Plant Archives Vol. 26, No. 2, 2026 pp. 2514-2520 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.2.344

INFLUENCE OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH, YIELD AND QUALITY OF CHIA (*Salvia hispanica* L.)

M. Sharon[1]*, M. Kalpana[1], A. Chandini Raj[1] and M. Raghavendra Reddy[2]

[1]Department of Plantation, Spice, Medicinal and Aromatic Crops, Dr. YSRHU-COH, Venkataramannagudem, West Godavari-534 101, Andhra Pradesh, India.

[2]Department of Soil Science, Dr. YSRHU-COH, Venkataramannagudem, West Godavari-534 101, Andhra Pradesh, India.

*Corresponding author E-mail : sharonvdp2001@gmail.com

(Date of Receiving-19-08-2026; Date of Revision-15-10-2026; Date of Acceptance-19-10-2026)

ABSTRACT

A field experiment was conducted during 2025–2026 at the College Farm, College of Horticulture, Dr. Y.S.R. Horticultural University, Venkataramannagudem, Andhra Pradesh, to study the influence of integrated nutrient management on the growth, yield and quality of chia (*Salvia hispanica* L). The experiment was laid out in a Randomized Block Design (RBD) with ten treatments and three replications. The treatments comprised different levels of recommended doses of fertilizers (RDF), biofertilizers, including phosphate-solubilizing bacteria (PSB), potassium-solubilizing bacteria (KSB) and *Azotobacter* and biocontrol agents, namely *Trichoderma viride* and *Pseudomonas fluorescens*. The results revealed that treatment T_4, comprising 100% RDF (60:40:40 N_2, P_2O_5, K_2O kg ha^{-1}) + PSB + KSB + *Azotobacter* ($1.25L^{-1}$)+ *T. viride* (5 kg ha^{-1}) + *P. fluorescens* ($5L^{-1}$) recorded the maximum plant height of 100.19 cm at harvest, 21.18 branches $plant^{-1}$ and 28.57 inflorescences $plant^{-1}$. The highest seed yield of 959.26 kg ha^{-1} and swelling factor of 31.81% were also recorded in T_4, whereas the absolute control (T_1) recorded the lowest seed yield of 437.04 kg ha^{-1} and swelling factor (27.50%), but the earliest 50% flowering at 80.53 days noticed in T_1. The improved performance under T_4 may be attributed to the combined effects of mineral fertilizers, biofertilizers and biocontrol agents on nutrient availability and plant growth. It is concluded that the combined application of 100% RDF, biofertilizers and biocontrol agents was the best-performing treatment for improving the growth, seed yield and swelling factor of chia, which can be recommended to farmers.

Key words : Chia, Integrated nutrient management, Biofertilizers, Biocontrol agents, Seed yield, Swelling factor.

Introduction

Chia (*Salvia hispanica* L.) has emerged as an important emerging crop in horticulture, gaining attention for its nutritional value, health benefits and potential for commercial cultivation in India. Its seeds are rich in omega-3 fatty acids, protein, dietary fibre, minerals and antioxidant compounds, making it a valuable functional food. In India, chia was introduced by the Central Food Technological Research Institute (CFTRI), Mysuru, in 2015 and its cultivation has gained attention as an emerging crop (Khanum *et al*., 2025).

Chia is gaining attention for its potential use in food products, nutritional supplements and value-added products because of its desirable nutritional properties. Its adaptability to different growing environments and increasing consumer interest in nutrient-rich foods have contributed to its growing importance as an emerging crop in India. The crop is attracting interest for commercial cultivation because of its nutritional value and potential to grow under rainfed and irrigated conditions, including in some marginal soils.

Successful chia production depends on appropriate nutrient management practices. The combined application of chemical fertilizers and organic nutrient sources can influence plant growth, nutrient uptake and seed yield (Pravalika *et al*., 2024 and Rashmi *et al*., 2024).

Integrated nutrient management through the combined application of chemical fertilizers, biofertilizers (*Azotobacter*, *PSB* and *KSB*) and biocontrol agents (*Trichoderma viride* and *Pseudomonas fluorescens*) may improve nutrient availability and support sustainable chia production. Chia seeds are nutritionally valuable because they contain omega-3 fatty acids, protein, dietary fibre and phenolic compounds, making them useful for functional food products and health-oriented diets (Ullah *et al*., 2016). Although, several studies have examined organic manures, fertilizer levels and nutrient management in chia, further research is needed to determine the most effective combination of inorganic fertilizers, organic manures and biofertilizers for improving growth, yield and seed quality under specific soil and climatic conditions. Hence, the present study was carried out to evaluate combined application of chemical fertilizers, biofertilizers (*Azotobacter, PSB* and *KSB*) and biocontrol agents (*Trichoderma viride* and *Pseudomonas fluorescens*) in the growth and yield of chia, providing valuable insights into effective cultivation strategies for this crop.

Materials and Methods

A field experiment was conducted during 2025–2026 at the College Farm, College of Horticulture, Dr. Y.S.R. Horticultural University, Venkataramannagudem, Andhra Pradesh, to study the effect of integrated nutrient management practices on the growth, yield and quality of chia (*Salvia hispanica* L.). The experiment was laid out in a Randomized Block Design (RBD) with ten treatments, each replicated thrice. Each plot measured 2 m × 2 m, with a spacing of 30 cm × 45 cm between plants and rows respectively. The treatments consisted of an absolute control (T_1), 100%, 75% and 50% recommended doses of fertilizers (RDF), along with different combinations of phosphate-solubilizing bacteria (PSB), potassium-solubilizing bacteria (KSB), *Azotobacter* and the biocontrol agents *Trichoderma viride* and *Pseudomonas fluorescens*. The crop was transplanted during November 2025 and observations were recorded on various growth, yield and quality parameters to evaluate the effectiveness of the different integrated nutrient management treatments.

Description of treatments

Treatments	Treatment combination
T_1	Absolute control
T_2	100% RDF (60:40:40 N:P_2O_5:K_2O kg ha^{-1})
T_3	100% RDF (60:40:40 N:P_2O_5:K_2O kg ha^{-1}) + PSB + KSB+ Azotobacter (1.25L^{-1})
T_4	100% RDF (60:40:40 N:P_2O_5:K_2O kg ha^{-1}) + PSB + KSB+ Azotobacter (1.25L^{-1}) + biocontrol agents (*Trichoderma viride* 5kg ha^{-1} + *Pseudomonas fluorescens* 5L^{-1})
T_5	75% RDF (45:30:30 N:P_2O_5:K_2O kg ha^{-1})
T_6	75% RDF (45:30:30 N:P_2O_5:K_2O kg ha^{-1}) + PSB + KSB+ Azotobacter (1.25L^{-1})
T_7	75% RDF (45:30:30 N:P_2O_5:K_2O kg ha^{-1}) + PSB + KSB+ Azotobacter (1.25L^{-1}) + biocontrol agents (*Trichoderma viride* 5kg ha^{-1} + *Pseudomonas fluorescens* 5L^{-1})
T_8	50% RDF (30:20:20 N:P_2O_5:K, O kg ha^{-1})
T_9	50% RDF (30:20:20 N:P_2O_5:K, O kg ha^{-1}) + PSB + KSB+ Azotobacter (1.25L^{-1})
T_{10}	50% RDF (30:20:20 N:P_2O_5:K_2O kg ha^{-1}) + PSB + KSB+ Azotobacter (1.25L^{-1})+ biocontrol agents (*Trichoderma viride* 5kg ha^{-1} + *Pseudomonas fluorescens* 5L^{-1})

Observations were recorded on five randomly selected and tagged plants in each plot at 30, 60 DAT and at harvest for the growth *viz*., plant height (cm), number of branches $plant^{-1}$, number of inflorescences $plant^{-1}$, yield such as days for 50% flowering, seed yield $hectare^{-1}$, quality parameters like swelling factor, were recorded and the data was analysed as per ANOVA outlined by Panse and Sukhatme (1985).

Results and Discussion

Vegetative parameters

Plant height (cm)

It was evident from Table 1 that maximum plant height was recorded in 100% RDF (60:40:40 N:P_2O_5:K_2O $kgha^{-1}$) + (PSB + KSB + Azotobacter) 1.25L^{-1} + biocontrol agents (*Trichoderma viride* 5kg ha^{-1} + *Pseudomonas fluorescens* 5 L^{-1}), which recorded 58.19 cm at 30 DAT, 90.54 cm at 60 DAT and 100.19 cm at harvest. This was followed by T_3 (100% RDF (60:40:40 N:P_2O_5:K_2O $kgha^{-1}$) + PSB + KSB+ Azotobacter (1.25L^{-1}), which recorded plant heights of 57.71, 90.07 and 99.61 cm at 30 DAT, 60 DAT and at harvest, respectively. Minimum plant height was recorded in T_1 (absolute control) with values of 52.70,72.20 and 82.80 cm at 30 DAT, 60 DAT and at harvest, respectively. The increase in plant height under T_4 may be attributed to the combined application of recommended fertilizers, biofertilizers and biocontrol agents, which may have improved nutrient availability and supported vegetative growth.

Comparable results were documented by Fageria (2009) and Marschner (2012) indicated that the combined

Table 1 : Effect of integrated nutrient management practices on plant height (cm) of chia.

Treatments	30 DAT	60 DAT	At harvest
T_1 : Absolute control	39.77^{f}	72.20^{g}	82.80^{g}
T_2 : 100% RDF (60:40:40 N P_2O_5 K_2O) kg ha^{-1}	56.07^{c}	88.20^{d}	98.07^{c}
T_3 :100% RDF (60:40:40 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) 1.25 Lha^{-1}	57.71^{a}	90.01^{ab}	99.61^{b}
T_4 :100% RDF ((60:40:40 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) 1.25 L ha^{-1} +Bio-control agent (*Trichoderma viride* 5kg ha^{-1})+(*Pseudomonas fluorescens*) 5L ha^{-1}	58.19^{a}	90.54^{a}	100.19^{a}
T_5:75%RDF (45:30:30 N P_2O_5 K_2O) kg ha^{-1}	55.80^{c}	87.20^{e}	97.33^{d}
T_6 : 75%RDF (45:30:30 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter)-1.25 Lha^{-1}	56.44^{bC}	88.93^{c}	98.60^{bc}
T_7 :75%RDF (45:30:30 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) -1.25 L ha^{-1}+ Bio-control agent (*Trichoderma viride* 5kg ha^{-1})+(*Pseudomonas fluorescens*) 5L ha^{-1}	57.07^{b}	89.57^{bc}	99.10^{ab}
T_8: 50% RDF ((30:20:20 N P_2O_5 K_2O) kg ha^{-1}	53.17^{e}	85.53^{f}	96.10^{f}
T_9: 50% RDF (30:20:20 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) 1.25 L ha^{-1}	54.60^{d}	86.60^{e}	96.70^{e}
T_{10}: 50% RDF (30:20:20 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) 1.25 L ha^{-1}+ Bio-control agent (*Trichoderma viride* 5kg ha^{-1})+(*Pseudomonas fluorescens*) 5L ha^{-1}	55.10^{d}	86.93^{e}	97.03^{de}
Mean	**54.39**	**86.57**	**96.55**
SEm±	**0.212**	**0.266**	**0.195**
CD@0.05	**0.68**	**0.53**	**0.35**

RDF(recommended dose of fertilizers), **PSB**(phospate solubilizing bacteria), **KSB**(potassium solubilizing bacteria), **DAT**(days after transplanting).

application of inputs may have enhanced nitrogen fixation, phosphorus solubilization and potassium availability, thereby promoting plant growth. The lower plant height observed in T_1 (absolute control) may be due to the limited availability of essential nutrients in the absence of external nutrient inputs.

Number of branches plant^{-1}

Data on number of branches plant^{-1} (Table 2) revealed that the highest number of branches plant^{-1} was recorded in 100% RDF (60:40:40 N:P_2O_5 :K_2O kg ha^{-1}) + PSB + KSB + Azotobacter (1.25 L^{-1}) + biocontrol agents (*Trichoderma viride* 5kg ha^{-1} + *Pseudomonas fluorescens* 5L^{-1}), which recorded 10.30 at 30 DAT, 15.20 at 60 DAT and 21.18 at harvest. This was followed by T_3 (100% RDF + PSB + KSB + Azotobacter (1.25 L^{-1}), which recorded 10.10,14.80 and 20.60 branches plant^{-1} at 30 DAT, 60 DAT and at harvest, respectively. The lowest number of branches plant^{-1} was recorded in T_1 (absolute control), with values of 8.33,11.50 and 13.00 branches plant^{-1} at 30 DAT, 60 DAT and harvest, respectively. The increase in plant height under T_4 may be attributed to the combined application of recommended fertilizers, biofertilizers and biocontrol agents, which may have improved nutrient availability and supported vegetative growth.

The greater number of branches plant^{-1} may be attributed to the favourable growing conditions and improved availability of essential nutrients under integrated nutrient management practices. The combined application of recommended doses of fertilizers, phosphate-solubilizing bacteria (PSB), potassium-solubilizing bacteria (KSB) and Azotobacter, along with biocontrol agents, may have supported vegetative growth and branch development. The improved availability of nutrients may have promoted cell division and the development of lateral shoots. Similar findings were reported by Pravalika *et al*. (2024).

Number of inflorescence plant^{-1}

The data pertaining to the number of inflorescence plant^{-1} presented in the Table 3 revealed that the highest number of inflorescences plant^{-1} was recorded in application of 100% RDF (60:40:40 N:P_2O_5 :K_2O kg ha^{-}

Table 2 : Effect of integrated nutrient management treatments on number of branches plant^{-1} of chia.

Treatments	30 DAT	60 DAT	At harvest
T_1 : Absolute control	8.33^{g}	11.50^{h}	13.00^{j}
T_2 : 100% RDF (60:40:40 N P_2O_5 K_2O) kg ha^{-1}	9.10^{a}	11.80^{d}	15.80^{g}
T_3 :100% RDF (60:40:40 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) 1.25 Lha^{-1}	10.10^{ab}	14.80^{b}	20.60^{b}
T_4 :100% RDF ((60:40:40 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) 1.25 L ha^{-1} +Bio-control agent (*Trichoderma viride* 5kg ha^{-1})+(*Pseudomonas fluorescens*) 5L ha^{-1}	10.30^{a}	15.20^{a}	21.18^{a}
T_5:75%RDF (45:30:30 N P_2O_5 K_2O) kg ha^{-1}	9.03^{b}	11.60^{g}	15.33^{h}
T_6 : 75%RDF (45:30:30 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) -1.25 Lha^{-1}	9.57^{c}	12.70^{d}	18.20^{d}
T_7 :75%RDF (45:30:30 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) -1.25 L ha^{-1}+ Bio-control agent (*Trichoderma viride* 5kg ha^{-1})+(*Pseudomonas fluorescens*) 5L ha^{-1}	9.80^{bc}	13.17^{c}	19.60^{c}
T_8: 50% RDF ((30:20:20 N P_2O_5 K_2O) kg ha^{-1}	8.67^{f}	11.80^{f}	14.24^{i}
T_9: 50% RDF (30:20:20 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) 1.25 L ha^{-1}	9.13e	16.23^{g}	16.23^{f}
T_{10}: 50% RDF (30:20:20 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) 1.25 L ha^{-1}+ Bio-control agent (*Trichoderma viride* 5kg ha^{-1})+(*Pseudomonas fluorescens*) 5L ha^{-1}	9.27^{d}	12.30^{e}	17.20^{e}
Mean	**9.33**	**13.11**	**17.13**
SEm±	**0.105**	**0.003**	**0.004**
CD @ 0.05	**0.31**	**0.01**	**0.01**

RDF(recommended dose of fertilizers), **PSB**(phospate solubilizing bacteria), **KSB**(potassium solubilizing bacteria), **DAT**(days after transplanting).

^{1}) + PSB + KSB + Azotobacter (1.25L^{-1}) + biocontrol agents (*Trichoderma viride* 5kg ha^{-1} + *Pseudomonas fluorescens* 5L^{-1}) (T_4) with 28.57 inflorescences plant^{-1} followed by T_3 (100% RDF (60:40:40 N:P_2O_5 :K_2O kg ha^{-1}) + PSB + KSB + Azotobacter (1.25L^{-1}), recorded 28.40 inflorescences plant^{-1}, which was on par to T_7 (75% RDF (45:30:30 N:P_2O_5 :K_2O kg ha^{-1}) + PSB + KSB + Azotobacter (1.25 L^{-1}) + biocontrol agents (*Trichoderma viride* 5kg ha^{-1} + *Pseudomonas fluorescens* 5L^{-1}), which recorded 28.13 inflorescences plant^{-1}. The lowest number of inflorescences per plant was recorded in T_1 (absolute control) with 22.33 inflorescences plant^{-1}.

The higher number of inflorescences plant^{-1} under T_4 may be attributed to the combined application of fertilizers, biofertilizers and biocontrol agents, which may have improved nutrient availability and promoted branching and reproductive development. Similar effects of nutrients on chia growth parameters were reported by Soliman *et al*. (2024) and Appalla *et al*. (2024).

Phenological parameters

Days to 50% flowering

Statistically significant difference among treatments was observed for days to 50 per cent flowering, as presented in Table 4. The earliest flowering was recorded in T_1 (absolute control) at 80.53 days followed by T^ 50% RDF (30:20:20 N:P_2O_5 :K_2O kg ha^{-1}) at 82.52 days. Treatments T_2 to T_7, T_9 and T_{10} were statistically on par with respect to days to 50% flowering that occur between 83.50 and 83.80 days. The treatment T_4 (100% RDF (60:40:40 N:P_2O_5 :K_2O kg ha^{-1}) + PSB + KSB + Azotobacter (1.25L^{-1}) + biocontrol agents (*Trichoderma viride* 5kg ha^{-1} + *Pseudomonas fluorescens* 5L^{-1}) took 83.80 days to 50% flowering.

The earlier 50 per cent flowering in T_1 (absolute control) may be attributed to comparatively earlier transition from vegetative to reproductive growth under limited nutrient availability, whereas the application of fertilizers and biofertilizers may have prolonged vegetative growth and delayed flowering slightly. In chia, flowering is also influenced by environmental factors, particularly

Table 3 : Effect of integrated nutrient management treatments on number of inflorescence plant^{-1} of chia.

T_1 : Absolute control	22.33^{h}
T_2 : 100% RDF (60:40:40 N P_2O_5 K_2O) kg ha^{-1}	27.17^{d}
T_3 :100% RDF (60:40:40 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) 1.25 Lha^{-1}	28.40^{b}
T_4 :100% RDF ((60:40:40 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) 1.25 L ha^{-1} +Bio-control agent (*Trichoderma viride* 5kg ha^{-1})+(*Pseudomonas fluorescens*) 5L ha^{-1}	28.57^{a}
T_5:75%RDF (45:30:30 N P_2O_5 K_2O) kg ha^{-1}	26.80^{e}
T_6 : 75%RDF (45:30:30 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter)-1.25 Lha^{-1}	27.50^{c}
T_7 :75%RDF (45:30:30 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter)-1.25 L ha^{-1}+ Bio-control agent (*Trichoderma viride* 5kg ha^{-1})+(*Pseudomonas fluorescens*) 5L ha^{-1}	28.13^{b}
T_8: 50% RDF ((30:20:20 N P_2O_5 K_2O) kg ha^{-1}	26.03^{g}
T_9: 50% RDF (30:20:20 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) 1.25 L ha^{-1}	26.17^{g}
T_{10}: 50% RDF (30:20:20 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) 1.25 L ha^{-1}+ Bio-control agent (*Trichoderma viride* 5kg ha^{-1})+(*Pseudomonas fluorescens*) 5L ha^{-1}	26.53^{f}
Mean	**26.76**
SEm ±	**0.092**
CD @ 0.05	**0.27**

RDF(recommended dose of fertilizers), **PSB**(phospate solubilizing bacteria), **KSB**(potassium solubilizing bacteria), **DAT**(days after transplanting).

Table 4 : Effect of integrated nutrient management treatments on days to 50 percent flowering of chia.

T_1 : Absolute control	80.53^{c}
T_2 : 100% RDF (60:40:40 N P_2O_5 K_2O) kg ha^{-1}	83.67^{a}
T_3 :100% RDF (60:40:40 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) 1.25 Lha^{-1}	83.76^{a}
T_4 :100% RDF ((60:40:40 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) 1.25 L ha^{-1} +Bio-control agent (*Trichoderma viride* 5kg ha^{-1})+(*Pseudomonas fluorescens*) 5L ha^{-1}	83.80^{a}
T_5:75%RDF (45:30:30 N P_2O_5 K_2O) kg ha^{-1}	83.61^{a}
T_6 : 75%RDF (45:30:30 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter)-1.25 Lha^{-1}	83.69^{a}
T_7 :75%RDF (45:30:30 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter)-1.25 L ha^{-1}+ Bio-control agent (*Trichoderma viride* 5kg ha^{-1})+(*Pseudomonas fluorescens*) 5L ha^{-1}	83.71^{a}
T_8: 50% RDF ((30:20:20 N P_2O_5 K_2O) kg ha^{-1}	82.52^{b}
T_9: 50% RDF (30:20:20 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) 1.25 L ha^{-1}	83.50^{a}
T_{10}: 50% RDF (30:20:20 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) 1.25 L ha^{-1}+ Bio-control agent (*Trichoderma viride* 5kg ha^{-1})+(*Pseudomonas fluorescens*) 5L ha^{-1}	83.56^{a}
Mean	**83.24**
SEm±	**0.108**
CD @ 0.05	**0.324**

RDF(recommended dose of fertilizers), **PSB**(phospate solubilizing bacteria), **KSB**(potassium solubilizing bacteria), **DAT**(days after transplanting).

photoperiod and temperature. Similar variations in flowering time in response to nutrient levels and sowing conditions were reported by Singh *et al.* (2023).

Yield parameters

Seed yield hectare^{-1} (kg)

The relevant data on seed yield hectare^{-1} were presented in Table 5 and Fig. 1. From the table, it was noticed that the seed yield of chia hectare^{-1} ranged from 437.04 to 959.26 kg ha^{-1} with an average of 796.74 kg ha^{-1}. The highest seed yield of 959.26 kg ha^{-1} was recorded in T_4 (100% RDF (60:40:40 N:P_2O_5 :K_2O kg ha^{-1}) + PSB + KSB + Azotobacter (1.25 L^{-1}) + biocontrol agents (*Trichoderma viride* 5kg ha^{-1} + *Pseudomonas*

Table 5 : Effect of integrated nutrient management treatments on seed yield hectare^{-1} (kg) of chia.

T_1 : Absolute control	437.04^{j}
T_2 : 100% RDF (60:40:40 N P_2O_5 K_2O) kg ha^{-1}	834.81^{e}
T_3 :100% RDF (60:40:40 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) 1.25 Lha^{-1}	925.93^{b}
T_4 :100% RDF ((60:40:40 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) 1.25 L ha^{-1} +Bio-control agent (*Trichoderma viride* 5kg ha^{-1})+(*Pseudomonas fluorescens*) 5L ha^{-1}	959.26^{a}
T_5:75%RDF (45:30:30 N P_2O_5 K_2O) kg ha^{-1}	797.78^{f}
T_6 : 75%RDF (45:30:30 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter)-1.25 Lha^{-1}	871.85^{d}
T_7 :75%RDF (45:30:30 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter)-1.25 L ha $^{-1}$+ Bio-control agent (*Trichoderma viride* 5kg ha^{-1})+(*Pseudomonas fluorescens*) 5L ha^{-1}	920.450^{c}
T_8: 50% RDF ((30:20:20 N P_2O_5 K_2O) kg ha^{-1}	725.93^{i}
T_9: 50% RDF (30:20:20 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) 1.25 L ha^{-1}	753.33^{h}
T_{10}: 50% RDF (30:20:20 N P_2O_5 K_2O) kg ha^{-1}+ Biofertilizers (PSB+KSB+Azotobacter) 1.25 L ha^{-1}+ Bio-control agent (*Trichoderma viride* 5kg ha^{-1})+(*Pseudomonas fluorescens*) 5L ha^{-1}	770.37^{g}
Mean	**796.74**
SEm±	**0.004**
CD @ 0.05	**0.01**

RDF(recommended dose of fertilizers), **PSB**(phospate solubilizing bacteria), **KSB**(potassium solubilizing bacteria), **DAT**(days after transplanting)

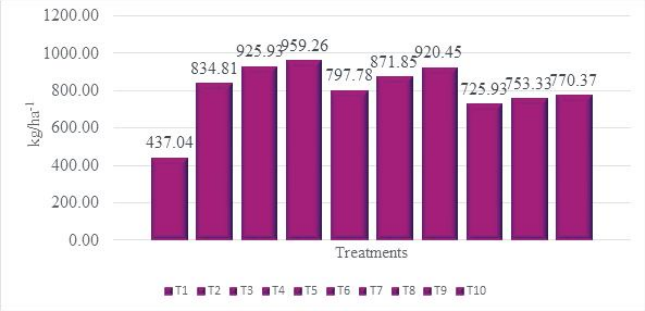


Fig. 1 : Effect of integrated nutrient management treatments on seed yield hectare^{-1} of chia.

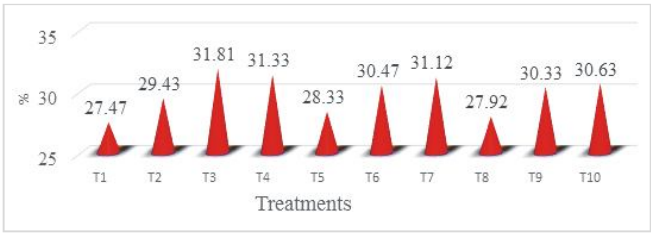


Fig. 2 : Effect of integrated nutrient management treatments swelling factor (%)of chia.

fluorescens 5L^{-1}), followed by T_7 (75 % RDF (45:30:30 N:P_2O_5 :K_2O kg ha^{-1}) + PSB + KSB + Azotobacter (1.25L^{-1}) + biocontrol agents (*Trichoderma viride* 5kg ha^{-1} + *Pseudomonas fluorescens* 5L^{-1}) (945.10 kg ha^{-1}) and T_3 (100% RDF (60:40:40 N:P_2O_5 :K_2O kg ha^{-1}) + PSB + KSB + Azotobacter (1.25L^{-1}) 925.93 kg ha^{-1}, which were statistically on par with T_4. The lowest seed yield of 437.04 kg ha^{-1} was recorded in T_1 (absolute control). The higher yield under T_4 may be attributed to improved nutrient availability and plant growth resulting from the combined application of fertilizers, biofertilizers and biocontrol agents.

The higher seed yield hectare^{-1} recorded in T_4 may be attributed to the combined application of fertilizers, biofertilizers and biocontrol agents, which may have improved nutrient availability, vegetative growth and seed formation. *Azotobacter,* PSB and KSB may have enhanced nutrient availability, while *Trichoderma viride* and *Pseudomonas fluorescens* may have supported root health and overall plant performance. These combined effects may have contributed to the maximum seed yield of 959.26 kg ha^{-1}. Similar findings on nutrient management in chia were reported by Pravalika *et al*. (2024).

Quality Parameters

Swelling factor (%)

From the Fig. 2, it was evident that **t**he swelling factor of chia seeds showed significant variation among the integrated nutrient management treatments. The swelling factor (%) ranging from 27.50 to 31.81. Maximum swelling factor of 31.81% was recorded on application of 100% RDF (60:40:40 N:P_2O_5 :K_2O kg ha^{-1}) + PSB + KSB + Azotobacter (1.25L^{-1}) + biocontrol agents (*Trichoderma viride* 5kg ha^{-1} + *Pseudomonas fluorescens* 5L^{-1}). It was statistically on par with T_3

(100% RDF (60:40:40 N:P_2O_5 :K_2O kg ha^{-1}) + PSB + KSB + Azotobacter (1.25L^{-1} (31.74%) and T_7 (75% RDF (45:30:30 N:P_2O_5 :K_2O kg ha^{-1}) + PSB + KSB + Azotobacter (1.25 L^{-1}) + biocontrol agents (*Trichoderma viride* 5kg ha^{-1} + *Pseudomonas fluorescens* 5L^{-1}) (30.81%), whereas minimum swelling factor of 27.50% was recorded in T_1 (absolute control).

The higher swelling factor recorded in T_4 may be attributed to the combined application of recommended fertilizers, biofertilizers and biocontrol agents, which may have improved nutrient availability and seed development. The improved availability of nitrogen, phosphorus and potassium may have supported plant metabolism and seed quality. Similar findings on the influence of nitrogen nutrition on swelling properties were reported by Karimzadeh and Omid (2004).

Conclusion

The present investigation revealed that integrated nutrient management practices improved the growth, yield and quality of chia (*Salvia hispanica* L.). Among the treatments, application of 100% RDF + PSB + KSB + Azotobacter + biocontrol agents (*Trichoderma viride* + *Pseudomonas fluorescens*) and application of 75% RDF + PSB + KSB + Azotobacter + biocontrol agents (*Trichoderma viride* + *Pseudomonas fluorescens*) recorded the maximum plant height, number of branches, number of inflorescences, seed yield and swelling factor. Thus, application of 60:40:40 kg N:P_2O_5 :K_2O kg ha^{-1} + PSB + KSB + Azotobacter (1.25L^{-1}) + biocontrol agents (*Trichoderma viride* 5kg ha^{-1} + *Pseudomonas fluorescens* 5L^{-1}) and 45:30:30 N:P_2O_5 :K_2O kg ha^{-1}) + PSB + KSB + Azotobacter (1.25L^{-1}) + biocontrol agents (*Trichoderma viride* 5kg ha^{-1} + *Pseudomonas fluorescens* 5L^{-1}) were the best-performing treatment for improving the productivity and quality of chia.

References

Appalla, P.K.M., Yogananda S.B., Thimmegowda P., Fathima P.S., Ananthakumar M.A. and Ramanji R.S. (2024). Performance of chia (*Salvia hispanica*) under spacing and nutrient management practices in Cauvery Command Area. *Int. J. Environ. Clim. Change*, **14(3)**, 313–324.

Fageria, N.K. (2009). *The Use of Nutrients in Crop Plants*. CRC Press, Boca Raton, Florida.

Harisha, C.B, Boraiah K.M., Basavaraj P.S., Halli H.M., Singh R.N., Rane J., Sammi Reddy K., Halagundegowda G.R., Chaudhary A., Verma A.K., Ravi Y., Asangi H. and Senthamil E. (2025). Optimizing sowing time and weather conditions for enhanced growth and seed yield of chia (*Salvia hispanica* L.) in semi-arid regions. *Peer J*., doi: 10.7717/Peer J.19210. PP:13-19.

Karimzadeh, G. and Omidbaigi R. (2004). Growth and seed characteristics of Isabgol (*Plantago ovata* Forsk) as influenced by some environmental factors. *J. Agricult. Sci. Technol.*, **6(3)**, 103–110.

Khanum, R., Siddayya, Ganapathy M.S., Anand S.R. and Ranganath G. (2025). Production and marketing constraints of chia cultivation: A study in Mysuru and Chamarajanagara district of Karnataka. *Mysore J. Agricult. Sci.*, **59(2)**, 292.

Panse, V.G. and Sukhatme P.V. (1985). *Statistical Methods for Agricultural Workers*. Indian Council of Agricultural Research, New Delhi.2nd edition.187-202.

Pravalika, K.M., Yogananda S.B., Thimmegowda P., Fathima P.S. and Ananth Kumar M.A. (2024). Influence of row spacing and organic nutrient management practices on growth, yield and nutrient uptake of chia (*Salvia hispanica*). *The Indian J. Agricult. Sci.*, **94(5)**, 518–522.

Singh, N.U., Venkatachalapathi V., Amrutha T.G., Naveen D.V. and Srinivasa Reddy M.V. (2023). Crop growth, yield attributes, yield and quality of chia (*Salvia hispanica* L.) as influenced by spacing and fertilizer levels. *Int. J. Environ. Clim. Change*, **13(10)**, 1585–1597

Soliman, W.S., Hendawy S.F., Abbas A.M., Salaheldin S. and Esmail S.M. (2024). Bio-stimulants as alternatives to mineral fertilizers: Influence on chia (*Salvia hispanica* L.) growth, yield and fatty acid composition. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, **52(2)**.

Ullah, R, Nadeem M., Khalique A., Imran M., Mehmood S., Javid A. and Hussain J. (2016). Nutritional and therapeutic perspectives of chia (*Salvia hispanica* L.): A review. *J. Food Sci. Technol*., **53(4)**, 1750–1758.