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EFFECT OF DIFFERENT NUTRIENT MANAGEMENT PRACTICES ON GROWTH AND YIELD OF CHICKPEA (*Cicer arietinum* L.) UNDER SCARCITY ZONE OF ANDHRA PRADESH

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Chickpea (*Cicer arietinum* L.), commonly known as Bengal gram, is often referred to as the "king of pulses." This vital crop thrives in arid and semi-arid regions and is rich in essential amino acids. India stands out as a global leader in both the production and consumption of chickpeas, accounting for 39% of the total land area dedicated to pulses and 50% of total pulse production in 2022-23. Chickpea is cultivated across an area of 10.91 million hectares, with an annual production of 13.76 million tonnes. The average productivity in India is 900 kg per hectare, in contrast to the global figures of 14.80 million hectares and 15.08 million tonnes, respectively. In Andhra Pradesh, chickpea is grown on 4,51,000 hectares, producing 4,90,000 tonnes, with a higher average productivity of 1,105 kg per hectare (Agricultural Statistics at a Glance - 2022).

To support India's growing population, it is essential to enhance chickpea productivity through effective management practices, with a particular focus on nutrient management. This approach is crucial for achieving higher yields while maintaining soil fertility. Relying heavily on chemical fertilizers not only raises cultivation costs but also diminishes soil productivity by eliminating organic sources of nutrients (Rana *et al.*, 2018; Rajanna *et al.*, 2023).

Rhizobium inoculants are widely recognized as effective biofertilizers that enhance chickpea growth and yield by fixing atmospheric nitrogen through symbiotic relationships. Among nitrogen-fixing bacteria, the symbiotic associations between legumes and rhizobia provide the largest contribution of fixed nitrogen in agricultural systems (Heba *et al.,* 2021; Paramesh *et al.*, 2023). Inoculating chickpea seeds with effective and suitable strains of rhizobia is crucial, especially in soils with low or no bacterial presence. This practice significantly improves nodulation, nitrogen fixation, growth, and yield of chickpeas. Consequently, rhizobium inoculation may serve as a cost-effective alternative to expensive nitrogen fertilizers and has proven beneficial in enhancing crop performance.

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Seaweeds, or marine algae, are macroscopic organisms that attach to the seabed in both shallow and deep coastal waters, often growing on solid substrates like rocks, pebbles, and dead corals. In the present investigation, the seaweed extract used was sourced from IFFCO and is available as a concentrate with a composition of 28% w/w. The chemical composition of this seaweed extract is detailed by Manimaran *et al*. (2018) (Table 1). The application of seaweed extract (SWE) in agriculture offers an effective and eco-friendly alternative to inorganic fertilizers. Seaweeds serve as organic bio-fertilizers, which can significantly reduce nitrogen and phosphorus runoff from farmland. Incorporating seaweed species into soil leads to chemical changes that enhance soil fertility by improving organic matter content, neutralizing soil reactions, and reducing the carbon-to-nitrogen ratio in both sandy and clay soils.

Currently, research on the synergistic effects of seaweed extract and rhizobium on the growth parameters of chickpea is limited. Considering this gap, the present investigation was conducted to evaluate various nutrient management practices and their impact on the growth and yield of chickpea in the scarcity zone of Andhra Pradesh.

A field experiment was conducted at the Agricultural College Farm, Mahanandi campus of Acharya N. G. Ranga Agricultural University, Andhra Pradesh, during the *rabi* season of 2022-23. The soil at the experimental site is sandy loam in texture, neutral in pH (7.24), low in organic carbon (0.44%), low in available nitrogen (164.2 kg ha^{-1}), and high in both available phosphorus (27.1 kg ha^{-1}) and available potassium (641.2 kg ha^{-1}). The recommended fertilizer dosage for chickpea is 20-50-0 kg N, P_2O_5, K_2O ha^{-1}, and fertilizers were applied according to the experimental treatments. All nitrogen and phosphorus were applied as basal at the time of sowing using urea and single super phosphate, respectively. The experiment was designed as a randomized block design with seven treatments, each replicated thrice. The nutrient management practices evaluated included 100% Recommended Dose of Fertilizers (RDF) (20-50-0 kg N, P_2O_5, K_2O ha^{-1})

Table 1. Chemical composition of seaweed extract

Nutrients	Content
Nitrogen (N)	0.18 %
Phosphorus (P_2O_5)	0.48 %
Potassium (K_2O)	1.89 %
Calcium	0.11 %
Magnesium	0.01 %
Sodium	0.13 %
Iron	256.0 ppm
Zinc	11.87 ppm
Copper	15.62 ppm
Manganese	13.12 ppm
Growth hormones: Auxins, Cytokinnins, Gibberellins *etc.,*	Trace amounts

(T_1), 75% RDF combined with seed treatment using rhizobium (T_2), 75% RDF with seed soaking in 0.1% seaweed extract for 30 minutes (T_3), and 75% RDF with foliar application of 0.3% seaweed extract at 25 days after sowing (T_4), 75% RDF with both seed treatment using rhizobium + foliar application of 0.3% seaweed extract at 25 days after sowing (T_5), 75% RDF + seed soaking in 0.1% seaweed extract for 30 minutes + foliar application of 0.3% seaweed extract at 25 days after sowing (T_6) and 75% RDF combined + seed soaking in 0.1% seaweed extract for 30 minutes + seed treatment with rhizobium + foliar application of 0.3% seaweed extract at 25 days after sowing (T_7).

The chickpea variety NBeG-452 was sown on November 9, 2022, using a spacing of 30 cm × 10 cm. Seed treatment with Rhizobium was done according to the specified treatment protocols. A foliar application of seaweed extract at a concentration of 0.3% was done at 25 days after sowing (DAS) in the respective treatments. Hand weeding was carried out twice, at 20 DAS and 35 DAS. Additionally, two supplemental irrigations were provided during prolonged dry spells to support crop development. Biometric assessments were done to evaluate growth parameters, including plant height, number of branches, dry matter accumulation, leaf area index, SPAD chlorophyll content, and yield attributes, such as the number of pods per plant, number of seeds per pod, and 100-seed weight of the chickpea. Seed and stover yields from the net plot area were sun-dried to achieve a constant weight, with results expressed in kg ha^{-1}. All collected data were subjected to statistical analysis using analysis of variance (ANOVA) for a randomized block design. The significance of results was tested using the F-test at a 5% level of probability, and treatment means were compared using the critical difference method as outlined by Panse and Sukhatme (1985).

Effect of nutrient management practices on growth parameters of chickpea

The study revealed that plant height, number of branches per plant, and dry matter production of chickpea at various growth stages—namely, 30 and 60 days after sowing (DAS), as well as at harvest—were significantly influenced by different nutrient management practices (Table 2). All growth parameters exhibited a progressive increase with the advancing age of the crop, regardless of the treatments applied. Among the nutrient management strategies evaluated, the combination of 75% recommended dose of fertilizers (RDF), seed soaking in 0.1% seaweed extract for 30 minutes, seed treatment with Rhizobium, and foliar application of 0.3% seaweed extract at 25 DAS resulted in superior plant height, number of branches per plant, and dry matter accumulation. This treatment was statistically comparable to the combination of 75% RDF, seed soaking with 0.1% seaweed extract, and foliar application at 25 DAS across different growth stages.

Integrated nutrient management practices, particularly the combination of 75% RDF with seaweed extract and Rhizobium, significantly enhanced plant height at all growth stages. This improvement can be attributed to the growth hormones, essential minerals, and macro- and micronutrients present in the seaweed extract, which stimulate both Rhizobium and plant activities, thereby facilitating cell division and enlargement, and promoting overall plant growth. These findings are consistent with the research conducted by Bhuiyan *et al.* (2008) and Deepana *et al.* (2021). The combination of Rhizobium inoculants and seaweed extract also led to a higher number of branches at all growth stages, likely due to the vigorous growth induced by the plant growth regulators in the seaweed extract. This observation aligns with the studies of Boghdady *et*

Table 2. Effect of different nutrient management practices on chickpea plant height, number of branches per plant and dry matter accumulation

Treatments	Plant height (cm)			Number of branches plant^{-1}			Dry matter accumulation (kg ha^{-1})		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
100 % RDF (20 N - 50P_2O_5 - 0 K_2O kg ha^{-1})	21.6	39.3	43.8	7.9	21.5	22.8	367	1709	3799
75 % RDF + seed treatment with Rhizobium	19.9	38.0	40.2	6.3	17.8	21.3	331	1502	3225
75 % RDF + seed soaking with 0.1 % seaweed extract for 30 minutes	20.3	38.1	42.2	6.2	18.0	20.3	338	1541	3419
75 % RDF + foliar application with 0.3 % seaweed extract at 25 DAS	20.4	39.0	42.7	6.3	19.3	21.9	342	1578	3566
75 % RDF + seed treatment with Rhizobium + foliar application with 0.3 % seaweed extract at 25 DAS	20.9	39.7	43.2	6.5	18.2	21.4	351	1624	3631
75 % RDF + seed soaking with 0.1 % seaweed extract for 30 minutes + foliar application with 0.3 % seaweed extract at 25 DAS	21.9	40.6	44.1	7.5	20.6	22.9	359	1685	3688
75 % RDF + seed soaking with 0.1 % seaweed extract for 30 minutes + seed treatment with Rhizobium + foliar application with 0.3 % seaweed extract at 25 DAS	22.0	41.5	45.7	8.1	22.3	23.6	379	1762	3896
SEm±	0.55	1.26	1.32	0.20	0.58	0.49	10.8	49.8	103.9
CD (*p≤0.05*)	1.7	3.2	4.1	0.6	1.8	2.0	33	154	320

al. (2016) and Kurakula and Rai (2021).

Furthermore, the higher dry matter accumulation associated with integrated nutrient management practices at all growth stages may be attributed to increases in leaf area, plant height, and number of branches. The enhancement of photosynthetically active leaf area likely contributed to greater photosynthate production, resulting in increased dry matter accumulation. These results corroborate the findings of Katiyar *et al.* (2020) and Namvar *et al.* (2011).

Effect of nutrient management practices on leaf area index and SPAD chlorophyll in chickpea

The leaf area index (LAI) of chickpea was measured at various growth stages, specifically at 30 and 60 days after sowing (DAS), and at harvest. The results demonstrated a significant influence of different nutrient management practices on LAI (Fig. 1). The LAI progressively increased up to 60 DAS, followed by a slight decline at harvest, which can be attributed to the senescence of older leaves. Among the nutrient management strategies evaluated, the combination of 75% recommended dose of fertilizers (RDF), seed soaking in 0.1% seaweed extract for 30 minutes, seed treatment with Rhizobium, and foliar application of 0.3% seaweed extract at 25 DAS yielded the highest LAI at all growth stages. Integrated nutrient management practices, specifically the combination of 75% RDF with foliar application of seaweed extract and Rhizobium inoculation, significantly promoted leaf area development in chickpea. This enhancement can be linked to the presence of growth hormones and essential nutrients, including nitrogen, phosphorus, and potassium, found in the seaweed extract. These components stimulate Rhizobium activity and support plant growth processes such as cell division and enlargement, leading to an increased LAI. Research by Bhattacharya and Chandra (2013), Deepana *et al*. (2021), and Radjassegarin and Perumal (2021) supports the finding that seeds treated with lower concentrations of seaweed extract in combination with Rhizobium resulted in higher LAI. On the other hand, the treatment of 75% RDF combined solely with Rhizobium (T_2) produced a lower LAI, indicating the importance of the synergistic effects of these integrated practices.

The chlorophyll content of chickpea was assessed at various growth stages, specifically at 30 and 60 days after sowing (DAS) and at harvest, revealing significant

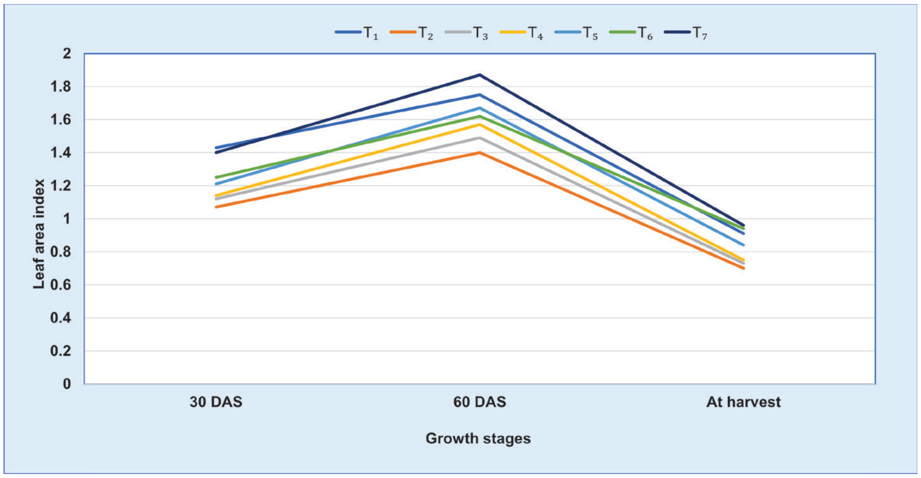

Fig. 1. Leaf area index of chickpea at different growth stages as influenced by different nutrient management practices

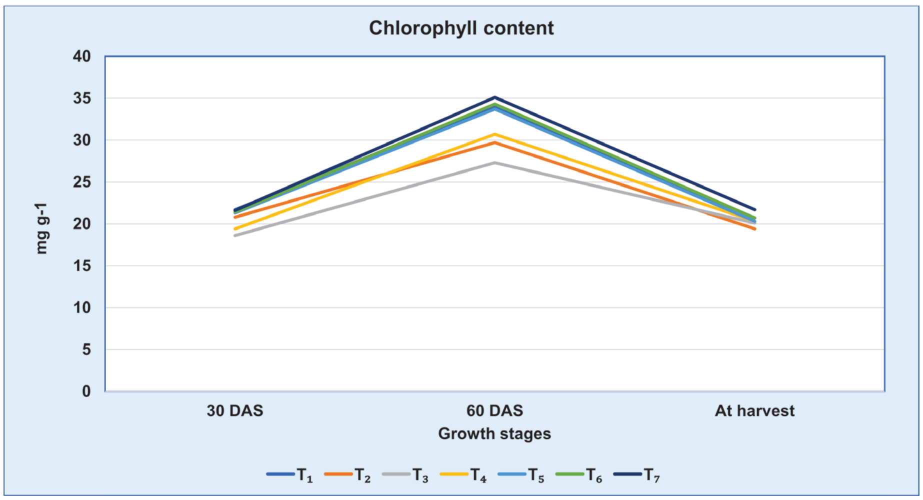

Fig. 2. Chlorophyll content of chickpea at different growth stages as influenced by different nutrient management practices

differences attributable to various nutrient management practices (Fig. 2). Chlorophyll content progressively increased up to 60 DAS, followed by a decline toward harvest. This increase can be attributed to increased leaf activity, resulting in elevated chlorophyll levels. The subsequent decline is likely due to chlorophyll degradation associated with leaf senescence. Among the nutrient management strategies evaluated, the combination of 75% recommended dose of fertilizers (RDF), seed soaking in 0.1% seaweed extract for 30 minutes, seed treatment with Rhizobium, and foliar application of 0.3% seaweed extract at 25 DAS resulted in significantly higher chlorophyll content across all growth stages. The enhanced chlorophyll levels observed with this integrated approach can be linked to the presence of growth-promoting substances such as betaines and inorganic salts in the seaweed extract, which may increase chloroplast size, granule development, and chlorophyll concentration. These findings align with the research of Bambara and Ndakidemi (2009), Deepana *et al.* (2021), and Kalaivanan and Venkatesalu (2012), which support the beneficial effects of seaweed extracts on chlorophyll synthesis. Furthermore, seaweed extract-treated plants exhibited higher levels of essential nutrients, including nitrogen, copper, iron, magnesium, zinc, sulfur, and manganese, all of which contribute to the synthesis and maintenance of chlorophyll (Radjassegarin and Perumal, 2021).

Effect of nutrient management practices on yield attributes and yield of chickpea

The number of pods per plant, 100-seed weight, and seed and stover yields of chickpea varied significantly due to different nutrient management practices applied in the current study (Table 2). The combination of 75% recommended dose of fertilizers (RDF), seed soaking

Table 3. Effect of different nutrient management practices on yield attributes and yield of chickpea

Treatments	Number of pods plant^{-1}	Number of seeds pod^{-1}	100-seed weight (g)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})
100% RDF (20N -50 P_2O_5 – 0 K_2O kg ha^{-1})	46.4	1.03	29.4	2177	3546
75 % RDF + seed treatment with Rhizobium	40.7	1.00	26.7	1987	3123
75 % RDF + seed soaking with 0.1 % seaweed extract for 30 minutes	41.8	1.00	27.6	2037	3354
75 % RDF + foliar application with 0.3% seaweed extract at 25 DAS	41.5	1.00	27.6	2040	3466
75 % RDF + seed treatment with Rhizobium + foliar application with 0.3 % seaweed extract at 25 DAS	42.3	1.03	29.0	2064	3518
75 % RDF + seed soaking with 0.1% seaweed extract for 30 minutes + foliar application with 0.3 % seaweed extract at 25DAS	43.0	1.03	29.3	2170	3530
75 % RDF + seed soaking with 0.1% seaweed extract for 30 minutes + seed treatment with Rhizobium + foliar application with 0.3 % seaweed extract at 25 DAS	46.5	1.03	29.9	2273	3572
SEm±	1.35	0.03	0.8	67.3	110.1
CD (*p≤0.05*)	4.2	NS	2.5	208	339

in 0.1% seaweed extract for 30 minutes, seed treatment with Rhizobium, and foliar application of 0.3% seaweed extract at 25 days after sowing (DAS) resulted in the highest values for these parameters. This treatment was statistically comparable to both 100% RDF and a combination of 75% RDF with seed soaking and foliar application of seaweed extract. The increased number of pods per plant observed with the application of RDF, seaweed extract, and Rhizobium can be attributed to the enhanced nitrogen availability to the plants. This finding aligns with the research of Namvar *et al.* (2011) and Malik *et al.* (2013). However, the number of seeds per pod did not show significant variation across the different nutrient management practices investigated in this study. Integrated nutrient management practices led to higher seed yields in chickpea. The application of RDF is critical for achieving optimal seed yield, as reported by Bejandi *et al.* (2012). Furthermore, the use of seaweed extract in conjunction with Rhizobium inoculant enhanced growth and yield attributes, as well as the partitioning and translocation of photosynthates from source to sink. The combination of seaweed extract and Rhizobium biofertilizer likely increased seed yield due to the presence of growth hormones in the seaweed extract and the contributions of symbiotic nitrogen fixation and other bio-stimulatory activities of Rhizobium. These findings are consistent with the results reported by Radjassegarin and Perumal (2021).

In conclusion, the present study demonstrates that the combined application of seaweed extract and Rhizobium, in conjunction with 75% of the recommended dose of fertilizers, significantly enhances the growth parameters, yield attributes, and overall yield of chickpea. These findings highlight the effectiveness of integrated nutrient management practices as a sustainable and viable option for improving chickpea cultivation, particularly in the scarcity-prone regions of Andhra Pradesh. This approach not only promotes plant growth and productivity but also contributes to sustainable agricultural practices by optimizing resource use and enhancing soil health. The integration of bio-stimulants like seaweed extract with traditional fertilizers and biological inoculants like Rhizobium presents a promising strategy for increasing agricultural resilience in challenging environments.

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