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Growth, Yield and Quality of Rabi Groundnut (*Arachis hypogaea* L.) as Influenced by Sources of Calcium and Sulphur under Different Site - Specific Nitrogen Management in Rice-Groundnut Cropping System

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The injudicious and imbalanced fertilizer use under the existing farming system necessitates the adoption of amelioration methods and balanced use of nutrients especially nitrogen (N). There is lack of information on effects of various sources of calcium and sulphur in groundnut along with

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balanced nitrogen management which needs to be addressed. A field experiment was carried out during 2020-21 and 2021-22 at Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India to study the growth, yield and quality parameters of groundnut as affected by site specific nitrogen management in rice and various sources of calcium and sulphur in groundnut. The experiment was laid out in split plot design with six main plot treatments i.e. Soil test based nitrogen (STBN) (100 kg N/ha), 75% N through STBN + 25% N through farmyard manure (FYM), 75% N through STBN + 25% N through vermicompost, N @ 20kg at basal and at leaf colour chart (LCC) < 3, N @ 20kg at basal and at chlorophyll value determined by soil plant analysis development (SPAD) < 35 and no nitrogen to rice during *Kharif* and three sub plot treatments i.e. lime @ 0.2 LR, gypsum @ 250 kg/ha and lime @ 0.2 LR + gypsum @ 250 kg/ha to groundnut during *Rabi* each in three replications. Application of 75% N through STBN + 25% N through vermicompost to preceding rice and lime @ 0.2 LR+ gypsum @ 250 kg/ha to groundnut crop resulted in highest plant height at harvest, number of nodules per plant and dry matter accumulation at harvest. Yield attributing characters like pods/plant, kernel/pod and 100 - pod weight of groundnut were highest due to application of 75% N through STBN + 25% N through vermicompost to preceding rice (17.86, 1.87 and 67.2 g, respectively) followed by 75% N through STBN + 25% N through FYM. Application of lime @ 0.2 LR + gypsum @ 250 kg/ha to groundnut recorded more pods/plant (16.86), kernels/pod (1.78) and 100 - pod weight (66.39 g). The treatment receiving 75% N through STBN + 25 % N through vermicompost in rice and application of lime @ 0.2 LR + gypsum @ 250 kg/ha to groundnut resulted significantly maximum pod yield (2,596 kg/ha and 2,291 kg/ha), haulm yield (4,554 kg/ha and 4,343 kg/ha) and harvest index (36.30% and 34.38%) in groundnut. Oil yield (682.2 kg/ha) in groundnut was recorded highest in the treatment lime @ 0.2 LR + gypsum @ 250 kg/ha followed by only gypsum @ 250 kg/ha application to groundnut. Similarly, application of lime @ 0.2 LR + gypsum @ 250 kg/ha to groundnut recorded highest protein yield (424.6 kg/ha).

Keywords: Pod yield; lime; gypsum; vermicompost.

1. INTRODUCTION

"Rice-groundnut cropping system is a major system followed in Odisha, India owing to its versatility in meeting both food security and oil needs thereby maintaining the soil health through biological nitrogen fixation. But farmers are routinely applying more nitrogen (N) fertilizer or blanket dose than a crop can use without considering the nutrient supply capacity of the soil and crop need often resulting in low N use efficiency and deterioration of soil health" [1]. Thus, fertilizer N recommendations must be based on the crop demand and supply capacity of the soil. Groundnut is an important edible oilseed crop that prefers mostly neutral pH. But most of the soils in Odisha are red sandy, red loamy and lateritic soils which are generally acidic and deficient in organic matter, N, calcium (Ca), phosphorus (P), molybdenum (Mo) and boron (B). Therefore, there lies a production gap due to various constraints such as non-availability of irrigated conditions, imbalance use of nutrients, soil acidic conditions etc. The potential can be increased by amelioration of soil acidity by raising pH by adding suitable quantity of lime and proper balanced use of nutrients. Also, the farmers are confined mostly in NPK fertilizers thus neglecting sulphur application which is important for oil synthesis and uptake of various macro and micronutrients in groundnut [2]. Gypsum is a soluble source of calcium and sulphur, therefore, readily available to the developing pods. Sulphur and calcium applied together are considered to be important in the pod zone for the development of pegs [3]. Applying lime in combination with gypsum would bring more Ca and/or magnesium (Mg) further down the soil profile [4], thus alleviating to some extent subsoil acidity. Lime application along with integrated nutrient management is often recommended to increase the phyto-availability of essential nutrients and ameliorate the other acidity-induced fertility constraints on such soils [5]. Thus, keeping in view the above an efficient combination of various site specific nitrogen management practices in rice along with sources of calcium and sulphur to groundnut were followed to study the growth, yield and quality traits in groundnut.

2. MATERIALS AND METHODS

A field experiment was conducted during Kharif and Rabi seasons of 2020-21 and2021-22 at Agronomy Main Research Farm, Department of Agronomy, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha. "The climate

of the area is warm and moist characterised by hot and humid summer and mild winter, and falls in the moist and hot category group. The soil of experimental plot was loamy sand in texture, acidic, medium in organic carbon, available phosphorus and potassium but low in available nitrogen. The experiment was laid out in a split-plot design with six main plot treatments i.e. Soil test based nitrogen (STBN) (100 kg N/ha), 75% N through STBN + 25% N through FYM, 75% N through STBN + 25% N through vermicompost, N @ 20kg at basal and at LCC < 3, N @ 20kg at basal and at SPAD < 35 and no nitrogen to rice (var. MTU-1061) during *Kharif* and three sub plot treatments i.e. lime @ 0.2 LR (0.48 t/ha), gypsum @ 250 kg/ha and lime @ 0.2 LR + gypsum @ 250 kg/ha to groundnut (var. ICGV-91114) during *Rabi* each in three replications" [6]. The groundnut variety ICGV-91114 was grown as test variety after rice (variety-MTU-1061) harvest during both the experimental years. Recommended doses of P_2O_5 and K_2O @ 40 kg/ha each to rice and N-P_2O_5- K_2O @ 20-40-40 kg/ha were applied to groundnut. Lime requirement was estimated by Woodruff buffer method and applied @ 0.2 LR i.e. 0.48 t/ha to groundnut in the respective treatments. Biometric determinations on various growth parameters like height, leaf area index and dry matter accumulation of groundnut have been carried out at 30, 60, 90 DAS and at harvest on randomly selected and 10 tagged plants from each plot. Root nodules of groundnut were carefully separated, cleaned, counted, oven dried and weighed at 30, 60 and 90 DAS. Determinations on yield attributes like number of pods/plant, kernels/pod, pod weight and kernel weight were taken after separating the main product, cleaning, drying, counting and weighing at harvest. The shelling out turn was worked out by dividing kernel weight by pod weight and multiplying by 100. Yield determinations like pod and haulm yield were recorded after separation, drying and weighing after harvest. Harvest index was calculated as ratio of pod yield to pod yield and haulm yield and expressed as percentage. The oil content in kernel was estimated by Soxhlet's apparatus using petroleum ether as extractant [7] and oil yield was obtained by multiplying oil content with pod yield and the shelling out turn taking 8% moisture in pods into account.

Oil yield (kg/ha) = "Oil content "(%) / 100 * "Shelling out turn "(%) / 100 * "Pod yield "("kg/ha") * "Moisture "(%) / 100

Protein content in kernels of groundnut was computed by multiplying percent seed nitrogen with a factor of 6.25 [8]. The protein yield/ha was calculated by multiplying protein content with corresponding seed yield taking into account 8% moisture content in pods. The obtained results on the above characteristics in groundnut were recorded and data were analyzed statistically as per procedure prescribed by Gomez and Gomez [9].

3. RESULTS AND DISCUSSION

3.1 Growth Parameters of Groundnut

Application of site - specific nitrogen management practices to preceding rice and various sources of calcium and sulphur to groundnut significantly affected different growth parameters as presented in Table 1. The plant height increased progressively with advancement in crop growth age up to harvest. With respect to site specific nitrogen management practices applied to preceding rice, application of 75 % N through STBN + 25 % N through vermicompost resulted in significantly highest plant height at harvest (38.68 cm), number of root nodules per plant (97.4), nodule weight per plant (112.9 mg/plant) at 90 DAS and dry matter accumulation at harvest (643.0 g/m^2) followed by the treatment 75 % N through STBN + 25 % N through FYM and STBN. Lowest values were obtained by no nitrogen treatment to preceding rice. Application of 75 % N through STBN + 25 % N through vermicompost to rice recorded the highest leaf area index (LAI) (3.67) at 90 DAS which was at par with 75 % N through STBN + 25 % N through FYM (3.62). The maximum increase in growth characters in groundnut due to the residual effect of above site specific nitrogen management treatments might be due to combined effect of organic and inorganic fertilizers that increased nutrient availability and microbial activity, resulting in better nutrient absorption and crop growth. The results are similar to the findings of some researchers [10-13]. Similarly, pooled data showed significantly taller plant height (36.13 cm), maximum number of root nodules per plant (82.0) and nodule weight per plant (95.8 mg/plant) at 90 DAS and dry matter accumulation at harvest (596.2 g/m^2) by application of lime @ 0.2 LR + gypsum @ 250 kg/ha followed by the treatment lime@ 0.2 LR. Again, application of lime @ 0.2 LR+ gypsum@ 250 kg/ha to groundnut produced the highest LAI (3.42) at 90 DAS which was at par with application of lime @ 0.2 LR (3.38). The increase

in growth attribute when lime was added to groundnut may be because liming increases the pH levels in soil thus increasing alkalinity which provides a source of calcium and magnesium essential for plant growth. As for the increase in growth attribute when sulphur was applied may be because sulphur is essential for nitrogen-fixing nodules on legumes and in the formation of chlorophyll. Similar findings were also reported by several workers [14-17].

3.2 Yield and Yield Attributes of Groundnut

3.2.1 Yield attributes

Among different site specific nitrogen management practices applied to preceding rice, application of 75 % N through STBN + 25 % N through vermicompost to rice significantly produced the highest number of pods per plant (17.86), 100 pod weight (67.2 g), 100 kernel weight (47.4 g) and shelling out turn (70.6 %) followed by the treatment receiving 75 % N through STBN + 25 % N through FYM and STBN as per pooled data. Again, application of 75 % N through STBN + 25 % N through vermicompost to rice significantly produced the highest number of kernels per pod(1.87) which was found to be at par with the treatment receiving 75 % N through STBN+ 25 % N through FYM. Lowest values were obtained in no nitrogen treatment to rice. The increased yield attributes in the inorganic with vermicompost and FYM based treatments might be due to combined effect of organic and inorganic fertilizers that improved soil physical conditions to conserve moisture, increased nutrient availability and microbial activity, resulting in better nutrient absorption, crop growth and pod formation. These are in corroboration to the findings of Singh et al [11][18][13]. Similarly, pooled data revealed that application of lime @ 0.2 LR+ gypsum@ 250 kg/ha to groundnut resulted in highest number of pods per plant (16.86), 100 pod weight (66.4 g), 100 kernel weight (45.9 g) and number of kernels per pod (1.78) followed by application of lime @ 0.2 LR and gypsum@ 250 kg/ha when applied alone. However, application of various sources of calcium and sulphur to groundnut was found to have no significant effect among the treatments for shelling out turn in groundnut as per pooled data (Table 2). Application of lime with gypsum resulted in higher yield attributes in groundnut as there is a specific requirement of both Ca and S for normal growth of groundnut as stated by Harris [19][20]. The increase in yield attributes on application of sulphur may be because of the favourable effect of sulphur on the growth of groundnut [17]. The findings are in corroboration with that of Dosani et al [21-23][16].

3.2.2 Yield

Pooled data suggested that application of 75 % N through STBN + 25 % N through vermicompost to rice significantly produced the highest pod yield, haulm yield and harvest index (2596 kg/ha, 4554 kg/ha and 36.30 %) followed by the treatment receiving 75 % N through STBN + 25 % N through FYM (2460 kg/ha, 4506 kg/ha and 35.65 %) and STBN (2270 kg/ha, 4338 kg/ha and 34.32 %). Lowest values were obtained by no nitrogen treatment. Similarly, among the various sources of calcium and sulphur, application of lime @ 0.2 LR+ gypsum@ 250 kg/ha to groundnut resulted in highest pod yield, haulm yield and harvest index (2291 kg/ha, 4343 kg/ha and 34.38 %) followed by application of lime @ 0.2 LR and gypsum @ 250 kg/ha (Table 2). Due to improvement in growth attributes such as dry matter production, LAI, CGR, nodule count and weight etc. owing to application of lime and gypsum along with residual effect of available nutrients from vermicompost or FYM, there was better translocation of photosynthates to sink leading to higher yield of groundnut. Improvement in vegetative structures for nutrient absorption and photosynthesis, strong sink strength through development of reproductive structures and production of assimilates under influence of applied sulphur through gypsum maintained balance source-sink might have resulted in increased yield attributes and thus yield. Similarly, calcium through lime plays an important role in the reproductive development of groundnut. This is probably because in the absence of both xylem and phloem supply of Ca, the penetrating gynophores modify themselves into absorbing organs of Ca from the immediate fruiting zone [24]. Several workers observed increase in groundnut yield due to application of both lime and gypsum [23-26],[17]. Similarly, among lime and gypsum, lime was more efficient than gypsum in increasing exch. Ca in the 0-150 mm soil layer, possibly because of the higher Ca concentration in the lime than in the gypsum and because of the leaching of Ca when applied as gypsum to this soil [27].

Table 1. Growth parameters of groundnut as influenced by various site specific nitrogen management practices in rice and sources of lime and sulphur in groundnut (pooled over 2020-21 and 2021-22)

Treatment	Maximum plant height at 90 DAS* at harvest (cm)	Maximum number of root nodules/plant at 90 DAS	Maximum nodule weight/plant at 90 DAS (g)	Maximum dry matter accumulation (g/m^2) at harvest	Maximum Leaf area index (LAI) at 90 DAS
Site specific nitrogen management in rice					
STBN (100kg N /ha)	36.53	82.1	94.9	593.7	3.44
75 % STBN + 25 % N through FYM	37.65	94.6	109.6	626.1	3.62
75 % STBN + 25 % N through vermicompost	38.68	97.4	112.9	643.0	3.67
N @ 20kg at basal and at LCC < 3	34.40	71.6	80.0	554.6	3.35
N @ 20kg at basal and at SPAD < 35	35.17	75.3	86.4	576.1	3.40
No Nitrogen	30.32	56.2	64.5	420.7	2.85
S.E(m)±	0.134	0.27	0.38	1.95	0.031
C.D. (0.05)	0.40	0.8	1.1	5.75	0.09
Sources of calcium and sulphur in groundnut					
Lime @ 0.2 LR	35.50	78.3	90.7	559.4	3.38
Gypsum@ 250 kg/ha	34.74	75.3	87.7	551.5	3.36
Lime @ 0.2 LR+ Gypsum@ 250 kg/ha	36.13	82.0	95.8	596.2	3.42
S.E(m)±	0.093	0.18	0.21	1.15	0.014
C.D. (0.05)	0.26	0.5	0.6	3.27	0.04
*DAS – Days after sowing					

3.2.3 Interaction effect

"The interaction effect was found to be significant among the treatments as regards to pod yield (Table 3). Application of 75 % N through STBN + 25 % N through vermicompost in rice with lime @ 0.2 LR+ gypsum@ 250 kg/ha application in groundnut resulted in the highest pod yield (2740 kg/ha), followed by the application of 75 % N through STBN+ 25 % N through FYM in rice with lime @ 0.2 LR + gypsum@ 250 kg/ha application in groundnut (2592 kg/ha)". Nayak et al [6] The interaction effect may be due to maintained higher pH in the soil by neutralizing the acidity and by buffering action of applied organic manure and liming and increased organic status of soils that improved physical conditions of soils and microbial activity resulting in higher growth, yield attributes and yield. This is similar to as reported by some workers [28][11].

3.2.4 Oil content and oil yield of groundnut

"As per pooled analysis, application of 75 % N through STBN + 25 % N through vermicompost to rice resulted in highest oil content (48.19 %) which was found to be at par with treatment receiving 75 % N through STBN + 25 % N through FYM (48.03 %). Further, application of 75 % N through STBN + 25 % N through vermicompost to rice resulted in highest oil yield (798.7 kg/ha) followed by the application of 75 % N through STBN + 25 % N through FYM (749.2 kg/ha)" [6] (Table 4). Improvement in oil content of groundnut under combined and balanced balanced application of mineral fertilizers and vermicompost might be associated with improved availability and uptake efficiency of nutrients like: P, potassium (K), iron (Fe) and zinc (Zn) due to vermicompost [29,30]. Similarly, application of lime @ 0.2 LR+ gypsum@ 250 kg/ha to groundnut resulted in highest oil content and oil yield (47.79 % and 682.2 kg/ha respectively) followed by the application of gypsum @ 250 kg/ha (47.55 % and 660.5 kg/ha respectively) (Table 4). Lime and gypsum increased the oil content and yield because enough calcium content in soil around the peanut pods leads to increased yield, oil content and protein content of the kernel. Improvement in oil content with sulphur application might be due to involvement of sulphur directly in oil synthesis. These are similar as reported by Sharma et al [32][14].

Table 2. Yield and yield attributes of groundnut as influenced by various site specific nitrogen management practices in rice and sources of lime and sulphur in groundnut (pooled over 2020-21 and 2021-22)

Treatment	Number of pods at harvest	Number of kernels/ pod	100 – pod weight (g)	100-kernel weight (g)	Shelling out turn (%)	Pod yield (kg/ha)	Haulm yield (kg/ha)	Harvest index (%)
Site specific nitrogen management in rice								
STBN (100kg N/ha)	16.93	1.78	66.5	45.9	69.1	2,270	4,338	34.32
75 % STBN + 25 % N through FYM	17.49	1.84	66.8	46.8	70.0	2,460	4,506	35.65
75 % STBN + 25 % N through vermicompost	17.86	1.87	67.2	47.4	70.6	2,596	4,554	36.30
N @ 20kg at basal and at LCC < 3	16.24	1.72	65.3	44.9	68.9	2,047	4,128	33.10
N @ 20kg at basal and at SPAD < 35	16.54	1.74	65.9	45.4	68.9	2,171	4,242	33.83
No Nitrogen	12.33	1.52	63.5	42.0	66.2	1,432	3,256	30.53
S.E(m)±	0.139	0.014	0.11	0.10	0.18	15.5	12.7	0.153
C.D. (0.05)	0.41	0.04	0.3	0.3	0.5	46	37	0.45
Sources of calcium and sulphur in groundnut								
Lime @ 0.2 LR	16.01	1.74	65.8	45.4	68.8	2,118	4,108	33.82
Gypsum@ 250 kg/ha	15.83	1.70	65.3	45.0	68.9	2,078	4,061	33.66
Lime @ 0.2 LR+ Gypsum@ 250 kg/ha	16.86	1.78	66.4	45.9	69.1	2,291	4,343	34.38
S.E(m)±	0.047	0.008	0.05	0.06	0.10	5.8	11.5	0.10
C.D. (0.05)	0.130	0.023	0.1	0.2	NS	16	33	0.27

Table 3. Interaction effects of site specific nitrogen management practices and sources of calcium and sulphur on pod yield of groundnut (pooled over 2020-21 and 2021-22)

Site specific nitrogen management in rice (N)	Sources of calcium and sulphur in groundnut (L)		
	Lime @ 0.2 LR	Gypsum@ 250 kg/ha	Lime @ 0.2 LR+ Gypsum@ 250 kg/ha
	Pod yield (kg/ha)		
STBN (100kg N /ha)	2229	2196	2385
75 % STBN + 25 % N through FYM	2413	2374	2592
75 % STBN + 25 % N through Vermicompost	2549	2500	2740
N @ 20kg at basal and at LCC < 3	2011	1953	2176
N @ 20kg at basal and at SPAD < 35	2128	2092	2293
No Nitrogen	1380	1354	1562
	SEm (±)		**CD (0.05)**
N	15.45		45.58
L	5.77		16.39
N x L	19.28		56.14
L x N	14.12		40.15

Table 4. Oil content, oil yield, protein content and protein yield of groundnut as influenced by various site specific nitrogen management practices in rice and sources of lime and sulphur in groundnut (pooled over 2020-21 and 2021-22)

Treatment	Oil content (%)	Oil yield (kg/ha)	Protein content (%)	Protein yield (kg/ha)
Site specific nitrogen management in rice				
STBN (100kg N /ha)	47.71	684.2	20.11	420
75 % STBN + 25 % N through FYM	48.03	749.2	20.28	458.5
75 % STBN + 25 % N through vermicompost	48.19	798.7	20.36	486.1
N @ 20kg at basal and at LCC < 3	47.43	651	19.98	375.8
N @ 20kg at basal and at SPAD < 35	47.67	648.5	20.07	400.2
No Nitrogen	46.39	452.3	18.61	245.3
S.E(m)±	0.094	14.68	0.24	6.55
C.D. (0.05)	0.28	43.3	0.71	19.3
Sources of calcium and sulphur in groundnut				
Lime @ 0.2 LR	47.37	649.2	19.87	388.6
Gypsum@ 250 kg/ha	47.55	660.5	19.74	379.7
Lime @ 0.2 LR+ Gypsum@ 250 kg/ha	47.79	682.2	20.08	424.6
S.E(m)±	0.06	6.79	0.122	2.62
C.D. (0.05)	0.17	19.3	NS	7.4

3.2.5 Protein content and protein yield of groundnut

Perusal of pooled data on protein content and protein yield of groundnut (Table 4) revealed that application of 75 % N through STBN + 25 % N through vermicompost to rice resulted in highest protein content (20.36 %) which was found to be at par with all the treatments except no nitrogen treatment. Further, application of 75 % N through STBN + 25 % N through vermicompost to rice resulted in highest protein yield (486.1 kg/ha) followed by the application of 75 % N through STBN + 25 % N through FYM (458.5 kg/ha). The better supply of nitrogen through STBN + vermicompost might have helped in better absorption and utilization of all plant nutrients and a large proportion of photosynthates may have diverted to protein formation [32]. There was no significant difference among the treatments due to application of sources of calcium and sulphur to groundnut with regards to protein content is concerned but application of lime @ 0.2 LR+ gypsum@ 250 kg/ha to groundnut resulted in highest protein yield (424.6 kg/ha) followed by application of lime @ 0.2 LR (388.6 kg/ha). The increase in oil yield and protein yield with the application of organic manures is consequence of the increase in oil content and protein content and grain yield [33].

Higher oil yield and oil content with increased application of sulphur also attributed to protein and enzyme synthesis as it is a constituent of sulphur containing amino acids namely methonine, cysteine and cystine. Similar results have been reported by Basu et al [34][31][30].

4. CONCLUSION

From the above study, it may be concluded that, a combination of inorganic and organic source of nitrogen particularly 75% STBN + 25% N either through vermicompost or FYM to rice along with lime + gypsum to succeeding groundnut can be recommended to farmers of Odisha, India for enhancing the growth, yield and quality parameters of groundnut.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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