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Direct and Residual Effect of Integrated Nutrient Management Practices in Groundnut-Maize Cropping System on Yield and Soil Fertility

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ABSTRACT

A field experiment was conducted "Integrated Nutrient Management in Groundnut (*Arachis hypogaea* L.)-Maize (*Zea mays* L.) Cropping System" during two consecutive years (2015-2016 and 2016-2017) at the Agricultural Research Station, Vizianagaram of Acharya N.G. Ranga Agricultural University (ANGRAU), in the North - Coastal Agro-Climatic Zone of Andhra Pradesh, to study the effect of integrated nutrient management practices on growth and yield of *kharif* groundnut and succeeding *rabi* maize. The present research was conducted to study the direct and residual effect of organics on groundnut (*Arachis hypogeae* L.) maize (*Zea mays* L.) crop sequence. Results demonstrate that combined application of RDF_{125}+FYM_{5t}+ *Rhizobium* inoculation +PSB+VAM resulted in 71.17% and 66.75% higher pod yield over RDF_{100}+FYM_{5t} (control) during both years of study. Among the different INM practices application of RDF_{125}+FYM_{5t}+ *Rhizobium* inoculation +PSB+VAM proved its superiority in terms of yield attributes, quality and pod yield of groundnut. Combined application of RDF_{150}+FYM_{5t}+ *Rhizobium* inoculation +PSB+VAM to the preceding groundnut crop influenced indirectly to produce more kernel yield of maize than RDF_{100}+FYM_{5t} (control) plots during both the years. In respect of direct treatments applied to maize, the treatment combination of RDF_{100}+ *Azospirillum* + PSB+VAM + groundnut residue incorporation compared to RDF_{100}+ *Azospirillum* + PSB+ VAM. Application of RDF_{125}+FYM_{5t}+ *Rhizobium* inoculation +PSB+VAM to groundnut followed by direct application of RDF_{100}+ *Azospirillum* + PSB+VAM + groundnut residue incorporation recorded highest system productivity and also leave highest amount of available N, P and K in the soil.

Key words: *Groundnut, Maize, Nutrient uptake, Soil parameters, System productivity, yield.*

Groundnut (*Arachis hypogaea* L.) is an important oilseed crop in India and commonly called as poor man's nut. Among the different agronomic management practices, use of organics is of prime importance under rainfed farming situations. High yields of groundnut and sustainability in its production can be obtained with better fertility management practices especially with integrated nutrient practices. Integrated nutrient practices in recent years gaining impetus due to realization of inherent advantages it confers in sustaining crop production under aberrant situations and also maintaining dynamic soil nutrient status and safe environment. Groundnut being a legume leaves lot of residual fertility which intern helps succeeding crop under rainfed farming situations. Further, incorporation of groundnut crop residues in the agricultural system helps to improve soil structure, soil microbial activity and soil moisture conservation and which in term helps to stabilize the production and productivity of the crops. The responses of the succeeding crops in a cropping system are influenced greatly by the preceding crops and the inputs applied thereon. Therefore, greater emphasis is being laid on the cropping system as a whole rather than on the individual crops in a sequence. Maintenance of soil fertility is important for obtaining higher and sustainable yield due to large turnover of plant nutrients in the soil-plant system. Maize (*Zea mays* L) is one of the important cereal crops next to wheat and rice in the world. Maize has high production potential compared to any other cereal crop. The productivity of maize is largely dependent on its nutrient management. It is well known that maize is a heavy feeder of nutrients and because of this nature; it is a very efficient converter of solar energy into dry matter. In view of above fore-going points, the present experiment was conducted to assess the effectives of different INM practices on the yield attributes, yield and nutrient uptake of groundnut and their residual effects on yield attributes, grain yield and system productivity of succeeding maize crop.

MATERIAL AND METHODS

A field experiment was conducted during two consecutive years (2015-16 and 2016-17) at the Agricultural Research Station, Vizianagaram of Acharya N.G. Ranga Agricultural University (ANGRAU), in the North - Coastal Agro-Climatic Zone of Andhra Pradesh.

Soil samples from 0 to 30 cm depth were collected before sowing of crops at random from the experimental fields in both the years and composite soil samples were analyzed initially for different physical and physico-chemical properties following standard methods as mentioned in below table. The results of the soil analysis in following table indicated that the experimental site was sandy loam in texture, neutral in reaction, low in organic carbon, medium in available nitrogen, high in available phosphorus and medium in available potassium. Soil samples were drawn plot wise, immediately after harvest of each of the crop to assess soil fertility dynamics.

The field experiment was laid out in a Randomized Block Design with groundnut as *kharif* season crop with six treatments and replicated four times. The treatments consisted of T_1-RDF_{100}+FYM_{5t} (Control); T_2-RDF_{125}+ FYM_{5t}+ *Rhizobium* inoculation +PSB+VAM; T_3-RDF_{150}+ FYM_{5t} + *Rhizobium* inoculation + PSB + VAM; T_4-RDF_{100}+FYM_{5t}+ *Rhizobium* inoculation +PSB+VAM; T_5-RDF_{75} +FYM_{5t}+ *Rhizobium* inoculation +PSB+VAM and T_6-RDF_{50}+FYM_{5t}+ *Rhizobium* inoculation +PSB +VAM. During the succeeding *Rabi*, the experiment was laid out in a split-plot design on maize with six treatments given to *kharif* groundnut as main plot treatments and each of these divided into four sub-plots to receive four rates of RDF application *viz.,* S_1-RDF_{100} + *Azospirillum* + PSB + VAM (Control); S_2-RDF_{100} + *Azospirillum* + PSB+ VAM + with groundnut residue incorporation; S_3-RDF_{75} + *Azospirillum* + PSB + VAM + with groundnut residue incorporation and S_4-RDF_{50} + *Azospirillum* + PSB + VAM + with groundnut residue incorporation.

Plant samples of groundnut and maize crops collected for the dry matter production at harvest from different treatments were utilized for chemical analysis after grinding into fine powder. Nitrogen content in the plants was estimated by modified Microkjeldhal method (Piper, 1950), Phosphorous content in plants was estimated by Vanado molybdo phosphoric acid method (Jackson, 1973) and potassium content in plants was estimated by Flame Photometer (Jackson, 1973).

From the results of chemical analysis, N, P and K uptake by both groundnut and maize was calculated as given below.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content(\%) x Weight of the dry matter (kg ha}^{-1}\text{)}}{100}$$

Physico-chemical properties of the experimental soil

	Particulars	Field Numbers		Method of Analysis
		19	25	
I	Mechanical Analysis			
	1. Sand (%)	74.5	73.8	International Pipette method (Piper, 1950)
	2. Silt (%)	11.2	12.7	
	3. Clay (%)	14.3	13.5	
	4. Texture (%)	Sandy loam	Sandy loam	
II	Chemical Analysis			
	1. pH (1:2 soil-water suspension)	6.6	6.8	Glass electrode pH meter (Jackson, 1973)
	2. Ec (dS m^{-1})	0.52	0.48	Conductivity bridge (Jackson, 1973)
	3. Organic Carbon (%)	0.42	0.38	Walkey and Black modified method (Walkey and Black, 1934)
	4. Available nitrogen (kg ha^{-1})	248	243	Alkaline permanganate (Subbiah and Asija, 1956)
	5. Available P_2O_5 (kg ha^{-1})	23.5	22.4	Olsen's extractant (Olsen *et al.,* 1954)
	6. Available K_2O (kg ha^{-1})	216	210	Flame photometry (Jackson, 1973)

Table 1. Plant height(cm), Drymatter production(kg ha^{-1}), yield attributes and pod yield (kg ha^{-1}) of groundnut as influenced by different integrated nutrient management practices during *kharif* 2015 and 2016

Treatments	2015					2016				
	Plant height at harvest	Drymatter at maturity	No.of gynophores Plant^{-1}	No.of Pods Plant^{-1}	Pod yield	Plant height at harvest	Drymatter at maturity	No.of gynophores Plant^{-1}	No.of Pods Plant^{-1}	Pod yield
T_1= RDF_{100}+FYM_{5t} (Control)	82.50	6063	35.00	14.25	1485	83.50	5800	34.25	14.25	1471
T_2= RDF_{125}+FYM_{5t} +*Rhizobium* +PSB+VAM	95.65	7908	44.50	25.00	2542	94.48	7795	44.50	24.50	2453
T_3= RDF_{150}+FYM_{5t} + *Rhizobium* +PSB+VAM	102.75	9743	46.00	20.00	2026	101.25	9228	45.50	18.50	1889
T_4= RDF_{100}+FYM_{5t} + *Rhizobium* +PSB+VAM	93.65	7768	43.50	23.50	2412	93.25	7470	43.25	23.00	2353
T_5= RDF_{75}+FYM_{5t} + *Rhizobium* +PSB+VAM	92.40	7453	40.25	20.25	2065	91.50	7320	40.00	19.50	1971
T_6 = RDF_{50}+FYM_{5t} + *Rhizobium* +PSB+VAM	85.25	6207	37.00	17.00	1711	85.00	6117	35.00	15.00	1566
Mean	92.03	7524	41.04	20.00	2040	91.50	7288	40.42	19.13	1950
SEm ±	2.27	265.41	1.01	0.96	104	1.39	196.35	0.77	0.95	98.09
CD (P=0.05)	6.86	800.06	3.07	2.91	313.51	4.19	591.88	2.34	2.9	295.7
CV (%)	14.95	14.71	13.96	11.67	10.19	13.04	13.94	13.85	10.09	10.05

Table 2. N, P and K content(%) and uptake(kg ha^{-1}) of haulms in groundnut at harvest as influenced by different integrated nutrient management practices during *kharif* 2015 and 2016

Treatments	2015						2016					
	N		P		K		N		P		K	
	Content	Uptake	Content	Uptake	Content	Uptake	Content	Uptake	Content	Uptake	Content	Uptake
T_1= RDF_{100}+FYM_{5t} (Control)	2.21	100.75	0.21	9.75	0.86	45.62	2.32	100.53	0.20	8.79	0.84	36.5
T_2= RDF_{125}+FYM_{5t} +*Rhizobium* +PSB+VAM	2.52	134.89	0.27	14.48	1.08	64.35	2.51	133.96	0.26	13.87	1.06	56.66
T_3= RDF_{150}+FYM_{5t} + *Rhizobium* +PSB+VAM	2.52	194.1	0.28	21.41	1.09	87.71	2.51	183.81	0.27	19.64	1.07	78.15
T_4= RDF_{100}+FYM_{5t} + *Rhizobium* +PSB+VAM	2.5	134.16	0.26	13.77	1.08	64.4	2.49	133.2	0.25	13.22	1.06	56.38
T_5= RDF_{75}+FYM_{5t} + *Rhizobium* +PSB+VAM	2.45	131.72	0.25	13.59	1.07	60.99	2.44	124.62	0.24	12.41	1.05	53.62
T_6 = RDF_{50}+FYM_{5t} + *Rhizobium* +PSB+VAM	2.30	103.18	0.23	10.25	0.93	46.44	2.34	106.4	0.22	9.91	0.91	41.53
Mean		133.13		13.88		61.59		130.42		12.97		53.81
SEm ±		6.48		0.71		2.26		5.64		0.59		2.41
CD (P=0.05)		19.53		2.15		6.84		17.02		1.79		7.28
CV (%)		10.73		10.31		12.65		10.66		12.29		10.98

The test variety groundnut cultivar, K-9 with spacing of 30 cm X 10 cm and maize cultivar DHM-117 with spacing 60 cm X 20 cm was adopted. The weather conditions prevailed during crop growth period of groundnut and maize were quite normal and congenial for the better growth and performance of the crops, during both the years of experimentation (2015-16 and 2016-17). Different growth parameters at various stages and yield were recorded and statistically analyzed following the analysis of variance for randomized block design and spilt plot design as suggested by Panse and Sukhatme (1978).

RESULTS AND DISCUSSION

Growth parameters of *kharif* groundnut

Growth parameters like plant height (cm), drymatter production and number of nodules plant^{-1} at harvest were significantly influenced by integrated nutrient management practices (Table 1). During both the years of investigation, plant height of *kharif* groundnut recorded at different growth stages exhibited significant increase with the advancement in the age of the crop. Plant height at harvest was significantly affected due to integrated nutrient management practices. The maximum plant height of groundnut at harvest was recorded with RDF_{150}+ FYM_{5t} + *Rhizobium* inoculation + PSB + VAM (T_3). Increased plant height may be due to the application of recommended dose of NPK, *Rhizobium* inoculation, phosphate solubilizing bacteria and VAM fungi along with FYM. This increase in growth of groundnut could be attributed to the enhanced nutrient use efficiency in the presence of organic manure. Further, the organic manure release nutrients slowly and may reduce the leaching losses, particularly N and simultaneously the ability of biofertilizers to transport major nutrients like N and P besides secreting plant growth promoting substances such as IAA and gibberellins might have helped in increasing the plant height. The superior performance of groundnut plant height under the influence of INM practices as projected in the present findings are in agreement with those of Abou-el- seoud and Abdel-megeed (2012) and Dhadge and Satpute (2014).

Drymatter accumulation also followed the similar trend, as that of plant height (Table 1). The highest drymatter accumulation was recorded with RDF_{150}+ FYM_{5t} + *Rhizobium* inoculation + PSB + VAM (T_3) applied to groundnut. It was significantly superior to the rest of the treatments. Each successive increment of fertilizers significantly increased the drymatter accumulation of groundnut upto the highest level *i.e.*, RDF_{150}+ FYM_{5t} + *Rhizobium* inoculation + PSB + VAM (T_3). Adequate fertilization to crops is known to improve the physiological and metabolical processes in the plant system creating a favourable environment for higher availability of nutrients. Thus could have helped the groundnut crop growth and development and hence the higher drymatter at higher level of nutrient application. Enhanced drymatter accumulation under INM practices, as recorded in this investigation corroborates the findings of Chavan *et al* (2014) and Patil *et al* (2014).

Yield attributes and yield of *kharif* groundnut

Number of gynophores plant^{-1} of groundnut were significantly influenced by the different INM treatments (Table 1). The maximum number of gynophores plant^{-1} was recorded in the treatment RDF_{150}+FYM_{5t}+ *Rhizobium* inoculation +PSB+VAM (T_3), which was however comparable with RDF_{125}+FYM_{5t}+ *Rhizobium* inoculation +PSB+VAM (T_2) and RDF_{100}+FYM_{5t}+ *Rhizobium* inoculation +PSB+ VAM(T_4). The increased number of gynophores plant^{-1} under the treatments RDF_{150}+FYM_{5t}+ *Rhizobium* inoculation +PSB+VAM (T_3) could be attributed to balanced application of nutrition comprising both organic manure and inorganic fertilizers along with biofertilizers. The performance of groundnut above soil surface exhibited a significant increase in the formation of higher number of gynophores which might be due to increased plant height and corresponding increase in number of branches and profuse flowering. This finding is in the accordance with the results reported by Singh *et al* (2011).

Various INM practices in different combinations have exerted significant influence on number of pods plant^{-1} (Table 1). The highest number of pods plant^{-1} was recorded with combination of RDF_{125}+FYM_{5t}+ *Rhizobium* inoculation +PSB+VAM (T_2), which was however comparable with other combination receiving RDF_{100}+FYM_{5t}+ *Rhizobium* inoculation +PSB+VAM (T_4). Increased number of pods plant^{-1} under RDF_{125}+FYM_{5t}+ *Rhizobium* inoculation +PSB+ VAM (T_2) might be attributed to integrated application of fertilizers, manure along with biofertilizers that produced adequate and balanced nutrition in readily available forms throughout the growth period. The uptake lead to greater photosynthetic activity, production of metabolites and the enzymatic activity might have increased the proliferation of the root system in increasing pods plant^{-1}. However, the applied nutrition in the combination of RDF_{125}+FYM_{5t}+ *Rhizobium* inoculation + PSB+VAM (T_2) with other integrated treatments did not exhibit extensive and lanky vegetative growth thus preventing the formation of gynophores at greater height. The greater production of metabolites and their translocation to various sinks especially productive structures could have rendered in the transformation of maximum number of gynophores into

Table 3. Available OC(%), N, P and K (kg ha^{-1}) in soil after harvest of groundnut as influenced by different integrated nutrient management practices during *kharif* 2015 and 2016

Treatments	2015				2016			
	OC	N	P_2O_5	K_2O	OC	N	P_2O_5	K_2O
T_1= RDF_{100}+FYM_{5t} (Control)	0.38	251	23.6	216.5	0.33	243.5	22.5	211
T_2= RDF_{125}+FYM_{5t} +*Rhizobium* +PSB+VAM	0.47	293.8	30.6	281.8	0.44	283.8	28.3	277.3
T_3= RDF_{150}+FYM_{5t} + *Rhizobium* +PSB+VAM	0.49	297.5	32.6	287.5	0.45	287.5	29.6	280.5
T_4= RDF_{100}+FYM_{5t} + *Rhizobium* +PSB+VAM	0.46	290.6	29.8	277.3	0.42	280.6	27.4	269.3
T_5= RDF_{75}+FYM_{5t} + *Rhizobium* +PSB+VAM	0.44	282.5	28.3	268.5	0.4	272.5	25.3	262.5
T_6 = RDF_{50}+FYM_{5t} + *Rhizobium* +PSB+VAM	0.42	260.5	25.4	217.5	0.37	250.5	23.5	212
Mean	0.44	279.3	28.4	258.2	0.4	269.7	26.1	252.1
SEm ±	0.02	8.74	1.82	19.03	0.02	8.68	1.63	18.79
CD (P=0.05)	0.06	26.35	5.5	57.36	0.06	26.18	4.93	56.65
CV (%)	10.5	11.6	12.9	14.74	10.7	13.15	12.6	14.91

Table 4. Drymatter accumulation (kg ha^{-1}) of maize at maturity as influenced by preceding groundnut and different integrated nutrient management practices during *rabi* 2015-16 and 2016-17

Treatments applied to *kharif*	Treatments applied to *rabi* maize (S)									
	2015-16					2016-17				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
T_1	14539	18430	17621	14545	16284	12434	17239	16420	13435	14882
T_2	18301	24101	22950	19302	21164	15126	22379	20017	17244	18691
T_3	18602	24216	22953	19524	21324	15992	22437	20067	17294	18948
T_4	17946	24005	22438	19085	20869	15031	22021	19833	17128	18503
T_5	14832	20654	20199	18861	18637	13792	20608	17971	15573	16986
T_6	14637	18864	18390	15076	16742	12572	17988	16560	13678	15199
Mean	16476	21712	20759	17732	19170	14158	20445	18478	15725	17202
		SEm±	CD (P=0.05)	CV (%)			SEm±	CD (P=0.05)	CV (%)	
	T	211.1	636.31	12.62		T	201.85	608.43	12.23	
	S	773.18	2192.21	14.76		S	718.25	2036.48	14.73	
	T at S	1745.45	NS	14.76		T at S	1627.1	NS	14.73	
	S at T	1893.89	NS	14.76		S at T	1759.4	NS	14.73	

Table 5. Kernel yield (kg ha^{-1}) of maize as influenced by preceding groundnut and different integrated nutrient management practices during *rabi* 2015-16 and 2016-17

Treatments applied to *kharif* groundnut (T)	Treatments applied to *rabi* maize (S)									
	2015-16					2016-17				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
T_1	7141	8331	7719	6561	7438	5306	7615	6649	6269	6460
T_2	7663	9406	9362	8267	8674	6697	9075	8611	7423	7951
T_3	8082	9442	9397	8313	8808	6774	9104	8663	7426	7992
T_4	7557	9404	9313	8241	8629	6424	8974	8395	7351	7786
T_5	7270	8423	8389	8138	8055	5997	8407	7223	6638	7066
T_6	7127	8347	7843	6990	7577	5494	7625	7121	6425	6666
Mean	7473	8892	8670	7752	8197	6115	8466	7777	6922	7320
		SEm±	CD (P=0.05)	CV (%)			SEm±	CD (P=0.05)	CV (%)	
	T	77.27	232.92	13.08		T	75.08	226.33	12.51	
	S	284.11	805.55	14.98		S	289.51	820.86	14.26	
	T at S	641.09	NS	14.98		T at S	649.82	NS	14.26	
	S at T	695.93	NS	14.98		S at T	709.15	NS	14.26	

Table 6. System productivity in terms of groundnut equivalent yield (kg ha^{-1}) of the groundnut-maize cropping system for 2015-16 and 2016-17

Treatments applied to *kharif* groundnut (T)	Treatments applied to *rabi* maize (S)									
	2015-16					2016-17				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
T_1	3351	3662	3502	3199	3428	2829	3315	3208	3161	3128
T_2	4544	4999	4987	4701	4808	4171	4824	4518	4346	4465
T_3	4137	4493	4481	4197	4327	3705	4437	4077	3853	4018
T_4	4386	4868	4844	4565	4666	4031	4697	4385	4159	4318
T_5	3965	4266	4257	4191	4170	3538	4312	3938	3740	3882
T_6	3572	3891	3760	3537	3690	3102	3904	3526	3312	3461
Mean	3992	4363	4305	4065	4181	3563	4248	3942	3762	3879
		SEm±	CD (P=0.05)	CV (%)			SEm±	CD (P=0.05)	CV (%)	
	T	36.45	109.87	13.95		T	29.79	87.79	12.29	
	S	74.23	210.46	11.19		S	87.21	247.27	11.01	
	T at S	181.81	NS	11.19		T at S	203.28	NS	11.01	
	S at T	188.2	NS	11.19		S at T	213.62	NS	11.01	

development of pods. These results exhibited in the present study corroborates with the findings of Choudhary *et al* (2011) and Singh *et al* (2011).

Pod yield of groundnut was significantly influenced by different integrated management practices (Table 1). The highest pod yield (2542 and 2453 kg ha^{-1} during 2015-16 and 2016-17, respectively) was recorded with the application of RDF_{125}+FYM_{5t}+ *Rhizobium* inoculation + PSB+VAM (T_2), which was however comparable to RDF_{100}+FYM_{5t}+ *Rhizobium* inoculation +PSB+VAM (T_4). Among the different rates of fertilizers and their combination with FYM and biofertilizers, the combined use of 125% RDF through fertilizer has remarkably recorded the highest pod yield of groundnut over all other RDF, FYM and Biofertilizers management practices. This might be attributed to efficient and greater partitioning of metabolites and adequate translocation and accumulation of photosynthates, amino acids, vitamins, etc., to developing reproductive structures under adequate fertilization. Increase in yield attributes might also be due to synergism in *Rhizobium* and PSB inoculation which increased root nodulation through better root development and congenial availability of the essential plant nutrients and their uptake manifested enhanced growth stature and better flowering, higher number of gynophores penetration into soil, increased the number of pods formation and augmented the yield structure resulting in higher yields of groundnut. Similar findings were also reported by Gunri and Nath (2012), Chavan *et al* (2014) and Sheetal *et al* (2014).

Nutrient uptake and soil parameters of groundnut

N P K uptake estimated at harvesting was significantly influenced by integrated nutrient management practices. A steady progressive increase in N P K uptake was noticed with increase of nutrient management practices. Application of RDF_{150}+FYM_{5t}+ *Rhizobium* inoculation +PSB+VAM (T_3) was recorded distinctively the highest nitrogen uptake. Increases in nitrogen, phosphorus and potassium contents in the by haulm (Table 2) with the application of farm yard manure along with *Rhizobium*, VAM, PSB might be due to enhanced supply of plant nutrients by direct addition through nitrogen fixation, solubilisation of native phosphorus content of soil and dislodging the exchangeable K from soil clay and also by increasing nutrient use efficiency, better absorption and utilization of nutrient in balanced form as observed by researchers such as Choudhary *et al* (2011) and Chavan *et al* (2014) agrees with the present investigation.

The soil parameters *viz.,* organic carbon content, N P and K status in soil after *kharif* groundnut was significantly influenced by integrated nutrient management practices to groundnut(Table 3). The highest organic carbon content, N P and K status after harvest of groundnut was recorded with the combination of RDF_{150}+FYM_{5t}+ *Rhizobium* inoculation +PSB+VAM (T_3) which was, however, on par with treatments RDF_{125}+FYM_{5t}+ *Rhizobium* inoculation +PSB+VAM (T_2), RDF_{100}+FYM_{5t}+ *Rhizobium* inoculation +PSB+ VAM (T_4). Application of FYM and *Rhizobium* inoculation of legumes resulted in improved soil fertility, due to increase of the organic carbon, available N, P and K content of the soil. This might be due to direct addition of N to the soil, which enhanced the microbial activity leading to consequent release of organic complex substances (chelating agents) which turned into greater solubility of available nutrients. The enhanced available nitrogen content of soil might also be due to favourable soil conditions under organic manure with multi inoculation of biofertilizers which might have helped in the mineralization of soil nitrogen resulting in higher build up of available N. The improvement in available P status is because, the roots of legumes secrete certain acidic substances which dissolve insoluble P convert into easily assimiable forms. Application of biofertilizers registered significantly higher K availability in soil due to easy decomposition of mineral constituents and their effect on dislodging the exchangeable K in to the soil solution. As groundnut is a food legume, it plays an important role in improving the fertility status of soil with the help of *Rhizobium* bacteria present in the roots. They are known to enrich the soil with nitrogen through symbiotic nitrogen fixation. Legumes also make soil fertile due to better root penetration causing removal of nutrients from deeper soil layers and thus enriching the top soil with such nutrients. Further, legumes also add a sizable amount of root parts and other residues at maturity thereby improving the nitrogen status of soil after decomposition. The present findings are also in conformity with the findings of these researchers Choudhary *et al* (2011) and Chavan *et al* (2014).

Growth parameters of *rabi* maize

Dry matter accumulation at maturity of maize was affected significantly by the direct treatments as well as the residual effect of the treatments applied to preceding groundnut (Table 4). The interaction effects were found non significant. Different integrated nutrient management practices applied to preceding *kharif* groundnut had significant influence on drymatter accumulation of *rabi* maize. The treatment with the application of RDF_{150}+FYM_{5t}+ *Rhizobium* inoculation +PSB+VAM (T_3) recorded significantly the highest drymatter production, which was however, on par with the combinations supplying RDF_{125}+FYM_{5t}+ *Rhizobium* inoculation +PSB+VAM(T_2) and RDF_{100}+FYM_{5t}+ *Rhizobium* inoculation +

PSB+VAM(T_4). Irrespective of the residual effect of the treatments adopted to the preceding groundnut, the treatments applied to the succeeding maize produced the highest drymatter with the combination supplying RDF_{100}+ *Azospirillum* +PSB+VAM + groundnut residue incorporation (S_2), when compared to all other treatments, which was however, comparable with the treatments RDF_{75}+ *Azospirillum* + PSB+ VAM+ groundnut residue incorporation (S_3). Judicious supply of fertilizers is known to enhance chlorophyll content, which in turn increased the photosynthetic activity rendering to increased accumulation of drymatter. Drymatter accumulation in maize with different treatment combinations might be due to the improvement in soil N status owing to the biological nitrogen fixation of the legumes. This may be due to the ability of biofertilizers to transport major nutrients like N and P besides secreting plant growth promoting substances such as IAA and gibberellins (Umesha *et al.*, 2014). Irrespective of the stage of the crop and year of experimentation, incorporation of groundnut crop residue has resulted in significant improvement in drymatter accumulation as groundnut crop is a legume. A narrow C:N ratio enhanced the range of mineralization resulting in the availability of nitrogen and 'N' from added fertilizer might have been readily available to the succeeding crop. Prolonged availability of N owing to reduced losses and fermentation of mineral complexes was clearly evident from the residue incorporation treatments. Similar findings were also reported by Abou-el- seoud and Abdel-megeed (2012) and Umesha *et al* (2014).

Kernel yield of *rabi* maize

Kernel yield of maize that followed groundnut in sequence was affected significantly by the direct and residual effect of the treatments imposed to preceding groundnut, but their interactions were found to be non significant (Table 5). The maximum kernel yield was recorded consistently following the residual effect of treatment associated with combination RDF_{150}+ FYM_{5t}+ *Rhizobium* inoculation + PSB+VAM (T_3), which was however, comparable with combinations RDF_{125}+ FYM_{5t}+ *Rhizobium* inoculation + PSB+VAM(T_2) and RDF_{100}+FYM_{5t}+ *Rhizobium* inoculation + PSB+VAM(T_4). In respect of direct treatments given to maize, the treatment combination RDF_{100}+ *Azospirillum* + PSB+VAM + groundnut residue incorporation (S_2) recorded the maximum kernel yield of 8892 and 8466 kgha^{-1} during 2015-16 and 2016-17, respectively, which was however, on par with combination RDF_{75}+ *Azospirillum* +PSB+VAM+ groundnut residue incorporation (S_3). Significant improvement in the kernel yield of maize by taking groundnut as preceding crop could be attributed to higher biomass production and nutrient uptake. Increase in the soil microbial population subsequent to groundnut crop harvest as well as due to the residue incorporation might have led to increased solubilization of all the nutrients for absorption, which might have resulted in the enhanced yield attributes and finally kernel yield as compared to without residue incorporation. Decomposition and mineralization of residues might have coincided with the early growth stages of succeeding maize which might have contributed for better performance of the maize over no residue incorporation (Aniket Kalhapure *et al.,* 2014). The positive response of maize at higher levels of nutrients application could be attributed to the overall improvement in crop growth by drymatter accumulation adequate increase in yield attributes, that have enabled the plants to absorb higher quantum of nutrients in order to manifest increased photosynthates and their translocation to sink which finally might have reflected in the kernel yield (Mohammadi and Sohrabi, 2012). As evident from the results, the VAM fungal inoculation can effectively modify the soil microbe population and community structure by increasing the soil enzymatic activities (Mahendra Singh *et al* 2016 and Partha Sarathi Patra *et al* 2017).

System productivity of groundnut maize cropping system

System productivity in terms of groundnut equivalent yield under integrated nutrient management to groundnut- maize sequence was significantly influenced by the residual effect of preceding *kharif* groundnut and direct treatments applied to succeeding *rabi* maize. The interaction effect of nutrient management practices to preceding groundnut and fertilizer schedules along with biofertilizers and groundnut residue incorporation to *rabi* maize was found non-significant (Table 6). The distinctly highest system productivity was recorded with the residual effect of nutrients supplied to *kharif* groundnut through the combination RDF_{125}+FYM_{5t}+ *Rhizobium* inoculation + PSB+VAM (T_2) compared with that of combination of organic and inorganic sources. In addition, among the direct treatments applied to maize, the treatments RDF_{100}+ *Azospirillum* + PSB+VAM + groundnut residue incorporation (S_2) recorded the maximum system productivity, which was however, closely followed by the combination with RDF_{75}+ *Azospirillum* +PSB+ VAM+ groundnut residue incorporation (S_3). The integrated nutrient management treatments to *kharif* groundnut and its residue incorporation besides direct application of INM treatments to *rabi* maize influenced the production of *rabi* maize through their after effects probably by improving the soil fertility and microbial activity for increased mineralization and better nutrient use efficiency. Hence, the system productivity was more through this strategy than due to the inorganic fertilizers alone. These results are in accordance with the findings Usadadiya and Patel (2013) and Devkant Prasad *et al* (2013).

CONCLUSION

Based on the forgoing findings of the investigation, it could be inferred that groundnut-maize cropping system under integrated use of 125%RDF, FYM@5tha^{-1}, *Rhizobium* inoculation, PSB and VAM (T_2) to *kharif* groundnut followed by incorporation of groundnut residue in combination with 100% RDF and biofertilizers (S_2) to *rabi* maize has higher system productivity and sustained soil fertility status.

LITERATURE CITED

Abou-El-Seoud I I and Abdel-Megeed A 2012 Impact of rock materials and biofertilizations on P and K availability for maize (*Zea maize*) under calcareous soil conditions. *Saudi Journal of Biological Sciences*. 19: 55–63.

Aniket Kalhapure, Balasaheb Shete, Madhukar Dhonde and Prashant Bodake 2014 Influence of different organic and inorganic sources of nutrients on maize (*Zea mays*). *Indian Journal of Agronomy* 59 (2): 295-300.

Chavan A P, Jain N K, Sagvekar V V and Taresh Kumar 2014 Integrated nutrient management in groundnut (*Arachis hypogaea* L.). *Research on Crops.* 15 (2) : 454-460.

Choudhary S K, Jat M K, Sharma S R and Singh P 2011 Effect of INM on soil nutrient and yield in groundnut field of semi-arid area of Rajasthan. *Legume Research.* 34 (4) : 283 – 287

Devkant Prasad M S, Yadava M S and Singh C S 2013 Diversification of rice (*Oryza Sativa*)-based cropping systems for higher productivity, profitability and resource-use efficiency under irrigated ecosystem of Jharkhand. *Indian Journal of Agronomy.* 58(3): 264.

Dhadge S M and Satpute N R 2014 Integrated nutrient management in groundnut(*Arachis hypogea* L.) – maize (*Zea mays*) cropping system. *International Journal of Agricultural Sciences*. 10(1) : 365-368.

Gunri S K and Nath R 2012 Effect of organic manures, biofertilizers and biopesticides on productivity of summer groundnut (Arachis hypogeae L.) in red and laterite zone of west Bengal. *Legume Res.*35 (2) : 144 – 148.

Jackson M L 1973 *Soil Chemical Analysis*. Prentice Hall India Private Limited, New Delhi p:41.

Mahendra Singh, Rajiv Rakshit, Kasturikasen Beura and Manohar Lal 2016 Field evaluation of Vesicular Arbuscular Mycorrhizal fungi (VAM) for microbial activities and yield of maize under alluvial soil. *Journal of Applied and Natural Science.* 8 (4): 2055-2059.

Mohammadi Khosro and Sohrabi Yousef 2012 Bacterial biofertilizers for sustainable crop production: a review. *ARPN Journal of Agricultural and Biological Science.* 7(5): 307–16.

Partha Sarathi Patra, Pabitra Adhikary, Shyamal Kheroar, Amrit Tamang, Ashim Chandra Sinha and Debasis Mahato 2017 Direct and Residual Effect of Organics on Groundnut – Maize Cropping Sequence. *Research Journal of Agricultural Sciences.* 8(2): 411-416.

Patil A B, Chavan L S and Jagtap D N 2014 Response of groundnut (*Arachis hypogaea* L.) varieties to nutrient management in *rabi*-hot weather season. *Legume Research.* 37 (4) : 395-401, 2014.

Panse V G and Sukhatme P V 1978 *Statistical Methods for Agricultural Workers*. ICAR, New Delhi. 199-211.

Piper C S 1950 *Soil and plant analysis.* Hans publishers, Bombay. India.

Sheetal T, Gabhane V V and Pushpa B 2014 Effect of integrated nutrient management on yield, quality, nutrient content and uptake of groundnut in shrink-swell soil. *International Journal of Agricultural Sciences.* 10(1):291-293.

Singh G P, Singh P L and Panwar A S 2011 Response of groundnut (*Arachis hypogaea*) to biofertilizer, organic and inorganic sources of nutrient in north east India. *Legume Research.* 34 (3) : 196 – 201.

Umesha S, Srikantaiah M, Prasanna K S, Sreeramulu K R, Divya M and Lakshmipathi R N 2014 Comparative Effect of Organics and Biofertilizers on Growth and Yield of Maize (*Zea mays. L*). *Current Agriculture Research Journal.* 2(1), 55-62.

Usadadiya V P and Patel R H 2013 Influence of preceding crops and nutrient management on productivity of wheat (*Triticum aestivum*)-based cropping system. *Indian Journal of Agronomy.* 58 (1): 15-18.

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