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Influence of foliar application of vitamins on yield, economics and correlation studies of turmeric

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Abstract
Vitamins can act as cofactors which are required to various metabolic reactions and plays an important role in regulating plant growth and development. In the present study, we observed the efficiency of four levels (25, 50, 75 and 100 ppm) of four different vitamins of ascorbic acid, thiamine, folate and niacin applied foliar, including control (water spray) in a randomised block design with three replications. The results revealed that application of all vitamins at all levels exerted a significant effect on the most studied characters and yield of the turmeric. Ascorbic acid spraying especially at 100 ppm concentration recorded significantly highest yield (37.39 t ha^{-1}) and economic returns (1.70) as compared to control and other treatments. Growth, yield and quality characters were highly positively correlated with each other among the treatments. Overall, the yield performance of turmeric and BC ratio has been improved by the application of vitamins and considered as suitable growth regulators for higher turmeric production.

Keywords: Ascorbic acid, thiamine, folate, niacin, yield, economics, turmeric

Introduction

Turmeric (*Curcuma longa*) has been originated from tropical South East Asia and belongs to Zingiberaceae family. It is often called as “Indian saffron’’ and “Golden spice” and also “Kitchen queen” which produces bright yellowish orange rhizomes below the ground. (Ferreira *et al.*, 2013) [7]. Turmeric is mainly used as spice in culinary, cosmetic and pharmaceutical preparations due to its medicinal properties. India is the major producer, consumer and exporter of turmeric in the world and commercially cultivated in different states. Turmeric has long been revered in Indian traditional Ayurvedic medicine for its healing properties. It has been used to cure numerous ailments, such as inflammation, wounds, infections, diarrhoea, arthritis, injuries, jaundice and other liver-related problems. In Unani medicine, turmeric is considered one of the safest herbs for treating blood disorders due to its blood-purifying and stimulating effects.

Turmeric comprises of curcumin, is widely utilized in the medicinal industry for its various beneficial properties, including antioxidant, anti-arthritic, antimutagenic and antimicrobial effects also shown potential in combating Alzheimer's disease (Mane *et al.*, 2018) [23]. In addition to curcumin, turmeric rhizomes have a variety of secondary metabolites that enhance their quality and therapeutic qualities (Kim *et al.*, 2011) [19]. Nutritional analysis of turmeric reveals that 100 g of the spice comprises 390 kcal, with 49.2 g of total carbohydrates, 21 g of fibre, 7.66 g of protein, 5.03 g of total fat, 0.1 g of calcium along with 0.23 g of phosphorus, 10 mg of sodium, 2300 mg of potassium, 46 mg of iron, 0.06 mg of thiamine and 0.01 mg of riboflavin (Kumar *et al.*, 2011) [21].

A wide range of plant growth promoting substances are used for enhancement of the yield and quality of crops and helps to increase their nutrient and water use efficiency. Application of vitamins as alternative to conventional growth regulators, which can enhance plant growth, development and overall yield while minimizing their negative effects on the environment. Vitamins are necessary organic substances that are present in trace amounts to preserve their natural form and are necessary for healthy plant development and growth (Hassanein *et al.*, 2009) [11]. They possess antioxidant properties, playing a key role in protecting plants from oxidative stress brought on by adverse circumstances, and contributing to the productivity of agricultural and horticultural crops (Robinson, 1973) [25].

Vitamins 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) [5].

According to Kodendaramaiah and Rao (1985) [20], B-vitamins indirectly support plant growth and development by raising the endogenous levels of several growth factors, including gibberellins and cytokinin. The application of ascorbic acid (100 ppm) resulted in considerably increased average tuber weight and marketable yield of potato (Gouda *et al.*, 2015) [10]. Coriander plants sprayed with 50 mM folic acid exhibited the highest levels of fresh biomass in the plants (Khan *et al.*, 2022) [18]. 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) [15]. Vendruscolo *et al.* (2023) [27] found that combine applying thiamine and niacin 100 mg l^{-1} of each on lettuce cultivars considerably improved the fresh biomass by 30% when compared to the control. Nahed *et al.* (2009) [24] demonstrated that the *Gladiolus grandiflorum* L. plants exhibited enhanced vegetative growth and flowering with the application of thiamine and ascorbic acid at 100 ppm.

Materials and Methods

The field trial was conducted at Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, West Bengal during 2023-24 and 2024-25. The foremost objective of the research is to study the influence of most effective vitamin and their optimum concentration for improving the yield, economic returns and their correlation between the growth, yield and quality parameters.

The experiment designed in completely randomised block design with 17 treatments and three replications. The land was ploughed thoroughly and divided into small plots (3m×1m). Application of FYM @ 25 t ha^{-1} and basal dose of fertilisers were applied during land preparation and seed rhizomes were planted at a spacing of 30cm×25cm. Recommended dose of fertilizers (NPK-150:60:150 kg ha^{-1}) were applied in split doses at basal, 45 and 60 days after planting including control. Ascorbic acid, Thiamine, Folate and Niacin (25, 50, 75 and 100 ppm) were applied three times at 60, 90 and 120 days after planting. Intercultural operations such as irrigation, mulching, weeding, earthing up and were done at regular intervals.

Treatment details

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

The projected or total yield of rhizomes per hectare was calculated based on plot yield, considering 75% area occupied by turmeric in the present experiment (Anon, 1995) [4]. Total curcumin production per hectare also calculated through multiplication of projected yield with dry recovery percentage and curcumin content and finally expressed in kg ha^{-1}. The economic assessment for the different treatments was done based on cost of production, gross return and net return considering the cost of inputs and market price of the produce during the period of experimentation (Shively, 2012) [26].

$$\text{Benefit cost ratio} = \frac{\text{Net returns}}{\text{Cost of production}}$$

Statistical analysis

The data was subjected to statistical analysis using variance techniques as described by Gomez and Gomez (1984) [9]. The significance of different treatments was tested by 'F' test at probability level of 0.05 and critical difference (CD) was calculated at 5%. Correlation coefficient analysis of vegetative, yield and quality characters of turmeric was done by following Karl Pearson correlation method using R software (version: 4.4.1).

Results and Discussions

Projected yield and total curcumin yield

Foliar application of vitamins significantly influenced the rhizome and total curcumin yield of turmeric during both seasons (Table. 1). It might be due to the increased nutrient uptake and efficiency as well as beneficial effect of vitamins on physiological functions within the turmeric plants. The steady increase in the projected yield was observed with the increasing concentration up to highest level in all vitamins and it was maximum with the ascorbic acid. The highest yield was associated with ascorbic acid 100 ppm (37.39 t ha^{-1}), which was followed by folate 100 ppm (35.39 t ha^{-1}) and thiamine 100 ppm (35.35 t ha^{-1}) as compared to the lowest yield in control (25.93 t ha^{-1}). The highest total curcumin production was observed in ascorbic acid 100 ppm (568.95 kg ha^{-1}), followed by folate 100 ppm (530.95 kg ha^{-1}) as compared lowest in control (277.08 kg ha^{-1}). 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. This integrated improvement in photosynthetic capacity, root-shoot balance and metabolic efficiency translates into enhanced tuber yield. Similar results were reported by Gahory *et al.* (2022) [8] in coriander, Hussain and Mustaf, (2019) [14] in squash and El-Hak *et al.* (2012) [6] in pea.

Correlation coefficients among vegetative, yield and quality characters of turmeric

There is highly positive correlation was associated among the growth, yield and quality characters. From this, we can observe that yield of the plant is more related with the healthy growth of the plant (Table. 2). The plant height showed highly significant and positive correlation with number of tillers (0.87), leaf number (0.81), leaf length

(0.83) and leaf breadth (0.84), weight of clump (0.86), weight of primary fingers (0.76), weight of secondary fingers (0.63), plot yield and projected yield per hectare (0.89). It showed positive relation with quality characters like curcumin (0.65), oleoresin (0.58), total phenols and dry recovery (0.72), leaf chlorophyll content (0.88). Number of tillers showed significant and positive association with weight of clump (0.86), number of leaves (0.84) and leaf length (0.80), leaf breadth (0.86), primary (0.84) and secondary fingers weight (0.49), plot and projected yield (0.82). Characters showing highly positive and significant correlation with leaf length were weight of clump (0.85), leaf breadth (0.83), weight of primary finger (0.77) and secondary finger (0.64) also with plot and projected yield (0.85).

Highly positive and significant correlation was observed between weight of clump and yield per plot and projected yield (0.95). It showed highly significant positive correlation with weight both primary and secondary finger, plant height, leaf number and quality attributes like dry recovery, total phenols, curcumin and oleoresin content. Rhizome yield per plot had highly positive and significant association with clump weight (0.95), weight of secondary finger (0.68) weight of primary finger (0.89), plant height (0.89), leaf breadth (0.88) and leaf number (0.85). This signifies that by improving these characters, rhizome yield can also be improved. Rhizome quality characters like dry recovery, curcumin, oleoresin and total phenols content as well as leaf chlorophyll content also showed highly positive relationship with growth and yield characters.

Hazra *et al.* (2000) [12] identified significant and positive correlation between the number of leaves per clump and turmeric yield. Therefore, it is possible to draw the conclusion that plant vigour and yield components influence rhizome yield. Jana *et al.* (2001) [17] discovered a substantial correlation between the weight of primary and secondary fingers per clump and the fresh rhizome production.

Influence of foliar application of vitamins on economics of turmeric cultivation

As per mean data (Table. 3), the maximum cost of production was Rs. 211,395/-noticed with folate 100 ppm, followed by thiamine 100 ppm (Rs. 210,459/-) as compared to untreated control recorded lowest cost of production (Rs. 206,355/-). In case of gross return, the highest value (Rs. 560,850/-) was observed in ascorbic acid 100 ppm followed by folate 100 ppm (Rs. 530,850/-) while the lowest gross return was observed in untreated control (Rs. 388,950/-). In respect of net return, the maximum value of Rs. 353,351/- registered in ascorbic acid 100 ppm, followed by thiamine 100 ppm (Rs. 319,791/-). The lowest value was obtained in untreated control (Rs. 182,595/-) due to less yield. Highest B: C ratio was noticed in ascorbic acid 100 ppm (1.70) followed by thiamine 100 ppm (1.52) and whereas lowest B: C ratio (0.88) was observed in untreated control.

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) [28]. Helal *et al.* (2005) [13] 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. Leonel *et al.* (2024) [22] reported that administration of niacin alone boosted growth parameters and productivity by 82% leading to a 50% increase in gross revenue in carrot. The significant improvement in different parameters like number of capsules per plant weight of 1000 seed and seed yield were observed in *Nigella sativa* with thiamine 200 ppm (Al-Rikabi and Lahmoud, 2022) [2]. The favourable effect of folic acid in faba bean (*Vicia faba*) was reported by Al-Maliky *et al.* (2019) [1] and Ibrahim *et al.* (2015) [16] in potato plants. Aminifard *et al.* (2018) [3] found that thiamine application at the rate of 250, 500 and 700 ppm increased the growth and yield-related attributes in fenugreek and coriander.

Table 1: Influence of vitamins on projected yield and total curcumin yield

Treatments	Projected yield (t ha^{-1})			Total curcumin yield (kg ha^{-1})		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
Ascorbic acid-25 ppm	31.00	31.93	31.46	357.24	383.17	370.20
Ascorbic acid-50 ppm	34.48	33.20	33.84	457.78	435.80	446.79
Ascorbic acid-75 ppm	32.45	35.15	33.80	401.19	464.92	433.06
Ascorbic acid-100 ppm	36.13	38.65	37.39	530.44	607.47	568.95
Thiamine-25 ppm	30.18	29.35	29.76	357.80	321.57	339.69
Thiamine-50 ppm	31.98	32.78	32.38	334.44	397.69	366.07
Thiamine-75 ppm	34.83	34.58	34.70	418.24	436.27	427.25
Thiamine-100 ppm	32.75	37.95	35.35	443.04	567.58	505.31
Folate-25 ppm	29.70	32.55	31.13	333.93	399.72	366.83
Folate-50 ppm	30.95	30.78	30.86	392.89	394.49	393.69
Folate-75 ppm	35.28	33.45	34.36	453.85	443.81	448.83
Folate-100 ppm	34.10	36.68	35.39	513.15	548.75	530.95
Niacin-25 ppm	27.98	32.08	30.03	294.58	353.35	323.97
Niacin-50 ppm	30.40	29.73	30.06	330.95	372.63	351.79
Niacin-75 ppm	33.40	33.03	33.21	373.80	440.19	406.99
Niacin-100 ppm	32.23	34.68	33.45	437.18	465.05	451.11
Control (Water spray)	25.85	26.00	25.93	270.80	283.35	277.08
S.Em. (±)	0.503	0.514	0.509	5.158	4.996	3.919
C.D. (P = 0.05)	1.450	1.481	1.465	14.857	14.392	11.290

Table 2: Correlation coefficients among vegetative, yield and quality characters of turmeric

Characters	PH	NOT	NOL	LL	LB	WOC	WPF	WSF	DR	CUR	OLE	TPH	CHL	PLY	PJY
PH	1.00														
NOT	0.87**	1.00													
NOL	0.81**	0.84**	1.00												
LL	0.83**	0.80**	0.80**	1.00											
LB	0.84**	0.86**	0.87**	0.83**	1.00										
WOC	0.86**	0.86**	0.86**	0.85**	0.91**	1.00									
WPF	0.76**	0.84**	0.83**	0.77**	0.83**	0.92**	1.00								
WSF	0.63**	0.49*	0.52*	0.64**	0.69**	0.73**	0.45 NS	1.00							
DR	0.72**	0.74**	0.73**	0.83**	0.70**	0.80**	0.77**	0.50*	1.00						
CUR	0.65**	0.62**	0.64**	0.63**	0.71**	0.79**	0.76**	0.50*	0.72**	1.00					
OLE	0.58*	0.59*	0.72**	0.64**	0.56*	0.71**	0.69**	0.32 NS	0.71**	0.68**	1.00				
TPH	0.72**	0.79**	0.73**	0.68**	0.79**	0.84**	0.88**	0.41 NS	0.60*	0.76**	0.60*	1.00			
CHL	0.88**	0.76**	0.84**	0.76**	0.82**	0.83**	0.82**	0.52*	0.73**	0.76**	0.64**	0.72**	1.00		
PLY	0.89**	0.82**	0.85**	0.85**	0.88**	0.95**	0.89**	0.68**	0.81**	0.77**	0.66**	0.84**	0.90**	1.00	
PJY	0.89**	0.82**	0.85**	0.85**	0.88**	0.95**	0.89**	0.68**	0.81**	0.77**	0.66**	0.84**	0.90**	1.00	1.00

*Significance at 5% **Significance at 1% NS-Non significant ($P \geq 0.05$)

Characters
PH: Plant height
NOT: Number of tillers
NOL: Number of leaves
LL: Leaf length
LB: Leaf breadth
WOC: Weight of clump
WPF: Weight of primary fingers
WSF: Weight of secondary fingers
DR: Dry recovery
CUR: Curcumin
OLE: Oleoresin
PH: Total phenols content
CHL: Chlorophyll
PLY: Plot yield
PJY: Projected yield

Table 3: Influence of vitamins on economic of turmeric

Treatments	Cost of production (Rs. ha^{-1})			Gross returns (Rs. ha^{-1})			Net returns (Rs. ha^{-1})			B:C Ratio		
	2023-24	2024-25	Mean	2023-24	2024-25	Mean	2023-24	2024-25	Mean	2023-24	2024-25	Mean
Ascorbic acid-25 ppm	203666	209616	206641	465000	478950	471900	261334	269334	265259	1.27	1.28	1.28
Ascorbic acid-50 ppm	203952	209902	206927	517200	498000	507600	313248	288098	300673	1.54	1.37	1.45
Ascorbic acid-75 ppm	204238	210188	207213	486750	527250	507000	282512	317062	299787	1.38	1.51	1.45
Ascorbic acid-100 ppm	204524	210474	207499	541950	579750	560850	337426	369276	353351	1.65	1.75	1.70
Thiamine-25 ppm	204748	210698	207723	452700	440250	446400	247952	229552	238677	1.21	1.09	1.15
Thiamine-50 ppm	205660	211610	208635	479700	491700	485700	274040	280090	277065	1.33	1.32	1.33
Thiamine-75 ppm	206572	212522	209547	522450	518700	520500	315878	306178	310953	1.53	1.44	1.48
Thiamine-100 ppm	207484	213434	210459	491250	569250	530250	283766	355816	319791	1.37	1.67	1.52
Folate-25 ppm	205060	211010	208035	445500	488250	466950	240440	277240	258915	1.17	1.31	1.24
Folate-50 ppm	206180	212130	209155	464250	461700	462900	258070	249570	253745	1.25	1.18	1.21
Folate-75 ppm	207300	213250	210275	529200	501750	515400	321900	288500	305125	1.55	1.35	1.45
Folate-100 ppm	208420	214370	211395	511500	550200	530850	303080	335830	319455	1.45	1.57	1.51
Niacin-25 ppm	203544	209494	206519	419700	481200	450450	216156	271706	243931	1.06	1.30	1.18
Niacin-50 ppm	203708	209658	206683	456000	445950	450900	252292	236292	244217	1.24	1.13	1.18
Niacin-75 ppm	203872	209822	206847	501000	495450	498150	297128	285628	291303	1.46	1.36	1.41
Niacin-100 ppm	204036	209986	207011	483450	520200	501750	279414	310214	294739	1.37	1.48	1.42
Control (Water spray)	203380	209330	206355	387750	390000	388950	184370	180670	182595	0.91	0.86	0.88

Cost of Inputs (Rs.)
Urea: 5.92 kg^{-1}
SSP: 10.00 kg^{-1}
MOP: 34.00 kg^{-1}
Seed rhizome: 30.00 kg^{-1}
FYM: 2000.00 t^{-1}
Man days: 363.00 day^{-1}(2023)
Man days: 400.00 day^{-1}(2024)
Niacin: 164.00 $25g^{-1}$
Ascorbic acid: 1146.00 $100g^{-1}$
Thiamine: 456.00 $10g^{-1}$
Folate: 560.00 $10g^{-1}$
Selling price of turmeric (Rs.): Rs.15.00 kg^{-1}

Conclusion
Turmeric is an economically important spice crop, which requires innovative techniques to enhance production and productivity. Vitamins such as ascorbic acid, thiamine, folate and niacin are safe, affordable and easy to apply through foliar spraying. Results of the current study offers a promising approach in increasing the turmeric yield, especially with high level of concentrations. Ascorbic acid at 100 ppm recorded highest yield, total curcumin and economic returns followed by folate and thiamine at 100 ppm concentration. So, we conclude that vitamins administration can be a strategic and sustainable method for increasing the yield and net returns of the turmeric growers.

Authors contribution
The authors confirm their contribution in conduct of experimentation, data collection, analysis and interpretation of results, manuscript preparation and review. We acknowledge the Indian Council of Agricultural Research for providing the financial assistance for conduct of PhD research work.

Disclosure statement
Authors have reported that there is no potential conflict of interest.

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