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INFLUENCE OF FOLIAR APPLICATION OF VITAMINS ON GROWTH AND YIELD OF TURMERIC (*CURCUMA LONGA* L.)

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ABSTRACT

Vitamins are considered as endogenous plant growth stimulants that play an important role in many physiological processes. With the increasing demand for production of turmeric vitamins can be used as a new and affordable organic technology to increase the nutrient efficiency of the plant, yield and maintain the environmental health. The present experiment was carried out during two (2023-24 and 2024-25) seasons at HRS, BCKV to study the influence of foliar spray of ascorbic acid (25,50,75 and 100 ppm), thiamine (25,50,75 and 100 ppm), folate (25,50,75 and 100 ppm) and niacin (25,50,75 and 100 ppm) and control. Results revealed that that foliar application of these vitamins significantly increased the growth and yield of turmeric plants, particularly at high level of concentrations. The increment was observed with increasing the concentration as compared to control. The best results obtained in ascorbic acid 100 ppm followed by folate 100 ppm which were associated with highest plant height, number of tillers and leaves per plant as well as weight of clump, plot yield and other clump characters of turmeric.

***Keywords*:** Turmeric, Vitamins, Ascorbic acid, Niacin, Folate and Thiamine.

Introduction

Turmeric is one of the major spices grown in various parts of India which is the largest producer, consumer and exporter in the world. It is a rhizomatous perennial herb and native of South East Asia, commonly referred as “Golden spice” and "Indian saffron" (Ravindran *et al.*, 2007). *Curcuma longa* L. is an important spice crop belonging to the family Zingiberaceae and has wide applications in daily culinary activities in household kitchen to dyeing industry since time immemorial. It also has extensive application as condiment, flavouring and colouring agent. Turmeric has also been used as a remedy for many diseases because of anti-cancer and anti-viral activities, hence finds use in the drug and cosmetic industry. It is being used for stomach diseases, blood purification, eliminate germs, liver protection and cholesterol level reduction (Singh *et al.*, 2003). The increasing demand for natural products as food additives makes turmeric an ideal choice as a food colorant. Turmeric grows best in hot and humid climate, requiring loamy, loose and friable soil having pH of 5.5-7 (Mirjanaik and Vishwanath, 2020). Being a long-duration crop, turmeric quickly depletes soil fertility and necessitates the addition of minerals and fertilizers for soil revitalization.

Vitamins are organic compounds that occur in various forms and are thought to be necessary for the proper growth of plants because they participate in physicochemical processes that sustain the plant functions. By acting as coenzymes, altering variables that regulate many physiological processes, including enzyme synthesis and stimulating growth even at low concentrations, these bio-regulator chemicals have a major impact on plant growth (Aziz *et al.,* 2009). The application of vitamins promotes alpha-ketoglutaric acid production, which forms proteins and amino acids when it reacts with ammonia. This process helps regulate the occurrence of disorders and promotes the manufacture of natural hormones such as IAA, cytokinin and gibberellins, as well as promoting cell division, plant pigments, enzymes, organic compounds and overall plant metabolism (Samiullah *et al.,* 1988). Vitamins applied topically have a major effect on variables that regulate plant growth, which in turn affect several physiological processes (Sadak and Dawood, 2014).

Ascorbic acid serves as a significant redox buffer and a cofactor for enzymes that control hormone production, photosynthesis and the regeneration of other antioxidants. It is involved in the numerous vital biological processes, including photo-inhibition, cell elongation, the cell cycle and numerous other significant enzymatic events (Rafique *et al.,* 2011). Folic acid plays a crucial role as a cofactor in different plant metabolic processes. According to Shohag *et al.* (2011), it contributes to DNA biosynthesis and methylation, two processes essential to regular cell activity. Nicotinamide adenine dinucleotide (NAD^+) and nicotinamide adenine dinucleotide phosphate ($NADP^+$) are the active forms of niacin (Vitamin B_3), which is a substitute derivative of pyridine. It supports the plant's defence mechanism and participates in numerous enzymatic oxidation and reduction activities, including NADH and NADPH, which transport hydrogen ions in energy-releasing reactions (Abdelhamid *et al*., 2013). Thiamine, is an essential element of the vitamin-B group and helps to mitigate drought stress. It functions as a coenzyme in the decarboxylation of α-keto acids, which are important in the metabolism of lipids and carbohydrates and include pyruvic acid and keto-glutamic acid (Sadak *et al.,* 2022).

El-Hak *et al.* (2012) suggested that foliar treatment of 200 ppm ascorbic acid augmented the plant height, nitrogen (N) and protein percentage in seeds, seed yield and quality of pea cv. Master. The application of ascorbic acid (100 ppm) resulted in considerably increased average tuber weight and marketable tuber yield (Gouda *et al.,* 2015) and ascorbic acid at 75 mg l^{-1} on broccoli plants (Ali and Majeed, 2023). Mehrdad *et al*. (2020) reported that the yield, quantitative and qualitative traits of tuberose (*Polianthes tuberosa* L.) were impacted by the application of varying levels of folic acid (0, 50, 100 and 150 mg l^{-1}) and coriander plants fed with 50 mM folic acid exhibited the highest levels of fresh biomass in the plants (Khan *et al*., 2022). Foliar application of niacin (200 ppm) greatly enhanced the plant height and dry weight of onion bulbs grown under salinity conditions (Hussein *et al*., 2014). Vendruscolo *et al.* (2023) evaluated the effects of thiamine (200 mg l^{-1}), niacin (200 mg l^{-1}) and 100 mg l^{-1} of each on growth of two lettuce cultivars resulted applying thiamine and niacin together considerably improved the fresh biomass for both cultivars by roughly 30% when compared to the control. Nahed *et al.* (2009) demonstrated that the *Gladiolus grandiflorum* L. plants exhibited enhanced vegetative growth and flowering with the application of thiamine and ascorbic acid at 100 ppm and increasing the concentration of thiamine from 50 to 200 ppm resulted in greater levels of soluble sugars and total phenols.

A relative method of fertilizing plants is foliar application, which is a simple procedure with benefits including quicker application, higher effectiveness, more accurate targeting and less ecological impact (Yadav *et al.,* 2023). It is also employed to apply plant nutritional components, growth regulators, stimulants, amino acids, pesticides and nanomaterials (Simoes *et al.,* 2017). Foliar fertilization is one of the best methods for applying fertilizers when there are problems with soil fixation and it usually uses less nutrient than soil application. The capacity to apply nutrients in small amounts without generating phytotoxicity is the main advantage of foliar nutrition (Oosterhuis and Weir, 2010).

Realizing the potentiality and importance of vitamins on growth, development and quality improvements in other crops the present investigation has been formulated to improve the growth, yield and quality of turmeric.

Material and Methods

The field experiment was carried out using complete randomised block design with three replications during 2023-24 and 2024-25 at Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, West Bengal to investigate the different concentrations of Ascorbic acid, Thiamine, Folate and Niacin influence on growth and yield characters of turmeric plants. The main objective of the study was to standardise the most effective vitamins and their concentration for improving the production of turmeric.

Treatment details

T_1- Ascorbic acid @ 25 ppm	T_{10} – Folate @ 50 ppm
T_2- Ascorbic acid @ 50 ppm	T_{11} – Folate @ 75 ppm

T_3- Ascorbic acid @ 75 ppm
T_4- Ascorbic acid @ 100 ppm
T_5- Thiamine @ 25 ppm
T_6- Thiamine @ 50 ppm
T_7- Thiamine @ 75 ppm
T_8- Thiamine @ 100 ppm
T_9- Folate @ 25 ppm
T_{12} – Folate @ 100 ppm
T_{13} – Niacin @ 25 ppm
T_{14} – Niacin @ 50 ppm
T_{15} – Niacin @ 75 ppm
T_{16} – Niacin @ 100 ppm
T_{17}–Control(Water spray)

Spray schedule: Vitamins were applied at 60, 90 and 120 days after planting.

The land was ploughed and levelled and divided into $3m^2$ area and the turmeric rhizomes of having size of 25-30 g (cv. Suguna) were planted with a spacing of 30cm×25cm. Total experimental area was applied with recommended dose of FYM (25 t ha^{-1}) at the time of land preparation and mineral fertilisers (NPK - 150:60:150 kg ha^{-1}) as basal and in two splits at 45 and 90 days after planting. Mulching with paddy straw and irrigation was done immediately after planting. Weeding and earthing up was done at monthly intervals and based on requirement in later stages. The vitamins Ascorbic acid, Thiamine, Folate and Niacin each with four different concentrations of 25, 50, 75 and 100 ppm were dissolved in water along with spreading agent and foliar sprayed in three intervals at 60, 90 and 120 days after planting. The control plots (RDF) were sprayed with distilled water.

Data recorded

Vegetative/Growth parameters

Five turmeric plants were selected randomly from each plot/replication, tagged and labelled and the following vegetative growth characters were recorded: plant height (cm), number of tillers, number of leaves, length of leaf (cm) and leaf breadth (cm).

Yield parameters

At the time of harvesting, the rhizome clump of selected five plants from each plot were cleaned off and the following data recorded for individual clump: weight of clump (g), length and breadth of clump (cm), weight of primary fingers (g) and secondary fingers (g) and mother rhizome (g), number of primary and secondary fingers. The plot yield (kg) was also calculated by considering the total rhizome yield from each plot.

Statistical analysis

The data related to all parameters were subjected to statistical analysis using variance techniques as describe by Gomez and Gomez (1984) and Panse and Sukhatme (1967). The significance of different treatments was tested by 'F' test at probability level of 0.05. The critical differences (CD) were calculated at 5% level of significance.

Results

Plant height

The findings (Table. 1) clearly showed that plant height of turmeric at different growth stages significantly influenced by the foliar application of vitamins in both the years. The maximum plant height was recorded in ascorbic acid 75 ppm (111.71 cm) at 90 days and thiamine 100 ppm (141.29 cm) at 120 days after planting. But in case of 150 and 180 days after planting, the application of ascorbic acid 100 ppm recorded the maximum height of plant (162.80 cm and 169.86 cm, respectively). The control recorded minimum height throughout the growth stages (84.60 cm, 99.73 cm, 129.38 cm and 141.09 cm). The increasing trend in plant height was observed in with increasing concentration up to highest level in four vitamins except folate where highest height was noticed up to 75 ppm.

Number of tillers $clump^{-1}$

The steady increase in production of tillers per clump was observed with the foliar application of vitamins up to highest concentration. Different treatments exhibited significant variations in various growth phases of turmeric with respect to production of tillers. Maximum number of tillers per clump at 90 and 180 days after planting was recorded under folate 100 ppm (1.68 and 4.54), conversely, the minimum number of tillers with the folate 25 ppm (1.20 and 3.24), respectively. Number of tillers per clump at 120 days after planting highest in thiamine 50 ppm (3.09) and at 150 days after planting with application of thiamine 100 ppm (4.06) treatments exhibited the highest number of tillers and while the lowest number of tillers were noted under control at 120 days (2.08) and 150 days after planting (2.76).

Number of leaves $clump^{-1}$

The average number of leaves under various vitamins treatments (Table. 3) showed significant variations throughout the growth period. As per pooled analysis, it is clearly observed that highest number of leaves per clump was counted under the treatment of folate 100 ppm (7.79, 14.27 and 16.56) at 90, 150 and 180 days after planting. But in case of 120 days after planting, treatment with the maximum number of leaves per clump (10.92) was observed in ascorbic acid 100 ppm. the lowest number of leaves were recorded in niacin 25 ppm (5.03 and 11.46) at 90 and 180 DAP, respectively. Whereas the control recorded with the lowest number of leaves 120 days (7.22) and 159 days (9.78) after planting. The increasing trends in production of leaves were noticed in both folate and niacin up to highest concentration used (25-100 ppm) but in case of ascorbic acid and thiamine it was noticed up to 75 ppm then slight reduction.

Length of leaf

The data in respect of leaf length is (Table. 4) clearly stated that foliar application of thiamine 100 ppm recorded highest leaf length (60.17 cm and 69.70 cm), as compared to lowest length of leaf (43.08 cm and 51.36 cm) was recorded in treatment of folate 25 ppm after 90 and 120 days planting, respectively. At 150 and 180 days after planting, foliar application of ascorbic acid 100 ppm recorded maximum leaf length (77.36 cm and 81.94 cm), whereas the minimum leaf length (61.40 cm and 67.53cm) was recorded under control, respectively.

Breadth of leaf

The data illustrated in the Table. 5 showed significant variations at various crop growth stages. At 90 days of planting, highest leaf breadth was recorded in ascorbic acid 75 ppm (16.47 cm) and ascorbic acid 100 ppm (17.31 cm, 17.80 cm and 18.35 cm) at 120, 150 and 180 days after planting, respectively. Conversely, the lowest leaf breadth was observed under the treatment of folate 25 ppm at 90 days (11.88 cm), 120 days (13.63 cm) and 150 days (14.98 cm) after planting. The minimum breadth of leaf (15.58 cm) was recorded in the control treatment at 180 DAP. The increased concentrations of vitamins enhanced the breadth of leaf. The steady increase in leaf breadth was observed in all four vitamins with increasing dose up to highest level.

Yield Parameters

Weight, length and breadth of clump

The treatments of vitamins exhibited significant variations in respect of clump weight of turmeric during both the years (Table. 6). An increase in clump weight was observed with increasing concentrations of all vitamins up to high level. The maximum clump weight was observed with the treatment of ascorbic acid 100 ppm (390.51 g) and minimum weight was recorded in control (269.86 g). Among the various treatments, the clump length was varied from 16.45 cm to 21.82 cm as per pooled analysis. The maximum length of clump was noticed in ascorbic acid 100 ppm (21.82 cm) and the plants under control (16.45 cm) recorded the minimum clump length. The highest breadth of clump was recorded in treatment of folate 100 ppm (16.38 cm) and the lowest was associated with the control (12.46 cm).

Number and weight of primary fingers

The data related to primary finger number is presented in Table. 7. The number of primary fingers in a clump is significantly influenced by the foliar application of various vitamins, as their number has increases with increasing concentration of vitamins. Maximum number of primary fingers were recorded in the treatment of ascorbic acid 100 ppm (10.86) and minimum was recorded in thiamine 25 ppm (7.28). Significant differences were observed among the treatments with respect to weight of primary fingers per clump (Table. 8). The pooled analysis was clearly indicated that maximum weight of primary fingers was recorded with the treatment of folate 100 ppm (218.45 g) and the lowest weight was associated in control (163.01 g).

Number and weight of secondary fingers

During the two years of study (Table. 7), significant differences were observed with number of secondary fingers per clump. The highest number of secondary fingers per clump was recorded in the treatment folate 100 ppm (21.01), while the lowest number was observed in control (11.25). The weight of secondary fingers showed significant variations due to different vitamins treatments during both the years and in pooled analysis (Table. 8). Maximum weight of secondary fingers was recorded in ascorbic acid 100 ppm (127.97 g) and minimum were associated with control (75.45 g).

Weight of mother rhizome Yield per plot (kg/3m^2)

It was evident from the Table. 8. that the significantly highest weight of mother rhizome per clump was observed in thiamine 100 ppm (55.83 g), followed by folate 100 ppm (51.32 g) as compared to lowest weight of mother rhizome in niacin 25 ppm (32.69 g). Data pertaining to plot yield (Table. 7) indicated significant differences among different treatments. Enhanced plot yield was observed with increasing concentrations of vitamins. The highest plot yield was recorded in ascorbic acid 100ppm (14.96 kg), followed by folate 100 ppm (14.16 kg) and the lowest plot yield was recorded in untreated control (10.37 kg).

Discussion

The exogenous application of vitamins as foliar sprays has shown significant potential in improving plant physiological processes. Vitamins such as ascorbic acid, thiamine, folic acid and niacin play crucial roles as cofactors, antioxidants and metabolic regulators, influencing a wide range of physiological functions that directly or indirectly enhance plant growth, stress tolerance and productivity (Youssif *et al.,* 2017). In tuber crops, which are often sensitive to oxidative stress during bulking stages, ascorbic acid application may help maintain membrane integrity, enhance carbon assimilation and promote tuber enlargement through improved photosynthetic and metabolic stability. Moreover, it supports cell division and wall synthesis, which are crucial during the expansion of underground storage organs (Shafeek *et al.,* 2020).

Helal *et al.* (2005) reported that foliar application of vitamin C increased the plant height, number of leaves per plant, pods per plant, seed yield, total leaf chlorophyll and crude protein content in seeds of pea. These finding are in good agreement with the finding of El-Hak *et al.* (2012) in pea. Application ascorbic acid 100 ppm resulted in a significant increase in plant height and chlorophyll content in squash plant (Hussain and Mustaf, 2019). Vendruscolo *et al.* (2023) reported that combined application of thiamine (100 ppm) and niacin (100 ppm) considerably improved fresh mass of 30% as compared to control in lettuce and Leonel *et al.* (2024) in carrot. The beneficial effect of ascorbic acid was also observed by Gahory *et al.* (2022) in coriander.

Folic acid has positive role on photosynthesis and increases chlorophyll content. It regulates hormone production, promotes cell division, regulate nucleic acid and protein synthesis and enhance nutrient uptake in faba bean (Al-Maliky *et al.*, 2019). Folic acid spray led to increase in growth of potato plants may be due to many cellular reactions such as, metabolism of amino acids, synthesis of methionine and the formation of lignin, chlorophyll and in the photo-respiration cycle Al-Said and Kamal. (2008). Aminifard *et al.* (2018) found that thiamine application at the rate of 250, 500 and 700 ppm increased the growth and yield-related attributes in fenugreek and coriander.

Conclusion

The present investigation revealed that foliar application of ascorbic acid, folate, niacin and thiamine had a positive effect on growth and yield of turmeric. Vitamins acts as organic fertilizers can be used as a new and convenient substitute to commercial growth regulators. Spraying of vitamins to the turmeric plants along with recommended dose of fertilizers and farm yard manure might be increased the nutrient efficiency, thereby improving the growth and yield. Different treatments of vitamins significantly increased the yield of turmeric especially at higher concentrations as compare to control. Therefore, vitamins application could be recommended for enhancing the turmeric production, particularly ascorbic acid at 100 ppm recorded the maximum growth and yield attributes followed by folate 100 ppm.

Table 1 : Influence of foliar application of vitamins on plant height of turmeric

Treatments	Plant height (cm)											
	90 DAP			120 DAP			150 DAP			180 DAP		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1	90.42	108.28	99.35	117.13	122.75	119.94	136.21	154.01	145.11	142.91	159.20	151.06
T_2	97.68	107.07	102.38	122.96	125.64	124.30	139.58	153.32	146.45	152.01	167.89	159.95
T_3	111.22	112.19	111.71	129.40	125.50	127.45	153.75	164.33	159.04	159.82	160.03	159.93
T_4	105.09	114.69	109.89	138.55	132.05	135.30	163.73	161.87	162.80	169.54	170.17	169.86
T_5	94.15	106.24	100.20	125.88	133.03	129.46	148.65	155.79	152.22	155.38	161.05	158.22
T_6	108.99	113.41	111.20	134.49	127.75	131.12	159.31	154.56	156.94	156.41	169.69	163.05
T_7	100.98	110.32	105.65	135.71	136.33	136.02	149.39	163.99	156.69	168.36	162.69	165.53
T_8	107.05	114.21	110.63	145.31	137.26	141.29	162.14	162.07	162.11	166.06	168.52	167.29
T_9	85.57	104.42	95.00	103.79	115.49	109.64	150.49	145.63	148.06	149.13	153.03	151.08
T_{10}	84.32	89.23	86.78	127.40	126.29	126.85	141.85	152.17	147.01	156.07	159.02	157.55
T_{11}	101.81	109.05	105.43	132.79	131.88	132.34	151.33	157.74	154.54	162.06	169.41	165.74
T_{12}	108.09	112.63	110.36	129.32	135.18	132.25	155.23	165.38	160.31	157.73	163.49	160.61
T_{13}	77.35	103.85	90.60	110.91	121.08	116.00	125.67	142.88	134.28	138.44	154.50	146.47
T_{14}	95.59	108.08	101.84	130.73	116.15	123.44	143.79	160.14	151.97	154.26	151.61	152.94
T_{15}	87.64	87.50	87.57	141.08	132.33	136.71	154.45	147.92	151.19	150.54	166.38	158.46
T_{16}	106.66	111.05	108.86	131.29	122.10	126.70	146.61	159.38	153.00	160.58	165.29	162.94
Control	78.32	90.87	84.60	104.40	95.05	99.73	128.20	130.55	129.38	141.89	140.28	141.09
S.Em.(±)	**1.241**	**1.269**	**1.220**	**1.611**	**1.546**	**1.527**	**1.368**	**1.744**	**1.487**	**1.649**	**1.863**	**1.545**
C.D. (P=0.05)	**3.576**	**3.656**	**3.515**	**4.641**	**4.454**	**4.398**	**3.940**	**5.023**	**4.284**	**4.750**	**5.367**	**4.449**

Table 2 : Influence of foliar application of vitamins on number of tillers per clump

Treatments	Number of tillers per clump											
	90 DAP			120 DAP			150 DAP			180 DAP		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1	1.25	1.93	1.59	2.56	2.14	2.35	3.06	3.21	3.40	3.59	3.52	3.29
T_2	1.10	1.75	1.43	2.98	2.68	2.83	3.32	3.88	3.60	4.06	4.18	4.09
T_3	1.52	1.70	1.61	2.68	2.59	2.64	3.93	4.08	4.01	4.40	4.28	4.34
T_4	1.51	1.57	1.54	3.01	1.88	2.45	3.85	3.95	3.90	4.28	4.48	4.38
T_5	1.30	1.23	1.27	2.03	3.10	2.57	3.35	3.41	3.38	3.68	3.68	3.68
T_6	1.46	1.58	1.52	2.93	3.24	3.09	3.73	3.98	3.86	4.10	4.56	4.33
T_7	1.02	1.64	1.33	2.66	2.51	2.59	3.79	3.74	3.77	4.17	4.34	4.26
T_8	1.61	1.71	1.66	2.87	2.92	2.90	3.95	4.16	4.06	4.36	4.46	4.41
T_9	1.36	1.03	1.20	2.81	2.47	2.79	3.22	2.77	3.11	3.45	3.26	3.24
T_{10}	1.26	1.47	1.37	2.38	2.45	2.42	3.48	3.50	3.49	3.86	3.96	3.91
T_{11}	1.21	1.55	1.38	2.64	2.62	2.63	3.59	3.96	3.78	4.03	4.40	4.22
T_{12}	1.56	1.80	1.68	3.02	2.99	3.01	3.92	4.05	3.99	4.42	4.65	4.54
T_{13}	0.97	1.52	1.25	2.25	2.08	2.17	3.15	2.48	2.82	3.58	3.16	3.37
T_{14}	0.98	1.19	1.09	2.74	2.22	2.48	2.18	3.83	3.69	3.50	3.62	3.56
T_{15}	1.31	1.49	1.40	2.31	2.89	2.60	3.26	3.16	3.21	3.88	4.26	4.07
T_{16}	1.16	1.59	1.38	2.62	2.36	2.49	3.36	3.58	3.47	4.06	4.05	4.06
Control	1.35	1.31	1.33	2.13	2.03	2.08	2.72	2.80	2.76	3.26	3.44	3.35
S.Em.(±)	**0.037**	**0.023**	**0.028**	**0.041**	**0.038**	**0.039**	**0.053**	**0.055**	**0.054**	**0.060**	**0.063**	**0.061**
C.D. (P=0.05)	**0.108**	**0.067**	**0.079**	**0.117**	**0.110**	**0.113**	**0.153**	**0.158**	**0.155**	**0.173**	**0.180**	**0.177**

Table 3 : Influence of foliar application of vitamins on number of leaves per clump

Treatments	Number of leaves per clump											
	90 DAP			120 DAP			150 DAP			180 DAP		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1	6.54	6.69	6.62	8.98	10.03	9.51	11.36	11.14	11.25	13.41	14.87	14.14
T_2	5.55	7.75	6.65	10.39	9.86	10.13	13.23	12.93	13.08	15.09	15.92	15.51
T_3	7.09	8.22	7.66	9.52	12.17	10.85	13.37	14.07	13.72	15.25	17.51	16.38
T_4	6.95	8.01	7.48	10.27	11.56	10.92	12.24	13.35	12.80	14.16	16.88	15.52
T_5	4.83	5.84	5.34	7.63	8.52	8.08	9.76	10.16	9.96	11.88	14.62	13.25
T_6	6.84	8.03	7.44	9.81	10.39	10.10	12.85	13.21	13.03	14.82	15.82	15.32
T_7	7.29	7.44	7.37	10.05	11.26	10.66	12.99	13.94	13.47	14.96	17.13	16.05
T_8	6.75	8.14	7.45	9.53	11.33	10.43	13.79	14.13	13.96	15.86	15.96	15.91
T_9	4.73	5.63	5.18	9.16	8.32	8.74	9.24	12.58	10.91	12.88	15.13	14.01
T_{10}	6.24	7.29	6.77	9.45	11.71	10.58	11.89	12.27	12.08	13.68	13.25	13.47
T_{11}	6.36	7.93	7.15	9.24	11.03	10.14	12.08	14.51	13.30	13.87	16.24	15.06
T_{12}	7.12	8.45	7.79	9.70	10.39	10.05	13.05	15.49	14.27	15.66	17.46	16.56
T_{13}	4.86	5.19	5.03	7.49	7.46	7.48	8.97	10.83	9.90	11.55	11.36	11.46
T_{14}	5.90	6.58	6.24	8.77	9.64	9.21	11.17	12.09	11.63	13.22	13.91	13.57
T_{15}	6.17	7.23	6.70	9.17	10.62	9.90	11.65	13.42	12.54	13.57	15.38	14.48
T_{16}	6.64	7.59	7.12	10.76	10.73	10.75	12.51	13.85	13.18	14.46	15.88	15.17
Control	5.14	6.17	5.66	7.07	7.36	7.22	9.19	10.36	9.78	12.32	11.93	12.13
S.Em.(±)	**0.096**	**0.112**	**0.104**	**0.126**	**0.161**	**0.138**	**0.192**	**0.206**	**0.199**	**0.213**	**0.237**	**0.225**
C.D. (P=0.05)	**0.276**	**0.323**	**0.299**	**0.363**	**0.465**	**0.397**	**0.554**	**0.595**	**0.572**	**0.613**	**0.683**	**0.648**

Table 4 : Influence of foliar application of vitamins on length of the leaf

Treatments	Length of leaf (cm)											
	90 DAP			120 DAP			150 DAP			180 DAP		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1	50.98	53.52	52.25	59.26	58.15	58.71	65.96	68.15	67.06	73.88	72.52	73.20
T_2	47.84	52.05	49.95	56.19	59.43	57.81	67.55	71.89	69.72	69.73	76.93	73.33
T_3	53.58	58.47	56.03	63.22	65.58	64.40	73.12	74.71	73.92	76.82	79.09	77.96
T_4	59.68	60.28	59.98	68.85	66.93	67.89	80.27	74.45	77.36	84.47	79.41	81.94
T_5	42.59	51.22	46.91	54.81	60.11	57.46	64.61	69.57	67.09	75.24	72.86	74.05
T_6	52.02	55.17	53.60	58.05	63.83	60.94	61.57	68.73	65.15	68.79	75.22	72.01
T_7	56.91	59.35	58.13	61.98	74.75	68.37	75.96	77.76	76.86	80.09	82.06	81.08
T_8	58.21	62.13	60.17	67.14	72.26	69.70	77.43	76.08	76.76	71.41	82.42	76.92
T_9	40.59	45.57	43.08	49.62	53.09	51.36	61.97	63.83	62.90	66.59	72.66	69.63
T_{10}	50.21	52.96	51.59	58.60	62.81	60.71	67.53	65.83	66.68	80.85	68.70	74.78
T_{11}	57.03	56.08	56.56	65.74	65.58	65.66	72.69	70.60	71.65	76.09	76.08	76.09
T_{12}	54.56	59.06	56.81	66.89	70.23	68.56	74.51	75.68	75.10	78.04	81.87	79.96
T_{13}	41.66	48.28	44.97	51.76	53.51	52.64	61.26	62.98	62.12	66.03	69.98	68.01
T_{14}	49.72	41.60	45.66	53.97	54.82	54.40	63.97	65.29	64.63	67.97	68.02	68.00
T_{15}	52.83	54.43	53.63	60.47	61.07	60.77	70.77	69.23	70.00	74.91	74.46	74.69
T_{16}	55.35	57.28	56.32	62.68	68.48	65.58	72.06	71.40	71.73	75.52	76.17	75.85
Control	44.73	46.85	45.79	52.88	56.05	54.47	61.63	61.17	61.40	68.24	66.82	67.53
S.Em.(±)	**0.808**	**0.835**	**0.821**	**0.933**	**0.971**	**0.951**	**1.080**	**1.069**	**1.074**	**1.156**	**1.151**	**1.152**
C.D. (P=0.05)	**2.327**	**2.404**	**2.365**	**2.687**	**2.797**	**2.741**	**3.110**	**3.079**	**3.094**	**3.329**	**3.315**	**3.319**

Table 5 : Influence of foliar application of vitamins breadth of the leaf

Treatments	Breadth of leaf (cm)											
	90 DAP			120 DAP			150 DAP			180 DAP		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1	14.96	15.43	15.20	16.16	15.83	16.00	16.38	15.94	16.16	16.55	16.67	16.61
T_2	15.57	16.56	16.07	15.87	17.23	16.55	16.28	17.34	16.81	16.84	17.49	17.17
T_3	16.61	16.32	16.47	16.52	16.56	16.54	17.23	17.97	17.60	17.84	18.16	18.00
T_4	16.22	16.63	16.43	17.14	17.48	17.31	17.51	18.08	17.80	18.24	18.45	18.35
T_5	12.08	13.68	12.88	14.02	14.98	14.50	15.92	15.47	15.70	16.27	16.43	16.35
T_6	15.92	16.12	16.02	16.42	17.01	16.72	16.55	17.03	16.79	16.69	17.69	17.19
T_7	15.21	15.81	15.51	16.91	16.34	16.63	17.03	16.98	17.01	17.71	17.21	17.46
T_8	16.37	14.29	15.33	17.26	15.31	16.29	17.44	16.21	16.83	18.22	17.33	17.78
T_9	10.25	13.50	11.88	12.68	14.57	13.63	15.02	14.94	14.98	15.43	15.90	15.67
T_{10}	15.35	14.35	14.85	15.76	14.76	15.26	16.24	15.29	15.77	16.43	15.54	15.99
T_{11}	14.78	14.74	14.76	16.68	15.63	16.16	17.25	16.03	16.64	17.43	16.61	17.02
T_{12}	15.87	15.91	15.89	16.83	16.77	16.80	17.35	17.09	17.22	17.59	17.37	17.48
T_{13}	12.88	15.15	14.02	13.92	15.35	14.64	15.34	15.87	15.61	15.50	16.08	15.79
T_{14}	14.47	15.66	15.07	15.35	15.91	15.63	15.51	16.42	15.97	15.88	17.11	16.50
T_{15}	16.15	14.43	15.29	16.31	15.88	16.10	16.78	16.42	16.60	16.95	16.81	16.88
T_{16}	16.27	15.14	15.71	16.52	16.15	16.34	17.17	16.69	16.93	17.38	17.02	17.20
Control	13.77	14.05	13.91	13.84	15.85	14.85	14.21	16.16	15.19	14.65	16.51	15.58
S.Em.(±)	**0.228**	**0.230**	**0.229**	**0.244**	**0.243**	**0.243**	**0.254**	**0.255**	**0.254**	**0.259**	**0.258**	**0.259**
C.D. (P=0.05)	**0.656**	**0.663**	**0.659**	**0.703**	**0.700**	**0.701**	**0.732**	**0.736**	**0.732**	**0.745**	**0.743**	**0.745**

Table 6 : Influence of foliar application of vitamins on weight, length and breadth of clump

Treatments	Weight of clump (g)			Length of clump (cm)			Breadth of clump (cm)		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1	303.35	330.44	316.90	20.88	19.22	20.05	15.38	16.30	15.84
T_2	330.13	372.44	351.29	18.54	20.74	19.64	14.83	15.78	15.31
T_3	358.19	400.26	379.23	21.67	19.52	20.60	15.35	16.53	15.94
T_4	367.15	413.87	390.51	22.03	21.61	21.82	15.86	16.71	16.29
T_5	300.81	302.17	301.49	19.46	16.43	17.95	13.81	15.12	14.47
T_6	312.50	357.32	334.91	17.08	19.66	18.37	13.57	15.33	14.45
T_7	326.11	377.15	351.63	20.83	19.47	20.15	15.72	16.60	16.16
T_8	329.42	398.12	363.77	19.63	21.05	20.34	14.99	17.18	16.09
T_9	292.84	332.80	312.82	18.11	19.93	19.02	15.32	13.74	14.53
T_{10}	310.76	352.90	331.83	19.34	18.41	18.88	13.10	15.13	14.12
T_{11}	332.33	373.46	352.90	19.62	20.77	20.20	14.82	16.28	15.55
T_{12}	347.06	389.83	368.45	18.73	21.32	20.03	15.81	16.94	16.38
T_{13}	284.77	322.77	303.77	18.90	17.11	18.01	13.94	12.65	13.30
T_{14}	278.38	346.10	312.24	18.08	16.40	17.24	12.90	15.04	13.97
T_{15}	327.01	376.73	351.87	20.35	19.07	19.71	14.69	15.84	15.27
T_{16}	332.15	397.94	365.05	20.34	19.22	19.78	15.57	16.26	15.92
Control	264.94	274.77	269.86	16.20	16.69	16.45	12.10	12.81	12.46
S.Em. (±)	**4.083**	**4.657**	**4.137**	**0.302**	**0.264**	**0.265**	**0.164**	**0.208**	**0.173**
C.D. (P=0.05)	**11.763**	**13.415**	**11.917**	**0.871**	**0.761**	**0.764**	**0.473**	**0.598**	**0.498**

Table 7 : Influence of foliar application of vitamins on number of primary and secondary fingers per clump and plot yield

Treatments	Number of primary fingers			Number of secondary fingers			Plot yield (kg $plot^{-1}$) ($3m^2$)		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1	8.58	9.46	9.02	18.94	15.87	17.41	12.40	12.77	12.59
T_2	8.55	9.34	8.95	16.50	18.66	17.58	13.79	13.28	13.54
T_3	9.65	10.09	9.87	19.03	21.56	20.30	12.98	14.06	13.52
T_4	10.11	11.61	10.86	18.61	21.89	20.25	14.45	15.46	14.96
T_5	6.86	7.69	7.28	14.48	19.27	16.88	12.07	11.74	11.91
T_6	7.43	9.94	8.69	15.01	17.04	16.03	12.79	13.11	12.95
T_7	9.81	10.41	10.11	18.48	21.36	19.92	13.93	13.83	13.88
T_8	8.35	10.73	9.54	16.50	20.96	18.73	13.10	15.18	14.14
T_9	8.73	9.04	8.89	12.01	17.83	14.92	11.88	13.02	12.45
T_{10}	8.21	9.23	8.72	15.15	21.44	18.30	12.38	12.31	12.35
T_{11}	9.23	10.62	9.93	16.95	19.33	18.14	14.11	13.38	13.75
T_{12}	10.07	9.41	9.74	18.92	23.10	21.01	13.64	14.67	14.16
T_{13}	7.90	8.85	8.38	16.80	11.77	14.29	11.19	12.83	12.01
T_{14}	7.19	7.64	7.42	14.87	16.31	15.59	12.16	11.89	12.03
T_{15}	9.49	10.11	9.80	17.32	20.64	18.98	13.36	13.21	13.29
T_{16}	8.86	9.72	9.29	18.14	20.51	19.33	12.89	13.87	13.38
Control	7.24	7.91	7.58	10.04	12.45	11.25	10.34	10.40	10.37
S.Em. (±)	**0.126**	**0.153**	**0.483**	**0.184**	**0.219**	**0.180**	**0.201**	**0.206**	**0.203**
C.D. (P=0.05)	**0.363**	**0.441**	**1.391**	**0.531**	**0.630**	**0.520**	**0.580**	**0.593**	**0.586**

Table 8 : Influence of foliar application of vitamins on weight of mother rhizome, primary fingers and secondary fingers per clump

Treatments	Weight of mother rhizome (g)			Weight of primary fingers (g)			Weight of secondary fingers (g)		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1	32.27	45.58	38.93	165.61	175.58	170.60	105.84	108.49	107.17
T_2	30.12	47.78	38.95	191.27	209.64	200.46	103.72	113.56	108.64
T_3	37.21	56.97	47.09	207.92	225.10	216.51	113.21	123.63	118.42
T_4	50.59	45.17	47.88	199.06	235.05	217.06	121.07	134.87	127.97
T_5	34.76	38.39	36.58	157.71	169.61	163.66	108.52	95.71	102.12
T_6	46.62	39.29	42.96	169.25	208.36	188.81	96.59	104.41	100.50
T_7	39.81	51.41	45.61	194.78	208.36	201.57	97.12	115.31	106.22
T_8	52.72	58.94	55.83	181.06	228.87	204.97	103.51	111.76	107.64
T_9	30.22	35.50	32.86	168.91	197.07	182.99	88.79	99.16	93.98
T_{10}	33.59	43.69	38.64	160.37	201.13	180.75	114.55	101.18	107.87
T_{11}	38.41	49.79	44.10	207.92	222.32	215.12	84.38	95.56	89.97
T_{12}	47.99	54.65	51.32	197.46	239.43	218.45	101.78	89.61	95.70
T_{13}	27.98	37.39	32.69	176.62	180.61	178.62	81.82	106.47	94.15
T_{14}	34.11	42.59	38.35	160.07	195.73	177.90	90.94	102.56	96.75
T_{15}	45.18	53.10	49.14	172.90	202.51	187.71	107.60	120.18	113.89
T_{16}	45.40	53.12	49.26	185.75	218.86	202.31	99.94	112.27	106.11
Control	30.76	36.44	33.60	170.65	155.36	163.01	66.38	84.52	75.45
S.Em. (±)	**0.605**	**0.718**	**0.659**	**2.837**	**2.974**	**2.895**	**1.529**	**1.666**	**1.595**
C.D. (P=0.05)	**1.742**	**2.067**	**1.898**	**8.174**	**8.566**	**8.340**	**4.403**	**4.799**	**4.596**

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Conflict of Interest

The authors have declared that there is no conflict of interest.

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