Eco. Env. & Cons. 30 (1) : 2024; pp. (338-344)
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ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2024.v30i01.061

Optimising Vegetative Growth in Sprouting Broccoli through Integrated Nutrient Management for Sustainability

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(Received 20 July, 2023; Accepted 23 September, 2023)

ABSTRACT

As a sustainable approach to nutrient management, soil application of organic and inorganic fertilizers in an integrated manner can enhance the growth parameters of sprouting broccoli. In this context, a field experiment was conducted with broccoli Var. Green Magic 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 with the objective to study the effect of Integrated Nutrient Management (INM) on the vegetative growth of sprouting broccoli. The experiment was laid out in a Randomized Block Design (RBD) with fourteen treatments in three replications. The required quantity of NPK as per the recommended dose of fertilizer, farmyard manure (FYM), vermicompost and biofertilizers were added to the soil at the time of bed preparation. The results revealed that the treatment, **T_{11}:** 50% RDF + 50% N through Vermicompost + Biofertilizer, outperformed all the other treatments in terms of all the growth parameters. The plots administered with this treatment demonstrated more number of leaves per plant, with greater leaf lengths and wider leaves. Therefore, this approach can be considered a highly favourable alternative to the indiscriminate use of chemical fertilizers, which can deplete soil nutrition and quality in an uncontrolled manner.

Key words: *INM, Sprouting broccoli, Vegetative growth, Vermicompost*

Introduction

Brassica oleracea var. *italica*, commonly referred to as broccoli, occupies a prominent position among cruciferous vegetables in India. Its cultivation is notably prevalent in regions such as Himachal Pradesh, the hilly areas of Uttar Pradesh, Jammu and Kashmir, and the northern plains. Broccoli is distinguished as a nutritional powerhouse, characterized by elevated levels of essential vitamins. Particularly, it exhibits a substantial content of vitamin C, renowned for its immunomodulatory and antioxidant attributes. Additionally, broccoli serves as an abundant source of vitamin A, pivotal for ocular health and cutaneous integrity, vitamin B2 (riboflavin), which plays a fundamental role in diverse metabolic processes, and calcium, essential for the development of robust skeletal and dental structures (Sanwal *et al.* 2006). These nutritional attributes underscore the burgeoning popularity of broccoli, especially among the health-conscious demographic population, particularly those of higher socioeconomic strata.

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In modern agriculture, the increasing demand for vegetables has pushed farmers to try and grow more to meet this demand. This has made farming more competitive. To attain this objective, farmers have resorted to the liberal application of chemical fertilizers, aiming to stimulate vegetative growth and augment crop yield. Ironically, despite the abundance of nutrients in these fertilizers, this heavy reliance on chemicals has actually led to lower productivity over time. Consequently, a compelling need emerges for farmers to adopt a more nuanced approach to plant nutrition management. They should consider a more balanced approach, which means using a mix of organic and inorganic fertilizers. This approach, called integrated nutrient management (INM), not only improves and maintains soil fertility but also makes the soil's physical, chemical, and biological properties better. It also reduces the risk of nutrient deficiencies, including important secondary and micronutrients. All of this can help create a more sustainable agricultural system. In alignment with these principles, the present study is embarked upon to elucidate the ramifications of Integrated Nutrient Management on the vegetative growth of sprouting broccoli.

Materials and Methods

The experiment was undertaken during the *Rabi* cropping seasons of 2021-22 and 2022-23 at the Research Farm, Department of Vegetable Science, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, Uttar Pradesh. The primary objective of the investigation was to assess the effects of Integrated Nutrient Management (INM) on the vegetative growth parameters of sprouting broccoli var. Green Magic. The experimental design adopted for this research was a Randomized Block Design (RBD) featuring fourteen distinct treatments, each with three replications. The treatments included T_0 : Control, T_1 : 100% RDF @ 120: 80: 60, N: P: K (kg/ha), T_2 : 75% RDF + 25% N through FYM, T_3 : 75% RDF + 25% N through Vermicompost, T_4 : 75% RDF + 25% N through FYM + Biofertilizer, 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 cultivated within a controlled environment polyhouse for approximately 28-30 days before transplanting them in the field. Subsequently, during the bed preparation phase, precise quantities of farmyard manure (FYM) and vermicompost were methodically incorporated into the soil of designated plots, adhering to the treatment-specific combinations. Furthermore, biofertilizers, specifically Phosphate Solubilizing Bacteria (PSB) and *Azotobacter*, were inoculated into the soil 2-3 days prior to the transplantation event. To meet the nutritional requirements of the sprouting broccoli, nitrogen, phosphorus, and potassium were administered in the form of urea (46% N), di-ammonium phosphate (46% P_2O_5), and muriate of potash (60% K_2O), respectively, in accordance with the treatment protocols. During the transplantation phase, the entire recommended dosage of phosphorus and potassium, in conjunction with one-third of the total nitrogen, was dispensed. The remaining 50% of nitrogen was judiciously split into two applications, with one occurring 30 days post-transplantation and the other immediately preceding head initiation. Vigorous and uniform seedlings, aged around four weeks and characterized by the presence of 4-5 leaves and an average height ranging between 8-10 cm, were transplanted into meticulously prepared experimental plots. These seedlings were spaced at intervals of 60 cm × 45 cm. Subsequently, the recommended agronomic practices for broccoli cultivation were rigorously implemented. Observations were recorded on five randomly selected plants per replication for number of leaves per plant, leaf length (cm) and leaf width (cm) at three critical stages namely 30 days after transplanting (DAT), 60 DAT, and at the point of maturity. The data obtained were subjected to statistical analysis and the results have been documented and presented in tabular form.

Results and Discussion

The data recorded on vegetative parameters clearly indicated that the number of leaves per plant, leaf length (cm) and leaf width (cm) were significantly influenced by the integrated nutrient management practices.

Number of leaves per plant

Table 1 and Figure 1 present empirical data elucidating the influence of integrated nutrient management on number of leaves per plant. At 30 days after transplantation (DAT), it was observed that the application of T_{11}: 50% RDF + 50% N through Vermicompost + Biofertilizer, resulted in the highest number of leaves per plant, recording values of 9.07 and 10.10. In contrast, T_0: Control exhibited the lowest leaf count at this stage, registering figures of 6.37 and 6.72. Upon reaching the 60 DAT, T_{11}: 50% RDF + 50% N through Vermicompost + Biofertilizer, maintained its supremacy with the maximum leaf count of 17.08 and 16.67. Conversely, T_0: Control continued to demonstrate the least number of leaves, ascertaining values of 11.23 and 11.90. Upon reaching the harvesting stage, the maximum number of leaves was observed in T_{11}: 50% RDF + 50% N through Vermicompost + Biofertilizer, valued at 18.27 and 19.79. Meanwhile, T_0: Control exhibited the minimum number of leaves at this stage, registering values of 11.77 and 12.60.

The utilization of a combined application of organic fertilizers such as vermicompost and biofertilizers holds tremendous potential for significantly enhancing the performance of broccoli plants. This heightened performance of broccoli plants characterized by an increased leaf count per plant, can be ascribed to the boost in soil microbial activity facilitated by the application of these organic inputs. Vermicompost and biofertilizers provide a nourishing environment for beneficial soil microorganisms, fostering their proliferation. The enhanced nutrient uptake is a crucial element in the equation. As the plants have access to a richer nutrient source, they can more efficiently satisfy their nutritional requirements. This, in turn, translates to an augmentation in

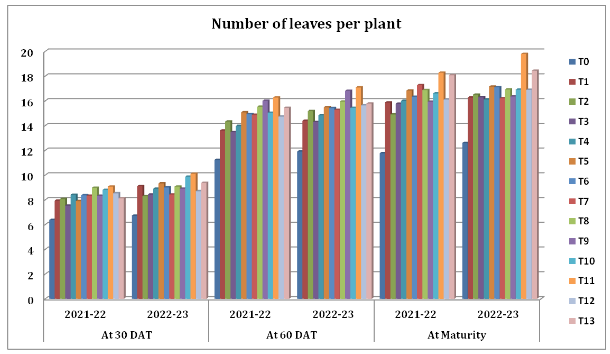

Fig. 1. The effect of Integrated Nutrient Management on number of leaves per plant of sprouting broccoli

Table 1. The effect of Integrated Nutrient Management on number of leaves per plant of sprouting broccoli

Treatment	Details	Number of leaves per plant					
		At 30 DAT		At 60 DAT		At Maturity	
		2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
T_0	Control	6.37	6.72	11.23	11.90	11.77	12.60
T_1	100% RDF @ 120: 80: 60, N: P: K (kg/ha)	7.93	9.10	13.60	14.39	15.87	16.27
T_2	75% RDF + 25% N through FYM	8.07	8.30	14.33	15.17	14.90	16.50
T_3	75% RDF + 25% N through Vermicompost	7.53	8.43	13.47	14.29	15.77	16.30
T_4	75% RDF + 25% N through FYM + Biofertilizer	8.40	8.90	13.97	14.84	16.00	16.11
T_5	75% RDF + 25% N through Vermicompost + Biofertilizer	7.90	9.33	15.07	15.48	16.83	17.15
T_6	75% RDF + 12.5% N through FYM + 12.5% N through Vermicompost	8.37	9.00	14.93	15.42	16.33	17.10
T_7	75% RDF + 12.5% N through FYM + 12.5% N through Vermicompost + Biofertilizer	8.33	8.43	14.87	15.27	17.27	16.21
T_8	50% RDF + 50% N through FYM	8.97	9.07	15.52	15.94	16.87	16.92
T_9	50% RDF + 50% N through Vermicompost	8.33	8.90	16.00	16.81	15.93	16.35
T_{10}	50% RDF + 50% N through FYM + Biofertilizer	8.80	9.87	15.03	15.43	16.60	16.90
T_{11}	50% RDF + 50% N through Vermicompost + Biofertilizer	9.07	10.10	16.27	17.08	18.27	19.79
T_{12}	50% RDF + 25% N through FYM + 25% N through Vermicompost	8.53	8.70	14.73	15.63	16.10	16.89
T_{13}	50% RDF + 25% N through FYM + 25% N through Vermicompost + Biofertilizer	8.13	9.37	15.43	15.78	18.07	18.43
	SE(m) ±	0.330	0.386	0.663	0.677	0.443	0.432
	CD (P=0.05)	0.96	1.12	1.93	1.97	1.29	1.25

the overall photosynthetic processes within the broccoli plants. Similar results were reported by Meena *et al*. (2017), Mohanta *et al.* (2018), Singh *et al.* (2020) and Sagar *et al.* (2023). where they provided empirical evidence of the positive correlation between organic fertilizer application, increased soil microbial activity, nutrient uptake, and enhanced photosynthesis in plants which leads to a good vegetative growth in broccoli.

Leaf length (cm)

The impact of integrated nutrient management on leaf length (cm) is depicted in Table 2 and Figure 2. Notably, at 30 days after transplanting (DAT), the treatment T_{11} :: 50% RDF + 50% N through Vermicompost + Biofertilizer yielded the longest leaves, measuring 9.60 cm and 10.09 cm. In contrast, T_0: Control recorded the shortest leaves at 5.80 cm and 6.47 cm during the same period. Moving forward to 60 DAT, T_{11} : 50% RDF + 50% N through Vermicompost + Biofertilizer continued to excel with the greatest leaf length of 49.96 cm and 49.01 cm, while T_0: Control exhibited the minimum leaf length of 33.53 cm and 34.51 cm. At the final harvest stage, T_{11} : 50% RDF + 50% N through Vermicompost + Biofertilizer consistently produced the longest leaves, measuring 48.88 cm and 50.06 cm. In contrast, T_0: Control recorded the minimum leaf length of 37.95 cm and 38.92 cm.

Atal *et al.* (2019) in his study underscores the beneficial impact of vermicompost on vegetable production. The favourable impact of both organic and inorganic fertilizers on leaf length within the framework of Integrated Nutrient Management (INM) can be ascribed to various fundamental mechanisms. Vermicompost enriches the soil with essential nutrients, particularly nitrogen, crucial for chlorophyll production and leaf growth. It also enhances soil structure and root development, enabling more efficient nutrient uptake. Additionally, the synergy of beneficial soil microorganisms and the nitrogen-fixing ability of biofertilizers further accentuate the positive effects on leaf length. The combined application of vermicompost and biofertilizer in INM creates a conducive growth environment, resulting in longer and healthier broccoli leaves, as supported by previous studies by Manivannan and Singh (2004), Dass *et al.* (2009), Sharma *et al*. (2018) and Tiwari *et al*. (2021).

Leaf Width (cm)

The data portraying the influence of integrated nutrient management on leaf width (cm) have been displayed in Table 3 and Figure 3. At 30 DAT, the

Table 2. The effect of Integrated Nutrient Management on Leaf length (cm) of sprouting broccoli

Treatment	Details	Leaf length (cm)					
		At 30 DAT		At 60 DAT		At Maturity	
		2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
T_0	Control	5.80	6.47	33.53	34.51	37.95	38.92
T_1	100% RDF @ 120: 80: 60, N: P: K (kg/ha)	7.42	8.81	37.59	36.22	38.21	39.79
T_2	75% RDF + 25% N through FYM	8.27	9.01	36.05	38.88	39.02	40.08
T_3	75% RDF + 25% N through Vermicompost	8.49	9.16	37.53	38.22	43.96	45.11
T_4	75% RDF + 25% N through FYM + Biofertilizer	9.19	8.46	40.71	41.58	42.10	43.15
T_5	75% RDF + 25% N through Vermicompost + Biofertilizer	9.42	9.99	42.23	43.81	42.69	43.79
T_6	75% RDF + 12.5% N through FYM + 12.5% N through Vermicompost	8.75	8.45	41.47	42.20	42.80	43.74
T_7	75% RDF + 12.5% N through FYM + 12.5% N through Vermicompost + Biofertilizer	9.04	9.71	39.41	40.10	45.39	46.50
T_8	50% RDF + 50% N through FYM	8.41	9.19	42.99	43.48	45.04	46.63
T_9	50% RDF + 50% N through Vermicompost	8.19	8.31	39.44	41.59	42.90	43.88
T_{10}	50% RDF + 50% N through FYM + Biofertilizer	8.94	9.36	42.68	43.46	44.47	45.50
T_{11}	50% RDF + 50% N through Vermicompost + Biofertilizer	9.60	10.09	46.96	49.01	48.88	50.06
T_{12}	50% RDF + 25% N through FYM + 25% N through Vermicompost	8.25	8.90	41.19	41.54	42.53	42.82
T_{13}	50% RDF + 25% N through FYM + 25% N through Vermicompost + Biofertilizer	9.18	9.68	44.97	45.64	45.20	46.21
	SE(m) ±	0.367	0.363	1.59	1.406	1.368	1.558
	CD (P=0.05)	1.07	1.06	4.65	4.09	3.97	4.53

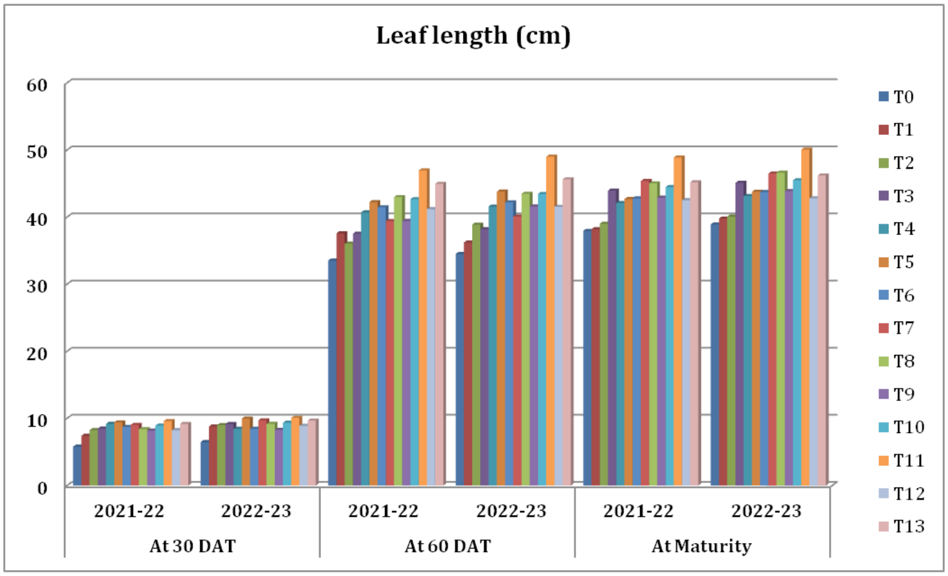

Fig. 2. The effect of Integrated Nutrient Management on Leaf length (cm) of sprouting broccoli

application of T_{11}: 50% RDF + 50% N through Vermicompost + Biofertilizer resulted in the most significant leaf width, registering values of 6.70 cm and 7.79 cm. Conversely, T_0: Control exhibited notably narrower leaves, with dimensions of 3.10 cm and 3.47 cm. As the study progressed to 60 DAT, the trend persisted, with T_{11}: 50% RDF + 50% N through Vermicompost + Biofertilizer consistently yielding the widest leaves at 21.69 cm and 23.60 cm, while T_0: Control remained comparatively restricted in leaf width at 15.66 cm and 14.03 cm. At the conclusive harvest stage, the effectiveness of T_{11}: 50% RDF +

Table 3. The effect of Integrated Nutrient Management on leaf width (cm) of sprouting broccoli

Treat-ment	Details	Leaf width (cm)					
		At 30 DAT		At 60 DAT		At Maturity	
		2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
T_0	Control	3.10	3.47	15.66	14.03	16.91	17.91
T_1	100% RDF @ 120: 80: 60, N: P: K (kg/ha)	4.25	4.81	17.24	16.75	18.85	19.90
T_2	75% RDF + 25% N through FYM	4.49	5.03	16.84	17.80	18.37	19.08
T_3	75% RDF + 25% N through Vermicompost	4.68	5.15	16.70	17.76	19.34	20.79
T_4	75% RDF + 25% N through FYM + Biofertilizer	5.14	4.93	17.67	18.01	19.81	20.11
T_5	75% RDF + 25% N through Vermicompost + Biofertilizer	4.84	5.65	20.14	21.52	21.04	23.13
T_6	75% RDF + 12.5% N through FYM + 12.5% N through Vermicompost	4.77	4.57	19.34	20.69	20.57	22.38
T_7	75% RDF + 12.5% N through FYM + 12.5% N through Vermicompost + Biofertilizer	4.83	5.49	18.24	19.34	22.51	26.55
T_8	50% RDF + 50% N through FYM	4.73	5.00	20.78	21.71	22.37	23.43
T_9	50% RDF + 50% N through Vermicompost	4.83	5.61	20.47	19.87	21.04	22.63
T_{10}	50% RDF + 50% N through FYM + Biofertilizer	5.04	4.97	19.07	21.20	24.29	24.62
T_{11}	50% RDF + 50% N through Vermicompost + Biofertilizer	6.70	7.79	21.69	23.60	25.52	27.44
T_{12}	50% RDF + 25% N through FYM + 25% N through Vermicompost	4.48	5.05	18.03	16.47	21.27	22.63
T_{13}	50% RDF + 25% N through FYM + 25% N through Vermicompost + Biofertilizer	5.39	5.53	20.68	22.80	24.95	25.93
	SE(m) ±	0.303	0.206	0.653	0.727	0.773	0.802
	CD (P=0.05)	0.88	0.60	1.91	2.11	2.25	2.33

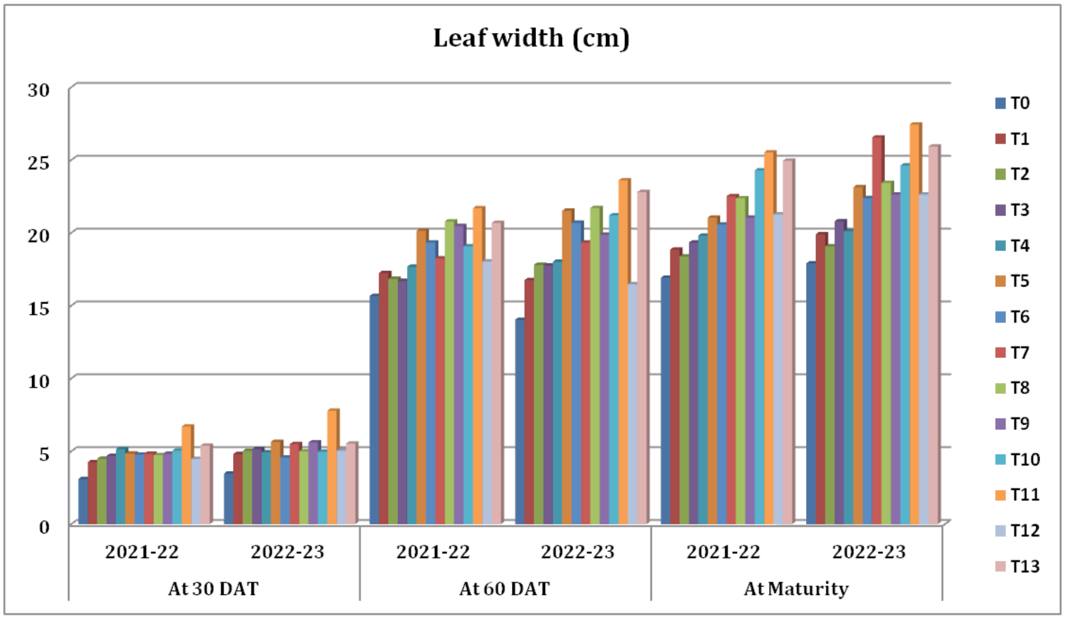

Fig. 3. The effect of Integrated Nutrient Management on leaf width (cm) of sprouting broccoli

50% N through Vermicompost + Biofertilizer in promoting leaf width became even more pronounced, recording measurements of 25.52 cm and 27.44 cm, while T_0: Control sustained the narrowest leaf width at 16.91 cm and 17.91 cm.

The integrated nutrient management (INM) approach, which includes organic manure and specifically vermicompost, can have a positive effect on leaf width in broccoli, as it enhances the overall growth and nutrient availability for the plant (Akbar *et al*., 2009). Accordingly, the application of organic manure in treatments appears to have a positive impact on the growing environment, primarily by enhancing aeration and water holding capacity. This improvement in environmental conditions is likely responsible for increasing fertilizer use efficiency. Subsequently, this enhanced growth due to the application of vermicompost can be attributed to several factors associated with it, including its ability to hold moisture, supply micronutrients, and make major nutrients more accessible due to favourable soil conditions. It is worth noting that the nitrogen content present in these organic inputs, plays a pivotal role in stimulating the growth of leaf buds. Nitrogen is a crucial component for plant growth, particularly in leafy vegetables like broccoli. The availability of nitrogen in organic fertilizers like vermicompost can significantly contribute to an increase in leaf width.

Conclusion

In this study, it is evident that the treatment T_{11}: 50% RDF + 50% N through Vermicompost + Biofertilizer outperformed all the other treatments in terms of number of leaves, leaf length and leaf width. At its core, this research underscores the necessity of transitioning away from chemical fertilizers and embracing Integrated Nutrient Management (INM) through the use of both organic and inorganic fertilizers. This shift is crucial for preserving soil fertility, upholding ecosystem well-being, and securing a sustainable future for food production. It’s not merely a matter of preference but rather an imperative to protect ecosystems’ vitality and ensure the well-being of future generations.

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.

Conflict of Intrests

The authors declare that they have no conflict of interests.

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