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System productivity of groundnut-maize cropping system as affected by biofertilizers and crop residue incorporation

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Abstract
A field experiment was conducted on "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 nitrogen management practices involving biofertilizer inoculations on growth and yield of *kharif* groundnut and succeeding *rabi* maize. Among all the RDF along with bio-fertilizers application, maximum values for vegetative parameters were recorded with the application of 150% RDF + FYM 5 t ha^{-1} and the higher pod yield and yield attributes were recorded with 125% RDF + FYM 5 t ha^{-1} which was, however, comparable with with100% RDF + FYM 5 t ha^{-1}. The research results of succeeding maize revealed that, growth parameters, yield attributes, yield and economic returns were significantly influenced by the treatments given to preceding groundnut crop in the sequence. Among all the treatments, the plant height, drymatter production, yield attributes and the yield maximum recorded with the treatment combination of 100%RDF+ *Azospirillum*+ PSB+ VAM+ with groundnut crop residue incorporation which was, however, comparable to combinations RDF_{125}+FYM_{5t}+ *Rhizobium* inoculation +PSB+VAM and RDF_{100}+FYM_{5t}+ *Rhizobium* inoculation +PSB+VAM.

Keywords: Groundnut-maize cropping system, integrated nutrient management, biofertilizers, crop residue incorporation, economics, system productivity

Introduction
Generally, fertilizers are recommending on the basis of individual crop response. As the determination of the fertilizer dose for cropping system is complex due to factors like soil, nutrient fixation and residual effects. The importance of growing legumes for sustaining and improving soil fertility has been well known fact. Groundnut-maize is one of the cropping systems that is gaining productivity under intensive cultivation on *Alfiisols*. Information on nutrient requirement for this intensive cropping system is limited, when nutrients are supplied through integrated nutrient management practices. Sustainability of higher yield could be achieved through integrated nutrient management. Therefore, the present experiment on integrated nutrient management in groundnut-maize crop sequence was conducted.

Materials and Methods
A field experiment was conducted at the Agricultural Research Station, Vizianagaram of Acharya N.G. Ranga Agricultural University (ANGRAU), in the North - Coastal Agro-Climatic Zone of Andhra Pradesh. The results of the soil analysis 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 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.

The field experiment was laid 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} + AS + PSB + VAM + with groundnut residue incorporation.

The test variety groundnut cultivar, K-9 with spacing of 30 X 10 cm and maize cultivar DHM-117 with spacing 60x20cm was adopted. Different growth parameters at various stages and yield were recorded and statistically analysed following the analysis of variance for randomised block design as suggested by Panse and Sukhatme (1978) [12].

Results and Discussion

Growth parameters of *kharif* groundnut

Growth parameters like plant height (cm), drymatter production and number of nodules plant^{-1} were significantly influenced by integrated nutrient management practices (Table 1).

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	Dry matter at maturity	No. of gynophores Plant^{-1}	No. of Pods Plant^{-1}	Pod yield	Plant height at harvest	Dry matter 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	104.00	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	2.90	295.67
CV (%)	14.95	14.71	13.96	11.67	10.19	13.04	13.94	13.85	10.09	10.05

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 30 DAS, 60 DAS, 90 DAS and harvest was significantly affected due to integrated nutrient management practices. The maximum plant height of groundnut at 30DAS, 60 DAS, 90 DAS and 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 (FYM). Further, the organic manure release nutrients slowly and may reduce the leaching losses, particularly N and simultaneously the ability of bio fertilizers 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) [5].

Drymatter accumulation also showed the similar trend, as that of plant height. The highest drymatter accumulation was recorded with RDF_{150}+ FYM_{5t} + *Rhizobium* inoculation + PSB + VAM (T_3) applied to groundnut (Table 1). It was significantly superior to the rest of the treatments. 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) [11] and Patil *et al*. (2014) [6].

Yield attributes and yield of *kharif* groundnut

Numbers 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) [3].

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 bio fertilizers helped in balanced nutrition in readily available forms throughout the growth period. The uptake of available nutrients lead to greater photosynthetic activity and production of more metabolites 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 helped in the transformation of maximum number of gynophores into development of pods. These results exhibited in the present study corroborate the findings of Choudhary *et al.* (2011) [3] and Singh *et al.* (2011) [3].

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 significantly highest pod yield of groundnut over all other RDF, FYM and Bio fertilizers management practices. This might be attributed to efficient and greater partitioning of metabolites and adequate translocation and accumulation of photo synthates, amino acids, vitamins, etc., to developing reproductive structures under adequate fertilization. This seems to have resulted in increased yield attributing characters and finally yield. Similar findings were also reported by Gunri and Nath (2012) [7], Chavan *et.al.* (2014) [2] and Sheetal *et al.* (2014) [13].

Economics of *kharif* Groundnut

Integrated nutrient management practices exerted profound influence on economic returns of the groundnut cultivation during both the years of study (Table 2) The highest gross return (Rs.144736 and Rs.139905 ha^{-1} during 2015-16 and 2016-17, respectively), net returns (Rs.84108 and Rs.79277 ha^{-1} during 2015-16 and 2016-17, respectively), benefit cost ratio and returns per rupee invested were realized 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$_4$), but, were distinctly superior to RDF$_{150}$ + FYM$_{5t}$ + *Rhizobium* inoculation + PSB + VAM (T$_3$) and RDF$_{75}$ + FYM$_{5t}$ + *Rhizobium* inoculation + PSB + VAM (T$_5$). Application of RDF$_{150}$ + FYM$_{5t}$ + *Rhizobium* inoculation + PSB + VAM (T$_3$) and RDF$_{75}$ + FYM$_{5t}$ + *Rhizobium* inoculation + PSB + VAM (T$_5$) did not show any disparity among them in respect of gross returns, but, was significantly superior to RDF$_{50}$ + FYM$_{5t}$ + *Rhizobium* inoculation + PSB + VAM (T$_6$) and RDF$_{100}$ + FYM$_{5t}$ (T$_1$). The lowest gross return (Rs.85707 and Rs.84714 ha^{-1} during 2015-16 and 2016-17, respectively) were obtained with RDF$_{100}$ + FYM$_{5t}$ (T$_1$).

Gross returns from groundnut in response to integrated nutrient management practices are descending order of RDF$_{125}$ + FYM$_{5t}$ + *Rhizobium* inoculation + PSB + VAM (T$_2$), RDF$_{100}$ + FYM$_{5t}$ + *Rhizobium* inoculation + PSB + VAM (T$_4$), RDF$_{75}$ + FYM$_{5t}$ + *Rhizobium* inoculation + PSB + VAM(T$_5$), RDF$_{150}$ + FYM$_{5t}$ + *Rhizobium* inoculation + PSB + VAM (T$_3$), RDF$_{50}$ + FYM$_{5t}$ + *Rhizobium* inoculation + PSB +VAM (T$_6$) and RDF$_{100}$ + FYM$_{5t}$ (T$_1$) during both the years of study.

Among the integrated nutrient management practices, application of RDF$_{125}$ + FYM$_{5t}$ + *Rhizobium* inoculation + PSB + VAM (T$_2$) attained significantly higher economic returns (Gross returns, Net returns and B:C ratio) during both the years owing to higher kerenel yield and in turn higher gross and net returns in this treatment which is comparable with RDF$_{100}$ + FYM$_{5t}$ + *Rhizobium* inoculation + PSB + VAM (T$_4$).

Table 2: Gross Returns (GR) (Rs. ha^{-1}), Net Returns (NR) (Rs. ha^{-1}) Benefit Cost Ratio (BCR) and Returns per Rupee invested (RRI) of groundnut as influenced by different integrated nutrient management practices during *kharif* 2015 and 2016

Treatments	2015					2016		
	GR	NR	BCR	RRI	GR	NR	BCR	RRI
T$_1$= RDF$_{100}$+FYM$_{5t}$ (Control)	85707	28822	1.51	0.51	84714	27829	1.49	0.49
T$_2$= RDF$_{125}$+FYM$_{5t}$ +*Rhizobium* +PSB+VAM	144736	84108	2.39	1.39	139905	79277	2.31	1.31
T$_3$= RDF$_{150}$+FYM$_{5t}$ + *Rhizobium* +PSB+VAM	117288	55908	1.91	0.91	109751	48371	1.79	0.79
T$_4$= RDF$_{100}$+FYM$_{5t}$ + *Rhizobium* +PSB+VAM	137517	77632	2.30	1.30	134294	74409	2.24	1.24
T$_5$= RDF$_{75}$+FYM$_{5t}$ + *Rhizobium* +PSB+VAM	118315	59187	2.00	1.00	113001	53873	1.91	0.91
T$_6$ = RDF$_{50}$+FYM$_{5t}$ + *Rhizobium* +PSB+VAM	98230	39850	1.68	0.68	90087	31707	1.54	0.54
Mean	116965	57584	1.96	0.96	111958	52577	1.88	0.88
SEm ±	5729	5729	0.09	0.09	5446	5446	0.08	0.08
CD (P=0.05)	17269	17269	0.29	0.29	16416	16416	0.27	0.27
CV (%)	10.79	14.13	10.46	13.16	10.84	14.84	9.56	14.25

Thus, it was revealed from the present investigation that integration of proper organic, inorganic and biofertilizers treatment combinations will definitely increase the pod yield (kg ha^{-1}) and profitability of groundnut crop. However, suitable management of these nutrients is essential. It can be concluded that adoption of a balanced nutrient management approach will safeguard the higher productivity and returns from rupee spent. These results are in accordance with the findings of Singh *et al.* (2013) [4], Chavan *et al.* (2014) [11] and Madhu Bala and Kedar Nath (2015) [8].

Growth parameters of *rabi* maize

Plant height of succeeding maize recorded at different stages has shown a significant increase with advancement in the age of the crop. The height of maize recorded at 90DAS (Table 3) was significantly influenced by different levels of fertilizers, biofertilizers along with groundnut residue incorporation. The interactions between them did not influence significantly the crop performance at all stages of crop growth. Plant height of maize was significantly affected by different integrated nutrient management practices imposed to preceding *kharif* groundnut. The treatment, RDF_{150}+ FYM_{5t}+ *Rhizobium* inoculation +PSB+VAM (T_3) recorded significantly the highest plant height compared to all the combinations, which was however, comparable with the combinations that received 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 given to the preceding groundnut, the treatments applied to the succeeding maize registered the highest plant height with the combination of RDF_{100} + *Azospirillum* + PSB + VAM + groundnut residue incorporation (S_2), which was however comparable to RDF_{75}+ *Azospirillum* + PSB + VAM + groundnut residue incorporation (S_3). Increased plant height of maize may be attributed enhanced the applied nutrient use efficiency in the presence of groundnut residue by mycorrizal colonizaton in the rhizosphere and promoted growth. The positive response of nutrients on plant growth across different soils and regions as noticed in the present investigation were also reported earlier by Umesha *et al.* (2014) [16].

Table 3: Plant height (cm) of maize at 90 DAS 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	225.00	258.25	252.75	245.90	245.48	190.00	243.70	234.50	218.10	221.58
T_2	249.50	287.20	283.75	257.25	269.43	224.55	296.50	281.00	229.65	257.93
T_3	253.25	287.50	284.75	259.00	271.13	227.65	297.50	285.00	230.38	260.13
T_4	247.15	286.65	282.50	256.90	268.30	222.35	295.00	270.40	228.25	254.00
T_5	241.20	268.80	265.15	256.20	257.84	219.75	259.25	252.50	227.85	239.84
T_6	228.75	260.65	257.55	247.35	248.58	194.65	248.05	237.00	219.25	224.74
Mean	240.81	274.84	271.08	253.77	260.12	213.16	273.33	260.07	225.58	243.03
		SEm±	CD (P=0.05)	CV (%)			SEm±	CD (P=0.05)	CV (%)	
	T	1.23	3.71	10.01		T	1.86	5.61	12.24	
	S	5.33	15.10	10.03		S	5.13	14.55	10.34	
	T at S	11.82	NS	10.03		T at S	12.80	NS	10.34	
	S at T	13.04	NS	10.03		S at T	12.56	NS	10.34	

Drymatter accumulation at maturity by 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 dry matter. Dry matter 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 bio fertilizers to transport major nutrients like N and P besides secreting plant growth promoting substances such as IAA and gibberellins (Umesha *et al.*, 2014) [16]. 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) [16].

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* 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	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	211.10	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	1627.09	NS	14.73	
	S at T	1893.89	NS	14.76		S at T	1759.35	NS	14.73	

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 variation in kernel yield observed across the treatments imposed in groundnut-maize sequence was consistent during both the years of the study. 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 (Aniket Kalhapure *et al.*, 2014) [1]. 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). The beneficial role of INM practices as reflected in the present investigation in enhancing the yield was very well established and also corroborated with the results as reported by Mahendra Singh *et al.* (2016) [9] and Partha Sarathi Patra *et al.*, 2017. [10]

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	

Economics of Maize

Maize that followed groundnut in sequence exerted profound influence on economic returns by the direct and residual effect of the treatments imposed to preceding groundnut, but, their interactions were found non significant during both the years of study. (Table 6, 7, 8 and 9).

Table 6: Gross returns (Rs.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	103549	120803	111922	95131	107851	76936	110411	96415	90907	93667
T_2	111116	136386	135746	119872	125780	97100	131582	124861	107627	115293
T_3	117183	136914	136255	120531	127721	98222	132005	125606	107678	115878
T_4	109576	136360	135031	119494	125115	93142	130122	121730	106585	112895
T_5	105422	122137	121644	118004	116802	86950	121906	104727	96244	102457
T_6	103338	121030	113729	101349	109861	79669	110557	103257	93168	96663
Mean	108364	128938	125721	112397	118855	88670	122764	112766	100368	106142
		SEm±	CD (P=0.05)	CV (%)			SEm±	CD (P=0.05)	CV (%)	
	T	1120.41	3377.28	13.32		T	1088.73	3281.77	12.51	

	S	4119.64	11680.52	14.18	S	4197.90	11902.43	14.16
	T at S	9295.90	NS	14.18	T at S	9422.49	NS	14.16
	S at T	10091.00	NS	14.18	S at T	10282.72	NS	14.16

Table 7: Net returns (Rs.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	54204	67958	60635	45396	57048	27591	57566	45128	41172	42864
T_2	61771	83541	84459	70137	74977	47755	78737	73574	57892	64490
T_3	67838	84069	84968	70796	76918	48877	79160	74319	57943	65075
T_4	60231	83515	83744	69759	74312	43797	77277	70443	56850	62092
T_5	56077	69292	70357	68269	65999	37605	69061	53440	46509	51654
T_6	53993	68185	62442	51614	59058	30324	57712	51970	43433	45860
Mean	59019	76093	74434	62662	68052	39325	69919	61479	50633	55339
		SEm±	CD (P=0.05)	CV (%)			SEm±	CD (P=0.05)	CV (%)	
	T	1120.41	3377.28	13.43		T	1088.73	3281.77	14.42	
	S	4119.64	11680.52	12.16		S	4197.90	11902.43	13.28	
	T at S	9295.90	NS	12.16		T at S	9422.49	NS	13.28	
	S at T	10091.00	NS	12.16		S at T	10282.72	NS	13.28	

Table 8: B:C Ratio 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	2.10	2.29	2.18	1.91	2.12	1.56	2.09	1.88	1.83	1.84
T_2	2.25	2.65	2.58	2.41	2.47	1.97	2.49	2.43	2.16	2.26
T_3	2.37	2.66	2.59	2.42	2.51	1.99	2.50	2.45	2.17	2.28
T_4	2.22	2.63	2.58	2.40	2.46	1.89	2.46	2.37	2.14	2.22
T_5	2.14	2.37	2.31	2.37	2.30	1.76	2.31	2.04	1.94	2.01
T_6	2.09	2.29	2.22	2.04	2.16	1.61	2.09	2.01	1.87	1.90
Mean	2.20	2.48	2.41	2.26	2.34	1.80	2.32	2.20	2.02	2.08
		SEm±	CD (P=0.05)	CV (%)			SEm±	CD (P=0.05)	CV (%)	
	T	0.02	0.07	12.45		T	0.02	0.06	13.28	
	S	0.08	0.23	10.16		S	0.08	0.23	10.94	
	T at S	0.18	NS	10.18		T at S	0.18	NS	10.94	
	S at T	0.19	NS	10.16		S at T	0.19	NS	10.94	

Table 9: Returns per rupee invested 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	1.10	1.29	1.18	0.91	1.12	0.56	1.09	0.88	0.83	0.84
T_2	1.25	1.58	1.65	1.41	1.47	0.97	1.49	1.43	1.16	1.26
T_3	1.37	1.59	1.66	1.42	1.51	0.99	1.50	1.45	1.17	1.28
T_4	1.22	1.58	1.63	1.40	1.46	0.89	1.46	1.37	1.14	1.22
T_5	1.14	1.31	1.37	1.37	1.30	0.76	1.31	1.04	0.94	1.01
T_6	1.09	1.29	1.22	1.04	1.16	0.61	1.09	1.01	0.87	0.90
Mean	1.20	1.44	1.45	1.26	1.34	0.80	1.32	1.20	1.02	1.08
		SEm±	CD (P=0.05)	CV (%)			SEm±	CD (P=0.05)	CV (%)	
	T	0.02	0.07	12.45		T	0.02	0.06	13.28	
	S	0.08	0.23	10.16		S	0.08	0.23	10.94	
	T at S	0.18	NS	10.18		T at S	0.18	NS	10.94	
	S at T	0.19	NS	10.16		S at T	0.19	NS	10.94	

Among the integrated nutrient management practices in groundnut, combined application of RDF_{150} + FYM_{5t} + *Rhizobium* inoculation + PSB +VAM (T_3) attained significantly higher economic returns *viz.*, gross returns, net returns, B:C ratio and returns per rupee invested during both the years owing to higher grain yield and in turn higher gross and net returns in this treatment which is closely comparable with the combination RDF_{125} + FYM_{5t} + *Rhizobium* inoculation + PSB + VAM (T_2).

With respect to direct treatments assigned to maize, the treatments RDF_{100} + *Azospirillum* + PSB + VAM + groundnut residue incorporation (S_2) recorded significantly higher gross returns, net returns, benefit cost ratio and returns per rupee in maize during both the years of the study which was, however, on par with RDF_{75} + *Azospirillum* + PSB + VAM + groundnut residue incorporation, but, distinctly superior to RDF_{50} + *Azospirillum* + PSB + VAM + groundnut residue incorporation (S_4) and RDF_{100} + *Azospirillum* + PSB + VAM (S_1).

Thus, it was revealed from the present investigation that residual effects of treatments applied to preceding groundnut followed by its residue incorporation with direct application of integration of proper treatment combinations to maize, produced better growth and yield attributes and ultimately resulted in the highest yield and economic returns of maize in groundnut-maize sequence. It might be attributed to the balanced nutrient management approach which safeguard the higher productivity and returns from rupee spent. The present findings of the study are in close conformity with those reported by Gundlur, *et al.* (2014) [6] and Aniket Kalhapure *et al*. (2014) [1].

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 10). 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) [17, 4].

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.

Table 10: 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	188.20	NS	11.19		S at T	213.62	NS	11.01	

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