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Soil properties of rhizosphere under maize based cropping system

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Abstract
This field experiment was conducted for two consecutive years during 2014-15 and 2015-16 on loamy sand soil of Agronomy Main Research Farm, Department of Agronomy, Central Research Station of the Odisha University of Agriculture and Technology, Bhubaneswar. The treatments consisted of three legumes as main plot treatments taken up during the *kharif* season and two residue management practices as sub-plot treatments and four nitrogen levels as sub-sub plot treatments. It shows that soil microbial population increased linearly over the initial level by taking a legume-cereal sequence. Further the incorporation of legume residues improved the microbial population over no residue incorporation treatments. Decreased trend of the total microbes was seen after the harvest of maize. An increase in available N, P and K was noticed with increase in nitrogen levels during both the years of study. After the harvest, cowpea recorded the highest available soil nitrogen values of 278 and 284 kg ha^{-1} in the first and second year respectively as well as highest total bacterial count of 228 x 10^4 g^{-1} of soil was recorded with cowpea residue incorporation with nitrogen application at 180 kg ha^{-1}.

Keywords: maize, cowpea, groundnut, clusterbean, intercropping, residue incorporation, microbial, soil quality

Introduction
Food security, nutritional security, maintenance of soil health, enhancement of productivity and leaving rightful heritage for future generation are the main focus of our agricultural development. Among the various food crops, cereals have been the main focus of this progress and have been the keepings of the transformation of Indian agriculture from security to surplus. Among various cereal crops, maize (*Zea mays* L.) is one of the most predominant one. High amounts of chemical fertilizers have been used to increase output in monocropping systems. However, large-scale monoculture led to a decline in the biological diversity, destroyed the capability of self-adjustment of the farmland ecosystem and caused diseases. Intercropping could be a potential candidate used to develop a sustainable agriculture systems, which focused on low input and high output. It is growing of two or more crops in the same field during the growing season. Intercropping can effectively improve the mobilization and uptake of nitro-gen (N), phosphorus (P) (Li *et al*. 2014) [7], potassium (K), and micronutrients through interspecific interactions in rhizosphere (Inal *et al*. 2007; Zuo and Zhang 2008) [4]; efficient acquisition of nutrients (Li *et al*. 2014) [7], establishment of soil microbial diversity (Lacombe *et al*. 2009) [6] and better utilization of resources.
Soil microorganisms and soil enzyme activities play important roles in biochemical processes in the rhizosphere ecosystem including nutrient cycling, decomposition of organic matter and suppression of soil-borne pathogens (Li *et al*. 2012). The plant can affect its rhizosphere microbial community by release of root exudates (Kourtev *et al*. 2003) [5]. Changes in microbial community composition can influence the potential of soil enzymes. Alteration in microbial community can be observed due to quantity and qualitative differences in root exudation between intercropping and monocropping systems (Baudoin *et al*. 2003) [2]. The changes in soil microbial communities may be both a cause and a reflection of the better performance in the intercropping systems. Recently, many studies have focused on rhizospheric microbial community and biochemical processes between intercropping crops (Zhou *et al*. 2011; Bainard *et al*. 2013). Dai *et al*. (2013) [11, 1, 3] used phospho-lipid fatty acid (PLFA) analysis and proposed that peanut intercropped with medicine plant Atractylodes lancea could significantly increase the soil urease, invertase activities and soil Gram-negative bacteria (G–), which have the potential to reduce the accumulation of phenolic allelochemicals

in soil. Peanut (*Arachis hypogaea* L.) is an important oil seed and cash crop, which has been used to intercrop with many plants. Many studies have suggested that maize intercropping was a successful crop management strategy, which could facilitate peanut acquisition of Fe and Zn and improve yield of both crops (Inal *et al*. 2007; Zuo and Zhang 2009) [4, 12]. However, there is little information about the relationships among the microbial community, soil enzymes and soil nutrients in the intercropping system of maize. There has been an increase of interest in the rhizospheric biological processes and plant-microbe interactions.

Material and methods:

In this current study, the treatments consisted of three legumes, viz., groundnut (C_1), cowpea (C_2) and cluster bean (C_3) as main plot treatments taken up during the *kharif* season and two residue management practices viz., residue incorporation (I_1) and no residue incorporation (I_2) as sub-plot treatments and four nitrogen levels 75 % RDN (N_1), 100 % RDN (N_2), 125 % RDN (N_3) and 150 % RDN (N_4) as sub-sub plot treatments to maize as 120 kg N ha^{-1} being the recommended dose during *rabi* in Odisha and this corresponds to 90 kg ha^{-1}, 120 kg ha^{-1}, 150 kg ha^{-1} and 180 kg ha^{-1} respectively. The experiment was laid out in split –split plot design with three replications. During the field experimentation, a composite soil sample was collected from each experimental plot from 0-30 cm depth before sowing and after harvest from each treated pot. The collected soil samples were dried under shade, powdered using wooden pestle and mortar and passed through 2mm sieve and preserved in polythene bags for analysis of pH, EC, organic carbon and available nitrogen, phosphorus and potassium. For organic carbon analysis, the 2 mm sieved soil samples were subjected for further grinding and passed through 0.2 mm sieve.

Chemical properties and the methods employed for analysis of the soil

Sl. No.	Particulars	Method adopted
1	pH	Digital electronic pH meter with 1:2.5, soil: water (Jackson, 1973)
2	EC (dSm^{-1})	Digital electrical conductivity meter (Jackson, 1973)
3	Organic carbon (g kg^{-1})	Walkly and Black chromic acid wet oxidation method (Jackson, 1973)
4	Available nitrogen (kg ha^{-1}	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
5	Available phosphorus (kg ha^{-1})	Bray's-1 method (Jackson, 1973)
6	Available potassium (kg ha^{-1})	Ammonium acetate flame photometer method (Jackson, 1973).

The enumeration of total fungi, bacteria, Azotobacter and Rhizobium in the soil samples collected from the experimental plots before sowing and after harvest of different legumes, after incorporation of the crop residues and after harvest of maize was estimated by following the standard dilution plate count technique by pour plate technique. Nutrient agar (NA) for bacteria, Martins Rose Bengal with streptomycin sulphate agar (MRBA) for fungi, Ashyb's agar for *Azotobacter*, Yeast extract Mannitol agar (YEMA) with congo red for *Rhizobium* were used for enumeration (Appendix-I). The petriplates were incubated after plating at 30 ^{o}C for two to four days and population was counted and expressed as number of cells per gram on dry weight basis for bacteria, *Azotobacter* and *Rhizobium* and cfug^{-1} of soil for fungi.

$$\text{CFU/ml} = \frac{\text{No. of colony} \times \text{inverse of dilution taken}}{\text{Volume of inoculum taken}}$$

The objectives of this study were to determine the effects of intercropping on rhizosphere microbial community composition, soil properties and relationship between microbial community and soil nutrients.

Results and Discussion

Soil microbial population

The population of soil microbes was assessed at four stages *viz.*, initial, after the harvest of *kharif* legumes as well as after the incorporation of legumes and after the harvest of *rabi* maize. The data presented in Table 2. revealed that there was an increase in microbial population compared to initial population during both the years of experimentation. Improvement in soil microbial population viz., total bacterial, *Rhizobium*, *Azotobacter*, Actinomycetes and fungi was observed over the initial population when legumes were grown during *kharif.* Among the legumes, maximum number of soil microbes was found after the harvest of cowpea followed by cluster bean and groundnut. During both the years of experimentation, the micro flora count was more in the second year compared to first year of experimentation.

Soil incorporation of legume crop residues has further improved the micro flora population during both the years. The maximum bacterial population of 175.3 x 10^4 g^{-1} of soil and 218.4 x 10^{4}g^{-1} of soil were found with incorporation of cowpea residues followed by cluster bean during 2014-15 and 2015-16, respectively. The least population of microbes was observed after the soil incorporation of groundnut residues during both the years of experimentation (Table 2).

Perusal of data presented in Table 3. revealed that there was a decreasing trend in the population of entire soil microbes after the harvest of *rabi* maize during both the years and maintained similar trend as that was observed in the initial as well as after the harvest of *kharif* legumes. Further it was observed that the microbial population increases with increased level of nitrogen application. The highest total bacterial count of 177 x 10^4 g^{-1} of soil and 228 x 10^4 g^{-1} of soil was recorded with cowpea residue incorporation with nitrogen application at 180 kg ha^{-1} during 2014-15 and 2015-16, respectively, while the lowest total bacterial count of 67 x 10^4 g^{-1} of soil and 102 x 10^4 g^{-1} of soil were recorded in groundnut without residue incorporation and with nitrogen application at 90 kg ha^{-1}.

Soil bulk density

The bulk density of soil was estimated at three phases viz., initial, after the harvest of legumes and after the incorporation of legume residues during both the years of experimentation. It was observed that the soil bulk density decreased over the initial value with all the legumes cultivation. The lowest bulk density of 1.49 and 1.44 g cc^{-1} were recorded with cowpea during 2014-15 and 2015-16, respectively. Similarly maximum bulk density of 1.51 and 1.46 g cc^{-1} were obtained with groundnut for the corresponding period.

Legume residue incorporation had shown further decrease in soil bulk density over no residue incorporation. The lowest bulk density values of 1.47 and 1.4 g cc^{-1} were recorded with cowpea residue incorporation in the first and second year, respectively, while the highest value (1.48 and 1.43 g cc^{-1}) was obtained with groundnut residue incorporation in both the years (Table 1).

Soil characteristics after harvest of legumes

The analytical data on different soil characters after the harvest of different legumes was presented in Table 3 for both the years of study. The data revealed that, there was not much variation in soil pH, EC and organic carbon content after the harvest of legumes during 2014-15 and 2015-16.The available N, P and K in the soil were found to be higher in plots after the harvest of cowpea during the first and second year of study as compared to groundnut and cluster bean plots.

Post harvest status of available N, P and K in the soil after the harvest of maize

Residual fertility of the soil is dependent on the initial nutrient reserve of the soil, addition of nutrients to the crop and utilization by the crop. The available N, P and K in the soil were the highest in plots of groundnut and cluster bean compared to cowpea after the harvest of maize. The residual values of available N, P and K were recorded more or less equal than the initial values which indicated that soil fertility was maintained with different management practices. Further, the available status of N, P and K was more in plots where residues were incorporated compared to their removal. The differential behavior of a legume in influencing the soil fertility largely depended on the growth of the legume. Also, the higher yield of cereals might have removed large amount of nutrients leaving the soil under nutrient stress. These results are in confirmity with the findings of Tripathi and Hazra (2002), Shrikant Chital *et al.* (2003) and Tarfa *et al.* (2006) [10, 8, 9].

Conclusion

Soil fertility was maintained at the end of crop sequence. After the legume harvest, the available N, P and K in the soil was more in cowpea followed by cluster bean and groundnut. Similarly after the harvest of maize, the available N, P and K in the soil was highest in groundnut followed by cluster bean and cowpea. Incorporation of legume crop residues was found to be beneficial in improving the soil physical and biological properties and yields of the crops.

Table 1: Bulk density (gcc^{-1}) of the soil as influenced by *kharif legumes* and residue incorporation practices during 2014-15 and 2015-16

Soil Bulk density (gcc^{-1})	2014-15	2015-16
Initial	1.52	1.47
After harvest of *kharif* legumes-		
Groundnut	1.51	1.46
Cowpea	1.49	1.44
Cluster bean	1.50	1.46
After incorporation of legume residues -		
Groundnut	1.48	1.43
Cowpea	1.47	1.40
Cluster bean	1.48	1.42

Table 2: Soil microbial population (Initial, after the legume harvest and after the legume residue incorporation)

Treatments	2014-15					2015-16				
	Total bacterial count ($x10^4g^{-1}$of soil)	Rhizobium count ($x10^4g^{-1}$of soil)	*Azotobacter* count ($x10^4g^{-1}$of soil)	Actinomycetes count ($x10^4g^{-1}$ of soil)	Fungal count ($x10^4$ $cfug^{-1}$of soil)	Total bacterial count ($x10^4g^{-1}$of soil)	Rhizobium count ($x10^4g^{-1}$of soil)	*Azotobacter* count ($x10^4g^{-1}$of soil)	Actinomycetes count ($x10^4g^{-1}$ of soil)	Fungal count ($x10^4$ $cfug^{-1}$of soil)
Initial	48	12	20	12	44	76	23	28	18	63
After legume harvest										
Groundnut	72	22	30	16	67	97	33	41	23	83
Cowpea	88	30	39	22	78	122	43	50	32	102
Cluster bean	81	26	34	20	70	110	38	45	27	90
After incorporation of the legume residues										
Groundnut	153	52	61	44	74	182	68	74	51	78
Cowpea	175	66	75	52	90	218	83	87	61	100
Cluster bean	160	61	68	48	80	200	74	81	57	87

Table 3: Soil characteristics after harvest of different *kharif* legumes during 2014 and 2015

Kharif legumes	2014						2015					
	pH	EC (dSm^{-1})	OC (%)	N ($kgha^{-1}$)	P ($kgha^{-1}$)	K ($kgha^{-1}$)	pH	EC (dSm^{-1})	OC (%)	N ($kgha^{-1}$)	P ($kgha^{-1}$)	K ($kgha^{-1}$)
Groundnut	4.71	0.47	0.38	253.2	60.3	193.4	4.78	0.45	0.38	260.2	64.3	213.1
Cowpea	4.72	0.49	0.42	278.3	71.7	207.8	4.81	0.48	0.43	284.6	72.2	221.1
Clusterbean	4.71	0.48	0.41	265.7	68.5	198.6	4.77	0.46	0.42	271.8	68.4	216.6
Initial status	4.71	0.46	0.34	204.2	55.2	184.2	4.78	0.45	0.36	218.3	61.3	208.4

Groundnut - 20-40-40kg NPK ha^{-1}
Cowpea - 20-40-20kg NPK ha^{-1}
Clusterbean - 20-40-20kg NPK ha^{-1}

Table 4: Soil microbial population as affected by different treatments after the harvest of maize

Treatments	2014-15					2015-16				
	Total bacterial count ($X10^4 g^{-1}$ of soil)	Rhizobium count ($X10^4 g^{-1}$ of soil)	*Azotobacter* count ($X10^4 g^{-1}$ of soil)	Actinomycetes count ($X10^4 g^{-1}$ of soil)	Fungal count ($X10^4$ cfug^{-1} of soil)	Total bacterial count ($X10^4 g^{-1}$ of soil)	Rhizobium count ($X10^4 g^{-1}$ of soil)	*Azotobacter* Count ($X10^4 g^{-1}$ of soil)	Actinomycetes count ($X10^4 g^{-1}$ of soil)	Fungal count ($X10^4$ cfug^{-1} of soil)
$C_1 I_1N_1$	74	25	30	21	50	113	35	48	31	66
$C_1 I_1N_2$	102	32	41	29	60	135	48	57	38	71
$C_1 I_1N_3$	134	47	57	36	68	176	61	63	44	75
$C_1 I_1N_4$	155	58	66	45	74	205	72	80	55	80
$C_1 I_2N_1$	67	20	27	20	44	102	32	40	28	64
$C_1 I_2N_2$	89	26	36	27	55	128	44	46	34	68
$C_1 I_2N_3$	120	36	45	33	64	157	51	60	42	71
$C_1 I_2N_4$	141	46	56	44	70	188	66	68	54	78
$C_2 I_1N_1$	79	33	33	25	56	123	56	62	38	73
$C_2 I_1N_2$	108	41	43	34	72	168	72	72	49	85
$C_2 I_1N_3$	145	54	45	42	83	201	80	80	57	93
$C_2 I_1N_4$	177	73	56	53	92	228	92	93	63	103
$C_2 I_2N_1$	72	30	31	23	52	116	48	60	34	70
$C_2 I_2N_2$	95	38	41	30	63	151	62	67	46	81
$C_2 I_2N_3$	130	48	45	38	72	172	74	73	50	90
$C_2 I_2N_4$	172	63	53	47	84	185	78	80	59	98
$C_3 I_1N_1$	78	28	31	23	53	126	50	56	36	70
$C_3 I_1N_2$	105	37	40	31	68	145	61	61	43	77
$C_3 I_1N_3$	142	50	34	40	76	182	73	70	50	82
$C_3 I_1N_4$	162	66	40	48	81	219	86	84	58	89
$C_3 I_2N_1$	77	24	31	22	52	118	49	43	36	68
$C_3 I_2N_2$	104	29	40	30	58	133	58	51	41	74
$C_3 I_2N_3$	140	40	43	37	64	164	66	63	46	80
$C_3 I_2N_4$	168	50	52	45	76	197	75	70	54	86
Initial status	48	12	20	12	44	76	23	28	18	63

C_1=Groundnut I_1=Residue incorporation N_1=75% RDN (90kgha^{-1})
C_2=Cowpea I_2= No Residue incorporation N_2=100% RDN (120kgha^{-1})
C_3=Cluster bean N_3=125% RDN(150kgha^{-1})
N_4= 150% RDN(180kgha^{-1})

Table 5: Available N, P and K (kg ha^{-1}) in the soil after harvest of maize as influenced by legume crops, residue management practices and nitrogen levels

Treatments	N levels (kgha^{-1})	2014-15			2015-16		
		N	P	K	N	P	K
$C_1 I_1$	N_1	210.2	57.2	184.3	217.5	59.2	206.7
$C_1 I_1$	N_2	218.1	58.3	187.1	224.4	60.2	207.3
$C_1 I_1$	N_3	236.3	59.3	191.5	236.3	61.1	208.4
$C_1 I_1$	N4	245.2	61.0	195.4	249.3	61.7	210.1
$C_1 I_2$	N_1	204.7	56.8	180.2	211.3	59.0	204.7
$C_1 I_2$	N_2	209.8	57.4	185.3	221.2	59.5	205.3
$C_1 I_2$	N_3	227.0	58.6	188.6	231.3	60.3	206.1
$C_1 I_2$	N4	239.6	60.2	193.7	244.2	61.1	207.2
C_2I_1	N_1	205.7	55.5	180.3	212.5	58.3	202.1
C_2I_1	N_2	208.1	56.2	182.1	214.7	59.2	202.6
C_2I_1	N_3	220.6	57.4	187.6	223.5	59.3	203.5
C_2I_1	N4	230.5	58.8	192.3	234.2	60.1	204.1
$C_2 I_2$	N_1	202.3	54.5	174.6	209.3	58.1	201.1
$C_2 I_2$	N_2	207.6	54.8	180	213.5	58.2	201.1
$C_2 I_2$	N_3	217.5	56.3	184.3	220.4	58.4	202
$C_2 I_2$	N4	228.1	57.6	191.1	232	58.5	202.8
$C_3 I_1$	N_1	206.3	55.5	182.7	220.3	59.0	205.7
$C_3 I_1$	N_2	217.6	56.3	185.3	222.5	60.1	206.2
$C_3 I_1$	N_3	227.5	57.5	190.1	231.6	60.5	206.8
$C_3 I_1$	N4	238.2	59.5	194.2	243.5	60.8	207.3
$C_3 I_2$	N_1	203.5	55.7	184.3	209.7	58.2	204.1
$C_3 I_2$	N_2	210.7	56.2	186.1	219.6	58.5	204.5
$C_3 I_2$	N_3	221.7	57.4	190.2	230.7	59.1	205.1
$C_3 I_2$	N4	235.8	58.7	193.3	241.6	59.6	205.4
Initial status		204.2	55.2	184.2	218.3	61.3	208.4

C_1=Groundnut I_1=Residue incorporation N_1=75% RDN (90kgha^{-1})
C_2=Cowpea I_2= No Residue incorporation N_2=100%RDN (120kgha^{-1})
C_3=Cluster bean N_3=125%RDN (150kgha^{-1})
N_4=150%RDN (180kgha^{-1})

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