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EFFECT OF INTEGRATED NUTRIENT MANAGEMENT PRACTICES ON GROWTH, YIELD AND ECONOMICS OF GROUNDNUT (*ARACHIS HYPOGAEA* L.) GROWN ON ACIDIC SOILS IN KANDHAMAL DISTRICT OF ODISHA, INDIA

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ABSTRACT

The experiment was conducted during *Kharif* 2022 at farmer's field in Kandhamal district of Odisha under Krishi Vigyan Kendra, Kandhamal, OUAT, Bhubaneswar, Odisha, India to study the effect of integrated nutrient management on growth, yield and economics of groundnut (*Arachis hypogaea* L.). The experiment was laid out in Randomized Block Design (RBD) consisted of four treatments with five replications. The treatments comprised of T_1: Farmer's practice (FYM @ 1.5 t ha^{-1} and fertilizer @ 22:23:18 kg N:P_2O_5:K_2O ha^{-1}), T_2: 100% RDF @ 20:40:40 Kg N:P_2O_5:K_2O ha^{-1}+ FYM @ 7 t ha^{-1}+ borax @ 15 kg ha^{-1}, T_3: Soil test based NPK + FYM @ 2 t ha^{-1} + lime @ 0.2 LR + seed inoculation with *Rhizobium* @ 20 g kg^{-1} seed and T_4: Soil test based NPK + FYM @ 2 t ha^{-1}+ lime @ 0.2 LR + sulphur @ 40 kg ha^{-1}. From the experiment, it was found that integrated application of chemical fertilizers as per soil test results, organic manures (FYM @ 2 t ha^{-1}), lime @ 0.2 LR and secondary nutrient (sulphur) was the best option for achieving better yield. The highest plant height (55.3 cm), number of pods per plant (15.3), 100 kernel weight (46.7 g), shelling per cent (72.4 %), pod yield (1520 kg ha^{-1}), haulm yield (2080 kg ha^{-1}), oil yield (567.9 kg ha^{-1}), net return (Rs. 47,200 ha^{-1}) and B C ratio (1:2.3) were recorded with the treatment T_4 followed by and T_3. The highest total nodules per plant (84.4) was counted under T_3. Whereas, the lowest values of plant height (44.6 cm), number of total root nodules plant^{-1} (60.1), number of pods per plant (11.2), 100 kernel weight (36.5 g), shelling per cent (60.2 %), pod yield (1160 kg ha^{-1}), haulm yield (1670 kg ha^{-1}), oil yield (288.4 kg ha^{-1}), net return (Rs. 29,900 ha^{-1}) and B C ratio (1:1.9) were recorded with the treatment T_1 (Farmer's practice).

Key words : Growth attributes, Yield, Sulphur, Oil yield, Net return.

Introduction

Groundnut (*Arachis hypogaea* L.) crop is native to South America. It is grown all over the world and commonly known as 'King of Oilseeds'. It is an excellent source of nutrition to both human and animal due to its high protein content. At world level groundnut is the fourth major edible oil source and third major vegetable protein to human population. Seeds of groundnut composed on an average of 50% oil, 25% protein, 20% starch and 5% minerals and fiber, thus it is considered a rich nutritional source to humans (Paramasivan *et al.*, 2024). In the world, it is cultivated over an area of 29.5 million ha with production and productivity of 48.5 million tons and 1647 kg ha^{-1} respectively. India, China, USA, Senegal, Indonesia, Nigeria, Brazil and Argentina are the major groundnut producing countries. India is the second largest producer of groundnut in the world (Mohanty *et al.*, 2022). The major groundnut producing states of India are Gujarat, Rajasthan, Tamil Nadu, Madhya Pradesh, Andhra Pradesh, Karnataka, Maharashtra, Telangana, Odisha, West Bengal and Uttar Pradesh. In India, it occupies an area of 5.70 million ha and production of 10.13 million tons with a productivity of 1777 kg ha^{-1} (GOI, 2023). In

Odisha, it is cultivated in an area of 204.82 thousand ha with a production of 892.3 thousand tons with an average productivity of 1894 kg ha^{-1} (GoO, 2020). Kandhamal is one of the tribal dominated districts of Odisha, which is situated between 19º 34´ to 20º 36´ north latitude and 83º34´ to 84º34´ east longitude. Most of the farmers of the district grow groundnut mainly during kharif season. In Kandhamal, the groundnut is cultivated in an area of 2.08 thousand ha with a production of 3.05 thousand tons and an average productivity of 1464 kg ha^{-1}(Anonymous, 2020). The Inadequate and imbalanced use of nutrient is one of the major factors responsible for low productivity in groundnut in the district.

Farm yard manure (FYM) is mainly to replenish and keep soil humus status and maintain the optimum conditions for the activities of soil microorganisms. Effects of applied FYM on soil environments hasten germination and vigour of seedlings thereby promoting early emergence which may be attributable to high porosity, aeration, water holding capacity and presence of growth promoting substances (Malik *et al.*, 2023). FYM application also improves physical, chemical and biological environment of soil conducive for better plant growth (Rama Devi *et al.*, 2021).

About 73 per cent of soils of Kandhamal district are acidic in nature. Liming is one of the potential options that increase soil pH, favoring the availability of nutrients like P, Ca, Mg, B and Mo. Application of lime and phosphorus on acid soil has beneficial effect on groundnut production (Dessalegn *et al*., 2023). Liming is a widely accepted amelioration practices for efficient utilization of native and applied soil nutrients and economic use of added fertilizer sources (Chatterjee *et al*., 2005).

It is well known that peanuts require slightly more boron than other legume crops. Boron is responsible to boost enzymatic and photosynthetic activities of groundnut. It also contributes to the metabolism of nucleic acids and proteins. In addition to boosting photosynthetic and enzymatic activity, boron enhances pollen grain viability, pollen tube growth, and germination (Haokip *et al*., 2024 and Prusty *et al.*, 2020). In leguminous crops like groundnut, a bacterium responsible for fixing nitrogen in the root zones/nodules provides a good amount of nitrogen to the soil, which is not only utilized by the existing crop but also by the next crop. It also improves the soil fertility, soil structure and texture. Among all plant growth promoting rhizobacteria (PGPR), *Rhizobium* has important role in the form of biofertilizer inoculation in groundnut to improve plant growth and yield attributes and yield (Palai *et al*., 2021).

Sulphur is one of the primary components of three amino acids cysteine, cystine and methionine. Application of sulphur is also important for acerating the efficiency of other plant nutrients (Kumar *et al.,* 2013). Adequate sulphur application in combination with balanced amounts of other nutrients enhances the yield, yield attributes and oil yield of oilseed crops (Mukhi *et al.*, 2024). The macro and micronutrient reserves of soil are depleted due to intensive cropping with high yielding cultivars. As a result, the deficiency of micro-nutrients like zinc and boron, in addition to primary nutrients-nitrogen, phosphorus, potassium and sulphur are becoming more and more common in Indian soils (Mukhi *et al*., 2024 and Singh *et al*., 2022). For sustainable high productivity over a longer period, soil fertility has to be maintained at fairly high level (Karunakaran *et al*., 2010). Integrated nutrient management (INM) ensures the plant nutrient supply through optimization of benefits from all possible sources of plant nutrients in an integrated manner to achieve as well as sustain the desired crop productivity while maintaining soil fertility. Therefore, it is necessary to maintain the soil fertility for sustainable production through the judicious use of organic manures and chemical fertilizers (Malik *et al*., 2023). Ameliorating soil acidity along with judicious use of organic and inorganic sources of nutrients increase the nutrient use efficiency results in higher production and monetary relief.

However, no study has been carried out to evaluate the suitable integrated nutrient management packages on growth, pod yield and economics of groundnut in Kandhamal district which comes under North Eastern Ghat Agroclimatic zone of Odisha.

Materials and Methods

A field experiment was conducted to assess the effect of integrated nutrient management practices on growth, yield and economics of groundnut (*Arachis hypogaea* L.) grown in acidic soils during *Kharif* 2022 at different farmer's field in Kandhamal district of Odisha under Krishi Vigyan Kendra, Kandhamal, Odisha University of Agriculture and Technology, Bhubaneswar. The initial soil samples before conducting the trial were collected and analyzed. The pH was determined by electric pH meter and available nitrogen was determined by alkaline permanganate method as reported by Piper (2019) and available phosphorus and potash by Bray's No. 1 method and flame photometer method, respectively. The Electrical Conductivity (EC) was determined by Conductivity Bridge as described by Jackson (1967). The oxidizable soil organic carbon content (g kg^{-1}) was analysed by the method proposed by Walkley and Black

(1934). The available sulphur (0.15% $CaCl_2$ extractable) was analysed as proposed by Chesnin and Yien (1951) and the boron content in the soil was determined by spectrophotometer using azomethine-H (John *et al.*, 1975). The soils of the experimental site were acidic in reaction and the pH varied between 5.04 and 5.27, sandy clay loam in texture and the content of available nitrogen, phosphorus, potassium, sulphur, boron and zinc were varied between 221.8 and 248.1 kg ha^{-1}, 8.2 and 13.1 kg ha^{-1}, 207.2 and 304.6 kg ha^{-1}, 5.7 and 7.7 mg kg^{-1}, 0.31 and 0.44 mg kg^{-1} and 0.36 and 0.47 mg kg^{-1}, respectively. The organic carbon content at initiation of the experiment was in a range of 3.7 to 4.6 g kg^{-1} soil.

The experiment was laid out in Randomized Block Design (RBD) consisted of four treatments with five replications. The treatments comprised of T_1: Farmer's practice (FYM @ 1.5 t ha^{-1} and fertilizer @ 22-23-18 kg N-$P_2O_5K_2O$ ha^{-1}), T_2: 100% RDF @ 20:40:40 kg N-P_2O_5-K_2O ha^{-1}+ FYM @ 7 t ha^{-1} + borax @ 15 kg ha^{-1}, T_3: Soil test based NPK + FYM @ 2 t ha^{-1} + lime @ 0.2 LR + seed inoculation with *Rhizobium* @ 20 g kg^{-1} seed and T_4: Soil test based NPK + FYM @ 2 t ha^{-1}+ lime @ 0.2 LR + sulphur @ 40 kg ha^{-1}. The groundnut variety Devi was sown during June 2022 with a spacing of 30 cm × 10 cm. The recommended dose of fertilizer (RDF) @ 20-40-40 kg N-P_2O_5-K_2O ha^{-1} was applied in T_2 treatment, whereas the NPK as per soil test recommendations was applied in T_3 & T_4 treatments. The fertilizer @ 22-23-18 kg N - P_2O_5 - K_2O ha^{-1} and FYM @ 1.5 t ha^{-1} were applied in T_1 treatment (Farmer's practice) whereas FYM @ 7 t ha^{-1}in T_2 and 2 t ha^{-1} each in T_3 and T_4 were applied. In the present investigation, the micronutrient boron was applied through basal in the form of borax @ 15 kg ha^{-1} to the treatments T_2. Sulphur was applied through basal in the form of bentonite-S, which contained 90% sulphur to the treatments T_4. While the lime @ 0.2 LR was applied behind the plough in furrows mixed with FYM at the time of final ploughing.

Nitrogen as per the treatment was applied in two equal splits first at sowing as basal and rest 50% at 21 DAS. The full dose of P, K, S and B as per the treatment were applied as basal dose. The *Rhizobium* biofertilizer @ 20 g per kg seed was used as seed treatment before sowing in Treatment T_3. The intercultural operations were followed as per the recommended package of practices. Ten plants were randomly selected excluding the boundary area to record observations for various growth and yield contributing characters of groundnut. All the necessary cultural practices were uniformly carried out for successful harvest of the crop.

Shelling per cent was calculated as per the formula given below:

$$\text{Shelling } \% = \frac{\text{Weight of kernel}}{\text{Weight of pods}} \times 100$$

Oil content in kernel was determined by using Soxhlet extraction procedure AOAC (1995). The groundnut seeds of individual plots were dried at 60°C for 6 hours, grinded in pestle and mortar and 2 g sample was weighed in thimble and placed in Soxhlet extractor. The oil was extracted with petroleum ether (40-60°C) for 6 hours in a distillation flask. After distillation of sample, petroleum ether was evaporated in an oven for one hour at 105°C. The sample was cooled and weighed and oil percentage was then calculated as per the given formula:

$$\text{Oil content in kernel } (\%) = \frac{\text{Weight of extracted oil}}{\text{Weight of sample}} \times 100$$

Oil yield was calculated from oil content of individual sample multiplied by respective kernel yield and expressed in kg ha^{-1}. To determine the most economic treatment, the economics of each treatment were calculated based on the current market price of the produce and inputs used. Benefit cost ratios (B:C) for each treatment were determined after calculating the gross and net return. Gross return (` ha^{-1}) was calculated by multiplying total produce (yield) by the relevant market prices at the time. The economic parameters were calculated by using the following formula.

$$\text{Gross return}\left(\frac{\text{Rs.}}{\text{ha}}\right) = \text{Price of the produce}\left(\frac{\text{Rs.}}{\text{q}}\right) \times \textit{Yield}\left(\frac{\text{q}}{\text{ha}}\right)$$

$$\text{Net return}\left(\frac{\text{Rs.}}{\text{ha}}\right) = \text{Gross return}\left(\frac{\text{Rs.}}{\text{ha}}\right) - \text{Cost of Cultivation}\left(\frac{\text{Rs.}}{\text{ha}}\right)$$

$$\textit{Benefit Cost Ratio} = \frac{\textit{Gross return}\left(\frac{\text{Rs.}}{\text{ha}}\right)}{\text{Cost of Cultivation}\left(\frac{\text{Rs.}}{\text{ha}}\right)}$$

The data obtained during the trial were analyzed following the standard statistical procedure given for RBD by Panse and Sukhatme (1985). To evaluate whether there was a significant difference between the treatments,

the Critical Difference (CD) at the 5% level was utilized.

Results and Discussion

Effect on growth attributes

Data pertaining to growth attributes are presented in Table 1. The results revealed that application of soil test based NPK + FYM + lime + sulphur (T_4) significantly registered higher values of all the growth attributes plant height (55.3 cm), plant spread (26.3 cm), root length (16.5 cm) over all the treatments. Whereas, the number of effective root nodules plant^{-1} (25.7) was counted highest under the treatment T_3 where seed inoculation with *Rhizobium* was practiced.

Mukhi *et al*. (2024) reported that a significant response of adequate sulphur in soil contributed to enhance cell division, elongation, tissue development, multiplication and synthesis of essential amino acids, formation of chlorophyll as a result increased the growth attributes. These findings agree with the results of earlier workers (Aier and Nongmaithem, 2020; Rao *et al*., 2013 and Yadav *et al*., 2018).

Application of FYM might be improved the physical, chemical and biological environment (Mohanty *et al*., 2022). The increased in growth attributes in T_4 might be due to application of lime and sulphur. Liming increases the soil pH level which provides a source of calcium and magnesium essential for plant growth. The favorable soil condition created by addition of lime with the supplement of sulphur might have given a congenial environment to the crop which helped in better crop growth and increased phosphorus uptake (Haneklaus *et al*., 2007). In case of T_3 where application of soil test based NPK along with FYM, lime and biofertilizer (*Rhizobium*) recorded the higher value of plant height (52.3 cm), plant spread (23.8 cm), root length (14.7 cm) and number of effective root nodules plant^{-1} (25.7) as compared to T_2 and T_1. This might be due to balanced fertilization and the flattering effect of FYM improving physical, chemical and biological environment as well as well refining the activity of applied and native *Rhizobium*. The lower values of growth attributes viz. plant height (44.6 cm), plant spread (15.2 cm), root length (9.7 cm) and number of effective root nodules plant^{-1} (15.4) were recorded in T_1 (Farmer's practice) due to imbalanced fertilization and soil acidic environment. These findings agree with the results of earlier workers (Kamalakannan, 2017 and Kulkarni *et al*., 2018).

Table 1 : Effect of integrated nutrient management practices on growth attributes of groundnut.

Treatments	Plant height (cm)	Plant spread (cm)	Root length (cm)	Total number of root nodules plant^{-1}	Number of effective root nodules plant^{-1}
T_1: Farmer's practice	44.6	15.2	9.7	60.1	15.4
T_2: 100% RDF* + FYM + borax	47.9	19.8	11.9	70.3	19.1
T_3: Soil test based NPK+FYM + lime + *Rhizobium*	52.3	23.8	14.7	84.4	25.7
T_4: Soil test based NPK+FYM+ lime + sulphur	55.3	26.3	16.5	79.6	22.5
CD (p=0.05)	**2.06**	**1.19**	**1.11**	**4.14**	**1.18**
SEm (±)	**0.67**	**0.38**	**0.36**	**1.34**	**0.38**

*Recommended dose of fertilizer (RDF) @ 20-40-40 kg N-P_2O_5-K_2O ha^{-1}.

Table 2 : Effect of integrated nutrient management practices on yield attributes of groundnut.

Treatments	No. of pods plant^{-1}	100 kernel weights (g)	Shelling (%)
T_1: Farmer's practice	11.2	36.5	60.2
T_2: 100% RDF* + FYM + borax	13.2	39.3	65.5
T_3: Soil test based NPK+FYM + lime + Rhizobium	14.1	42.3	69.9
T_4: Soil test based NPK+FYM+ lime + sulphur	15.3	46.7	72.4
CD (p=0.05)	**0.81**	**2.0**	**2.11**
SEm (±)	**0.26**	**0.65**	**0.68**

* Recommended dose of fertilizer (RDF) @ 20-40-40 kg N-P_2O_5-K_2O ha^{-1}.

Table 3 : Effect of integrated nutrient management practices on yield and oil yield of groundnut.

Treatments	Biological yield (kg ha^{-1})	Pod yield (kg ha^{-1})	Kernel yield (kg ha^{-1})	Haulm yield (qha^{-1})	Oil content (%)	Oil yield (kg ha^{-1})
T_1: Farmer's practice	2830	1160	698.3	1670	41.3	288.4
T_2: 100% RDF* + FYM + borax	3115	1325	867.9	1790	43.8	380.1
T_3: Soil test based NPK+FYM + lime + Rhizobium	3330	1430	999.6	1900	46.1	460.8
T_4: Soil test based NPK+FYM+ lime + sulphur	3600	1520	1100.5	2080	51.6	567.9
CD (p=0.05)	**110.89**	**70.85**	**37.22**	**78.14**	**1.77**	**23.82**
SEm (±)	**35.90**	**22.99**	**12.08**	**25.36**	**0.58**	**7.73**

* Recommended dose of fertilizer (RDF) @ 20-40-40 kg N-P_2O_5-K_2O ha^{-1}

Table 4 : Effect of integrated nutrient management practices on economics of groundnut.

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
T_1: Farmer's practice	33900	63800	29900	1.9
T_2: 100% RDF* + FYM + Borax	36100	72875	36775	2.0
T_3: Soil test based NPK+FYM + lime + Rhizobium	35000	78650	43650	2.2
T_4: Soil test based NPK+FYM+ lime + sulphur	36400	83600	47200	2.3

* Recommended dose of fertilizer (RDF) @ 20-40-40 kg N-P_2O_5-K_2O ha^{-1}

Effect on yield attributes

There was significant variation in yield attributes *viz.* number of pods plant^{-1}, 100 kernel weight, shelling per cent of groundnut. The data in Table 2 showed that the highest number of pods plant^{-1} (15.3), 100 kernel weight (46.7) and shelling per cent (72.4) were recorded under T_4 which received soil test-based fertilizer application along with FYM, lime and sulphur. This might be due to balanced fertilization including FYM, secondary nutrient sulphur and liming make the favorable condition for better vegetative growth and nodulation, which constructively prejudiced the flowering and fruiting of groundnut. The result is in conformity with the findings of Banu *et al.* (2017), Sisodiya *et al.* (2017), Patil *et al.* (2018), Das *et al.* (2017) and Dey and Nath (2015).

Whereas the lowest values of yield attributes number of pods plant^{-1} (11.2), 100 kernel weight (36.5) and shelling per cent (60.2) were recorded under T_1 (Farmer's practice).

Effect on yield

There was improvement in biological, pod, kernel and haulm yield of groundnut among various integrated nutrient management packages (Table 3). The maximum biological yield (3600 kg ha^{-1}), pod yield (1520 kg ha^{-1}), kernel yield (1100.5 kg ha^{-1}) and haulm yield (2080 kg ha^{-1}) were recorded under T_4 which received soil test based NPK+FYM+ lime + sulphur followed by T_3 (Soil test based NPK+FYM + lime + *Rhizobium*) where biological yield (3330 kg ha^{-1}), pod yield (1430 kg ha^{-1}), kernel yield (999.6 kg ha^{-1}) and haulm yield (1900 kg ha^{-1}) were achieved.

The combined application of RDF, FYM and boron (T_2) produced the biological yield of 3115 kg ha^{-1}, pod yield of 1325 kg ha^{-1}, kernel yield of 867.9 kg ha^{-1} and haulm yield of 1790 kg ha^{-1}. The yield increased in T_2 over farmer's practice might be due to balanced fertilization, use of organic manure and application of micronutrient boron. The minimum values of groundnut yield as biological yield of 2830 kg ha^{-1}, pod yield of 1160 kg ha^{-1}, kernel yield of 698.3 kg ha^{-1} and haulm yield of 1670 kg ha^{-1} were obtained under farmer's practice (T_1). The yield enhancement of groundnut might be due to combined nutrient source of organic (FYM), inorganic fertilizers (soil test based NPK), liming and sulphur provided cooperative effect and in turn upgraded the soil condition, stimulate root system with more nutrient uptake and expressed superior progress of plant growth resulting in higher photosynthetic activity and translocation of photosynthates to the sink. The present findings are in

close agreement with the results of Joshi *et al.* (2018), Mohanty *et al.* (2022), Patil *et al.* (2015) and Chatterjee *et al.* (2005).

The oil content and oil yield of groundnut kernel as affected by different nutrient management practices are presented in Table 3. The maximum oil content (51.6 %) and oil yield (567.9 kg ha^{-1}) were recorded in the treatment T_4 (Soil test based NPK+FYM+ lime + sulphur) followed by T_3, T_2 and T_1. The lowest value of oil content (41.3%) and oil yield (288.4 kg ha^{-1}) were obtained in the treatment T_1(Farmer's practice). Sulphur is a constituent of glucosinolate which plays a vital role in synthesis of oil. The application of sulphur might have favoured the synthesis of CoA and lipoic acid resulting in increased oil content of oilseed crops (Mathew and George, 2013). The increment of oil yield was also due to balanced and adequate availability of nutrients, resulted higher oil content and oil yield (Mukhi *et al.,* 2024). These findings are in agreement with finding of earlier workers (Chaudhari *et al.,* 2015, Swamy *et al.,* 2019).

Effect on economics

It was observed from Table 4 that the highest gross return of Rs. 83,600/- ha^{-1}, net return of Rs. 47,200/-ha^{-1} and Benefit: Cost ratio (B:C) of 2.3 were recorded in the treatment T_4 (Soil test based NPK+ FYM+ lime + sulphur) followed by T_3 (Soil test based NPK+FYM + lime + Rhizobium) with values of gross return Rs.78,650/ - ha^{-1}, net return Rs. 43650/- ha^{-1} and B:C ratio of 2.2.

In case of RDF, FYM and boron applied treatment (T_2) the gross return of Rs. 72,875/- ha^{-1}, net return of Rs. 36,775/- ha^{-1} and Benefit: Cost ratio (B:C) of 2.0 were also recorded. However, the lowest gross return of Rs. 63,800/- ha^{-1}, net return of Rs. 29,900/- ha^{-1} and Benefit: Cost ratio (B:C) of 1.9 were calculated in the treatment T_1 (Farmer's Practice). The highest economic parameters were recorded in T_4 and this might be due to application of balanced fertilization including liming and secondary nutrient sulphur boosted the seed yield of groundnut. Similar results were reported earlier by Aier and Nongmaithem (2020) and Rama Devi *et al.* (2021).

Conclusion

It has been observed that treatment with soil test based NPK, FYM @ 2 t ha^{-1}, lime @ 0.2 LR and sulphur @ 40 kg ha^{-1} resulted in highest growth and yield attributes, yield and economics of groundnut followed by soil test based NPK, FYM @ 2 t ha^{-1}, lime @ 0.2 LR and seed inoculation with *Rhizobium* @ 20 g kg^{-1} seed. Thus, it can be concluded that application of soil test based NPK together with liming @ 0.2 LR, organic manure (FYM @ 2 t ha^{-1} and sulphur @ 40 kg ha^{-1} is the most suitable combination integrated nutrient management package for groundnut growers as it is highly productive, profitable and economically efficient.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (Chat GPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

Competing interests

Authors have declared that no competing interests exist.

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