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Integrated nutrient management in rainy season groundnut (*Arachis hypogaea*)

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ABSTRACT

A field experiment was conducted at Berhampur during rainy (*kharif*) season of 2003 and 2004 on loamy sand soil to study the effect of integrated use of FYM, recommended dose of fertilizer (RDF) *i.e.* 20-17.4-33.3 kg N-P-K/ha, *Rhizobium*, gypsum (250 kg/ha) and boron (1 kg/ha) on performance of groundnut (*Arachis hypogaea* L.) and soil fertility. Results revealed that application of FYM + 75% RDF + *Rhizobium* + gypsum + boron recorded significantly higher pods/plant, 100 pod weight resulting in higher pod (2.66 tonne/ha), kernel yield (1.92 tonne/ha) and nutrient uptake (151.4-17.0-58.6-0.8-0.07 kg N-P-K-S-B/ha). This treatment also had generated maximum net return (Rs. 22,000/ha). The increase in pod yield of this treatment was 65 and 14% higher over RDF and application of 5 t FYM + 75% RDF + *Rhizobium* + lime @¼ lime requirement (LR) + boron respectively. Application of FYM + 75% RDF + gypsum was the second best pod yielding treatment. However, the calcium uptake was highest (48.6 kg/ha) with FYM + 75% RDF + *Rhizobium* + Lime @ ¼ LR + boron application. There was build up of available N in the soil but P,K,S and B were depleted after cropping. Available Ca had depleted in all the treatments except the treatments using lime and combination of FYM and gypsum.

Keyword: Boron, Farmyard manure, Groundnut, Gypsum, Lime, Nutrient uptake, *Rhizobium,* Yield

Groundnut (*Arachis hypogaea* L.) is the major *kharif* oilseeds crop of India. In Orissa, about 40% of the total groundnut cultivation is done during rainy season. But its productivity is low (1,044 kg/ha) primarily due to its cultivation in acidic soils with low N, P, Ca, S, B besides inadequate organic matter. Groundnut is an exhaustive crop and removes large amount of macro and micronutrients from soil. None of the sources of nutrient alone can meet the total plant nutrient need of crop adequately. Hence, integrated use of nutrients from chemical, organic, bio-fertilizer is the most efficient way to supply plant nutrients for sustained crop productivity and improved of soil fertility (Singh and Singh, 2002). Keeping the above points in view, an experiment was conducted to study the combined effect of farmyard manure, fertilizer, *Rhizobium*, gypsum, lime and boron on productivity, nutrient uptake and nutrient balance of soil in rainy season groundnut.

MATERIALS AND METHODS

The field experiment was conducted at Centre for Pulses Research, Orissa University of Agriculture and Technology, Berhampur ($19^0 18'$ N latitude, $84^0 54'$ E longitude and 34 m above MSL.) in the East and South-Eastern Coastal Plain Zone of Orissa, during rainy seasons of 2003 and 2004. During 2004, the experiment was conducted in the site adjacent to the experimental plot of 2003. The soil of the experimental site was loamy sand (*Aeric Haplustalfs* order *Alfisols*) with pH 5.4, low in available N, P and S (186.5, 7.5 and 18.5 kg/ha) medium in potassium (164.2 kg/ha), low in boron (0.204 ppm) and exchangeable calcium (1.5 c.mol (p^+)/kg). Lime requirement (LR) of soil was 2.6 tonne/ha. The experiment was laid out in randomized block design with 3 replications involving fourteen treatments *viz.,* T_1 recommended dose of fertilizer (RDF) i.e. 20-17.4-33.3 kg N-P-K/ha; T_2 RDF + *Rhizobium* (seed treatment); T_3 RDF + gypsum @ 250 kg/ha; T_4 RDF + lime @ ¼ LR ; T_5 RDF + boron @1 kg/ha; T_6 RDF + *Rhizobium* + gypsum @ 250 kg/ha + boron @ 1 kg/ha; T_7 RDF + Lime @ ¼ LR + *Rhizobium* + boron @ 1 kg/ha; T_8 FYM @ 5 t/ha + 75% RDF; T_9 FYM @ 5 t/ha + 75% RDF + *Rhizobium*; T_{10} FYM @ 5 t/ha + 75% RDF + gypsum @ 250 kg/ha ; T_{11} FYM @ 5 t/ha + 75% RDF + Lime @ ¼ LR; T_{12} FYM @ 5 t/ha + 75% RDF + boron @ 1 kg/ha; T_{13} FYM @ 5 t/ha + 75% RDF + *Rhizobium* + gypsum @ 250 kg/ha + boron @ 1 kg/ha and T_{14} FYM @ 5 t/ha + 75% RDF + *Rhizobium* + Lime @ ¼ LR + boron @ 1 kg/ha. FYM contained 0.71, 0.11 0.6 and 30% N, P, K and moisture, respectively with pH 7.5.

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Valencia bunch type groundnut 'Smruti' was sown at 30 cm × 10 cm spacing on 9 July and 8 July 2003 and 2004 and was harvested on 26 October, 2003 and 28 October, 2004, respectively. Seeds were inoculated with *Rhizobium* culture @ 20 g/kg of seed prior to sowing as per treatment. Fine ground lime as $CaCO_3$ @ ¼ LR was applied and thoroughly incorporated in to the soil 30 days before sowing. Fine ground gypsum ($CaSO_4$ containing 14% S and 18% Ca) @ 250 kg/ha was applied in 2 equal splits, half as basal and remaining half during interculture operation at 18 days after sowing.

Boron @ 1 kg/ha was applied through borax ($Na_2B_4O_7$ $10H_2O$) containing 10% B as basal in furrows with fertilizers in the form of diammonium phosphate, urea and muriate of potash. The crop received 1,342.3 mm rainfall in 46 rainy days and 872.5 mm rainfall in 36 rainy days during 2003 and 2004, respectively. Cyclonic rainfall of 358.3 mm from 5 to 9 october, 2003 was received by the crop which coincided with late maturity stage of the crop. However, it did not have any adverse effect on the yield. All the agronomic and plant protection practices were followed as per the treatments during crop growth. Soil samples from each treatment were collected up to 30 cm depth after harvest of the crop during each year of experiment. The available Ca, S and B content were determined by complexometric titration, turbidimetric and hot water soluble method, respectively. The plant samples at harvest were collected and dried separately for haulm, kernel, shell and N, P, K, Ca, S and B content were determined through standard procedures. Oil content of the kernels was determined following cold percolation method. The protein content of kernel was determined by multiplying N concentration with a factor 6.25. The nutrient uptake was determined by multiplying their concentration with corresponding treatment yield. The nutrient balance was computed as per the method followed by Singh *et al*. (2007).

RESULTS AND DISCUSSION

Yield attributes and yield

Integrated application of FYM @ 5 t/ha + 75% recommended dose of fertilizer + *Rhizobium* + gypsum @ 250 kg/ha + boron @ 1 kg/ha recorded significantly higher pod yield (Table 1) over all other treatments. Adequate and continuous supply of macro and micro-nutrients had positive influence on yield attributes, and recorded 138.8, 48.3, 44.8, 65.2, and 32.7% higher number of mature pods/plant, 100 pod weight, 100 kernel weight, pod yield, haulm yield, respectively over recommended dose of fertilizer (Table 1).

Farmyard manure acted as buffer in the soil with low pH (5.4). It improved the physio-chemical condition of

Table1. Effect of integrated nutrient management on yield attributes, yield and economics of groundnut (Pooled data)

Treatment	No. of nodules/ plant at 35 DAS	Pods/ plant	100 pod weight (g)	100 kernel weight (g)	Pod yield (t/ha)	Haulm yield (t/ha)	Shelling (%)	Kernel yield (t/ha)	Oil content (%)	Protein content (%)	Cost of cultivation (x10^{3}Rs/ha)	Net Returns (x10^{3}Rs/ha)	Benefit: cost ratio
$N_{20}P_{17.4}K_{33.3}$(RDF)	21.3	9.8	81.2	40.2	1.61	3.64	56.6	0.91	36.9	17.8	16.45	8.72	0.53
RDF + *Rhizobium*	92.3	10.4	81.4	40.3	1.68	3.76	58.1	0.97	38.0	18.0	16.53	9.75	0.59
RDF + gypsum (250 kg/ha)	29.3	12.9	98.3	48.7	1.89	3.99	59.6	1.13	42.3	19.6	16.91	12.68	0.75
RDF + lime (¼ LR)	31.4	14.7	103.8	51.1	2.04	4.14	61.6	1.25	38.5	20.9	17.33	14.38	0.83
RDF + boron (1 kg B/ha)	25.4	10.6	85.9	42.1	1.75	3.87	58.3	1.02	38.1	18.2	17.67	9.89	0.56
RDF + *Rhizobium* + gypsum + B	94.5	14.0	99.9	44.5	2.01	4.05	60.6	1.22	42.9	20.4	17.91	13.43	0.75
RDF + *Rhizo bium* + lime + B	107.4	15.7	104.8	51.8	2.14	4.21	62.2	1.33	39.6	21.3	18.59	14.87	0.80
FYM_5 + 75% RDF	35.8	15.1	104.1	51.6	2.06	4.11	61.8	1.27	39.4	21.2	18.15	13.61	0.75
FYM_5 + 75% RDF + *Rhizobium*	116.3	15.9	105.7	51.9	2.16	4.22	62.3	1.34	39.7	21.5	18.19	15.47	0.85
FYM_5 + 75% RDF + gypsum	54.5	20.4	109.9	54.0	2.45	4.66	64.7	1.59	43.4	22.2	18.46	19.94	1.08
FYM_5 + 75% RDF + lime	49.3	17.4	107.3	53.6	2.26	4.35	63.1	1.43	41.0	21.7	18.79	16.54	0.88
FYM_5 + 75% RDF + B	45.3	16.1	106.6	52.6	2.17	4.22	63.3	1.37	40.0	21.6	19.22	14.80	0.77
FYM_5 + 75% RDF + *Rhizobium* + gypsum + B	137.0	23.4	120.4	58.2	2.66	4.83	72.1	1.92	43.5	24.5	19.47	22.00	1.13
FYM_5 + 75% RDF + *Rhizobium* + lime + B	122.0	19.9	108.9	53.9	2.33	4.56	64.4	1.53	41.3	22.1	19.98	17.39	0.87
SEm±	2.8	0.4	1.1	1.4	0.05	0.09	1.8	0.04	0.6	0.4			
CD (P=0.05)	8.5	1.2	3.5	3.9	0.13	0.25	5.1	0.11	1.7	1.3			

the soil, provided favourable environment, stimulated the uptake of nutrients and increased the yield over the treatments where FYM was not added. Rao and Shaktawat (2002) had similar observations. Inoculation with *Rhizobium* improved the nodulation that enhanced N fixation, activation of amino acids for synthesis of carbohydrates, and consequently expressed in increase in number of pods/plant, 100 kernel weight and pod yield. This agrees with findings of Balasubramanian and Palaniapan (1994).

Gypsum provided S and Ca. Sulphur the integral part of amino acids like cysteine, cystine and methionine recorded 17.9% higher oil content over application of RDF alone. Calcium is required for reproductive development and better pod filling. There was 16.7% increase in sound matured kernel percentage over recommended dose of fertilizer. Dutta and Mondal (2006) had reported similar findings. Boron facilitated translocation of photosynthates such as sugar and fat to the sink, increased the number of pods/plant, 100 pod and kernel weight over recommended dose of fertilizer. Application of FYM @ 5 t/ha + 75% recommended dose of fertilizer + gypsum recorded the second highest values of yield attributing characters and pod yield (2.45 t/ha) that was however, at par with FYM @ 5 t/ha + 75% recommended dose of fertilizer + *Rhizobium* + lime @ ¼ LR + boron @ 1 kg/ha (Table 1). It might be due to the fact that the combination of FYM with gypsum had better effect in increasing pod yield of groundnut over FYM and lime. FYM improved nutrient availability from organic and inorganic source by its buffering activity in acid soil. The soil was deficient in S and it is essential for groundnut. Gypsum provided both Ca and S. So combination of FYM and gypsum recorded better result than combination of FYM and lime.

Nutrient uptake

Highest uptake of nutrients (151.4-17-58.6-10.8-0.07 kg N-P-K-S-B/ha) were recorded with integrated application of FYM @ 5 t/ha + 75% recommended dose of fertilizer + *Rhizobium* + gypsum + B (Tables 3 and 4). The combined application of inorganic fertilizer with farmyard manure, *Rhizobium* and B could stimulate the uptake of nutrients due to enhanced microbial and *Rhizobium* activity, better root growth under congenial soil physical condition created by farmyard manure. The result corroborated the findings of Kachot *et al*. (2001). Increase in P uptake was due to increase in P availability from applied fertilizer and inherent soil source and combined effect of released organic acids and organic anions on decomposition of farmyard manure in acid lateritic soil. Dutta and Mondal (2006) also opined alike. Split application of gypsum ensured adequate Ca and S availability in the fruiting zone at pegging and pod development stages, which was absorbed by gynophores and increased their uptake. Ravikumar *et al.* (1994) had similar observations. Calcium uptake was highest (48.6 kg/ha) with farmyard manure + 75% recommended dose of fertilizer + *Rhizobium* + Lime + B (Table 4) over other nutrient management practices followed by farmyard manure + 75% recommended dose of fertilizer + *Rhizobium* + gypsum + B (47.2 kg/ha). The higher Ca uptake due to lime and gypsum application was due to increase in its availability in rhizosphere. Uptake of B was more due to high demand of boron for pod filling and increase in availability of boron in the root zone.

Table2. Effect of integrated nutrient management on yield attributes and economics of groundnut (Poled data)

Treatment	Oil content (%)	Protein content (%)	Cost of cultivation (x10^3 Rs/ha)	Net returns (x10^3 Rs/ha)	Benefit: cost ratio
$N_{20}P_{17.4}K_{33.3}$(RDF)	36.9	17.8	16.45	8.72	0.53
RDF + *Rhizobium*	38.0	18.0	16.53	9.75	0.59
RDF + gypsum (250 kg/ha)	42.3	19.6	16.91	12.68	0.75
RDF + lime (¼ LR)	38.5	20.9	17.33	14.38	0.83
RDF + B (1 kg/ha)	38.1	18.2	17.67	9.89	0.56
RDF + *Rhizobium* + gypsum + B	42.9	20.4	17.91	13.43	0.75
RDF + *Rhizobium* + lime + B	39.6	21.3	18.59	14.87	0.80
FYM_5 + 75% RDF	39.4	21.2	18.15	13.61	0.75
FYM_5 + 75% RDF + *Rhizobium*	39.7	21.5	18.19	15.47	0.85
FYM_5 + 75% RDF + gypsum	43.4	22.2	18.46	19.94	1.08
FYM_5 + 75% RDF + lime	41.0	21.7	18.79	16.54	0.88
FYM_5 + 75% RDF + B	40.0	21.6	19.22	14.80	0.77
FYM_5 + 75% RDF + *Rhizobium*+ gypsum + B	43.5	24.5	19.47	22.00	1.13
FYM_5 + 75% RDF + *Rhizobium* + lime + B	41.3	22.1	19.98	17.39	0.87
SEm ±	0.6	0.4			
CD (P=0.05)	1.7	1.3			

Table3. Balance sheet of available N,P and K as influenced by integrated nutrient management practices (Pooled data)

Treatment	Total available nutrients (Initial + added through different source) (kg/ha)			Nutrient uptake (kg/ha)			Available soil nutrient after last harvest (kg/ha)			Net gain (+)/loss (-) of nutrient in soil (kg/ha)		
	N	P	K	N	P	K	N	P	K	N	P	K
$N_{20}P_{17.4}K_{33.3}$(RDF)	206.5	24.9	197.5	74.9	7.2	30.6	135.2	7.0	130	3.6	-10.7	-36.9
RDF + *Rhizobium*	206.5	24.9	197.5	78.7	7.7	31.9	137.3	7.0	131	9.5	-10.2	-34.6
RDF + gypsum (250 kg/ha)	206.5	24.9	197.5	91.4	9.4	36.2	139.0	7.0	133	23.9	-8.5	-28.3
RDF + lime (¼ LR)	206.5	24.9	197.5	103.1	10.5	40.2	147.2	7.5	137	43.8	-6.9	-20.3
RDF + B (1 kg/ha)	206.5	24.9	197.5	82.1	8.4	32.9	136.3	7.0	133	11.9	-9.5	-31.6
RDF + *Rhizobium* + gypsum + B	206.5	24.9	197.5	99.8	10.0	38.6	145.4	7.1	135	38.7	-7.8	-23.9
RDF + *Rhizobium* + lime + B	206.5	24.9	197.5	110.3	11.5	43.5	151.5	7.6	138	55.3	-6.8	-16.0
FYM_5 + 75%RDF	226.5	24.4	210.1	104.9	10.7	41.7	149.5	7.2	140	28.0	-6.5	-28.4
FYM_5 + 75%RDF + *Rhizobium*	226.5	24.4	210.1	112.1	11.7	44.2	154.5	7.2	143	40.2	-5.5	-22.9
FYM_5 + 75%RDF + gypsum	226.5	24.4	210.1	132.9	15.6	53.2	167.8	7.2	147	74.3	-1.6	-9.9
FYM_5 + 75% RDF + lime	226.5	24.4	210.1	119.3	14.4	47.4	164.2	8.0	146	57.1	-2.0	-16.7
FYM_5 + 75% RDF + B	226.5	24.4	210.1	113.0	11.8	45.1	163.5	7.2	144	50.1	-5.4	-21.0
FYM_5 + 75%RDF + *Rhizobium* + gypsum + B	226.5	24.4	210.1	151.4	17.0	58.6	173.7	7.2	148	98.7	-0.2	-3.5
FYM_5 + 75% RDF + *Rhizobium* + lime + B	226.5	24.4	210.1	127.9	15.7	51.5	174.6	8.0	150	76.1	-0.7	-8.6

Table 4. Balance sheet of available Ca, S and B as influenced by integrated nutrient management practices (Pooled data)

Treatment	Total available nutrients (Initial +added through different sources) (kg/ha)			Nutrient uptake (kg/ha)			Available soil nutrient after last harvest (kg/ha)			Net gain (+)/loss (-) of nutrient in soil (kg/ha)		
	Ca	S	B	Ca	S	B	Ca	S	B	Ca	S	B
$N_{20}P_{17.4}K_{33.3}$(RDF)	600	18.5	0.4	23.5	2.6	0.03	500	10.2	0.23	-76.5	-5.7	-0.14
RDF + *Rhizobium*	600	18.5	0.4	24.7	2.6	0.03	500	10.3	0.23	-75.3	-5.6	-0.14
RDF + gypsum (250 kg/ha)	645	53.5	0.4	34.8	6.9	0.03	540	11.2	0.25	-70.2	-35.4	-0.12
RDF + lime (¼ LR)	834	18.5	0.4	41.1	4.1	0.04	795	10.5	0.25	+2.1	-3.9	-0.11
RDF + B (1 kg/ha)	600	18.5	1.4	25.0	2.7	0.04	492	10.5	0.31	-82.9	-5.3	-1.05
RDF + *Rhizobium* + gypsum + B	645	53.5	1.4	37.2	7.6	0.05	545	11.3	0.31	-62.8	-34.6	-1.04
RDF + *Rhizobium* + lime + B	834	18.5	1.4	42.8	4.2	0.05	802	11.4	0.32	+10.8	-2.9	-1.03
FYM_5 + 75%RDF	600	18.5	0.4	33.2	4.5	0.03	548	11.5	0.29	-18.8	-2.5	-0.08
FYM_5 + 75%RDF + *Rhizobium*	600	18.5	0.4	35.5	4.6	0.04	550	11.5	0.26	-14.5	-2.4	-0.10
FYM_5 + 75%RDF + gypsum	645	53.5	0.4	44.2	9.1	0.04	615	12.0	0.27	+14.2	-32.4	-0.09
FYM_5 + 75% RDF + lime	834	18.5	0.4	44.7	5.2	0.04	816	11.8	0.28	+26.7	-1.5	-0.08
FYM_5 + 75% RDF + B	600	18.5	1.4	34.7	4.6	0.05	551	11.6	0.34	-14.3	-2.3	-1.01
FYM_5 + 75%RDF + *Rhizobium* + gypsum + B	645	53.5	1.4	47.2	10.8	0.07	615	12.2	0.35	+17.2	-30.5	-0.98
FYM_5 + 75% RDF + *Rhizobium* + lime + B	834	18.5	1.4	48.6	5.5	0.06	822	11.8	0.35	+36.6	-1.2	-0.99

Available soil nutrients and nutrient balance

Available N in the soil increased after harvest of groundnut in all the treatments (Table 3) and the N balance was positive. The highest gain of 98.7 kg N/ha was observed with integrated application of farmyard manure + 75% recommended dose of fertilizer + *Rhizobium* + gypsum + B. Increase in N content in soil could be due to growing legume groundnut, higher amount of N fixation by *Rhizobium* under more favourable condition of soil and lysis of nodules and secretion of N from these nodules. Varalakshmi *et al*. (2005) had reported increase in N content of soil with integrated nutrient management in groundnut. Incorporation of farmyard manure, lime and P fertilizer reduced the fixation of water soluble P and increased the mineralization of organic P due to microbial action which resulted in increase in available P and in-

crease in P uptake. Thereafter the available P decreased due to fixation in acid soil and the P balance was negative. The negative balance was less under FYM and lime application due to less P fixation. Available K had been depleted (Table 3) in all the treatements due to higher uptake exceeding the quantum of nutrients applied and leaching loss of K under light textured soil with high precipitation. Calcium uptake was higher in all the treatments due to greater demand of Ca by groundnut resulting depletion of available Ca in all the treatments with negative Ca balance except the treatments using lime or farmyard manure along with gypsum (Table 4), where available Ca increased due to their incorporation in soil and computed Ca balance was positive. Due to heavy uptake of S, there was depletion of S in all the treatments. Further, S might have leached from the soil under high precipitation. There was depletion of available B in all the treatments (Table 4) including the B applied treatments due to leaching loss through heavy precipitation in the form of boric acid (H_3BO_3) in the light textured loamy sand soil.

Economics

Maximum net returns (Rs 22,000/ha) were recorded with application of FYM + 75% RDF + *Rhizobium* + gypsum + B with benefit: cost ratio of 1.13. The higher net returns and B:C ratio was due to higher yields.

It was concluded that to get maximum productivity and profitability from groundnut during *kharif* in acidic soils of Orissa, the crop should be manured with 5 t FYM/ha + 75% recommended dose of fertilizer + *Rhizobium* + gypsum @ 250 kg/ha + boron @ 1 kg/ha.

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