



Influence of cyanobacterial inoculants and planting methods of rice (*Oryza sativa*) on soil microbial parameters, aggregation and carbon content

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Rice (*Oryza sativa* L.) is a staple food crop in Asia where about 90% of world's rice is grown and consumed. Rice cultivation requires large amounts of water and scarcity of water is becoming more intensive day by day. Increase in prices of agricultural inputs prevents poor farmers from adopting modern production technologies. In such a situation, the system of rice intensification (SRI), which is a set of agronomic management practices for rice cultivation that enhances yield, reduces water requirements and raises input productivity needs due consideration. In rice, along with water, nutrient-use efficiency especially of nitrogen needs attention due to its low recovery. Different interventions have come forward to increase nitrogen recovery; and use of cyanobacteria bio-fertilizer in rice is one of them. The paddy field ecosystem represents a unique aquatic-terrestrial habitat, which provides a favourable environment for growth and nitrogen fixation by cyanobacteria. Besides nitrogen fixation, cyanobacteria are known to contribute to macro-aggregation and result in improving resistance to soil erosion because as primary producers, they contribute to the enrichment of soil with organic matter (OM) and improvement in biological activity (Acea *et al.* 2003). Besides cyanobacteria there are certain promising resources like rhizobacteria that exert beneficial effect on plant growth and development. With this background, a field study was conducted to study the effect of cyanobacteria inoculants on soil carbon stocks and aggregation, microbial parameters and contribution on plant growth.

The experiment was conducted during rainy season of 2011 at New Delhi (28°40' N latitude, 77°12' E longitude

and altitude of 228.6 m above the mean sea level). The soil was sandy clay loam in texture having 8.1 pH, 0.53% organic carbon, 134.9 kg/ha available N, 15.90 kg/ha available P and 260.83 kg/ha available K. The experiment was laid out in split-plot design with two methods of crop establishment, viz. conventional transplanting (CT) and system of rice intensification (SRI) in main-plot and six cyanobacteria inoculant treatments, viz. B₁: N₀, B₂: Recommended dose of nitrogen (RDN) (120 kg/ha), B₃: Compost application (1/3 RDN) + 2/3 RDN, B₄: BGA + PGPR + 2/3 RDN, B₅: Compost based BGA mix inoculant + 2/3 RDN and B₆: *Multani mitti* based BGA inoculant + 2/3 RDN in sub-plots (Table 1). In B₄, B₅ and B₆ treatments BGA and PGPR strains of *Ochromobacterium* sp. (PR-10) and *Anabaena* spp. (CR-2), *Anabaena* sp. (BF1, BE4) and *Noctoc* sp. (BF2, BF3) and *Anabaena* sp., *Noctoc* spp., *Tolipothrics* sp. and *Allocera* sp., respectively were applied. Cyanobacterial inoculants were applied at the time of transplanting and mineral N through urea was applied as per treatment in 3 splits at 5, 25 and 55 days after transplanting (DAT). Equal doses of P and K (60 kg/ha P₂O₅ and 60 kg/ha K₂O) were applied through inorganic sources in all the treatments including N control. In CT and SRI, 21 and 12 days old seedlings, respectively were transplanted in puddled fields. Rice variety Pusa Basmati 1401 was grown as per recommended practices. The soil samples were collected at 60 days after transplanting (DAT) and at harvest stage.

The soil microbial parameters studied included dehydrogenase activity (Casida *et al.* 1964), microbial biomass carbon (MBC) (Nunan *et al.* 1998), soil chlorophyll (Nayak *et al.* 2004) and acetylene reductase activity (ARA). Soil carbon was analysed according to Chan *et al.* (2001) modified Walkley and Black method and soil aggregation to Yoder (1936). Mean weight diameter (MWD) was determined as follows:

$$\text{MWD} = \sum x_i w_i$$

where, w_i is the proportion of each aggregate class i in relation to the weight of soil sample taken for analysis, x_i the mean diameter of the class (mm).

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Table 1 Effect of planting methods and cyanobacterial inoculants on soil microbial properties

Treatment	ARA(n mole ethylene/g/hr)		Soil chlorophyll (mg/ml)		Dehydrogenase (mg TPF/g soil/day)		Microbial biomass carbon (mg MBC/g soil)	
	60 DAT	At harvest	60 DAT	At harvest	60 DAT	At harvest	60 DAT	At harvest
<i>Planting Method</i>								
Conventional transplanting	1.65	1.31	1.83	1.35	12.88	7.79	239.11	152.33
SRI method	1.82	1.35	1.74	1.45	12.78	8.11	229.61	150.16
SEm±	0.016	0.013	0.017	0.015	0.213	0.090	2.940	4.987
LSD (P=0.05)	0.099	NS	NS	0.0949	NS	NS	NS	NS
<i>Bacterial inoculants</i>								
B1	0.73	0.70	0.94	0.51	5.02	2.69	84.00	57.00
B2	1.91	1.46	2.03	1.68	14.86	9.28	280.83	183.66
B3	1.98	1.49	1.96	1.61	14.80	9.24	268.66	178.66
B4	2.13	1.56	2.14	1.75	15.16	9.38	285.83	186.50
B5	2.01	1.50	1.96	1.57	14.57	9.14	264.16	170.66
B6	1.61	1.25	1.68	1.28	12.56	7.97	222.66	131.00
SEm±	0.080	0.0474	0.050	0.074	0.429	0.25	9.56	10.411
LSD (P=0.05)	0.236	0.139	0.147	0.220	1.266	0.752	28.21	30.720

B1: N₀, B2: Rec. dose of N (RDN-120 kg/ha), B3: Compost application (1/3 N) + 2/3 RDN, B4: BGA + PGPR + 2/3 RDN, B5: Compost based BGA + 2/3 RDN and B6: *Multani mitti* based BGA + 2/3 RDN

Results showed that ARA and chlorophyll of soil were higher at 60 DAT and decreased toward crop maturity. SRI method recorded significantly higher ARA at 60 DAT compared to conventional method, while soil chlorophyll was on par in both the methods of cultivation at 60 DAT. Among sub-plots, BGA+ PGPR + 2/3 RDN showed highest ARA activity and soil chlorophyll content which were significantly higher than *Multani mitti* based BGA inoculant + 2/3 N (fertilizer) (Table 1). Higher levels of N are known to inhibit N fixation by BGA (Prasanna *et al.* 2003) that is why even at 75 % N application, ARA activity was found

higher compared to full recommended dose of nitrogen in our study. Effectiveness of BGA in enhancing soil chlorophyll content was also increased due to the application of compost with BGA that might be the reason for higher chlorophyll content in all cyanobacteria inoculants where compost was used as a carrier except *Multani mitti* based BGA.

Dehydrogenase enzyme activity and MBC both at 60 DAT and at crop maturity was highest in BGA+PGPR and 2/3 RDN. It was significantly higher over *Multani mitti* based BGA inoculant + 2/3 RDN in both the studied parameters (Table 1). Difference in dehydrogenase enzyme

Table 2 Effect of planting methods and cyanobacterial inoculants on soil C content and mean weight diameter at 60 days after transplanting

Treatment	Labile carbon fraction (%)						Mean weight diameter (MWD)	
	Very labile		Labile		Less labile			
	Depth (cm)		Depth (cm)		Depth (cm)		(mm)	
	0-7.5	7.5-15	0-7.5	7.5-15	0-7.5	7.5-15	0-7.5	7.5-15
<i>Planting method</i>								
Conventional transplanting	0.83	0.610	0.65	0.54	0.44	0.28	0.96	0.58
SRI	0.70	0.614	0.67	0.56	0.44	0.28	1.04	0.59
SEm±	0.0018	0.002	0.003	0.003	0.002	0.0007	0.0004	0.009
LSD (P=0.05)	0.011	NS	NS	NS	NS	NS	0.003	NS
<i>Bacterial inoculants</i>								
B1	0.64	0.54	0.58	0.47	0.32	0.22	0.58	0.26
B2	0.81	0.63	0.68	0.57	0.47	0.29	1.11	0.66
B3	0.82	0.63	0.69	0.60	0.47	0.30	1.11	0.68
B4	0.81	0.62	0.67	0.56	0.46	0.29	1.09	0.64
B5	0.80	0.62	0.67	0.55	0.46	0.29	1.08	0.64
B6	0.72	0.61	0.67	0.54	0.46	0.29	0.99	0.63
SEm±	0.011	0.012	0.009	0.023	0.006	0.004	0.018	0.016
LSD (P=0.05)	0.034	0.037	0.027	0.066	0.018	0.013	0.053	0.05

activity and MBC was not significant in both the methods of planting. Microbial biomass and soil enzymes are considered as potential indicator of soil quality due to their relationship to soil biology, ease of measurement, rapid responses to changes in soil management and high sensitivity to changes originated by management and environment factor (Marx *et al.* 2001).

Soil carbon content was higher in 0-7.5 cm depth compared to 7.5-15 cm depth. This difference might be due to higher microbial activity and better soil physical condition in top 0-7.5 cm depth as compared to 7.5-15 cm depth. Very labile carbon fraction at 0-7.5 cm depth layer was higher in conventional method of cultivation compared to SRI method (Table 2). Among the sub-plot treatments, compost (1/3 N) + 2/3 RDN showed highest very labile fraction of C content after 60 days of crop growth at 0-7.5 cm depth due to compost application. Positive effect of manure application on SOC build-up under maize-wheat system in semi-arid India has earlier been reported by Benbi *et al.* (1998). Carbon content in other treatments including RDN (120 kg/ha), BGA+PGPR + 2/3 RDN and compost based BGA mixture inoculant + 2/3 RDN were at par. However, all these four treatments had significantly higher C content over *Multani mitti* based BGA inoculant + RDN; While the differences in C content were non-significant among all these treatments at 7.5-15 cm depth. Both methods of cultivation and sub-plot treatments containing cyanobacterial inoculants didn't have any effect on labile and less labile carbon content at both the depth.

Mean weight diameter (MWD) in SRI method at 0-7.5 cm depth was significantly higher over conventional method, while at 7.5-15 cm depth MWD in both the methods was at par (Table 2). Treatment containing compost application (1/3 N) + 2/3 RDN showed highest MWD of aggregates at 60 DAT at 0-7.5 cm depth, which was on par with BGA+PGPR and 2/3 RDN. Both treatments had significantly higher MWD compared to *Multani mitti* based BGA inoculant + 2/3 N (fertilizer). Cyanobacterial treatments didn't have any significant effect on MWD at 7.5-15 cm depth. MWD were higher in 0-7.5 cm depth compared to 7.5-15 cm depth. This difference might be due to higher C content in top 7.5 cm soil compared to 7.5-15 cm depth. Improvement in the soil aggregation due to cyanobacteria inoculation could be related to increase in soil carbon and exo-polysaccharides (EPS) that cause change in the soil micro-morphological characteristics of the aggregates (Issa *et al.* 2007). In the present study carbon content was higher in 0-7.5 cm depth due to cyanobacteria inoculation which might have contributed to better soil aggregation.

SUMMARY

It was concluded that cyanobacterial inoculants performed similar under SRI and conventional methods of rice cultivation. Inoculation of BGA + PGPR along with 2/3 RDN recorded highest ARA activity and chlorophyll content of soil. Treatment containing application of compost + 2/3 RDN helped to increase soil organic carbon content and thereby improved soil aggregation. BGA + PGPR with 2/3 RDN performed at par with compost + 2/3 N (fertilizer) in term of soil carbon content and mean weight diameter (MWD) which indicated that cyanobacteria have a positive effect on soil carbon content and soil aggregation.

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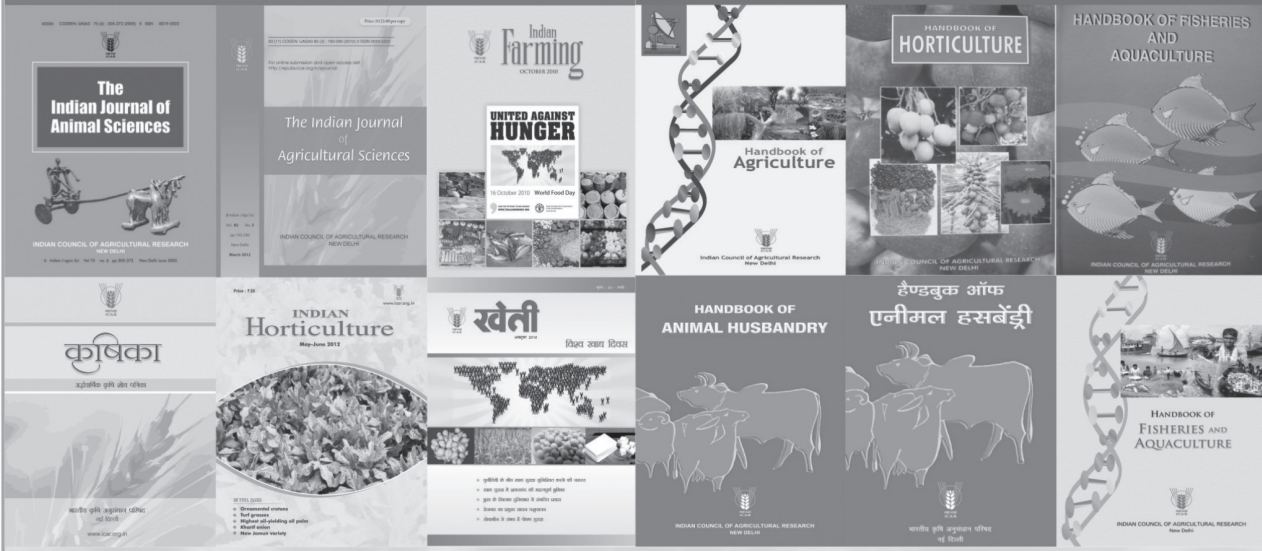


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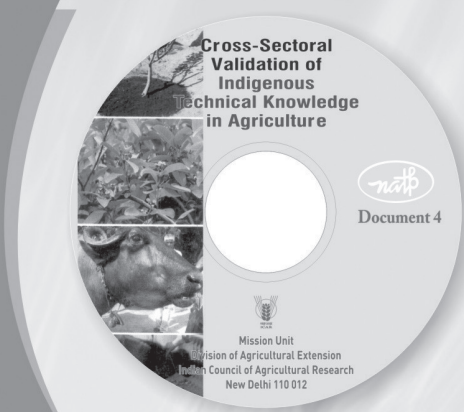
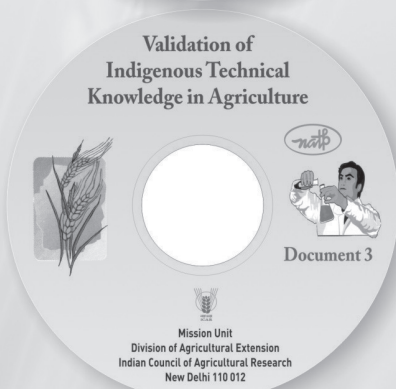
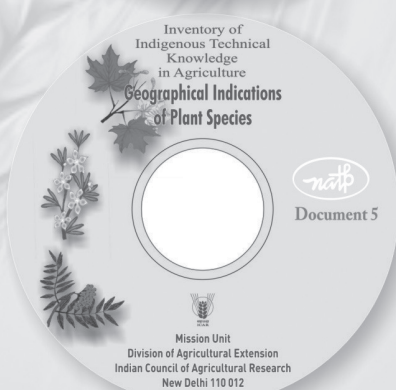
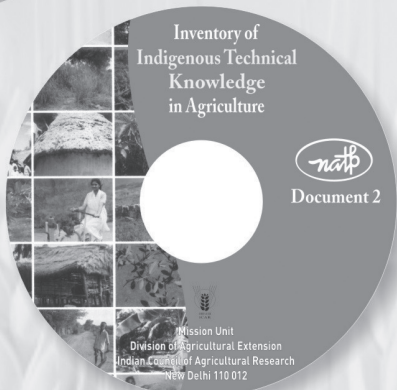


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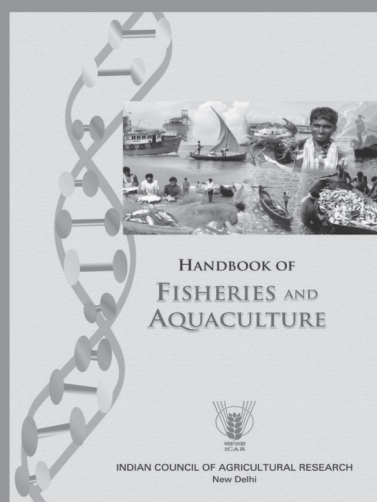
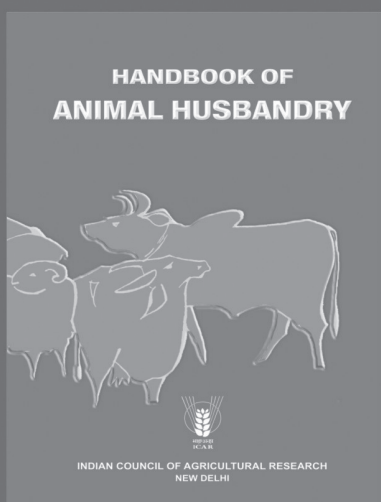
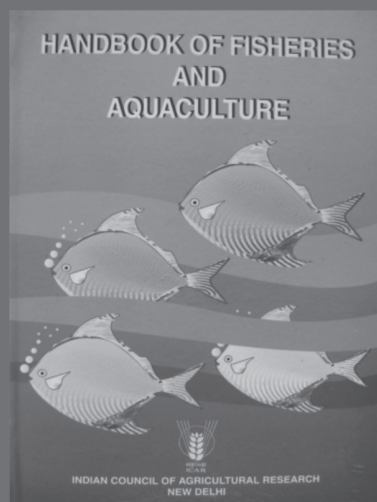
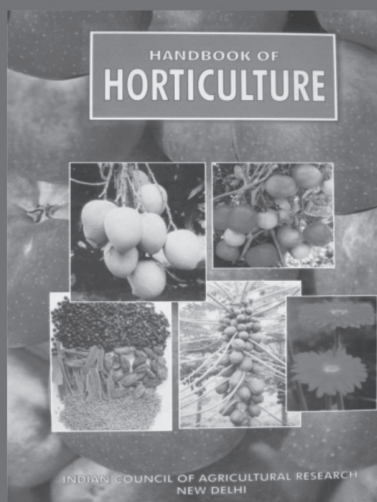
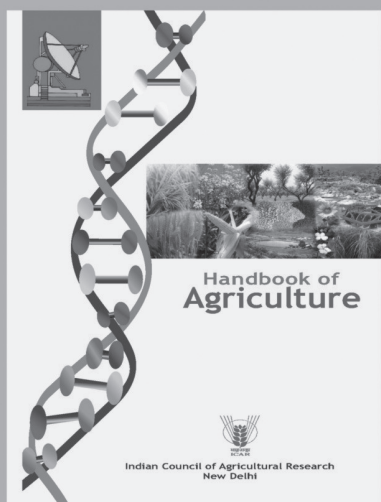


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