: Urdbean, *Rhizobium* sp., nodulation, yield, nutrient uptake, soil properties

Pulse crops have unique feature of restoring soil health by virtue of their deep root system and ability of atmospheric nitrogen (N) fixation. Besides, rich source of protein for vegetarian diet, these crops have been emerged as a viable option to improve soil health, conserve natural resources and sustain the agricultural productivity. Pulse crops obtain a major portion of their N need directly from atmosphere through biological N_2 fixation (BNF) by establishing symbiotic association with rhizobia, and also add N to the soil for use by the succeeding crops. Since, BNF is an important component of sustainable agriculture (Bohlool *et al.* 1992), seed inoculation of pulse crops with efficient rhizobial inoculants is recommended for adequate BNF for improving plant growth, yield and soil properties. Establishment of N_2 fixing symbiosis is highly dependent on legume-rhizobia specificity (Dudeja and Duhan 2005) and a large variation exists in the N_2 fixing ability of different rhizobia strains of same host. Therefore, selection of effective strains of rhizobia for different pulse crops is of paramount importance for the development of efficient bioinoculants (Boonkerd and Singleton 2002). Besides N_2 fixation, several rhizobia possess plant growth promoting (PGP) traits such as solubilization of insoluble phosphate in soil, secretion of plant growth hormones *etc*. (Afzal and Bano 2008; Gopalakrishnan *et al.* 2014). Application of such multi-functional rhizobia in pulse crops is expected to give better positive effects on yield and soil health by minimizing the use of chemical fertilizers. Urdbean

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(*Vigna mungo* L.) is a short duration pulse crop and fits well in different cropping systems. It is grown as sole or inter crop in different parts of the country on 4.01 million hectare (Mha) area with productivity of 547 kg ha^{-1}. Urdbean generally gives moderate to poor response to seed inoculation due to fierce competition met by native soil rhizobia and unfavourable soil and environmental conditions (Kundu and Dudeja 2008; Lebrazi and Benbrahim 2014). This stressed the need for isolation of rhizobia of multi-functional traits for urdbean and evaluation of their symbiotic potential under different soil and climatic conditions. This appears to be a cost effective and eco-friendly approach for increasing N_2 fixation, which would ultimately reduce the use of chemical fertilizers and decrease energy input. The present study was, therefore, undertaken for isolation of multi-functional rhizobia for urdbean and to compare their performance on nodulation, plant growth, yield and nutrient uptake by urdbean (*Vigna mungo* L.) and soil properties.

Materials and Methods

Isolation and characterization of Rhizobium sp.

Soil samples were collected of varying altitude and properties from districts Pithoragarh, Almora, Champawat, Pauri and Dehradun of Uttarakhand (Table 1). The collected samples were processed to pass through 2-mm sieve, 100 g soil was filled in plastic pots, 2-3 seeds of urdbean (cv. Pant Urd-31) were planted in each pot and crop was raised for 30 days under net house. The plants were uprooted from the pots with intact root nodules, roots were thoroughly washed and pink coloured nodules were used for isolation of *Rhizobium* sp. (Somasegaran and Hoben 1994). The isolates were selected on the basis of colony characteristics on yeast extract mannitol agar (YEMA) medium and were subjected to gram staining. The functional diversity of the isolates was assessed by utilization of 35 different carbohydrates as sole C source using Hi Carbo-kits procured from M/s HI Media, Mumbai. The obtained isolates were characterized for phosphate solubilization on Pikovaskya's agar medium plates (Pikovaskaya 1948), Indole acetic acid production on LB agar supplemented with 0.06% sodium dodecyl sulphate (SDS) and 1% glycerol (Brick *et al.* 1991) and siderophore production using Chrome Azurol S (CAS) agar media (Schwyn and Neilands 1987).

Evaluation of Rhizobium sp.

The performance of the *Rhizobium* sp. isolates was compared in a field experiment during *kharif* season of 2016 at N.E. Borlaug Crop Research Centre of the University (29° N latitude, 79.3° E longitude and at an altitude of 243.8 m above the mean sea level). The experimental soil was sandy loam of pH 6.90, electrical conductivity (EC) 0.24 dS m^{-1}, organic C (OC) 6.7 g kg^{-1} having 180, 20.1 and 261.2 kg ha^{-1} available N, phosphorus (P) and potassium (K), respectively. Treatments consisted of 18 *Rhizobium* sp. isolates along with uninoculated control and 20

Table 1. Soil properties of *Rhizobium* sp. isolates sites

S. No.	Rhizobia isolate	Sample site	Soil properties		
			pH	EC (dS m^{-1})	Mineral N (µg g^{-1})
1	P-2	Salmora, Pithoragarh	5.84	0.59	45.2
2	P-4	KVK, Pithoragarh	5.46	0.68	47.5
3	P-5	KVK, Pithoragarh	6.74	0.48	52.8
4	P-6	KVK, Pithoragarh	6.35	0.88	51.8
5	P-7	Aancholi, Pithoragarh	7.25	0.54	55.9
6	P-8	Aancholi, Pithoragarh	7.46	0.44	53.1
7	A-3	Hawalbagh, Almora	5.59	0.24	56.4
8	A-5	Hawalbagh, Almora	5.52	0.24	53.8
9	A-6	VPKAS, Almora	5.97	0.14	60.2
10	A-7	VPKAS, Almora	6.51	0.11	53.4
11	A-9	Barecheera, Almora	5.88	0.21	56.1
12	A-11	Ghatbathuria, Almora	5.53	0.27	58.0
13	A-15	Almora city	6.94	0.51	54.0
14	A-18	VPKAS, Almora	6.12	0.28	57.5
15	K-6	Banalu, Kotdwar	6.82	0.34	58.7
16	K-12	Sendikral, Kotdwar	7.25	0.32	55.6
17	C-1	Champawat	5.76	0.86	61.2
18	D-1	F.R.I, Dehradun	6.42	0.57	50.4

kg N ha^{-1}. The carrier based inoculants were prepared by growing the rhizobial isolates separately in yeast extract mannitol (YEM) broth for 4 days and mixing the broth culture with charcoal powder (neutralized with $CaCO_3$) in 1:2 ratio. The inoculants had 1.1×10^9 cells g^{-1}. The treatments were laid out in a randomized block design with three replications. The urdbean (cv. Pant Urd-31) was sown on 2nd August 2016 with a seed rate of 30 kg ha^{-1}. Seed inoculation was done by mixing the required quantity of the each inoculant @ 20 g kg^{-1} seed as per treatments. Five plants from each plot were randomly uprooted along with a soil block of about 25 cm diameter at 30 and 45 days after sowing (DAS). Adhered soil with roots was washed off with tap water carefully. The nodules were removed from root and counted. The dry weight of root nodules and plants was determined after drying in hot air oven to constant weight. Grain and straw yields were recorded at harvest. The N and P content in grain and straw was estimated as described by Page (1982) and their uptakes were computed. Soil samples of 0-15 cm depth were collected at harvest of crop from individual plots. A portion of the fresh soil sample was stored in refrigerator for the estimation microbial biomass C (MBC) by chloroform fumigation extraction method using Kc value of 0.45 (Vance *et al*. 1987). The remaining part of soil sample was processed to pass through 2-mm sieve and analyzed for OC, available N and P (Jackson 1973). The apparent balance of OC and available N and P in soil of each treatment was computed by subtracting the values of these parameters at the initiation of the study. The treatments were compared using the F-test by calculating the critical difference at 5% level of significance.

Results and Discussion

Characterization of Rhizobium sp. *isolates*

Cultural characteristics revealed that all isolates formed white, opaque, raised gummy and translucent colonies on YEMA medium in 4-5 days at 28±2 °C and designated as *Rhizobium* sp. isolates. The isolates were gram negative. Among these, 11 isolates (P-2, P-5, P-8, A-3, A-5, A-6, A-11, A-15, A-18, K-6 and K-12) and 6 isolates (P-5, A-3, A-6, A-11, A-15 and K-12) grew at 35 and 40 °C, respectively, *in vitro* condition. In agreement with the reports of Kumar and Ram (2012), the rhizobial isolates indicated different sole carbon source utilization (SCSU) profiles. The relatedness among the rhizobial isolates on the basis of SCSU indicated groupings of the isolates into four clusters (Fig. 1) comprising of

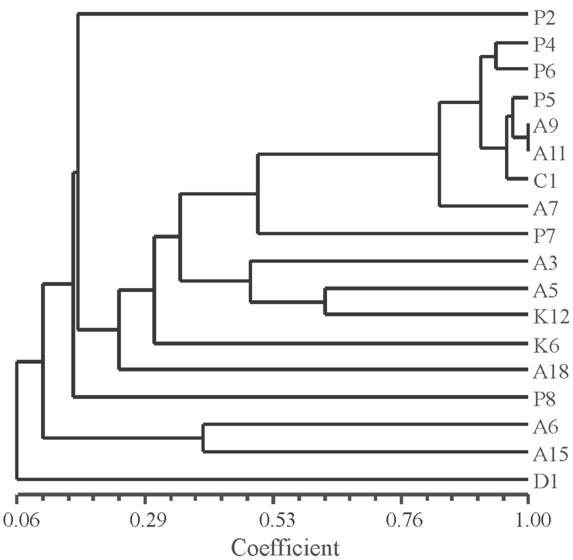

Fig. 1. Clustering of urdbean *Rhizobium* sp. isolates based on sole carbon source utilization

cluster I of isolates P-4, P-5, P-6, A-9, A-11 and C-1, cluster II of isolates A-7, P-7, A-3 and A-5, cluster III of isolates P-2, P-8, A-18, K-6 and K-12 and cluster IV of isolates A-6, A-15 and D-1. The isolates also differ in various PGP traits. Nine isolates (P-2, P-5, P-7, A-3, A-6, A-7, A-11, K-6 and C-1) indicated phosphate solubilization on Pikovaskya's medium (Sridevi and Mallaiah 2009), 7 isolates (P-7, P-8, A-3, A-6, A-7, A-15 and K-6) secreted IAA and 11 isolates (P-2, P-7, P-8, A-3, A-6, A-7, A-9, A-18, K-12, C-1 and D-1) produced siderophores under *in vitro* conditions (Gopalakrishnan *et al.* 2014) (Table 2).

Table 2. PGP traits of rhizobial isolates

Isolation	Phosphate solubilization	IAA production	Siderophore production
P-2	+	-	+
P-4	-	-	-
P-5	+	-	-
P-6	-	-	-
P-7	+	+	+
P-8	-	+	+
A-3	+	+	+
A-5	-	-	-
A-6	+	+	+
A-7	+	+	+
A-9	-	-	+
A-11	+	-	-
A-15	-	+	-
A-18	-	-	+
K-6	+	+	-
K-12	-	-	+
C-1	+	-	+
D-1	-	-	+

Table 3. Effect of different *Rhizobium* sp. isolates on root nodulation at 30 and 45 DAS

Treatments	Nodule number plant^{-1}		Nodule dry weight (mg plant^{-1})	
	30 DAS	45 DAS	30 DAS	45 DAS
Uninoculated control	35.8	51.3	33.7	51.8
20 kg N ha^{-1}	37.4	62.8	37.5	53.1
P-2	45.3	65.4	38.1	58.1
P-4	47.7	63.9	37.6	63.9
P-5	49.6	68.1	39.8	63.2
P-6	46.5	60.6	39.7	67.6
P-7	49.9	72.5	42.6	72.7
P-8	44.3	68.5	37.8	68.3
A-3	48.8	71.2	43.7	71.3
A-5	40.1	64.8	38.8	60.9
A-6	41.2	66.9	38.4	63.7
A-7	49.0	74.3	40.2	75.0
A-9	45.4	69.1	40.0	68.9
A-11	44.9	66.2	39.1	64.8
A-15	44.8	63.2	37.6	65.7
A-18	44.4	68.0	39.0	69.1
K-6	47.8	74.5	41.2	72.7
K-12	45.2	63.5	38.9	63.3
C-1	46.1	73.8	40.0	75.4
D-1	44.6	64.0	37.8	67.9
CD (P=0.05)	NS	9.8	NS	13.2

Table 4. Effect of different *Rhizobium* sp. isolates on urdbean plant dry weight and yield

Treatments	Plant dry weight (g plant^{-1})		Yield (kg ha^{-1})	
	30 DAS	45 DAS	Grain	Straw
Uninoculated control	2.4	10.5	1036	1753
20 kg N ha^{-1}	2.9	11.5	1155	1786
P-2	3.0	13.1	1200	1869
P-4	3.1	15.2	1220	1877
P-5	3.1	16.6	1260	1910
P-6	3.4	16.0	1223	1852
P-7	3.8	16.7	1308	1900
P-8	3.4	14.6	1193	1769
A-3	3.8	17.1	1316	2013
A-5	3.1	13.1	1142	1814
A-6	3.3	15.0	1232	1790
A-7	3.9	17.2	1328	2020
A-9	3.4	14.8	1222	1861
A-11	3.3	14.2	1242	1832
A-15	3.3	14.8	1242	1833
A-18	3.4	16.7	1229	1886
K-6	3.8	16.8	1304	1970
K-12	3.4	14.5	1180	1804
C-1	4.1	18.0	1321	1948
D-1	3.0	14.7	1154	1763
CD (P=0.05)	0.8	3.1	NS	NS

Symbiotic performance

Root nodulation

Different *Rhizobium* sp. isolates increased the number and dry weight of root nodules numerically at 30 DAS (Table 3). However, all the isolates, except P-6, gave significantly more nodule number over the uninoculated control at 45 DAS. Different isolates, except P-2, P-4, P-5, A-5, A-6, A-11 and K-12 also produced significantly more nodule dry weight over the uninoculated control at this crop age. Isolates A-7, P-7, C-1 and K-6 were found superior to others in nodule number and nodule dry weight. Such differences in number and dry weight of root nodules with different isolates may be due to better compatibility with host and variations in the effectiveness and competitiveness of the strains due to genetic diversity (Kundu and Dudeja 2008).

Plant dry weight

The plant dry weight due to inoculation of different *Rhizobium* sp. isolates increased significantly ranging from 25.0 to 70.8 per cent at 30 DAS and 24.8 to 71.4 per cent at 45 DAS over the uninoculated control (Table 4). The increases were statistically significant with all strains, except P-2, P-4, P-5, A-5 and D-1 at 30 DAS and P-2, P-4 and A-5 at 45 DAS over the uninoculated control. Isolate C-1 gave the highest plant dry weight at both the intervals and was followed by A-7. These isolates were also found relatively better than others in root nodulation resulting in higher plant biomass (Fatima *et al.* 2006). Superiority of these isolates over others may also be due to their ability of PGP traits such as P solubilization and secretion of IAA and siderophores (Sridevi and Mallaiah 2009). It may also be because of either presence of native strains of inferior competitive ability and effectiveness in soil than that used in the study (Svenning *et al.* 2001).

Grain and straw yields

Different *Rhizobium* sp. isolates did not favour the grain and straw yields significantly (Table 4). Isolate A-7 produced the highest grain and straw yields, being 28.2 and 15.2 per cent higher than the uninoculated control, respectively. It was followed by isolates C-1 and A-3 by producing 27.5 and 27.0 per cent more grain yield over the uninoculated control. *Rhizobium* sp. isolate A-3 also ranked next to A-7 in straw yield. Similar variations in the performance of rhizobial isolates on yields have been reported earlier by Tripathi *et al.* (2012) in mungbean and Khanna *et*

Table 5. Effect of different *Rhizobium* sp. isolates on N and P uptake by urdbean grain and straw

Treatments	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})	
	Grain	Straw	Grain	Straw
Uninoculated control	38.4	18.8	3.81	3.53
20 kg N ha^{-1}	44.8	21.3	4.66	4.15
P-2	50.6	25.1	5.15	4.54
P-4	58.4	29.0	5.34	4.51
P-5	51.7	24.7	5.49	4.72
P-6	54.8	24.9	5.22	4.42
P-7	67.5	34.9	6.57	5.23
P-8	55.3	24.9	5.40	4.77
A-3	66.8	33.1	6.54	5.46
A-5	47.6	23.6	5.55	5.12
A-6	58.2	25.7	5.77	5.07
A-7	71.8	39.2	5.46	6.12
A-9	55.5	26.2	4.87	4.64
A-11	59.3	27.2	5.24	4.26
A-15	55.0	24.9	5.55	4.67
A-18	55.9	25.6	4.97	4.38
K-6	64.8	31.4	6.45	6.61
K-12	47.9	23.1	4.58	4.77
C-1	68.0	34.4	5.92	6.15
D-1	48.7	22.9	4.94	4.06
CD (P=0.05)	11.6	10.3	NS	1.44

al. (2006) in lentil owing to better nodulation and plant dry matter production by these isolates possibly due to higher BNF efficiency and presence of PGP traits.

N uptake

Different *Rhizobium* sp. isolates improved the N uptake by grain and straw to varying extent in comparison to uninoculated control and fertilizer N treatment (Table 5). All the inoculated isolates, except A-5, K-12 and D-1 recorded significantly higher N uptake by grain than the uninoculated control. Similarly, isolates A-7, A-3, P-7 and C-1 also recorded significantly more N uptake by straw over the application of 20 kg N ha^{-1}. Isolate A-7 recorded the highest N uptake by grain and straw registering increases of 86.9 and 108.6 per cent over the uninoculated control and 60.4 and 83.8 per cent over fertilizer N treatment. It was statistically at par with isolates C-1, P-7, K-6 and A-3 in N uptake by grain and straw. The higher N uptake following inoculation with these isolates was possibly due to their greater BNF potential, as reflected in the nodulation and grain yield by these isolates. Yadav *et al*. (2011) also reported similar findings due to variability in the genetic make up and N_2 fixation ability of chickpea rhizobia strains.

P uptake

Different isolates gave non-significant increases of 20.2 to 72.4 per cent in P uptake by grain and significant increases of 15.0 to 87.2 per cent in P uptake by straw over the uninoculated control (Table 5). Maximum P uptake by grain was recorded with isolate P-7 followed by A-3. Isolates K-6, C-1, A-7, A-3, P-7, A-6 and A-5 were at par and recorded significantly more P uptake by straw over the uninoculated control. It may be attributed to P solubilization ability of these isolates resulting in greater P availability in soil enhancing P uptake by grain and straw, as reported by Sridevi and Mallaiah (2009). The higher P uptake by these isolates could also be explained by the observation of relatively more available P in soil after crop harvesting following their inoculation (Table 5). The superiority of P-7, A-3 and A-7 isolates over others in nutrient uptake may also be attributed to their ability of secretion of IAA and siderophores in addition to P solubilization.

Soil properties

Microbial biomass C

The MBC in soil after crop harvesting with all the isolates, except A-5 and A-18, increased significantly ranging from 84.6 to 255.3 per cent over the uninoculated control and 50.4 to 189.4 per cent over fertilizer N treatment (Table 6). The highest MBC in soil was recorded with isolate C-1, it was at par with A-3 and P-7 by registering 208.1 and 201.4 per cent higher MBC in soil over the uninoculated control, respectively. Microbial biomass is most labile pool of soil N and has positive correlation with available N in soil (Nannipieri *et al.* 2003). The differences in soil MBC under different treatments could be due to variation in crop growth, biomass production and release of root exudates. A part of crop biomass returns to soil through leaf fall, influences availability of organic substrates for microorganisms causing variations in microbial biomass (Bhatt and Chandra 2014). This fact is substantiated by the observation of significantly higher plant dry weight due to inoculation of different *Rhizobium* sp. isolates. The higher OC content in soil after crop harvesting in inoculated treatments also support these results.

Organic C

The OC in soil due to inoculation of different isolates ranged from 6.2 to 11.6 g kg^{-1} compared to 5.9 g kg^{-1} with uninoculated control (Table 6). Application of 20 kg N ha^{-1} showed non-significant

Table 6. Effect of different *Rhizobium* sp. isolates on soil organic C, microbial biomass C, available N and P (kg ha^{-1}) at urdbean harvest

Treatment	Microbial biomass C (μg g^{-1})	Organic C (g kg^{-1})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Apparent organic C balance (g kg^{-1})	Apparent available N balance	Apparent available P balance
Uninoculated control	87.9	5.9	165.4	22.9	-0.8	-14.8	+2.8
20 kg N ha^{-1}	107.9	6.2	187.5	24.3	-0.5	+7.25	+4.2
P-2	220.9	6.3	192.5	28.2	-0.4	+12.3	+8.1
P-4	256.7	8.8	196.7	31.6	+2.1	+16.5	+11.5
P-5	175.4	8.0	212.0	33.3	+1.3	+31.8	+13.2
P-6	162.3	8.4	215.1	37.9	+1.7	+34.9	+17.8
P-7	264.9	10.2	264.8	43.2	+3.5	+84.6	+23.1
P-8	207.6	7.5	213.7	32.3	+1.3	+33.5	+12.2
A-3	270.9	9.5	268.5	39.1	+2.8	+88.3	+19.0
A-5	121.4	6.6	204.2	27.9	-0.1	+24.0	+7.8
A-6	168.5	6.4	197.3	35.1	-0.3	+17.1	+15.0
A-7	228.1	9.0	277.1	40.4	+2.3	+96.9	+20.3
A-9	246.8	8.1	228.7	34.9	+1.4	+48.5	+14.9
A-11	203.7	8.4	240.8	32.3	+1.7	+60.5	+12.2
A-15	212.0	8.6	257.9	29.6	+1.9	+77.75	+9.5
A-18	116.5	6.2	247.3	30.8	-0.5	+67.05	+10.7
K-6	271.4	11.6	284.2	42.4	+4.9	+104.0	+22.3
K-12	182.9	6.4	195.2	27.6	-0.3	+15.0	+7.5
C-1	312.3	10.5	274.5	41.2	+3.8	+94.3	+21.1
D-1	191.8	6.6	205.4	29.4	-0.1	+25.2	+9.3
C.D. (5%)	42.3	2.0	32.8	9.1			

increase in OC in soil over the uninoculated control. All the isolates, except P-2, P-8, A-5, A-6, A-18, K-12 and D-1 recorded significantly higher OC in soil after harvesting, highest being with K-6. It was statistically at par with C-1 and P-7 and significantly better than all other isolates. All the isolates, except A-5, A-6, A-18 and K-12, enhanced the apparent OC balance in soil after harvest, highest being with K-6. The latter isolate was followed by C-1, P-7 and A-3 in apparent OC balance. Leaf shedding habit at maturity of urdbean was the reason of such increases in OC and apparent balance after crop harvesting. Inoculated treatments had more crop biomass and increased OC in soil due to addition of plant biomass in soil.

Available N and P

Available N and P status in soil (Table 6) increased significantly after urdbean harvesting with inoculation of different *Rhizobium* sp. isolates. All isolates, except P-2, P-4, A-6 and K-12, registered significantly more available N ranging from 16.4 to 71.8 per cent over the uninoculated control. The isolate K-6 recorded the highest available N in soil, was at par with P-7, A-3, A-7, A-15 and C-1 and significantly better than all the other tested isolates. Similarly, all the isolates, except P-2, P-4, A-5, A-15, A-18, K-12 and D-1 recorded significantly more available P over the uninoculated control ranging from 20.5 to 88.6 per cent, highest being with isolate P-7. Isolate P-7 was at par with P-6, A-3, A-6, A-7, A-9, K-6 and C-1 in soil available P. Inoculated isolates also increased the apparent available N and P in soil. The highest apparent available N balance was obtained with isolate K-6 followed by A-7, C-1 and A-3. Similarly, highest apparent available P balance in soil was recorded with isolate P-7 followed by K-6, C-1 and A-7. The increase in available N in soil may be attributed to improvement in nodulation and N_2 fixation following inoculation and P due to P solubilization activity of the isolates (Bhatt and Chandra 2014). Application of 20 kg N ha^{-1} was at par with uninoculated control in available N and P in soil.

Conclusions

The results of the study suggest that naturally isolated urdbean *Rhizobium* sp. from diverse soils differ in their effectiveness with respect to crop growth, yield and nutrient uptake, and soil fertility. The rhizobia isolates possessing PGP traits were found superior to those lacking in such activities. Isolate

A-7 was found most promising in improving the urdbean productivity and soil properties. The other potential isolates were P-7, A-3 and C-1.

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