Ann. For. Res. 67(1): 2024
ISSN: 18448135, 20652445

SYNERGISTIC EFFECTS OF INORGANIC AND BIO FERTILIZERS ON GROWTH AND PERFORMANCE OF SUMMER GROUNDNUT (*ARACHIS HYPOGEA* L.) UNDER BROWN FOREST SOILS OF ODISHA

Avhani Sahu[1], Rajesh Shriram Kalasare ✉[1], Ashirbachan Mahapatra[1], Masina Sairam[1], Chabolu Venkata Raghava[1], Manish Kumar Yadav[2], Roman Kumar Mahto[1] and Vishal Kumar Gupta[3]

Abstract Fertilizers are essential for agricultural success, significantly enhancing plant growth and productivity. However, the excessive use of chemical fertilizers can harm soil health and compromise long-term sustainability. Balancing the use of inorganic fertilizers with bio-fertilizers offers a promising alternative. This study, conducted over two years (2022 and 2023) at the Post Graduate Research Farm, M.S. Swaminathan School of Agriculture, focused on groundnut cultivation. The experiment used a robust factorial randomized block design with three replications and twelve treatments. The treatments included four levels of inorganic fertilizers: F1 (0% RDF), F2 (50% RDF), F3 (100% RDF), and F4 (150% RDF), combined with three bio-fertilizer levels: B1 (Control), B2 (Rhizobium seed inoculation @ 2.4 kg/ha), and B3 (Rhizobium soil application @ 2 kg/ha). The findings revealed that optimal growth and yield were achieved with the application of 150% RDF combined with Rhizobium seed inoculation @ 2.4 kg/ha. This performance was comparable to the application of 100% RDF with the same Rhizobium inoculation. Consequently, this combined application stands as a viable recommendation for farmers in southern Odisha who aim to cultivate groundnut during the summer season, ensuring enhanced growth and productivity.

Key words: Inorganic fertilizer, Seed inoculation, Soil application, Rhizobium, Groundnut, Yield.

Addresses: [1]*Department of Agronomy and Agroforestry, Centurion University of Technology and Management, Odisha – 761211, India. [2]Department of Agricultural Entomology, Centurion University of Technology and Management, Odisha -761211, India. [3]Department of Genetics and Plant Breeding, Centurion University of Technology and Management, Odisha -761211, India.

✉**Corresponding Author:** Kalasare R.S. (rajesh.kalasare@cutm.ac.in)

Manuscript: Received June 20, 2024; revised September 20, 2024; accepted November 01, 2024

Introduction

Groundnut (*Arachis hypogaea* L.) stands as a vital staple legume and oilseed crop, often referred to as the "poor man's nut" or the sovereign of vegetable oilseed crop. Globally, it holds the distinction of being the second most prevalent grain legume and the fourth most significant edible oilseed crop (Tiwari et al., 2018). India, notably, assumes a pivotal role as the world's second-largest producer of groundnut (Hauser, 2018). In the realm of vegetable protein sources, groundnut claims a formidable position, ranking third (Kamble et al., 2018). Renowned for its nutritional richness, groundnut boasts an array of proteins, minerals, and vitamins including vitamins A, B, and E, alongside various B_2 group members, albeit excluding B_{12}, with protein content reaching an impressive 21.43%, complemented by carbohydrates ranging from 6% to 24.9%, and a spectrum of minerals (Satpute et al., 2020). During the 2019-2020 period, groundnut adorned approximately 4.75 million hectares in India, yielding 1422 kg/ha, resulting in a total production of 6.73 million metric tonnes (Gautam and Singh, 2020).

After the green revolution in India, application of synthetic fertilizers had become a part of crop management practices (Somvanshi et al., 2020). Modern agriculture is highly dependent on chemical fertilizers, which give vital nutrients to support the growth and development of plants (Kumar et al., 2019). Immediate improvements in plant growth and yield can be achieved using inorganic fertilizers like urea, superphosphate and potassium chloride which contain readily available nutrients (Yahaya et al., 2023; Somvanshi et al., 2020). However, heavy dependence on such fertilizers in groundnut cultivation has consequences of soil degradation, decrease in microbial activity and environmental pollution caused by nutrient leaching and runoff (Baweja et al., 2020; Weight and Kelly, 1999). Meanwhile biofertilizers are made from natural sources including Rhizobium, Azospirillum and phosphate-solubilizing bacteria that are beneficial for soil health and environment friendly (Rabani et al., 2023; Singh et al., 2016). These biofertilizers help access to more nutrients out of the soil leading to sustainable agriculture (Shome et al., 2022). Biofertilizer utilization improves plant nutrition efficiency, promotes more crop production stimulation while reducing the need for chemical fertilizers hence minimizing their negative impacts on the environment (Salleh et al., 2021; Singh et al., 2016).

Synergistic benefits can potentially be offered by combining inorganic and biofertilizers, thus enhancing the availability and use of nutrients while promoting sustainable soil health in groundnut crop (Choudhary et al., 2011). This integrated nutrient management approach has the potential to optimize the growth environment for groundnut plants thereby improving their growth attributes leading to higher yields (Rao et al., 2018; Patil et al., 2017). On one hand, inorganic fertilizers provide quick access to nutrients that would support early growth stages of plants; on the other, bio-fertilizers enhance long-term soil fertility and health through improved microbial activity and organic matter decomposition (Dey et al., 2024; Arsalan et al., 2024).

Combination of biofertilizer and inorganic fertilizer helps to reduce the cost of cultivation and increases the yield of the crop. Biofertilizer plays an important role in increasing the nutrient use efficiency (Anzuay et al., 2024; Ghosh et al., 2023). So, application of inorganic fertilizer along with biofertilizer helps to improve the overall productivity. Keeping this in view an experiment was performed to study the influence of inorganic and bio fertilizers on growth and performance of groundnut under brown forest soils of Odisha.

Materials and Methods

The field experiment was conducted at the Post Graduate Research Farm, M.S. Swaminathan School of Agriculture, Centurion University of Technology and management located in the Gajapati district of Odisha, at 18º48'16" N latitude, 84º10'48" E longitude, and at an altitude of 64 meters above sea level. The study was conducted during the summer seasons of 2022 and 2023, with the experimental crop sown in February of each year and harvested in May of 2022 and 2023. Throughout the growth period, the weekly minimum and maximum temperatures ranged from 15°C to 40°C, accompanied by a weekly relative humidity fluctuating between 33% and 95% (Figure 1). The soil in the experimental field exhibited a sandy loam texture. The experiment followed a factorial randomized block design (FRBD) with three replications. Treatments comprised combinations of four levels of inorganic fertilizers (F1- 0% RDF, F2-50% RDF, F3-100% RDF, F4-150% RDF) and three levels of biofertilizers (B1: Control, B2: Rhizobium seed

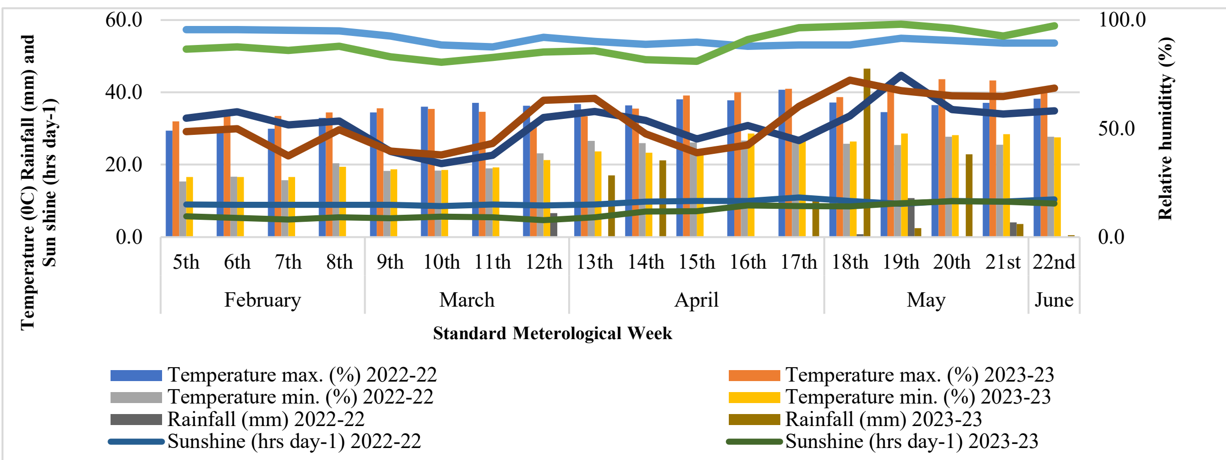

Fig. 1 Meteorological observation prevailed during the years crop period February to June 2022 and 2023

inoculation @ 2.4kg/ha, B3: Rhizobium soil application @ 2kg/ha). Groundnut variety Kadiri-6 was sown with a spacing of 30cm x 10 cm with seed rate of 120 kg/ha. All recommended agronomic practices were meticulously followed to ensure successful crop establishment. The prescribed fertilizer dose of 20:40:40 kg N, P_2O_5, K_2O was applied, with the entire dose of P_2O_5 and K_2O administered as basal application, while N was split into two equal parts basal and top dressing, respectively. Statistical analysis was performed using standard ANOVA techniques, and the significance of differences between treatment means was evaluated using appropriate critical difference (CD) values at a significance level of 5% (Gomez and Gomez, 1984).

Results and Discussion

Growth parameters

Significant impacts were observed on various parameters such as plant height (cm), dry matter accumulation (g/m), leaf area index, crop growth rate (g/m/day), number of nodules per plant, and weight of nodules per plant due to the application of different levels of inorganic fertilizers at various crop growth stages (refer to Table 1). Notably, the highest plant height in groundnut (75.77 cm) was attained with the application of 150% RDF, closely followed by 100% RDF (74.62 cm), while the lowest plant height was recorded with 0% RDF (64.95 cm). Regarding biofertilizer levels, Rhizobium seed

Table 1: Effect of inorganic and biofertilizer on growth parameters of groundnut

Treatment	**Plant height at harvest**	**Dry matter accumulation at harvest**	**Leaf area index (90 DAS)**	**Crop growth rate (90 DAS)**	**Number of nodules per plant (60 DAS)**	**Weight of nodule per plant (60 DAS)**
Inorganic Fertilizer Levels (F)						
F1: 0%RDF	64.95	344.87	1.19	2.82	53.17	1.62
F2: 50%RDF	69.39	368.12	1.73	3.08	55.28	2.01
F3: 100%RDF	74.62	389.89	2.48	3.61	62.00	2.80
F4: 150%RDF	75.77	391.61	2.74	3.65	63.06	2.90
S.Em.±	1.23	5.81	0.11	0.15	1.54	0.16
CD (P=0.05)	3.61	17.04	0.32	0.43	4.53	0.46
Biofertilizer Levels (B)						
B1: Control	68.95	362.26	1.77	3.02	55.35	2.04
B2: Seed Inoculation	74.50	392.94	2.41	3.76	63.03	2.81
B3: Soil Application	70.10	365.67	1.96	3.09	56.74	2.16
S.Em.±	1.07	5.03	0.10	0.13	1.34	0.14
CD (P=0.05)	3.13	14.76	0.28	0.37	3.92	0.40
Interaction (F×B)						
S.Em.±	2.13	10.07	0.19	0.26	2.67	0.27
CD (P=0.05)	NS	NS	NS	NS	NS	NS
General Mean	71.18	373.62	2.03	3.28	58.37	2.33

inoculation @2.4 kg/ha significantly increased plant height (74.50 cm) compared to the control, showing comparable results to Rhizobium soil application @ 2 kg/ha (70.10 cm). This trend was consistent across parameters such as dry matter accumulation (g/m), leaf area index, crop growth rate (g/m/day), number of nodules per plant, and weight of nodules per plant.

The influence of nitrogen and phosphorus levels on plant height was significant, likely attributable to enhanced meristematic growth and increased number and size of internodes. This improvement in meristematic activity led to increased leaf length, thereby elevating the leaf area index and enhancing photosynthetic activity, ultimately resulting in higher accumulation of photosynthates and increased dry matter accumulation. Consequently, the crop growth rate experienced an overall boost. Similar findings were reported by Kulkarni *et al.* (1986) and Karunakaran *et al.* (2010). Furthermore, Rhizobium spp. contributed to nitrogen supply, augmenting vegetative growth and leading to enhanced growth parameters. Adequate nitrogen and phosphorus supply improved root length, while the application of rhizobium increased the number of nodules, consequently increasing the weight of nodules per plant. These outcomes are in conformity with the findings of More *et al.* (2002) and Dhadge *et al.* (2014).

Yield attributes

The impact of inorganic and biofertilizers on yield attributes was notably significant (refer to Table 2). Among the various inorganic fertilizer treatments, the application of 150% RDF demonstrated superior performance, although statistically equivalent to 100% RDF. The highest number of pods per plant (35.14) was achieved with 150% RDF, on par with 100% RDF (25.91), while the lowest pod count was recorded with 0% RDF. A similar trend was observed in pod weight per plant and 100 kernel weight. The levels of biofertilizer exhibited a significant effect on the number of pods per plant. Rhizobium seed inoculation @ 2.4 kg/ha yielded the highest number of pods (35.16), followed closely by Rhizobium soil application @ 2 kg/ha (29.17) and the control	**Number of pods plant^{-1}**	**Weight of pod plant^{-1} (g)**	**100 kernel weight (g)**

(28.37). This**Table 2: Effect of inorganic and biofertilizer on yield attributes of groundnutTreatments**			
Inorganic Fertilizer Levels (F)			
F1: 0%RDF	25.91	34.04	40.91
F2: 50%RDF	28.39	35.63	43.59
F3: 100%RDF	34.16	39.72	45.77
F4: 150%RDF	35.14	40.59	46.07
S.Em.±	1.07	1.00	1.40
CD (P=0.05)	3.15	2.93	NS
Biofertilizer Levels (B)			
B1: Control	28.37	35.63	43.21
B2: Seed Inoculation	35.16	40.55	45.55
B3: Soil Application	29.17	36.30	43.50
S.Em.±	0.93	0.87	1.21
CD (P=0.05)	2.73	2.54	NS
Interaction (F×B)			
S.Em.±	1.86	1.73	2.42
CD (P=0.05)	NS	NS	NS
General Mean	30.90	37.62	44.08

pattern was mirrored in pod weight per plant and 100 kernel weight. Increased levels of inorganic fertilizer contributed to improved values of various yield attributes such as pod number, pod weight per plant, and seed indexes, likely due to enhanced vegetative growth and nodulation, resulting in augmented pod count and pod weight per plant. These findings are corroborated by previous studies conducted by Patil *et al.* (2018) and Vala *et al.* (2017). Rhizobium, by enhancing the availability of nitrogen and phosphorus, facilitated better translocation of photosynthesis toward the sink, leading to higher values in yield attributing characters. This aligns with the findings of Chaudhary (2014), Patil *et al.* (2014), and Alsamowal *et al.* (2016) in groundnut.

Yield

The perusal of data on yield differed significantly with the application of inorganic and biofertilizer except harvest index are presented in (Table 3). The highest kernel yield (2019.18 kg/ha) was achieved with 150% RDF which was statistically at par with 100% RDF (1909.61 kg/ha), followed by 50% RDF (1563.93 kg/ha). The lowest kernel yield was recorded by 0% RDF

(1377.74 kg/ha) when compared with other treatments. The haulm yield and biological yield followed the similar trend with that of kernel yield. Levels of biofertilizer recorded the highest kernel yield by Rhizobium seed inoculation @ 2.4 kg/ha (2016.91 kg/ha) which is at par with Rhizobium soil application @ 2 kg/ha (1607.18 kg/ha) followed by control (1528.77 kg/ha). Similarly, the haulm yield and biological yield also followed the same trend. Under proper fertilization, accumulation of photosynthates in the developing reproductive structures led to the increment in growth and yield attributing characters of plant. Further, proper fertilization resulted in the higher uptake of nutrients by the plants. This might be attributed to the higher yield of groundnut under different levels of inorganic fertilizers. These results are in conformity with the above finding of Bhalerao *et al.* (1993), and Chavan *et al.* (2014). Rhizobium inoculation helped to increase the growth and yield attributing characters of the plant. As a consequence, higher grain and straw yield were achieved due to the increment in the nodulation of root which led to the increment in root length. These results were found to be in conformity with Raychandhuri *et al.* (2003) and Chavan *et al.* (2014).

Regression analysis

The linear regression analysis plotted by considering the two years mean data between the growth and yield attributes with grain yield also found a strong coefficient of determination (Figures 2 to 8).

Table 3. Effect of inorganic and biofertilizer on the yield (kg/ha) of groundnut

Treatment	Kernel yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Inorganic Fertilizer Levels (F)				
F1: 0%RDF	1383.30	2308.16	3685.90	38.18
F2: 50%RDF	1563.93	2805.34	4369.28	35.77
F3: 100%RDF	1909.61	3295.89	5205.50	36.62
F4: 150%RDF	2019.18	3760.11	5779.29	335.75
S.Em.(±)	93.32	235.46	256.41	2.23
CD (P=0.05)	273.71	690.58	752.04	NS
Biofertilizer Levels (B)				
B1: Control	1528.77	2666.08	4194.84	37.00
B2: Seed Inoculation	2016.91	3589.99	5606.90	36.12
B3: Soil Application	1607.18	2871.06	4478.23	36.62
S.Em.(±)	80.82	203.91	222.06	1.93
CD (P=0.05)	237.04	598.06	651.28	NS

Interaction (F×B)				
S.Em.(±)	161.64	407.83	444.12	3.86
CD (P=0.05)	NS	NS	NS	NS
General Mean	1717.61	3042.37	4759.99	36.57

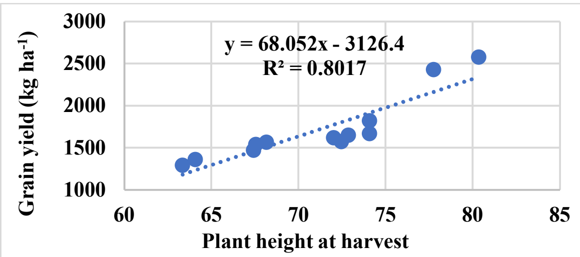

Fig. 2 Simple regression analysis of grain yield on plant height at harvest of groundnut

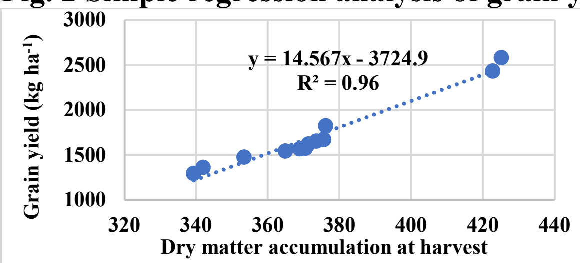

Fig. 3 Simple regression analysis of grain yield on dry matter accumulation at harvest of groundnut

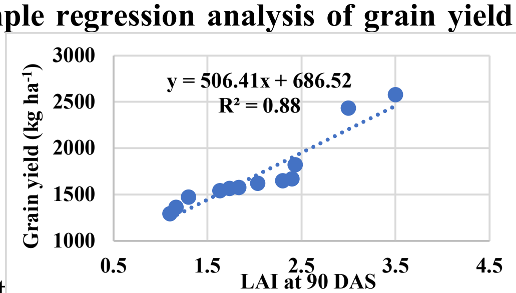

Fig. 4 Simple regression analysis of grain yield on leaf area index at 90 DAS of groundnut

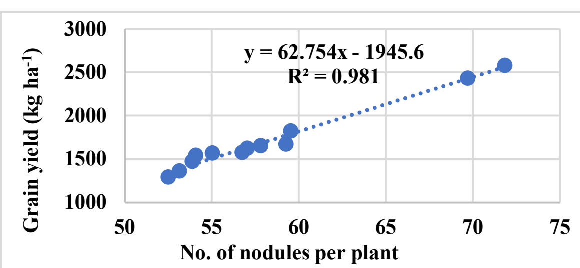

Fig. 5 Simple regression analysis of grain yield on number of nodules per plant of groundnut

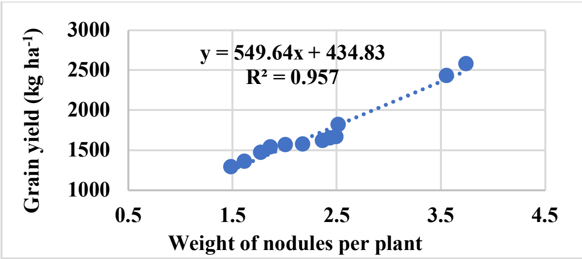

Fig. 6 Simple regression analysis of grain yield on weight of nodules per plant of groundnut

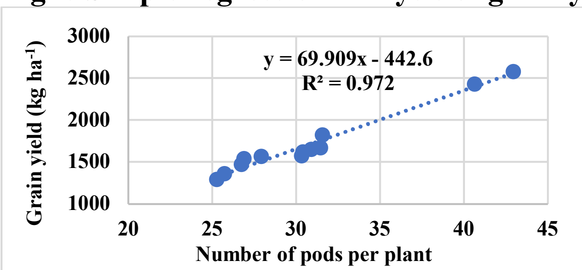

Fig. 7 Simple regression analysis of grain yield on number of pods per plant of groundnut

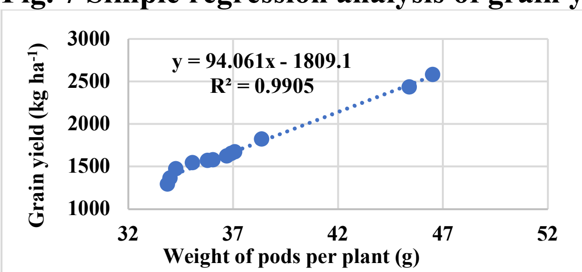

Fig. 8 Simple regression analysis of grain yield on weight of pods per plant of groundnut

The linear graphs were plotted by taking dependent variable (grain yield) in Y-axis and independent variable (agronomic traits) in X-axis. The linear regression model analyzed that there was a medium to strong coefficient of determination between the attributes and yield. The regression equation drawn between growth attributes and yield attributes with yield are presented in Figs. 3, 4 and 5. The regression analysis of growth attributes with grain yield for both the year were found to be strongly correlated with a R2 ranging from 0.94 to 0.91 for both the years, respectively. Similarly, yield attributing characters also showed a strong correlation with grain yield with a derived R2 value of 0.97 for both the years. The regression analysis clearly proved the impact of growth attributes and yield attributes on obtaining grain yield in groundnut.

Conclusion

The results of the study highlight the significant impact of inorganic and biofertilizers on the growth and yield of groundnut crops during the summer season in southern Odisha. Specifically, the combined application of 150% RDF and Rhizobium seed inoculation at 2.4 kg ha-1 emerged as the most effective strategy for achieving optimal growth and yield, closely followed by the combination of 100% RDF with the same Rhizobium inoculation rate. These findings offer valuable insights for farmers in the region, providing a practical and sustainable approach to enhance groundnut cultivation during the summer season.

Conflict of Interest

The authors declare that they do not have any conflict of interest.

Ethical Approval - Not Required.

References

Alsamowal, M. M., Hadad, M. A. & Elhassan, G. A. (2016). The effect of local mycorrhiza isolated, Rhizobium and fertilization on *Zea mays* and groundnuts plant productivity under field condition in Sudan. Journal of Agricultural Research, 2, 26-42. https://doi.org/10.53555/ar.v2i6.76

Anzuay, M. S., Viso, N. P., Ludueña, L. M., Morla, F. D., Dalmasso, R. Y., Angelini, J. G. & Taurian, T. (2024). Biological inoculants and chemical fertilizers application produce differential effects on rhizobacterial community structure associated to peanut (*Arachis hypogaea*) and maize (*Zea mays*) plants. Symbiosis, 92(1), 75-90. https://doi.org/10. 1007/s13199-015-0337-z

Arsalan, M., Latif, A., Khan, M., Syed, S., Ullah, R., Ahmad, I., Bilal, M., Mahmood, M. T., Ehsan, M., Latif, R. & Ghaffar, A. (2024). Integrated effect of organic amendments and chemical fertilizers on yield of groundnut and soil health under rainfed condition. Journal of Applied Research in Plant Sciences, 5(01), 99-104. https://doi.org/10.38211/ joarps.2024.05.215

Baweja, P., Kumar, S. & Kumar, G. (2020). Fertilizers and pesticides: Their impact on soil health and environment. Soil health, 265-285.

Bhalerao, P. D., Jadhao, P. N. & Fulzele, G. R. (1993). Response of promising groundnut (*Arachis hypogaea*) genotypes to fertilizer levels during summer. Indian Journal of Agronomy, 38, 505-507.

Chaudhary, V. J. (2014). Response of summer groundnut (*Arachis hypogaea* L.) to irrigation scheduling and sources of nitrogen under North Gujarat condition. M.Sc. (Agri.) Thesis (Unpublished), Submitted to Sardarkrushinagar Dantiwada Agricultural University, Sardar krushi nagar, Gujarat.

Chavan, A. P., Jain, N. K. & Mahadkar, U. V. (2014). Direct and residual effects of fertilizers and biofertilizers on yield, nutrient uptake and economics of groundnut (*Arachis hypogaea* L.)- rice (*Oryza sativa*) cropping system Indian Journal of Agronomy, 59, 53-58.

Choudhary, S. K., Jat, M. K., Sharma, S. R. & Singh, P. (2011). Effect of INM on soil nutrient and yield in Groundnut field of semi-arid area of Rajasthan. Legume Research-An International Journal, 34(4), 283-287.

Dey, D., Kundu, M. C., Sen, D. & Sachan, M. S. (2024). Conjoint application of lime, organics, inorganic fertilizers, and bio-fertilizers increases Groundnut productivity, available phosphorus and microbial biomass phosphorus in acidic soil of Tripura, India. International Journal of Plant & Soil Science, 36(4), 110-117.

Dhadge, S. M. & Satpute, N. R. (2014). Effect of integrated nutrient management on growth, yield and quality of summer groundnut (*Aarchis hypogaea* L.). International Journal of Agricultural Sciences, 10, 314-316.

Gautam, Y. & Singh, O. P. (2020). Profitability and resource utilization in Groundnut production under solar irrigation system. International Journal of Current Microbiology and Applied Sciences, 9, 1993-1999.
Ghosh, A., Gautam, S. K., Meetei, T. T., Singh, N., Shrivastava, A. & Patel, S. (2023). Effect of integrated application of bio-fertilizer and soil amendments on growth parameters of Groundnut (*Arachis hypogaea* L.). International Journal of Plant & Soil Science, 35(19), 1120-1129.
Hauser, A. (2018). Peanuts. Journal of Agricultural & Food Information, 19(3),195-202.
Kamble, B. M., Kathmale, D. K. & Rathod, S. D. (2018). Soil nutrient status, uptake, yield and economics of Groundnut-Wheat cropping sequence as influenced by organic sources and fertilizers. Journal of the Indian Society of Soil Science, 66(1), 66-75. https://doi.org/10.5958/0974-0228.2018. 00007 .5
Karunakaran, V., Rammohan, J., Chellamuthu, V. & Poonghuzhalan, R. (2010). Effect of integrated nutrient management on the growth and yield of groundnut (*Arachis hypogaea* L.) in coastal region of Karaikal. Indian journal of Agronomy, 55(2),128-132.
Kulkarni, J. H., Joshi, P. K. & Sajitra, V. K. (1986). Influence of phosphorus and potassium application on nodulation, nitrogen accumulation and yield of groundnut. Legume Research-An International Journal, 9, 34-38.
Kumar, R., Kumar, R. & Prakash, O. (2019). The impact of chemical fertilizers on our environment and ecosystem. Chief Ed, 35(69), 1173-1189. In book: Research Trends in Environmental Sciences: 2nd Chapter:5.
Mausumi Raychandhuri, M. R., Ngachan, S. V., Raychaudhari, S. & Singh, A. L. (2003). Yield response of groundnut (*Arachis hypoagea* L.) to dual inoculation and liming of an acid hill ultisol of Manipur. Indian Journal of Agricultural Sciences,73, 86- 88.
More, K. A., Gaikwad, C. B. & Dahat, D. V. (2002). Effect of N, P, Rhizobium and phosphate solubilizing bacteria on groundnut. J. Maharashtra Agricultural University, India. Journal of Food Legumes, 30 (03), 195-197.
Patil, D. B., Pawar, P. P., Wadile, S. C. & Patil, H. M. (2017). Effect of integrated nutrient management on growth and yield of kharif groundnut (*Arachis hypogaea* L.). International journal of horticulture and food science, 1(1), 21-23.
Patil, D. H., Shankar, M. A., Krishnamurthy, N., Shadakshari, Y. G. & Parama, V. R. R. (2018). Studies onsite specific nutrient management (SSNM) on growth and yield of groundnut (*Arachis hypogaea*) under irrigation in Southern Karnataka. Legume Research-An International Journal,41, 728-733. https://doi.org/10.18805/LR-3928
Patil, S. R., Kadam, S. R., Kalegore, N. K. & Dadgale, P. R. (2014). Effect of inorganic and bio-fertilizers on growth and yield of summer groundnut. Advance research journal of crop improvement, 5, 23-25.
Rabani, M. S., Hameed, I., Gupta, M. K., Wani, B. A., Fayaz, M., Hussain, H., Pathak, A., Tripathi, S., Gupta, C., Srivastav, M. & Ahad, M.B. (2023). Introduction of biofertilizers in agriculture with emphasis on nitrogen fixers and phosphate solubilizers. In Microbiomes for the Management of Agricultural Sustainability, 71-93. https://doi.org/10. 1007/978-3-031-32967-8_4

Rao, M. S., Prasad, P. V. N., Murthy, K. R., Sreelatha, T. & Rao, C. M. (2018). Integrated nutrient management in Groundnut (*Arachis hypogaea* L.)-Maize (*Zea mays* L.) cropping system. The Andhra Agricultural Journal, 65 (4), 769-778.

Salleh, N. S., Lazim, N. A. M. & Muhamad, I. I. (2021). Biofertilizer in promoting sustainable agriculture for food safety and security: A review. PERINTIS eJournal, 11(2), 117-129.

Satpute, A. V., Patil, J. B., Shende, S. M. & Patil, M. J. (2020). Effect of inorganic and bio-fertilizers on growth and yield of summer groundnut (*Arachis hypogaea* L.). International Journal of Chemical Studies, 8, 2644-2648. https://doi.org/10.22271/ chemi.2020.v8.i6al.11180

Shome, S., Barman, A. & Solaiman, Z. M. (2022). Rhizobium and phosphate solubilizing bacteria influence the soil nutrient availability, growth, yield, and quality of soybean. Agriculture, 12(8), 1136. https://doi.org/10.3390/agriculture12081136

Singh, M., Dotaniya, M. L., Mishra, A., Dotaniya, C. K., Regar, K. L. & Lata, M. (2016). Role of biofertilizers in conservation agriculture. Conservation agriculture: an approach to combat climate change in Indian Himalaya. Pp.113-134. https://doi.org/10.1007/978-981-10-2558-7_4

Somvanshi, P. S., Pandiaraj, T. &Singh, R. P. (2020). An unexplored story of successful green revolution of India and steps towards ever green revolution. Journal of Pharmacognosy and Phytochemistry, 9(1), 1270-1273.

Tiwari, S., Kumar, N., Pramanik, A., Joshi, E., Sasode, D. S., Sikarwar, R. S. & Singh, A. K. (2018). Breeding for foliar disease resistance in groundnut using conventional and molecular approaches. Proceedings of PSMB, 15, 56-62.

Vala, F. G., Vaghasia, P. M., Zala, K. P. & Buha, D. B. (2017). Effect of integrated nutrient management on productivity of summer groundnut (*Arachis hypogaea* L.). International journal of current microbiology and applied sciences, 6(10),1951-1957. https://doi.org/10.20546/ijcmas.2017.610.235

Weight, D. & Kelly, V. A. (1999). Fertilizer Impacts on Soils and crops of sub-Saharan Africa. MSU International Department of Agricultural Economics Development, Department of Economics Paper No. 21, ISSN 0731-3438.

Yahaya, S. M., Mahmud, A. A., Abdullahi, M. & Haruna, A. (2023). Recent advances in the chemistry of nitrogen, phosphorus and potassium as fertilizers in soil: A review. Pedosphere, 33(3), 385-406. https://doi.org/10.1016/j.pedsph.2022.07.012