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Effect of liquid biofertilisers in combination with inorganic fertilizers on nutrient status of soil under direct sown rice (*Oryza sativa*)

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Abstract
A field experiment entitled “soil nutrient transformations and performance of direct sown rice (*Oryza sativa*) as influenced by liquid biofertilizers” was conducted during *kharif,* 2019 at Agricultural College Farm, Bapatla, Andhra Pradesh. The results of the experiment indicated that application of different levels of fertilizers along with liquid biofertilizers significantly increased N, P and K status of the soil while their effect on soil organic carbon was non-significant. The highest organic carbon values (0.59, 0.58 and 0.56%) at maximum tillering, panicle initiation and harvest stages respectively was observed in T_6 (100% RDF + *Azospirillum* + PSB+ KRB). Among the different treatments, the highest available nitrogen contents (299 kg ha^{-1}, 290 kg ha^{-1} and 278 kg ha^{-1}) at maximum tillering, panicle initiation and harvest stages respectively were recorded in the treatment T_6 (100% RDF+*Azospirillum*+PSB+ KRB) followed byT_4 (100% RDF +*Azospirillum* + PSB) and T_5 (100% RDF + *Azospirillum* + KRB) and these were on par with each other. The highest available phosphorus content (66.33g ha^{-1}, 62.42kg ha^{-1} and 60.97 kg ha^{-1}) at maximum tillering, panicle initiation and harvest stages respectively was recorded in the treatment T_6 (100% RDF+*Azospirillum*+PSB+ KRB) followed by T_4 (100% RDF +*Azospirillum* + PSB) and T_5 (100% RDF + *Azospirillum* + KRB)) and these were on par with each other. Similar trend was noticed in the content of available potassium also. The lowest available nitrogen, phosphorus and potassium contents were recorded in the treatment T_1 (Control) at all stages.

Keywords: Liquid biofertilizers, *Azospirillum*, PSB, KRB, Direct sown rice

Introduction
Unlike conventionally transplanted rice, direct sown rice avoids puddling, transplanting and standing water at initial growth stages and the traditional wet land paddy requires more irrigation water. In view of the scarcity of water and late release of water into the canals, an innovative technology of sowing paddy seeds directly in the main field was developed rather than transplanting seedlings from the nursery. At present, 26 and 28 per cent of rice is direct-seeded in South Asia and in India, respectively (Rao *et al*., 2007) [12]. Biofertilizers are living microbial inoculants that are added to the soil to improve the plant growth. They are very cost effective and increases crop yield by 10-30%. They supplement chemical fertilizers and can replace them up to 25%. They stimulate plant growth and biological activity of the soil. They add nutrients through the natural processes of nitrogen fixation, solubilizing soil phosphorus and stimulating plant growth through the synthesis of growth-promoting substances. Liquid biofertilizer (LBF) formulation is the promising and updated technology. LBF facilitates a long survival of the organism by providing suitable medium which is sufficient for the entire crop cycle. They are believed to be the best alternative for the conventional carrier based biofertilizers. In view of the above facts, a field study was proposed to assess soil nutrient status influenced by the liquid biofertilizers under direct sown rice (O*ryza sativa*).

Material and Methods
A field experiment entitled “soil nutrient transformations and performance of direct sown rice (*Oryza sativa*) as influenced by liquid biofertilizers” was conducted during *kharif,* 2019 at Agricultural College Farm, Bapatla, Andhra Pradesh. The experimental soil was sandy clay in texture and slightly alkaline in reaction. The soil was medium in organic carbon, low in available nitrogen, medium in available phosphorus, high in available potassium and sufficient in all available divalent cationic micronutrients (Zn, Fe. Mn and Cu).

The experiment was laid out in RBD with eleven treatments replicated thrice. The treatments comprised of T_1-Control, T_2 - 100% Recommended Dose of Fertilizer (RDF), T_3 - 100% RDF + *Azospirillum*, T_4 - 100% RDF + *Azospirillum* +Phosphorus Solubilising Bacteria (PSB), T_5 - 100% RDF + *Azospirillum* + Potassium releasing bacteria (KRB), T_6 -100% RDF + *Azospirillum* +Phosphorus Solubilising Bacteria (PSB) + Potassium releasing bacteria (KRB), T_7 – 75% RDF + *Azospirillum*, T_8 -75% RDF + *Azospirillum* + PSB, T_9 -75% RDF + *Azospirillum* + KRB, T_{10} -75% RDF + *Azospirillum* + PSB + KRB, T_{11} - *Azospirillum* + PSB + KRB. The soil samples were estimated for organic carbon, available nitrogen, phosphorus and potassium were estimated as outlined by Walkley and Black, (1934) [16], Subbaiah and Asija (1956) [15], Olsen's method (Olsen *et al*., 1954) [10] and Jackson (1973) [7].

Results and Discussion

Organic carbon

The soil organic carbon was assessed during different growth stages of crop growth. The organic carbon content of soil was increased by the imposed treatments but the increase was not significant. The data presented in table 1 indicated that highest organic carbon values (0.59, 0.58 and 0.56%) at maximum tillering, panicle initiation and harvest stages, respectively was observed in T_6 (100% RDF + *Azospirillum* + PSB+ KRB) and the lowest values (0.50, 0.49 and 0.48%) at maximum tillering stage, panicle initiation and harvest stages, respectively was under the treatment T_1 (control), by application of liquid bio-fertilizers that contain living microorganisms can help to maintain or increase the content of organic matter (OM) and improve soil fertility in arable soils. This was probably due to the rapid decomposition of fresh or immature organic material and the intensive polymerization process (humification) of organic matter as influenced by the biofertilizers. These results were in accordance to Bozena *et al*., (2016) [3].

Available Nitrogen

The data presented in the table 2 revealed that Among the different treatments the highest available nitrogen contents (299 kg ha^{-1-}, 290 kg ha^{-1} and 278 kg ha^{-1}) were recorded in the treatment T_6 (100% RDF+*Azospirillum*+PSB+ KRB) followed by T_4 (100% RDF +*Azospirillum* + PSB) (297 kg ha^{-1}, 285 kg ha^{-1} and 276 kg ha^{-1}respectively) and T_5 (100% RDF + *Azospirillum* + KRB) (294 kg ha^{-1}, 283 kg ha^{-1} and 271 kg ha^{-1} respectively) and these were on par with each other. The lowest available nitrogen content (235 kg ha^{-1}, 221 kg ha^{-1} and 210 kg ha^{-1}) were recorded in the treatment T_1 (Control) at maximum tillering, panicle initiation and harvest stages, respectively. The available nitrogen content increased significantly by the combined application of inorganic fertilizers and biofertilizers. The important characteristic of *Azospirillum* is that they excrete ammonia in the rhizosphere in the presence of root exudates. The treatments with inorganic fertilizers and liquid biofertilizer resulted in higher nitrogen content in the soil. Similar results were found by Narula & Gupta (1986) [10] and Wu *et al*., (2005) [18]. The role of *Azospirillum* and phosphobacteria in enhancing the availability of nitrogen and phosphorus in the soil were reported by Copper (1979) [4] and Ram *et al*., (2011) [12].

Available phosphorus

The results table 3 revealed that among the different treatments highest available phosphorus content (66.33g ha^{-1}), 62.42kg ha^{-1} and 60.97 kg ha^{-1}) were recorded in the treatment T_6 (100% RDF+*Azospirillum*+PSB+ KRB) followed by T_4 (100% RDF +*Azospirillum* + PSB) (65.63 kg ha^{-1}, 61.36 kg ha^{-1} and 60.67 kg ha^{-1} and T_5 (100% RDF + *Azospirillum* + KRB) (62.12kg ha^{-1}, 58.15 kg ha^{-1} and 56.02 kg ha^{-1} respectively) and these were on par with each other. The lowest available phosphorus content (42.33 kg ha^{-1}, 39.52 kg ha^{-1} and 37 kg ha^{-1}) were recorded in the treatment T_1 (Control) at maximum tillering, panicle initiation and harvest stages, respectively.

The results revealed that available soil phosphorus significantly increased with combined application of liquid biofertilizer and inorganic fertilizer. The use of biofertilizer with chemical fertilizer can play an important role in improving P availability. The increase in soil P content might be due to the P-solubilizing potential of the isolates in biofertilizer. This may be attributed to the production of organic acids, chelating oxo-acids and solubilization of inorganic insoluble phosphates by microorganisms. Similar findings were reported by Molla & Chaudhry (1984) [9], Gupta *et al*., (1994) [6], and Akbari *et al*., (2010) [1] found that application of phosphate fertilizers along with PSB, enriched the soil available P resulting in improved yield of rice crop. The potential role of soil microorganisms for increasing the amount of available P by phytase activity has also been reported by Richardson (2001) [15].

Available potassium

The data presented in the table 4 revealed that among the different treatments the highest available potassium content (462 kg ha^{-1}, 459 kg ha^{-1} and 453 kg ha^{-1}) were recorded in the treatment T_6 (100% RDF + *Azospirillum* + PSB+ KRB) followed by T_5 (100% RDF + *Azospirillum* + KRB) (459 kg ha^{-1}, 457 kg ha^{-1} and 451 kg ha^{-1} T_4 (100% RDF +*Azospirillum* + PSB) (454 kg ha^{-1}, 449 kg ha-1and 442 kg ha^{-1} respectively) and these were on par with each other. The lowest available potassium content (376 kg ha^{-1}, 372 kg ha^{-1} and 363 kg ha^{-1}) were recorded in the treatment T_1 (Control) at all the three stages of crop growth. There was significant difference in soil available potassium among the treatments at all the stages of crop growth. The present study indicated that application of liquid biofertilizers along with inorganic fertilizers increased the available potassium content in soil. This may be due to variety of soil microbes which can release soluble potassium from potassium-bearing minerals. These microbes release organic acid, which quickly dissolves rock and chelate silicon ions, releasing K ions into the soil (Bennett *et al*., 1998 and Friedrich *et al*., 2004) [2, 5]. It has been shown that *Bacillus mucilaginosus* and *Bacillus edaphicus* can generate polysaccharide and carboxylic acids, such as tartaric acid and citric acid, to solubilize K compounds (Richards *et al*. 1989 and Lin *et al*., 2002) [14, 8]. The presence of indigenous potassium-solubilizing microbes might increase the concentration of available soil potassium.

Table 1: Effect of liquid biofertilizers in combination with inorganic fertilizers on organic carbon status of soil under direct sown rice

Treatment	Organic Carbon (%)		
	Tillering	Panicle initiation	Harvest
T_1 - Control	0.50	0.49	0.48
T_2 - 100% RDF	0.56	0.55	0.53
T_3 - 100% RDF + *Azospirillum*	0.57	0.56	0.54
T_4 - 100% RDF +*Azospirillum* + PSB	0.58	0.56	0.55
T_5 - 100% RDF + *Azospirillum* + KRB	0.58	0.57	0.56
T_6 - 100% RDF+*Azospirillum*+PSB+ KRB	0.59	0.58	0.56
T_7 - 75% RDF + *Azospirillum*	0.53	0.52	0.51
T_8 - 75% RDF + *Azospirillum* + PSB	0.54	0.53	0.52
T_9 - 75% RDF + *Azospirillum* + KRB	0.54	0.53	0.52
T_{10} - 75% RDF + *Azospirillum* + PSB+ KRB	0.54	0.53	0.53
T_{11} - *Azospirillum* +PSB + KRB	0.52	0.51	0.50
S.Em(±)	0.023	0.022	0.021
CD (P=0.05%)	NS	NS	NS
C.V (%)	7.31	7.32	7.14

Table 2: Effect of liquid biofertilizers in combination with inorganic fertilizers on available nitrogen status of soil under direct sown rice

Treatment	Available N(kg ha^{-1})		
	Tillering	Panicle initiation	Harvest
T_1 - Control	235	221	210
T_2 - 100% RDF	287	276	265
T_3 - 100% RDF + *Azospirillum*	292	281	270
T_4 - 100% RDF +*Azospirillum* + PSB	297	285	276
T_5 - 100% RDF + *Azospirillum* + KRB	294	283	271
T_6 - 100% RDF+*Azospirillum*+PSB+ KRB	299	290	278
T_7 - 75% RDF + *Azospirillum*	278	267	257
T_8 - 75% RDF + *Azospirillum* + PSB	276	265	255
T_9 - 75% RDF + *Azospirillum* + KRB	273	263	254
T_{10} - 75% RDF + *Azospirillum* + PSB+ KRB	280	269	259
T_{11} - *Azospirillum* +PSB + KRB	265	238	226
S.Em(±)	12.19	11.41	10.89
CD (P=0.05%)	35.95	33.68	32.14
C.V (%)	7.58	7.40	7.35

Table 3: Effect of liquid biofertilizers in combination with inorganic fertilizers on available phosphorus status of soil under direct sown rice

Treatment	Available P (kg P_2O_5 ha^{-1})		
	Tillering	Panicle initiation	Harvest
T_1 - Control	42.33	39.52	37.00
T_2 - 100% RDF	61.03	56.04	53.59
T_3 - 100% RDF + *Azospirillum*	61.17	57.24	55.62
T_4 - 100% RDF +*Azospirillum* + PSB	65.63	61.36	60.67
T_5 - 100% RDF + *Azospirillum* + KRB	62.12	58.15	56.02
T_6 - 100% RDF+*Azospirillum*+PSB+ KRB	66.33	62.42	60.97
T_7 - 75% RDF + *Azospirillum*	54.07	50.36	48.25
T_8 - 75% RDF + *Azospirillum* + PSB	57.26	53.17	51.35
T_9 - 75% RDF + *Azospirillum* + KRB	53.79	49.00	46.12
T_{10} - 75% RDF + *Azospirillum* + PSB+ KRB	57.10	53.35	50.02
T_{11} - *Azospirillum* +PSB + KRB	48.67	43.24	40.29
S.Em(±)	3.65	2.45	3.14
CD (P=0.05%)	10.78	7.24	5.94
C.V (%)	11.06	8.02	10.70

Table 4: Effect of liquid biofertilizers in combination with inorganic fertilizers on available potassium status of soil under direct sown rice

Treatment	Available Potassium(kg K_2O ha^{-1})		
	Tillering	Panicle initiation	Harvest
T_1 - Control	376	372	363
T_2 - 100% RDF	451	446	436
T_3 - 100% RDF + *Azospirillum*	453	448	440
T_4 - 100% RDF +*Azospirillum* + PSB	454	449	442
T_5 - 100% RDF + *Azospirillum* + KRB	459	457	451
T_6 - 100% RDF+*Azospirillum*+PSB+ KRB	462	459	453
T_7 - 75% RDF + *Azospirillum*	435	429	422
T_8 - 75% RDF + *Azospirillum* + PSB	437	429	424
T_9 - 75% RDF + *Azospirillum* + KRB	442	436	430

T_{10} - 75% RDF + *Azospirillum* + PSB+ KRB	440	437	429
T_{11} - *Azospirillum* +PSB + KRB	393	390	379
S.Em(±)	18.52	17.70	17.61
CD (P=0.05%)	54.63	52.22	51.96
C.V (%)	7.34	7.09	7.18

Conclusion

It can be concluded that application of different levels of fertilizers along with liquid biofertilizers significantly increased N, P and K status of the soil while their effect on soil organic carbon was non significant. Application of chemical fertilizers along with liquid biofertilizers significantly improved the nutrient status of the soil when compared to control.

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