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Direct and Residual Effects of Integrated Nitrogen Management on Soil Biological Properties and Yields of Rice Based Cropping Sequences

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ABSTRACT

A field experiment was conducted at College Farm, Agricultural College, Bapatla during *kharif* and *rabi* seasons of 2015-16 and 2016-17. The results of the investigation indicated that the adoption of INM (Integrated nitrogen management) comprising of 50% RDN+ 25% N through FYM+ 25% N through neem cake+ microbial consortium (Azpospirillum + PSB @ 2.5 kg ha^{-1}) recorded significantly higher grain yield and straw yield of rice and residual effect of INM and 100% RDF gave higher yields of blackgram, maize, sorghum, sunflower and mustard. Regarding biological properties, residual effect of INM had influenced the DHA activity by 11.8% and 13.43% during 2015-16 and 2016-17, respectively. Bacteria (15.11 to 20.0%), fungi (8.37 to 18.36%) and actinomycetes (5.9 to 16.45%) populations were increased by residual effect of INM.

Key words: *Biological properties, INM, Microbial populations, Rice, Rice fallow crops*

Crop demand for nutrients is met by a combination of inherent soil fertility and externally applied nutrients. For high yielding crops with high rates of drymatter accumulation removing higher rates of nutrients such as rice and maize, soil must allow unrestricted root growth be able to absorb nutrients at the rate for maximum growth. In order to cope with the food demand of a growing population, 60 per cent increase in rice production will be necessary during the next 25 years (Arth and Frenzel, 2000). To achieve this goal, NPK fertilization has to be done at nearly 3 fold from the present level. But escalating prices of industrial fertilizers and their possible degradation effect on soil health and pollution to environment warrants the need for excess use of chemical fertilizers. In this context, adoption of integrated nutrient management involving organic and inorganic sources is the best nutrient technology available.

Rice based cropping system is a predominant cropping system in coastal Andhra Pradesh. Complementary use of organic and biological sources of plant nutrients along with chemical fertilizer is of great importance for the maintenance of soil health and productivity, especially under intensive cropping system. There is immense need to exploit the alternate source of nutrients viz., organic manure, use of legumes in crop rotation and biofertilizer to sustain the productivity, soil health and soil fertility with more environment friendly nutrient management system.

MATERIAL AND METHODS

A field experiment was conducted for two consecutive years (2015-16 & 2016-17) on clayloam soils of Agricultural College Farm, Bapatla. The experiment was laid out in a two sample t-test for rice in *kharif* season with 2 treatments and replicated thrice. The treatments consists of M_1 100% RDF, M_2 (50% RDN+ 25% N through FYM + 25% N through neem cake + Azospirillum+PSB @ 2.5 kg ha^{-1}(INM). During the immediate *kharif*, the experiment was laid out in a split plot design without disturbing the soil for succeeding *rabi* crops with the two treatments given to *kharif* rice as main plot treatments and each of these divided into five sub-plots. The experiment was repeated in another field during *kharif* and *rabi* seasons. Popular cultivars of rice (BPT 5204), blackgram (PU 31), maize (Sandhya), sorghum(NSH-54), sunflower(Shreshta) and mustard (Konark) were used for this study. The soil is Vertisol with bulk density (1.42 & 1.43Mg m^{-3}), porosity (43.50 and 43.80%) and water holding capacity (45.10 and 45.80 %), slightly alkaline in reaction, (pH 7.70 and 7.50), two fields were non-saline in nature, cation exchange capacity (35.4 & 37.2 C mol (p^{+1}) Kg^{-1}), medium range of organic carbon(0.55 and 0.50%). Low nitrogen content(266 and 250 kg ha^{-1}), high in available P_2O_5 (59 and 53 kg ha^{-1}) and available potassium (630 and 668 kg ha^{-1}).

The nutrients were applied through the fertilizers like urea, single super phosphate, muriate of potash. Farm yard manure and neem cake were applied seven days before transplanting of rice on dry weight basis as per the treatment. The bacterial inoculants were applied at the time of sowing as per recommended dosage (Azospirillum + PSB @ 2.5 kg ha^{-1}). The nutrient content in applied organics was given in the table 1 and table 2 during first and second year of study respectively.

The recommended fertilizer dose of 120-40-40, 20-50-0, 200-60-50,40-40-40, 60-60-30 and 60-60-40 kg N, P_2O_5, and K_2O ha^{-1} to rice, blackgram, maize, sorghum, sunflower and mustard crops, respectively. The soil samples were analysed as per standarad procedures for soil biological properties. Soil dehydrogenase activity (Klein *et al*., 1971), bacteria population (Dhingra and Sinclair, 2000), fungi population (Martin, 1950) and actinomycetes population (Khuster's medium) were assayed.

The data obtained during *kharif* 2015-16 and 2016-17 were analyzed statistically using two sample T-test analysis of variance (Panse and Sukhatme, 2000). The t-test value calculated for 12 replications and t-test value was 2.07. If the t-test value was >2.07, it was significant, while < 2.07 includes non-significant. Whereas the data obtained during *rabi* 2015-16 and 2016-17 were analyzed statistically by following split plot design as suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Effect of INM on yield of rice

Data presented in table 2 indicated that the grain yield of rice during both the years of study significantly increased due to adoption of INM over 100% RDN. Application of organics along with 50% RDN produced the highest grain yield (5818 kg ha^{-1}) which was superior over inorganics i.e 4473 kg ha^{-1} during 2015-16 and 5896 kg ha^{-1} over 100% RDF i.e 4598 kg ha^{-1} during 2016-17. The increment of yield with INM was 30.0% and 28.22% during first and second years respectively. Shanmugan and Veeraputhran (2001), Bhattacharya *et al.* (2003) also reported beneficial effects of FYM on yield of rice due to better nutrition of crop. Application of combination of neem cake, different nitrogen levels and biofertilizers had a significant and vital effect on yield and quality attributes of crop.

Straw yields obtained were 6332 and 6350 kg ha^{-1} respectively during 2015-16 and 2016-17 due to adoption of INM against 5607 and 5657 kg ha^{-1} with 100% RDN. INM treatment recorded 12.9 % and 12.2 % higher straw yield over 100% RDN treatment during 2015-16 and 2016-17, respectively. The effects of FYM and neem cake were similar and significantly increased the straw yield of rice over control. These results are in consistent with those of Mahajan *et al.* (2012) who reported increased straw yields in rice with the combined application of FYM and inorganic fertilizers.

Residual effect of INM on yields of *rabi* crops

Seed yield of rabi crops are presented in table 3. Significantly higher seed yield of blackgram was obtained due to residual effect of M_2 treatment with values of 1118 and 1210 kg ha^{-1} in the year 2015-16 and 2016-17, respectively. These yields were higher by 21.9% and 10.40% over M_1 during first and second years, respectively due to the residual effect of INM treatment (M_2) imposed in rice during *kharif*. Similar results were obtained by Gajendrasingh *et al*. (2016) who reported that INM showed the highest seed yield compared to inorganics alone. Shashikumar *et al*. (2013) also stated that highest yields were obtained with organics in conjunction with inorganics. The residual effect of INM treatment was confirmed with the above significant increase in haulm yield.

Residual effect of INM to rice increased the kernel yield of maize by 866 and 1582 kg ha^{-1} over 100%RDN (M_1) of 6326 and 6100 kg ha^{-1} in first and second years, respectively. These results were in line with the findings of Singh *et al*. (2000). Experiments performed by Negassa *et al*. (2001) exhibited that there was significant residual effects of FYM which influenced maize grain yields.

The increase of 38.5% was obtained during 2015-16 and 31.5% during 2016-17 in M_2 over M_1 of sorghum grain yield. The grain yield of sorghum significantly improved with INM. Organic and inorganic fertilizers are efficient exogenous source of plant nutrients. When fertilizers are used in balance along with complementary use of organic and bio sources can help reverse environmental degradation by providing much needed nutrients to the soil, thereby increasing crop yields (Sudhanshu, 2013). The stover yield of sorghum significantly improved with the application of inorganic fertilizers @ 50% RDN + 25% N through FYM+ 25% N through neem cake+ recommended dose of bacterial inoculants to the preceding rice crop. The increase might be a result of improvement in soil properties which reflected on increasing biological yield as reported by Kachapur *et al*. (2001).

Significantly higher grain yields of sunflower were noticed with residual effect of M_2 treatment over 100% RDN. The increase of 47.16 % was obtained during first year and 58.2% during second year. Higher biomass production and large canopy spread would have induced the optimally fertilized plants to the increase in seed yield commensurate with large nutrient concentration in seed. Gudade *et al*. (2011) reported that the seed yield obtained under 100% RDF + organics was significantly higher than 50% and 100% RDF. Integrated nitrogen management in rice increased the stover yield of sunflower by 251(8.63%) and 465 (17.14%) compared with M_1 in first and

Table 1. Nutrient content of organics applied during 1st year and 2nd year

Nutrient	I^{st} year		II^{nd} year	
	FYM	Neem Cake	FYM	Neem Cake
C(%)	25.8	31.5	24.5	29.8
Total N (%)	0.616	4.08	0.58	4.89
Phosphorus (%)	0.24	0.21	0.35	0.42
Potassium (%)	0.41	0.42	0.48	0.43
Calcium (%)	0.88	1.053	0.95	1.02
Magnesium (%)	1.2	1.35	1.38	1.45
Sulphur (%)	0.32	1.55	0.28	1.05
Iron (ppm)	11.72	8.11	10.85	8.15
Manganese (Mn)	0.534	0.862	0.818	0.755
Copper (ppm)	0.074	0.132	0.08	0.115
Zinc (ppm)	0.11	0.35	0.15	0.78
C:N	41.8	7.72	42.24	6.09

Table 2. Effect of INM on rice yield

Treatment	2015-16		2016-17	
	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})
M_1: 100% RDN	4473	5607	4598	5657
M_2: 50% RDN+ 25% N thru FYM+ 25% N thru neem cake + bacterial consortium	5818	6332	5896	6350
t- value	7.34	3.61	8.95	3.61

second years, respectively. The stover yield increased from 2908 kg ha^{-1} to 3159 kg ha^{-1} during the year 2015-16 and from 2712 kg ha^{-1} to 3177 kg ha^{-1} during 2016-17. The increase in stover yield might be due to the fact that the applied FYM released the nutrients were in close conformity with the findings of Nanjundappa *et al*. (2001) and the applied FYM released the nutrients in adequate amount in the following season also.

Significantly higher seed yields of mustard was noticed in residual effect of M_2 treatment. The increase of 25% was obtained during 2015-16 and 24% during 2016-17. Similar results were found by Sonam *et al*., 2015. Thaneswar *et al*. (2017) elaborated that integrated application of 100% RDF along with vermicompost @ 5t/ha resulted in higher seed yield. Following integrated nitrogen management to rice increased the stover yield of mustard by 290 kg ha^{-1} and 76 kg ha^{-1} compared with NPK alone treatment (M_1) in first and second years respectively.

Effect of INM on soil biological properties

Dehydrogenase activity

The DHA ranged from 49.28 to 54.43 and 40.57 to 50.25 µg TPF g^{-1} $24h^{-1}$ during first and second years, respectively at different growth stages of rice. The dehydrogenase activity was relatively higher in INM (Inorganic + neem cake + FYM+ bacterial consortium) over M_1 and initial value. The dehydrogenase activity significantly increased in M_2 compared to M_1 at all stages of rice crop growth during the two years of experimentation. The increase was 2.37 to 4.77% and 1.10 to 5.22% during first and second years of study (Table 4).

During crop growth of rice, the highest DHA activity was observed at panicle initiation stage when compared to other stages. The DHA in flooded rice soil increased up to panicle initiation stage and after which the DHA decreased to harvest. The increase in DHA represents the most active growth period of rice crop and could be due to proliferation of anaerobic micro-flora in the rhizosphere at that stage. The

Table 3. Residual effect of INM on yields of *rabi* crops

Treatment	2015-16		2016-17	
	Seed/Kernel yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Seed/Kernel yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
Blackgram				
M_1	917	1437	1096	1502
M_2	1118	1528	1210	1615
t- value	14.1	5.15	4.75	12.85
Maize				
M_1	6326	7411	6100	7326
M_2	7192	8147	7682	8222
t- value	5.25	7.11	16.7	13.41
Sorghum				
M_1	2612	6457	2850	5906
M_2	3618	7127	3750	8325
t- value	5.44	4.86	3.73	18.36
Sunflower				
M_1	1024	2908	1125	2712
M_2	1507	3159	1780	3177
t- value	17.14	2.08	3.69	6.61
Mustard				
M_1	815	1515	915	1619
M_2	1025	1805	1135	1695
t- value	9.45	2.09	13.34	2.13

stabilized activity of DHA at harvest could be due to the fact that soil attains moisture content between field capacity and permanent wilting point and represents the effect of soil drying on dehydrogenase activity. Islam and Borthakur (2016) also stated that highest DHA activity at 60DAT (panicle initiation stage) which gradually declined when the crop attained maturity.

Soil bacteria population ranged from 25.58 to 32.15 x 10^5 and 26.04 to 28.78 x 10^5 cfu g^{-1} during 2015-16 and 2016-17, respectively. The soil bacteria count was higher with INM (Inorganic+ neem cake + FYM+ bacterial consortium) over initial value. The soil bacterial population significantly increased in M_2 compared to M_1 at all stages of rice crop growth during the two years of experimentation.

Bacterial population was higher at panicle initiation stage during both the years of study. These results coincided with Meghadubey *et al*. (2015). Integrated nutrient management contributed significantly in enhancing the total bacterial count. Islam and Borthakur (2016) also found that the bacterial population was the highest at panicle initiation and lowest at harvest. This might be attributed to increase in the root exudates in the panicle initiation in high moisture status leading to more intense microbial activity which gradually decline when the crop attained maturity to harvest stage.

Soil fungi population ranged between 10.16 to 19.75 x 10^3 cfu g^{-1} and 8.75 to 12.75 x 10^3 cfu g^{-1} during 2015-16 and 2016-17, respectively. Actinomycetes population ranged from 16.58 to 24.35 x 10^3 and 15.37 to 19.57 x 10^3cfu g^{-1} during two years of study.

Residual effect of INM on soil properties at harvest of *rabi* crops

Dehydrogenase activity

Main plot M_2 (51.34 and 42.54 ìg TPF g^{-1} 24 hr^{-1}) showed significantly higher dehydrogenase activity content over M_1 (45.92 and 37.50ìg TPF g^{-1} 24hr^{-1}) during both the years of study. The residual effect of INM was significant in improving DHA as it stimulated microbial population. Being chief carbon source, the organic sources supplemented through INM provided energy for soil microorganisms, and increased number of pores, which were considered important in soil-water-plant relationships and maintained good soil structure accompanied by better dehydrogense activity (Marinari *et al*., 2000).

Table 4. Effect of INM on soil biological properties during growth of rice

Treatment	2015-16				2016-17			
	Active tillering	Panicle initiation	Grain filling	Harvest	Active tillering	Panicle initiation	Grain filling	Harvest
Dehydrogenase activity (µg TPF g^{-1} 24 h^{-1})								
M_1: 100 % RDN	51.23	51.95	50.83	49.28	46.28	49.5	42.36	40.57
M_2: 50% RDN+25% N - FYM+ 25% N - neem cake + bacterial consortium	53.3	54.43	52.06	50.45	48.55	50.25	42.83	42.69
t- value	2.23	2.1	2.23	3	2.37	2.13	2.27	2.12
Initial	49.14				39.5			
Bacteria (x10^5 cfu g^{-1})								
M_1: 100 % RDN	27.91	29.41	26.41	25.58	26.16	26.2	26.08	26.04
M_2: 50% RDN+25% N - FYM+ 25% N - neem cake + bacterial consortium	30.75	32.15	28.57	28.35	28.65	28.78	28.65	28
t- value	5.4	3.76	5.4	8.66	4.12	4.21	3.33	3.14
Initial	20				25			
Fungi (x10^3 cfu g^{-1})								
M_1: 100 % RDN	14.29	17	10.75	10.16	9.54	9.75	9	8.75
M_2: 50% RDN+25% N - FYM+ 25% N - neem cake + bacterial consortium	16.65	19.75	13.05	12.65	12.5	12.75	11.05	10.85
t- value	3.24	2.55	4.54	4.34	3.96	3.57	3.86	2.95
Initial	10				8			
Actinomycetes (x 10^3cfu g^{-1})								
M_1: 100 % RDN	18.16	19.33	17.41	16.58	15.85	15.91	15.45	15.37
M_2: 50% RDN+25% N - FYM+ 25% N - neem cake + bacterial consortium	22.91	24.35	21.25	19.6	18.8	19.57	18.65	18.15
t- value	3.52	4.52	3.7	4.72	2.75	2.67	2.76	2.75
Initial	15				15			

Table 5. Residual effect of INM on soil DHA (ìg TPF g^{-1} 24 h^{-1}) at harvest of *rabi* crops

Treatment	2015-16					Mean	2016-17					Mean
	S_1	S_2	S_3	S_4	S_5		S_1	S_2	S_3	S_4	S_5	
M_1	51.16	41.00	43.88	45.40	48.25	45.92	42.30	34.00	34.50	35.90	40.80	37.50
M_2	59.90	45.16	47.58	54.00	50.10	51.34	45.61	41.70	41.50	42.20	41.70	42.54
Mean	55.50	43.08	45.73	49.70	49.17		43.95	37.85	38.00	39.05	41.25	

	SEm±	CD (p=0.05)	CV (%)		SEm±	CD (p=0.05)	CV (%)
Main plots(M)	0.32	1.99	12.6	Main plots(M)	0.6	3.69	9.86
Sub plots (S)	2.75	2.11	13.87	Sub plots (S)	1.33	2.01	8.19
Interaction (MXS)	3.89	NS		Interaction (MXS)	1.89	NS	

M_1=100 % RDN; M_2= 50% RDN+25% N – FYM + 25% N - neem cake + bacterial consortium
S_1= Blackgram; S_2=Maize; S_3= Sorghum; S_4=Sunflower; S_5= Mustard

Table 6. Residual effect of INM on soil bacteria (x 10^5cfu g^{-1}) at harvest of *rabi* crops

Treatment	2015-16					Mean	2016-17					Mean
	S_1	S_2	S_3	S_4	S_5		S_1	S_2	S_3	S_4	S_5	
M_1	30.5	21.3	21.3	26.6	29.4	25.8	33.6	28	27	28	26.6	28.6
M_2	35	30.5	25	28	30	29.7	36.6	32.5	31.5	35.6	35.5	34.34
Mean	32.7	25.9	23.1	27.3	29.7		35.1	30.25	29.25	31.8	31.05	

	SEm±	CD (p=0.05)	CV (%)		SEm±	CD (p=0.05)	CV (%)
Main plots(M)	0.92	3.80	12.90	Main plots(M)	0.91	5.08	12.30
Sub plots (S)	1.08	3.20	9.50	Sub plots (S)	1.29	3.87	11.00
Interaction (MXS)	1.50	NS		Interaction (MXS)	1.82	NS	

Table 7. Residual effect of INM on soil fungi (x 10^3 cfu g^{-1}) at harvest of *rab*i crops

Treatment	2015-16					Mean	2016-17					Mean
	S_1	S_2	S_3	S_4	S_5		S_1	S_2	S_3	S_4	S_5	
M_1	10.86	10.3	10.5	10.7	10.2	10.51	10.02	9.41	9.48	10.04	10.04	9.79
M_2	12.73	12.3	12.2	12.5	12.6	12.44	11.09	10.09	10.58	10.61	10.75	10.62
Mean	11.79	11.3	11.3	11.6	11.4		10.55	9.75	10.03	10.32	10.39	

	SEm±	CD (p=0.05)	CV (%)		SEm±	CD (p=0.05)	CV (%)
Main plots(M)	0.07	0.45	15.54	Main plots(M)	0.05	0.34	10.16
Sub plots (S)	0.12	0.3	10.56	Sub plots (S)	0.17	0.51	8.1
Interaction (MXS)	0.17	NS		Interaction (MXS)	0.24	NS	

Table 8. Residual effect of INM on soil actinomycetes (x 10^3 cfu g^{-1}) at harvest of *rabi* crops

WRVGFTG	2015-16					Mean	2016-17					Mean
	S_1	S_2	S_3	S_4	S_5		S_1		S_3	S_4	S_5	
M_1	16.33	15.33	16.13	15.76	16.38	15.98	20.5	17.5	18.2	19	19	18.84
M_2	19.05	18.36	18.4	18.78	18.5	18.61	22.6	18.5	18.5	20.7	19.5	19.96
Mean	17.69	16.84	17.26	17.27	17.44		21.55	18	18.35	19.85	19.25	

	SEm±	CD (p=0.05)	CV (%)		SEm±	CD (p=0.05)	CV (%)
Main plots(M)	0.037	0.22	8.30	Main plots(M)	0.041	0.35	10.50
Sub plots (S)	0.077	0.23	10.90	Sub plots (S)	0.125	0.29	8.87
Interaction (MXS)	0.109	NS		Interaction (MXS)	0.177	NS	

M_1=100 % RDN; M_2= 50% RDN+25% N - FYM+ 25% N - neem cake + bacterial consortium
S_1= Blackgram; S_2= Maize; S_3 = Sorghum; S_4= Sunflower; S_5= Mustard

Regarding subplots, significantly the mean highest DHA was observed with S_1 i.e blackgram crop (55.50 and 43.95 ìg TPF g^{-1} 24 hr^{-1}) during 2015-16 and 2016-17, respectively. During 2015-16, significantly higher DHA was observed in blackgram sequence followed by sunflower (S_4, 49.70 ìg TPF g^{-1} 24 hr^{-1}) and mustard (S_5, 49.17 ìg TPF g^{-1} 24 hr^{-1}) crops and superior over remaining cereal crops of sorghum(S_3, 45.73 ìg TPF g^{-1} 24 hr^{-1}) and maize (S_2, 43.08 ìg TPF g^{-1} 24 hr^{-1}). During 2016-17, the highest DHA was found in blackgram sequence followed by mustard (S_5, 41.25 ìg TPF g^{-1} 24 hr^{-1}) and sunflower (S_4, 39.05 ìg TPF g^{-1} 24 hr^{-1})crops and superior over remaining cereal crops of sorghum(S_3, 38 ìg TPF g^{-1} 24 hr^{-1}) and maize (S_2, 37.85 ìg TPF g^{-1} 24 hr^{-1}).

Bacteria

The mean highest bacteria population 29.7 x 10^5 and 34.34 x 10^5 was recorded with the M_2 treatment i.e 50% RDN+ 25% N through FYM + 25% N through neem cake and recommended bacterial inoculants during 2015-16 & 2016-17 years.

Regarding to subplots, the significant mean highest soil bacteria population (32.7 and 35.1 x 10^5 cfu g^{-1}) was recorded with M_1 (blackgram) crop during two years. The highest bacteria population 32.70 x 10^5 cfu g^{-1}) was followed by mustard and sunflower and superior over sorghum and maize crops. During 2016-17, the highest population was obtained with S1 blackgram crop 35.10 x 10^5 cfu g^{-1} followed by sunflower and mustard and lowest population was observed in sorghum followed by maize crop due to its exhaustive nature. Interaction effect of cropping systems and main treatments was also non- significant.

Fungi

Regarding two main plots, the significantly higher fungi population 12.44 & 10.62 was recorded with the M_2 treatment i.e 50% RDN+ 25% N through FYM+ 25% N through neem cake and recommended dose of bacterial inoculants compared to M_1 during first and second years, respectively. The INM improves the microbial populations favorably with inclusion of organics in that treatment.

According to sub plots, the highest mean fungi population was obtained with S_1 i.e blackgram crop (11.79 which is on par with sunflower (11.60x10^3 CFU g^{-1}) and mustard (11.40x10^3 CFU g^{-1}) during 2015-16 and same trend was followed in 2016-17, the highest fungi population was obtained in blackgram leads to add more organic matter and more microbial populations followed by sorghum and maize crops which is due to their exhaustive nature. Interaction effect was also non - significant between cropping systems.

Actinomycetes

The significantly higher actinomycetes population 18.61 & 19.96 was recorded with the M_2 treatment i.e 50% RDN+ 25% N through FYM+ 25% N through neem cake and recommended bacterial consortium.

Regarding to subplots, the mean highest populations observed in blackgram crop 17.69 and followed by mustard, sunflower and superior over sorghum and maize and lowest population was observed in maize crop during first season. During second year of study, the highest population (21.55) was observed in blackgram crop and followed by sunflower (19.85) and mustard (19.25) crops and significantly higher populations were recorded in sorghum(18.35) and maize(18.00) crop and the lowest populations in maize crop due to its exhaustive nature. Regarding to interaction studies, there was non-significant variation observed during two years.

CONCLUSION

Significantly higher dehydrogenase activity (DHA) and microbial populations were observed with S_1 i.e blackgram crop followed by sunflower which was on par with mustard and superior over cereal crops of sorghum and maize during 2015-16. During 2016-17, the highest DHA was found in blackgram sequence followed by mustard and sunflower crops superior over cereal crops of sorghum and maize. It was due to legume crop that had vigorous root growth, more root exudation compared to other crops. The lowest activities of enzyme in soils were due to presence of exhaustive crop of maize and sorghum in cropping system. Sorghum and maize being cereals and more exhaustive nature, the lowest DHA was obtained. Sunflower and mustard being dicots showed medium DHA activity.

Yield was significantly influenced by the residual effect of INM adopted in preceding rice. Blackgram yield was increased by 6.33% and 7.52% in M_2 when compared to M_1 during first and second years, respectively. Maize crop kernel yield was increased by 13.68% and 25.93% with M_2 treatment compared to M_1 during first and second years, respectively. Sorghum crop grain yield was increased by 30% with treatment of M_2 when compared to M_1 treatment. Sunflower seed yield was increased by 40-50% apprx with inclusion of M_2 than M_1. Mustard seed yield was increased by 24 to 26% with inclusion of M_2 compared to M_1.

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