International Journal of Environment and Climate Change

Volume 13, Issue 10, Page 4005-4015, 2023; Article no.IJECC.107081
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Integrated Nutrient Management for Sustainable Sprouting Broccoli (*Brassica Oleracea* L. Var. *italica*) Production

Pranjal Singh [a++*], Sanjive Kumar Singh [a#], Ram Batuk Singh [a†], Ashutosh Upadhyay [a++] and Bankey Lal [a++]

[a] *Department of Vegetable Science, CSA University of Agriculture and Technology, Kanpur, U.P., India.*

Authors' contributions

This work was carried out in collaboration among all authors. Author PS did the data collection, wrote the first draft of the manuscript. Author SKS designed the research program. Author RBS provided the facilities required during the course of the research. Author AU did analysis of the study. Author BL managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2023/v13i103076

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/107081

Original Research Article

Received: 17/07/2023
Accepted: 21/09/2023
Published: 25/09/2023

ABSTRACT

Aim: The objective of the research was to study the effect of Integrated Nutrient Management on the vegetative growth of sprouting broccoli (*Brassica Oleracea* L. Var. *italica*) Var. Green Magic.
Study Design: The field experiment was conducted in Randomised Block Design (RBD).
Place and Duration of Study: The experiment was conducted at the Research Farm of the Department of Vegetable Science, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur U.P during the *Rabi* seasons of 2021-22 and 2022-23.

[++] *Ph.D Research Scholar;*
[#] *Assistant Professor;*
[†] *Associate Professor;*
**Corresponding author: E-mail: pranjals8996@gmail.com;*

Methodology: During bed preparation, the required quantity of farmyard manure (FYM), vermicompost and biofertilizers was mixed into the soil in individual specified plots according to the treatment. The treatments included $\mathbf{T_0}$: Control, $\mathbf{T_1}$: 100% RDF @ 120: 80: 60, N: P: K (kg/ha), $\mathbf{T_2}$: 75% RDF + 25% N through FYM, $\mathbf{T_3}$: 75% RDF + 25% N through Vermicompost, $\mathbf{T_4}$: 75% RDF + 25% N through FYM + Biofertilizer, $\mathbf{T_5}$: 75% RDF + 25% N through Vermicompost + Biofertilizer, $\mathbf{T_6}$: 75% RDF + 12.5% N through FYM + 12.5% N through Vermicompost, $\mathbf{T_7}$: 75% RDF + 12.5% N through FYM + 12.5% N through Vermicompost + Biofertilizer, $\mathbf{T_8}$: 50% RDF + 50% N through FYM, $\mathbf{T_9}$: 50% RDF + 50% N through Vermicompost, $\mathbf{T_{10}}$: 50% RDF + 50% N through FYM + Biofertilizer, $\mathbf{T_{11}}$: 50% RDF + 50% N through Vermicompost + Biofertilizer, $\mathbf{T_{12}}$: 50% RDF + 25% N through FYM + 25% N through Vermicompost and $\mathbf{T_{13}}$: 50% RDF + 25% N through FYM + 25% N through Vermicompost + Biofertilizer. Observations were recorded on plant height (cm) and plant spread (cm) at 30 DAT, 60 DAT and at maturity and on stalk length (cm) and stalk diameter (cm) at maturity.

Results: The treatment $\mathbf{T_{11}}$: 50% RDF + 50% N through Vermicompost + Biofertilizer outperformed all the other treatments in terms of plant height (cm), plant spread (cm), stalk length (cm) and stalk diameter (cm).

Conclusion: The study emphasizes the vital necessity of transitioning to INM with organic and inorganic fertilizers to preserve soil fertility, ecosystem health, and sustainable food production for future generations.

Keywords: Biofertilizer; Brassica oleracea L. Var. italica; FYM; INM; vermicompost.

1. INTRODUCTION

Broccoli, scientifically known as *Brassica olearacea L. var. italica*, holds a significant place among cruciferous vegetables. In India, broccoli cultivation is prominent in Himachal Pradesh, the hilly areas of Uttar Pradesh as well as Jammu and Kashmir and the northern plains. Broccoli is a nutritional powerhouse, boasting high levels of essential vitamins. It is notably rich in vitamin C, known for its immuno-boosting properties and antioxidant benefits. Furthermore, broccoli serves as an excellent source of vitamin A, essential for vision and skin health, vitamin B2 (riboflavin), which supports various metabolic processes in the body, and calcium, crucial for strong bones and teeth [1]. These key factors attribute to the surge in popularity of broccoli among the affluent health-conscious individuals of the country.

In today's market, the growing demand for vegetables has pushed farmers to produce higher yields thus intensifying competition in the agricultural sector. To achieve this, farmers have turned to the application of heavy doses of chemical fertilizers to boost growth and yield. This overreliance on chemical fertilizers, in an attempt to increase food and fiber production has paradoxically resulted in diminishing productivity over time, despite the apparent nutrient abundance. Hence, there arises a pressing need for farmers to adopt a more balanced approach to plant nutrition management. This involves integrating organic and inorganic fertilizers in a judicious manner, a practice known as integrated nutrient management (INM). Integrated nutrient management not only enhances and maintains soil fertility but also benefits the physical, chemical, and biological properties of the soil [2]. Moreover, it helps prevent deficiencies in secondary and micronutrients, ensuring a more sustainable agricultural system. Accordingly, the present study was undertaken to know the effect on Integrated Nutrient Management on vegetative growth of sprouting broccoli.

2. METHODOLOGY

The experiment was conducted during *Rabi* seasons of 2021-22 and 2022-23 at the Research Farm of the Department of Vegetable Science, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur U.P. Geographically, Kanpur is situated in the alluvial belt of Gangetic Plains of Central Zone of U.P. It is positioned at 25.26" and 26.58" North latitude and 79.31" and 80.34" East longitude at an altitude of 127 meter above the mean sea level (MSL). This investigation was aimed at knowing the effect of Integrated Nutrient Management on the vegetative growth of sprouting broccoli Var. Green Magic. The experiment was laid out in a Randomized Block Design (RBD) with fourteen treatments in three replications. The treatments included $\mathbf{T_0}$ **:** Control, $\mathbf{T_1}$ **:** 100% RDF @ 120: 80: 60, N: P: K (kg/ha), $\mathbf{T_2}$ **:** 75% RDF + 25% N through FYM, $\mathbf{T_3}$ **:** 75% RDF + 25% N through Vermicompost, $\mathbf{T_4}$ **:** 75% RDF + 25% N through FYM + Biofertilizer, $\mathbf{T_5}$ **:** 75% RDF + 25% N through Vermicompost + Biofertilizer, **T_6 :** 75% RDF + 12.5% N through FYM + 12.5% N through Vermicompost, **T_7 :** 75% RDF + 12.5% N through FYM + 12.5% N through Vermicompost + Biofertilizer, **T_8 :** 50% RDF + 50% N through FYM, **T_9 :** 50% RDF + 50% N through Vermicompost, **T_{10}:** 50% RDF + 50% N through FYM + Biofertilizer, **T_{11} :** 50% RDF + 50% N through Vermicompost + Biofertilizer, **T_{12}:** 50% RDF + 25% N through FYM + 25% N through Vermicompost and **T_{13}:** 50% RDF + 25% N through FYM + 25% N through Vermicompost + Biofertilizer. Initially, seedlings were raised under a polyhouse in Pro-trays, and they were ready for transplanting to the main field in approximately 28-30 days. Meanwhile, during bed preparation, the required quantity of farmyard manure (FYM) and vermicompost was broadcasted and mixed into the soil in individual specified plots according to the treatment combinations to ensure proper mineralization before seedling transplanting. Nonetheless, biofertilizers like PSB and *Azotobacter* were mixed into the soil a mere 2-3 days prior to transplanting. Nitrogen, phosphorus, and potash were applied in the form of urea (46% N), di-ammonium phosphate (46% P_2O_5), and muriate of potash (60% K_2O), respectively. As per treatment combinations, the entire recommended dose of phosphorus, potassium, and one-third of the nitrogen was applied during transplanting. The remaining half of the nitrogen was split into two doses, one 30 days after transplanting and the other just before head initiation. The remaining half dose of nitrogen was split into two applications, with the first occurring at 30 days after transplanting and the second just before head initiation. Four weeks old healthy and uniform seedlings having 4-5 leaves with an average height of about 8-10 cm were transplanted in well prepared experimental plots in straight lines during evening hours at a spacing of 60 cm × 45 cm. Subsequently, the recommended package of practices for cultivation was diligently followed. Observations were recorded on five randomly selected plants per replication for plant height (cm) and plant spread (cm) at 30 DAT, 60 DAT and at maturity and on stalk length (cm) and stalk diameter (cm) at maturity. The field data recorded for agronomic traits were statistically analyzed using randomized block design (RBD), as per [3].

3. RESULTS AND DISCUSSION

The data recorded on vegetative parameters clearly indicated that the plant height (cm), plant spread (cm), Stalk length (cm) and stalk diameter (cm) were significantly influenced by the integrated nutrient management practices.

3.1 Plant Height (cm)

The data illustrating the impact of integrated nutrient management on plant height (cm) is presented in Table 1 and Fig. 1. At 30 days after transplantation (DAT), the highest plant heights of 27.13 cm and 28.90 cm were observed in **T_{11}:** 50% RDF + 50% N through Vermicompost + Biofertilizer. In contrast, the lowest plant heights of 19.04 cm and 19.92 cm were recorded in **T_0:** Control. Furthermore at 60 DAT, the tallest plants, measuring 49.49 cm and 50.58 cm, were found in **T_{11}:** 50% RDF + 50% N through Vermicompost + Biofertilizer. Conversely, the shortest plants at this stage were in **T_0:** Control, with heights of 42.10 cm and 44.38 cm. Upon reaching the harvesting stage, the maximum plant heights were observed in **T_{11}:** 50% RDF + 50% N through Vermicompost + Biofertilizer, reaching 51.03 cm and 52.31 cm. Meanwhile, **T_0:** Control exhibited the minimum plant heights at this stage, measuring 46.63 cm and 47.66 cm. The observed effect can be attributed to the combined benefits of Vermicompost and biofertilizers. Vermicompost supplies essential micronutrients like zinc, calcium, copper, and iron at optimal levels, aids in nutrient retention from inorganic fertilizers, enhances soil properties, and boosts microbial activity, making both micro and macro nutrients readily available. Biofertilizers, on the other hand, serve as microbial inoculants, facilitating the decomposition of organic matter. This synergistic combination of 50 % RDF, Vermicompost and biofertilizers collectively contribute to improved plant growth. This finding is in confirmity with the results of [4-8].

3.2 Plant Spread (cm)

The data in Table 2 and Fig. 2 showcases the effects of integrated nutrient management on plant spread. At 30 DAT, the most extensive plant spread, measuring 37.13 cm and 37.53 cm, was observed in **T_{11}:** 50% RDF + 50% N through Vermicompost + Biofertilizer. In contrast, the minimum plant spread, 25.87 cm and 26.32 cm, was recorded in **T_0:** Control. Subsequently at 60 DAT, the maximum plant spreads of 58.67 cm and 59.91 cm were found again in **T_{11}:** 50% RDF + 50% N through Vermicompost + Biofertilizer. Conversely, the smallest plant spread at this stage was in **T_0:** Control, with measurements of

Table 1. The effect of integrated nutrient management on plant height (cm) of sprouting broccoli

Plant height (cm)							
Treatment Details		**At 30 DAT**		**At 60 DAT**		**At Maturity**	
		2021-22	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**
T_0	Control	19.04	19.92	42.10	44.38	46.63	47.66
T_1	100% RDF @ 120: 80: 60, N: P: K (kg/ha)	23.01	23.72	45.70	46.59	48.85	49.10
T_2	75% RDF + 25% N through FYM	23.43	24.01	45.18	45.60	46.01	46.62
T_3	75% RDF + 25% N through Vermicompost	24.14	25.01	44.97	45.73	48.05	49.57
T_4	75% RDF + 25% N through FYM + Biofertilizer	23.78	24.54	47.11	47.98	48.99	49.30
T_5	75% RDF + 25% N through Vermicompost + Biofertilizer	25.21	25.54	48.06	48.74	48.86	49.52
T_6	75% RDF + 12.5% N through FYM + 12.5% N through Vermicompost	22.83	23.71	46.69	47.62	48.21	48.83
T_7	75% RDF + 12.5% N through FYM + 12.5% N through Vermicompost + Biofertilizer	21.74	22.75	46.74	47.73	48.67	48.56
T_8	50% RDF + 50% N through FYM	22.75	25.25	47.09	48.44	50.20	51.14
T_9	50% RDF + 50% N through Vermicompost	23.15	25.85	46.39	47.78	49.79	49.68
T_{10}	50% RDF + 50% N through FYM + Biofertilizer	24.25	26.11	48.23	48.85	48.68	49.61
T_{11}	50% RDF + 50% N through Vermicompost + Biofertilizer	27.13	28.90	49.49	50.58	51.03	52.31
T_{12}	50% RDF + 25% N through FYM + 25% N through Vermicompost	24.11	25.34	44.83	45.53	48.11	48.60
T_{13}	50% RDF + 25% N through FYM + 25% N through Vermicompost + Biofertilizer	25.79	27.28	49.13	49.30	50.13	50.78
	SE(m) ±	**0.569**	**4.863**	**1.093**	**0.851**	**0.655**	**0.602**
	CD (P=0.05)	**1.66**	**0.69**	**3.18**	**2.47**	**1.90**	**1.75**

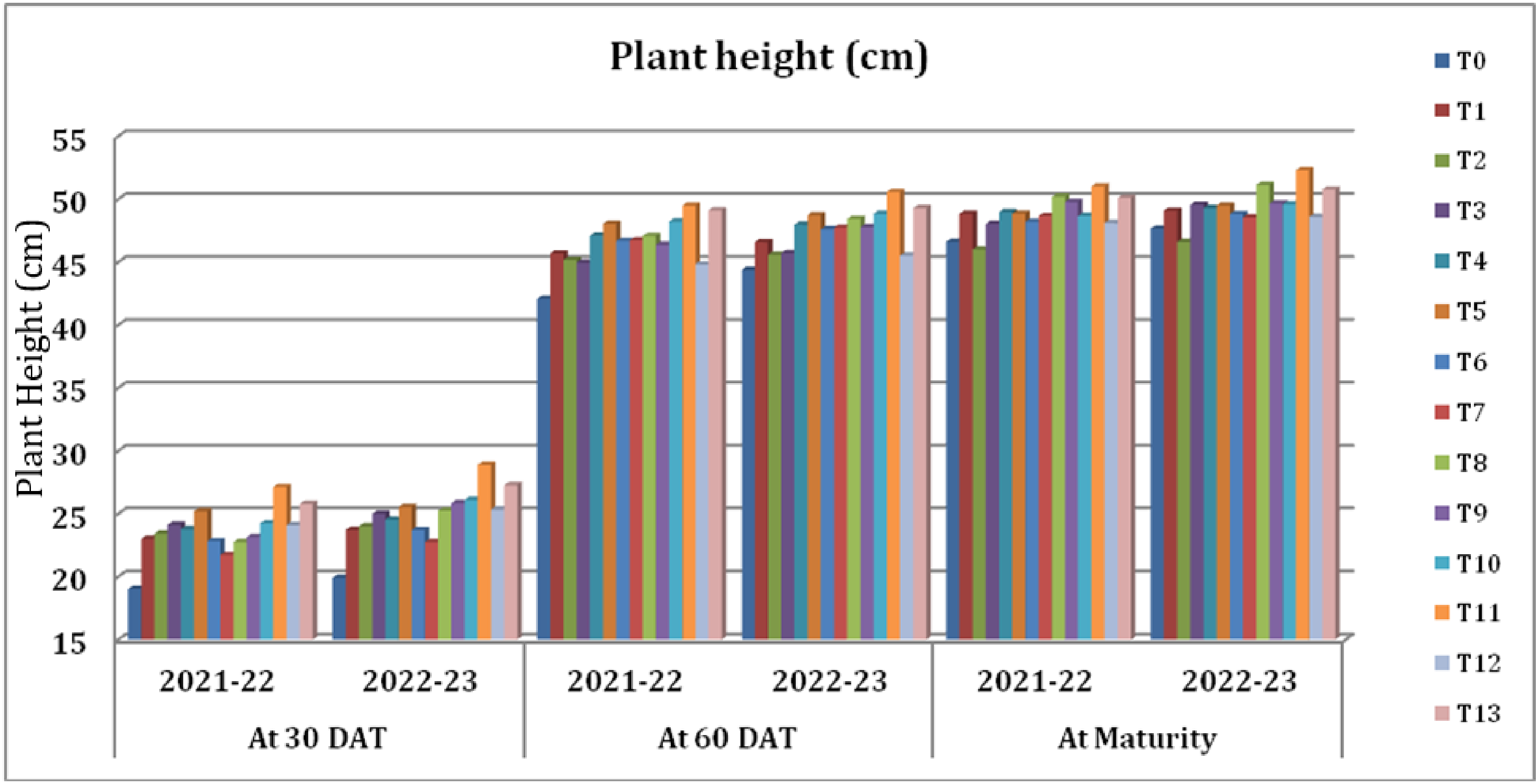

Fig. 1. The effect of integrated nutrient management on plant height (cm) of sprouting broccoli

Table 2. The effect of Integrated Nutrient Management on Plant spread (cm) of sprouting broccoli

Plant spread (cm)							
Treatment Details		**At 30 DAT**		**At 60 DAT**		**At Maturity**	
		2021-22	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**
T_0	Control	25.87	26.32	48.23	49.03	53.19	55.22
T_1	100% RDF @ 120: 80: 60, N: P: K (kg/ha)	31.20	30.82	50.53	51.79	59.46	60.07
T_2	75% RDF + 25% N through FYM	32.31	33.66	54.52	55.48	55.19	56.94
T_3	75% RDF + 25% N through Vermicompost	28.89	29.99	48.37	49.34	58.46	59.11
T_4	75% RDF + 25% N through FYM + Biofertilizer	34.34	34.14	49.65	51.52	67.23	67.30
T_5	75% RDF + 25% N through Vermicompost + Biofertilizer	34.26	34.96	54.47	56.85	67.36	67.69
T_6	75% RDF + 12.5% N through FYM + 12.5% N through Vermicompost	35.81	36.78	56.25	53.34	67.53	67.93
T_7	75% RDF + 12.5% N through FYM + 12.5% N through Vermicompost + Biofertilizer	34.81	35.61	54.84	55.46	65.00	66.10
T_8	50% RDF + 50% N through FYM	34.70	34.26	56.08	56.51	67.34	67.85
T_9	50% RDF + 50% N through Vermicompost	33.92	33.42	54.50	56.60	66.53	67.20
T_{10}	50% RDF + 50% N through FYM + Biofertilizer	34.02	34.20	54.73	55.39	67.17	68.00
T_{11}	50% RDF + 50% N through Vermicompost + Biofertilizer	37.13	37.53	58.67	59.91	68.80	70.05
T_{12}	50% RDF + 25% N through FYM + 25% N through Vermicompost	30.14	31.36	57.42	57.80	59.73	60.46
T_{13}	50% RDF + 25% N through FYM + 25% N through Vermicompost + Biofertilizer	35.37	35.54	55.00	55.93	66.30	67.78
	SE(m) ±	**1.247**	**1.222**	**1.461**	**1.198**	**0.434**	**0.576**
	CD (P=0.05)	**3.62**	**3.55**	**4.27**	**3.50**	**1.26**	**1.68**

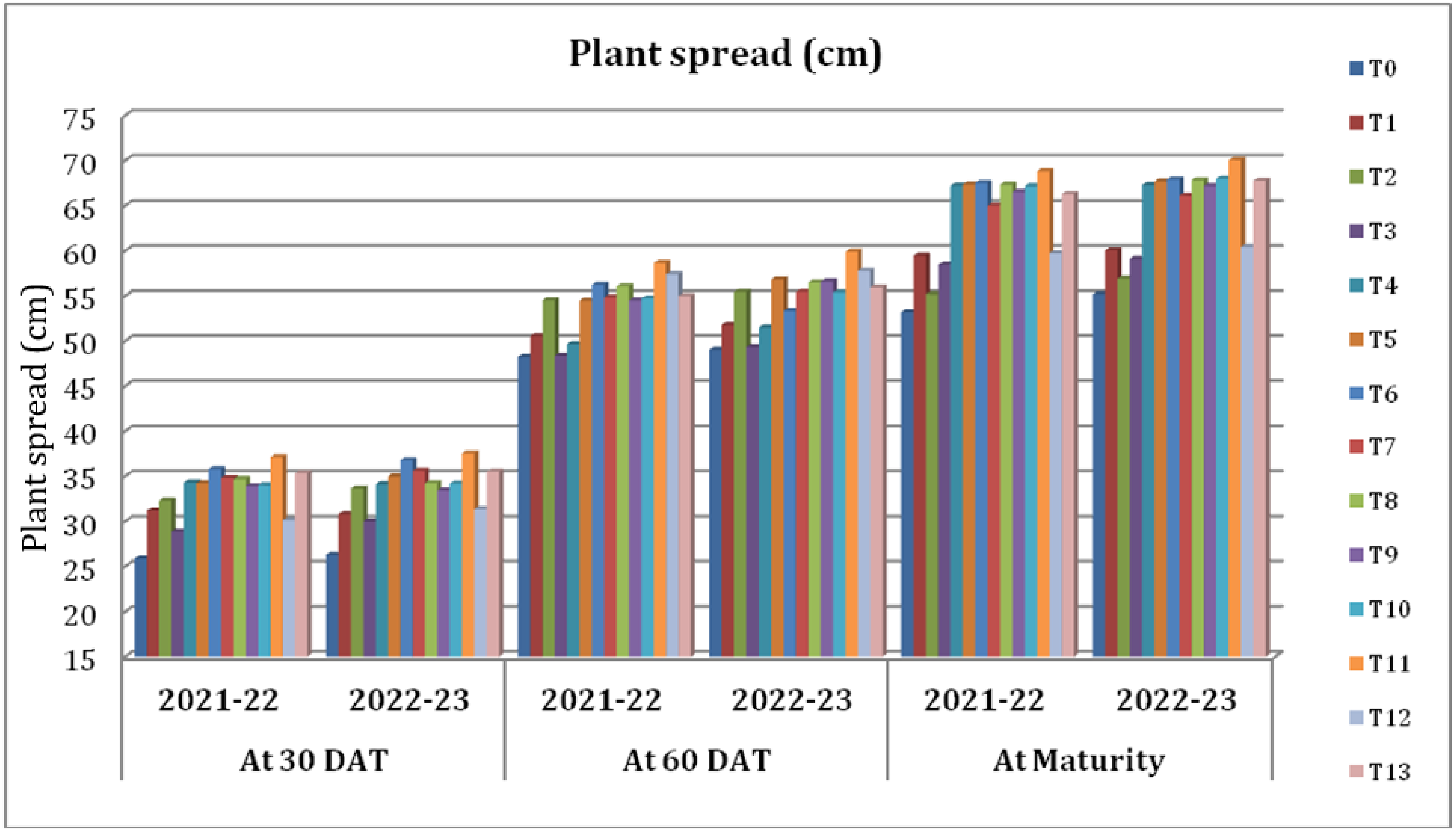

Fig. 2. The effect of integrated nutrient management on plant spread (cm) of sprouting broccoli

48.23 cm and 49.03 cm. Upon reaching the harvesting stage, the maximum plant spread was observed in **T_{11}:** 50% RDF + 50% N through Vermicompost + Biofertilizer, reaching 68.80 cm and 70.05 cm. Meanwhile, **T_0:** Control exhibited the minimum plant spread at this stage, measuring 53.19 cm and 55.22 cm. The plant spread and various growth parameters were notably amplified when biofertilizer and vermicompost were applied in combination, as demonstrated in studies [9-14]. Nitrogen is recognized as a pivotal nutrient for optimal plant growth and development. The improved plant spread achieved by applying nitrogen through vermicompost and biofertilizer can be attributed to the favourable soil conditions they foster, including enhanced moisture retention capabilities and increased availability of major nutrients.

3.3 Stalk Length (cm)

The data depicting the influence of integrated nutrient management on stalk length (cm) have been displayed in Table 3 and Fig. 3. At the final harvest the maximum stalk length (cm) of 20.81 cm and 22.10 cm was recorded with the application of **T_{11} :** 50% RDF + 50% N through Vermicompost + Biofertilizer. Whereas the minimum stalk length of 13.52 cm and 14.57 cm was recorded in **T_0:** Control. Similar results were reported [15]. Accordingly, the best treatment increased broccoli stalk length by optimizing nutrient availability, improving moisture retention, enhancing soil conditions and promoting the activity of beneficial microbes in the soil. This treatment provides essential nutrients like nitrogen and micronutrients, supporting plant growth and cell elongation for longer stalks.

3.4 Stalk Diameter (cm)

The data illustrating the impact of integrated nutrient management on stalk diameter (cm) is presented in Table 4 and Fig. 4. During the harvesting stage, the plots treated with **T_{11} :** 50% RDF + 50% N through Vermicompost + Biofertilizer exhibited the maximum stalk diameter of 4.03 cm and 4.62 cm. In contrast, **T_0:** Control reported minimum stalk diameter of 2.17 cm and 2.83 cm. results parallel to the present study were reported [16]. Accordingly, the most effective treatment combination according to the present study, delivers ample essential nutrients, including nitrogen and micronutrients, in a well-balanced manner. This nutrient equilibrium fosters cell expansion and growth, consequently leading to thicker stalks.

Table 3. The effect of Integrated Nutrient Management on stalk length (cm) of sprouting broccoli

Stalk length (cm)			
Treatment Details		**At 30 DAT**	
		2021-22	**2022-23**
T_0	Control	13.52	14.57
T_1	100% RDF @ 120: 80: 60, N: P: K (kg/ha)	15.35	16.02
T_2	75% RDF + 25% N through FYM	16.12	16.42
T_3	75% RDF + 25% N through Vermicompost	17.25	18.22
T_4	75% RDF + 25% N through FYM + Biofertilizer	19.12	20.15
T_5	75% RDF + 25% N through Vermicompost + Biofertilizer	17.84	18.35
T_6	75% RDF + 12.5% N through FYM + 12.5% N through Vermicompost	18.16	19.57
T_7	75% RDF + 12.5% N through FYM + 12.5% N through Vermicompost + Biofertilizer	19.02	20.42
T_8	50% RDF + 50% N through FYM	19.06	20.58
T_9	50% RDF + 50% N through Vermicompost	20.19	20.41
T_{10}	50% RDF + 50% N through FYM + Biofertilizer	19.28	20.41
T_{11}	50% RDF + 50% N through Vermicompost + Biofertilizer	20.81	22.10
T_{12}	50% RDF + 25% N through FYM + 25% N through Vermicompost	17.31	18.39
T_{13}	50% RDF + 25% N through FYM + 25% N through Vermicompost + Biofertilizer	19.33	20.26
	SE(m) ±	**0.568**	**0.712**
	CD (P=0.05)	**1.65**	**2.07**

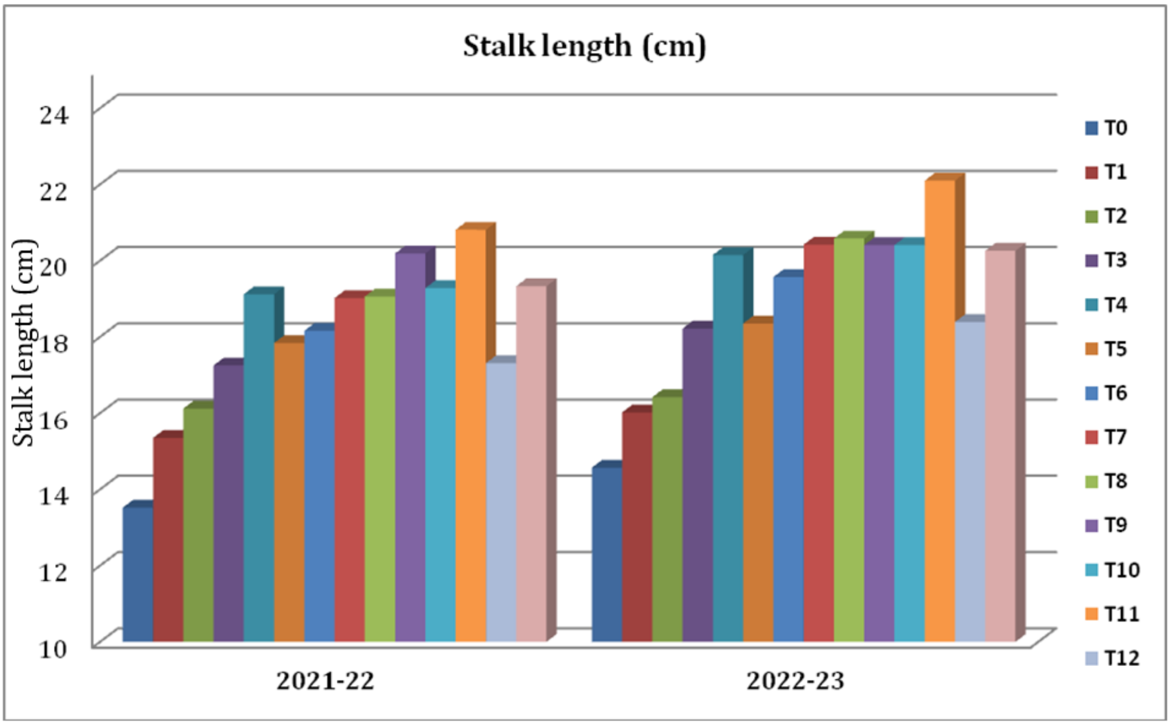

Fig. 3. The effect of integrated nutrient management on stalk length (cm) of sprouting broccoli

Table 4. The effect of Integrated Nutrient Management on stalk diameter (cm) of sprouting broccoli

Treatment Details		Stalk diameter (cm) At 30 DAT	
		2021-22	2022-23
T_0	Control	2.17	2.83
T_1	100% RDF @ 120: 80: 60, N: P: K (kg/ha)	2.75	3.73
T_2	75% RDF + 25% N through FYM	2.63	3.79
T_3	75% RDF + 25% N through Vermicompost	2.75	3.75
T_4	75% RDF + 25% N through FYM + Biofertilizer	2.84	3.87
T_5	75% RDF + 25% N through Vermicompost + Biofertilizer	2.61	3.58
T_6	75% RDF + 12.5% N through FYM + 12.5% N through Vermicompost	2.73	4.08
T_7	75% RDF + 12.5% N through FYM + 12.5% N through Vermicompost + Biofertilizer	2.89	3.59
T_8	50% RDF + 50% N through FYM	3.15	3.87
T_9	50% RDF + 50% N through Vermicompost	2.85	3.70
T_{10}	50% RDF + 50% N through FYM + Biofertilizer	2.94	3.75
T_{11}	50% RDF + 50% N through Vermicompost + Biofertilizer	4.03	4.62
T_{12}	50% RDF + 25% N through FYM + 25% N through Vermicompost	2.67	3.52
T_{13}	50% RDF + 25% N through FYM + 25% N through Vermicompost + Biofertilizer	3.01	4.15
	SE(m) ±	0.176	0.158
	CD (P=0.05)	0.51	0.46

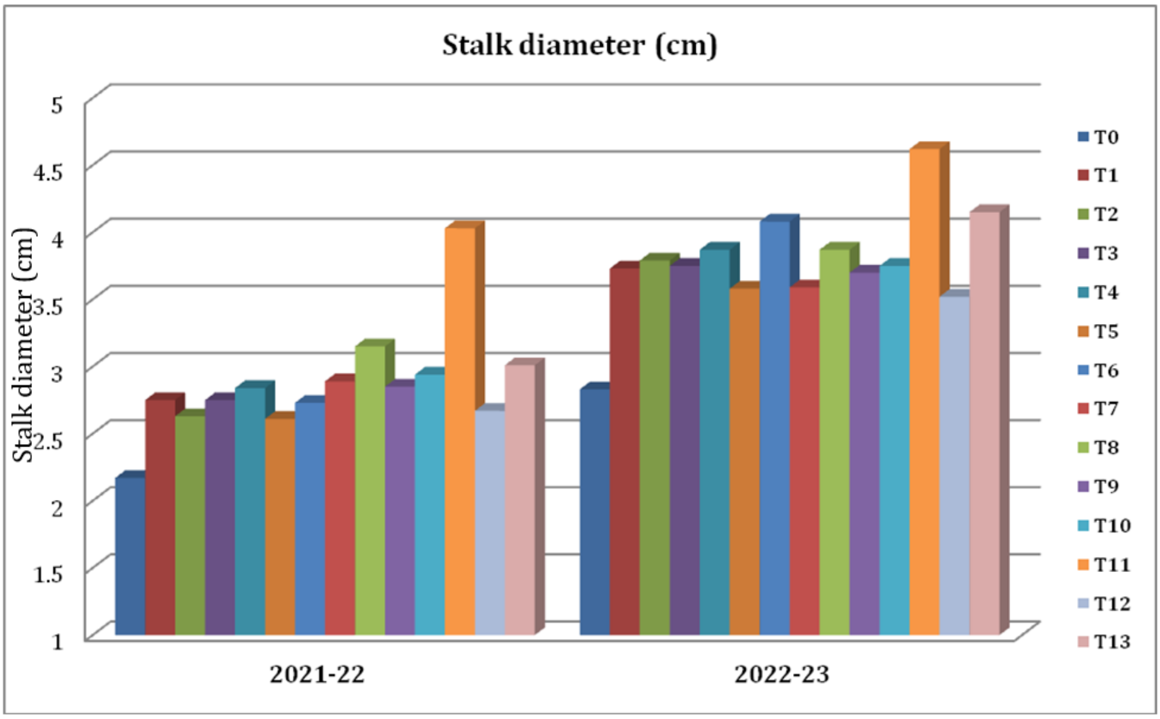

Fig. 4. The effect of integrated nutrient management on stalk diameter (cm) of sprouting broccoli

4. CONCLUSION

In this study, it is evident that treatment **T_{11}:** 50% RDF + 50% N through Vermicompost + Biofertilizer outperformed all the other treatments in terms of plant height (cm), plant spread (cm), stalk length (cm) and stalk diameter (cm). Fundamentally, this study highlights the need to shift from chemical fertilizers to INM with organic and inorganic fertilizers from the imperative to protect soil fertility, maintain ecosystem health, and ensure sustainable food production for the future. This transition isn't just a matter of choice, it's an essential mandate to safeguard the health of ecosystems and secure the welfare of generations to come.

ACKNOWLEDGEMENTS

The authors extend their heartfelt gratitude to the department where this study was conducted for their invaluable support and resources. Your assistance was instrumental in the successful completion of this research.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/107081