Biological Forum – An International Journal **15(10): 1011-1016(2023)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Influence of Foliar Treatment of Metabolite Elicitors on Plant Growth and Yield Parameters of Turmeric (*Curcuma longa* L.)

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(Received: 15 August 2023; Revised: 14 September 2023; Accepted: 30 September 2023; Published: 15 October 2023)
(Published by Research Trend)

ABSTRACT: The experiment was conducted at Horticultural Research Station, Mondouri, BCKV, West Bengal, during 2019-2020 and 2020-2021. According to recent research, the application of metabolic elicitors had a major impact on yield and quality. Elicitors like chitosan, salicylic acid and methyl jasmonate, were found to show positive effect on growth, yield and quality in various crops. The ultimate objective of this study is to identify the best elicitor and its concentration for enhancing the production of turmeric. The plants were foliar sprayed with different metabolite elicitors *viz.*, chitosan (250, 500 and 750 ppm), salicylic acid (100, 200 and 300 ppm), proline (50, 100 and 200 ppm) and methyl jasmonate (50, 100 and 200 ppm) at 60, 90, 120 and 150 days after planting (DAP). The plants under control plots were sprayed with distilled water as per the schedule. Significant variations in most of the parameters were observed among different treatments during both the years and in pooled analysis. The plants sprayed with salicylic acid-200 ppm recorded maximum number of tillers (3.47), clump weight (348.81 g), length of primary finger (9.64 cm), breadth of primary finger (2.36 cm), number of secondary fingers (15.35), yield plot^{-1} (13.26 kg 3m^{-2}), projected yield (33.14 t ha^{-1}), The maximum number of primary fingers (11.57), weight of primary finger (161.45 g) and breadth of secondary finger (1.90 cm) were observed in salicylic acid-100 ppm. The maximum plant height (184.72 cm), number of leaves (20.90) and tiller (3.47) were recorded in salicylic acid-300 ppm. The maximum length of clump (18.88 cm), breadth of clump (16.45 cm), length of secondary finger (4.69 cm), the maximum weight of primary finger (183.90 g) was recorded in methyl jasmonate -100 ppm.

Keywords: Turmeric, Elicitors, Foliar treatment, Growth, Yield, Chitosan, Salicylic Acid, Proline, Methyl jasmonate.

INTRODUCTION

Turmeric (*Curcuma longa* L.) is an herbaceous perennial plant, belongs to the family Zingiberaceae. It is old and revered Indian spice popularly known as "Indian saffron" and key spice crop of the tropics. Turmeric originated in South-East Asia and one of the important spice crops of the tropics. Turmeric is produced, consumed, and exported most frequently from India (Anandaraj *et al*., 2014). India being the world's largest producer of turmeric, gains importance for its oleoresin and curcumin, having medicinal value and ample export opportunity has been created in World Trade Centre (Tamil Selvan *et al*., 1999). In India, turmeric makes up around 6% of the entire section dedicated to spices and condiments. The major states in India that cultivate turmeric include Telangana, Andhra Pradesh, Tamil Nadu, Orissa, Karnataka, West Bengal, Gujarat, Meghalaya, Maharashtra, and Assam. Turmeric was grown in an area of 3, 33,024 hectares with a total production of 12, 21,717 tonnes during 2021-22 (Spice Board, 2022) in India. In West Bengal during the year 2021-22, area covered under turmeric was 18772 hectares and production was 50938 tonnes (Spice Board, 2022). Elicitors are the chemical compounds derived from various sources that can trigger physiological and morphological responses and also trigger the phytoalexin accumulation in the target living organisms. Elicitor molecules attach to the special receptor proteins located on plant cell membranes. The receptors are able to recognize the molecular pattern of elicitors, which trigger the intracellular defence signalling and results in the increased synthesis of secondary metabolites.

A recent analysis by Ray *et al.* (2016) indicates that the increasing use of Indian turmeric in food and non-food goods has increased both the country's exports and demand for the spice. It is used in many different industries as a coloring ingredient for cheese, cereals, soups, ice creams, yogurt, and other foods (Singh *et al.*, 2014). Since turmeric is used widely and its value-added products are in demand, output must be enhanced to keep up with demand (Anasuya and Sathiyabama 2016). The export demand of turmeric is increasing in the last few years due to its non-food as well as flavouring use. There-fore, the production of turmeric has to be increased to meet global requirements. Turmeric's curcumin content varies depending on genotype and environmental factors, therefore increasing and standardizing its bio-production is necessary for better commercialization (Anandaraj *et al.,* 2014). Recent research showed that the use of metabolic elicitors significantly affected both yield and quality. Elicitors like chitosan, salicylic acid and methyl jasmonate, proline were found to show positive effect on growth, yield and quality in various crops. In view of the above background, the experiment was undertaken with objectives to study the influence of foliar application of metabolite elicitors on plant growth and yield of turmeric. The ultimate objective of this study is to identify the best elicitor and its concentration for enhancing the production of turmeric. In this experiment, four elicitors with three concentrations were included. The elicitors are chitosan (250, 500 and 750 ppm), methyl jasmonate (50, 100 and 200 ppm), proline (50, 100, 200 ppm) and salicylic acid (100, 200 and 300 ppm) altogether 13 treatments included control and the variety was Suguna.

MATERIAL AND METHODS

The experiment was laid out in Randomized Block Design with three replications. Raised beds of 3.0 × 1.0 m^{-2} and 15 cm height were prepared. In this experiment the elicitors applied through foliar application at 60, 90, 120 and 150 days after planting. The planting and harvesting were done during middle of May and end of January respectively during both the years. The recommended dose of fertilizer was NPK @ 150:60:150 kg ha^{-1}. The doses of fertilizers were adjusted with the application of urea, single super phosphate and muriate of potash. Nitrogen was applied in 3 split doses, one third nitrogen and full phosphorus were applied as basal, whereas 1/3rd N and 1/2nd K where applied at 45 and 90 days after planting.

First irrigation was given immediately after planting; the subsequent irrigations were given depending upon the soil moisture and weather condition. Rhizomes of turmeric were planted to a depth of 3-4 cm. Crops were mulched immediately after planting with paddy straw at the rate of 10 t ha^{-1} and 5 t ha^{-1} at 45 and 90 days after planting. Earthing up was done before second and third mulching.

RESULTS

In this experiment, observations on growth parameters *viz.*, plant height, number of leaves $plant^{-1}$, number of tillers $plant^{-1}$ in five randomly selected turmeric plants were recorded at 150 and 180 days after planting. Rhizome characters and yield parameters were recorded during harvesting.

Plant height (cm) in pooled analysis, at 150 DAP maximum plant height (167.25 cm) was observed in salicylic acid-200 ppm followed by salicylic acid-300 ppm (162.31 cm) and methyl jasmonate-100 ppm (158.32 cm) as compared to lowest plant height in control (124.13 cm). At 180 DAP maximum plant height (184.72 cm) was observed in salicylic acid-300 ppm followed by salicylic acid-200 ppm (175.80 cm) and chitosan-750 ppm (170.65 cm) as compared to lowest plant height in control (142.06 cm). At 150 DAP the plant height increased steadily with increasing concentration of chitosan but height reduced beyond medium concentration in case of methyl jasmonate, proline and salicylic acid and at 180 DAP methyl jasmonate and proline the plant height increased up to medium concentration then decreased but positive responses were observed in both chitosan and salicylic acid up to highest concentration.

Number of leaves $plant^{-1}$ in pooled analysis, at 150 DAP the maximum number of leaves (16.75) was observed in salicylic acid-200 ppm followed by methyl jasmonate-100 ppm (16.11) and methyl jasmonate-200 ppm (16.04) as compared to minimum number of leaves under control (13.06). At 180 DAP the maximum number of leaves (20.90) was observed in salicylic acid-300 ppm followed by chitosan-750 ppm (19.93) and salicylic acid-200 ppm (19.51) as compared to minimum number of leaves under proline-200 ppm (16.45). At 150 DAP the leaf number increased up to medium concentration of methyl jasmonate, proline and salicylic acid but steady response observed up to highest concentration in chitosan. and at 180 DAP The leaf numbers increased up to highest concentration in chitosan and salicylic acid but response up to medium concentration was noticed in methyl jasmonate and proline.

Number of tillers $plant^{-1}$ in pooled analysis, At 150 DAP the maximum number of tillers (2.28) was observed in methyl jasmonate-100 ppm followed by salicylic acid-200 ppm (2.25) and chitosan-750 ppm (2.18) as compared to minimum (1.20) number of tillers under proline-200 ppm. At 180 DAP the maximum number of tillers (3.47) was observed in salicylic acid-200 ppm and salicylic acid-300 ppm followed by methyl jasmonate-100 ppm (3.24) and chitosan-500 ppm (3.18) as compared to minimum (2.06) number of tillers under proline-200 ppm and control. The increasing trend in tiller production with increasing concentration up to highest level was observed only with chitosan at 150 DAP and In 180 DAP tiller number increased up to medium concentration in all of four elicitors.

Weight of clump (g) in pooled analysis, the maximum (348.81 g) clump weight was observed in salicylic acid-200 ppm followed by chitosan-750 ppm (341.48 g) and salicylic acid-300 ppm (327.70 g) as compared to minimum (234.84 g) clump weight in proline-200 ppm. The increasing trends in clump weight with increasing concentration was observed only with chitosan up to highest level but positive response with other elicitors were observed up to medium concentration.

Length of clump (cm) in pooled analysis, the maximum (18.88 cm) length of clump was observed with treatment chitosan-750 ppm followed by salicylic acid-200 ppm (18.66 cm) and salicylic acid-300 ppm (17.70 cm) as compared to minimum (14.71 cm) length of clump with control. The length of clump was increased up to highest concentration in chitosan but up to medium concentration in other three elicitors.

Breadth of clump (cm) in pooled analysis, the maximum (16.45 cm) breadth of clump was observed with treatment chitosan-750 ppm followed by salicylic acid-200 ppm (16.02 cm) and methyl jasmonate-100 ppm (15.82 cm) as compared to minimum (13.85 cm) breadth of clump with control. The similar trends of responses were observed in increasing breadth of clump like length of clump.

Number of primary finger in pooled analysis, the maximum (11.57) number of primary fingers was noticed with treatment salicylic acid-100 ppm followed by methyl jasmonate-100 ppm (11.19) and salicylic acid-200 ppm (11.06) as compared to minimum (8.06) number of primary fingers with proline-200 ppm. Increasing trend in number of primary finger was noticed with increasing concentration up to highest level in chitosan but opposite trend as observed in case of salicylic acid.

Weight of primary finger (g) in pooled analysis, the maximum (183.90 g) weight of primary finger was observed with treatment methyl jasmonate-100 ppm followed by salicylic acid-200 ppm (175.88 g) and salicylic acid-100 ppm (173.55 g) as compared to minimum (121.28 g) weight of primary finger with proline-200 ppm. Increasing trend in increasing weight of primary finger was noticed in chitosan up to highest concentration but in case of other three elicitors the weight of primary finger decreased after medium concentration.

Length of primary finger (cm) in pooled analysis, the maximum (9.64 cm) length of primary finger was observed with treatment salicylic acid-200 ppm followed by methyl jasmonate-100 ppm (9.60 cm) and chitosan-750 ppm (9.54 cm) as compared to minimum (7.61 cm) length of primary finger with proline-200 ppm. A similar trend in increasing length was recorded like weight of primary finger.

Breadth of primary finger (cm) in pooled analysis, the maximum (2.36 cm) breadth of primary finger was observed with salicylic acid-200 ppm followed by chitosan-750 ppm (2.23 cm) and salicylic acid-300 ppm (2.19 cm) as compared to minimum (1.61 cm) breadth of primary finger with proline-50 ppm. The breadth increased up to higher concentration in case of both chitosan and proline but up to medium concentration in other two elicitors.

Number of secondary finger in pooled analysis, the maximum (15.35) number of secondary fingers was observed with treatment salicylic acid-200 ppm followed by salicylic acid-100 ppm (15.26) and salicylic acid-300 ppm (15.23) as compared to minimum (9.64) number of secondary fingers with control. The number increased with increase of concentration in chitosan but opposite trend was observed in methyl jasmonate. Maximum number was recorded with medium concentration of other two elicitors.

Weight of secondary finger (g) in pooled analysis, the maximum (161.45 g) weight of secondary finger was recorded with salicylic acid-100 ppm followed by salicylic acid-300 ppm (152.88 g) and methyl jasmonate-50 ppm (149.70 g) as compared to minimum (87.17 g) weight of under control. The weight increased from 121.99 to 148.18 g with increase in concentration of chitosan from 250 to750 ppm but weight decreased from 149.70 to 105.54g with increase of concentration from 50 to 200 ppm in methyl jasmonate. No such trend observed in proline and methyl jasmonate.

Length of secondary finger (cm) in pooled analysis, the maximum (4.69 cm) length of secondary finger was noticed with treatment chitosan-750 ppm followed by salicylic acid-300 ppm (4.49 cm) and salicylic acid-100 ppm (4.41 cm) as compared to minimum (3.17 cm) length of secondary finger with proline-50 ppm. As per pooled analysis, the length of secondary finger increased with increasing concentration up to highest level in case of chitosan and methyl jasmonate.

Breadth of secondary finger (cm) in pooled analysis, the maximum (1.90 cm) breadth of secondary finger was observed with salicylic acid-100 ppm followed by salicylic acid-200 ppm (1.85 cm) and salicylic acid-300 ppm (1.67 cm) as compared to minimum (1.24 cm) breadth of secondary finger with proline-50 ppm. As per pooled analysis, the breadth of secondary finger decreased with increasing concentration in salicylic acid but maximum breadth was recorded with medium concentration of other three elicitors.

Yield per plot (kg $3m^{-2}$) in pooled analysis, the maximum (13.26 kg $3m^{-2}$) yield $plot^{-1}$ was recorded with salicylic acid-200 ppm followed by chitosan-750 ppm (12.98 kg $3m^{-2}$) and salicylic acid-300 ppm (12.46 kg $3m^{-2}$) as compared to minimum (8.92 kg $3m^{-2}$) yield plot-1 with proline-200 ppm. The increasing trend in increasing yield $plot^{-1}$ (11.28 to 12.98 kg) was observed with increasing concentration (250-750 ppm) in case of chitosan. In other three elicitors the yield increased up to medium concentration then decreased.

Projected yield (t ha^{-1}) in pooled analysis, the maximum (33.14 t ha^{-1}) projected yield was observed with treatment salicylic acid-200 ppm followed by chitosan-750 ppm (32.45 t ha^{-1}) and salicylic acid-300 ppm (31.14 t ha^{-1}) as compared to minimum (22.30 t ha^{-1}) projected yield with proline-200 ppm. The similar trend of response in respect of concentration was observed here also like yield $plot^{-1}$.

DISCUSSION

Chitosan have been recognized as a product to enhance crop production due to its bioactivities: like growth stimulation and seed germination, increasing nutrient uptake, reducing oxidative stress, increasing chlorophyll content, photosynthetic and chloroplast enlargement in the leaves, antifungal, antiviral and antibacterial properties (Hadrami *et al*., 2010; Hadwiger 2013).

The administration of chitosan through seed treatment and foliar spray greatly increased the number of tillers, demonstrating the ability of chitosan to promote higher differentiation of vegetative buds to produce tillers. These findings were in consistent with Thengumpally (2019) in turmeric. The increment in fresh weight plant-1 after treatment with chitosan may be due to its impact on enhancing uptake and transport of minerals such as nitrogen, phosphorus and potassium.

The findings are in good agreement with those of Anasuya and Sathiyabama (2016), who found that as compared to a control, chitosan (0.1%, w/v) increased plant height, leaf number, and fresh weight per plant in turmeric. The rhizome yield was enhanced by up to 60% by fresh weight and 50% by dry weight when chitosan (0.1%) was applied topically above the control group.

Chitosan significantly increased turmeric yield, which may be related to improved photosynthetic pigments and biochemical plant processes that increased the amount of photosynthates directed towards the rhizomes (El-Tantawy 2009). Our results are similar with Thengumpally (2019) who reported that the foliar administration of chitosan had a good improvement in the turmeric yield. Our findings are also in line with Ullah *et al*. (2020) who reported that chitosan increased yield in tomato.

The significant effect of chitosan on plant growth may be attributed to an increase in the key enzyme activities of nitrogen metabolism (nitrate reductase, glutamine synthetase and protease) and increased photosynthesis which enhanced the plant growth (Mondal *et al*., 2012). It may be attributed to an increase in the availability and uptake of water and essential nutrients through adjusting cell osmotic pressure, and reducing the accumulation of harmful free radicals by increasing antioxidants and enzyme activities (Guan *et al*., 2009). These results are similar to Sofy *et al.* (2020); Manjusha *et al.* (2023) Chitosan may include amino groups that enhance plants' photosynthetic area, maximise photosynthesis and ultimately improve plant height because of the turmeric plants' favourable response to chitosan concentration. Ibraheim and Mohsen (2015) also found that different chitosan concentration positively improved plant height and other growth parameters of cucumber plants. Increased uptake of nitrogen and potassium eventually increases plant growth.

Salicylic acid application increases the plant height because of increased Rubisco chemical action and photosynthetic activity. It causes plant growth to increase with increasing cell division in both stem and roots, thus increasing plant height under greenhouse and field conditions. It has numerous functions, particularly the reduced transpiration and leaf abscission (Ashraf *et al*., 2010).

Salicylic acid treatments reported to have increased the cell division by stimulating the mitotic system of the apical meristem of roots which caused better plant growth (Sakhabutdinova *et al*., 2003; Basra *et al*., 2006). Salicylic acid intensified the net photosynthetic rate, internal CO_2 concentration and water use efficiency which ultimately influence the final yield (Shakirova, 2007). This root growth promoting domain of salicylic acid has now made it one of the most important, effective and cost beneficial phytohormone that has the potential to enhance the root growth in economically important vegetables and salad crops.

The growth yield and essential oil yield and essential oil yield of cumin were increased with the application of salicylic acid and methyl jasmonate in cumin, Fruit yield of 776.7 kg ha^{-1} and 611.3kg ha^{-1} were observed with salicylic acid 0.1mM and methyl jamonate 1.0 mM as compared to 439.0 kg ha-1 under control, showing significant increase about 77% band 40% as compared with control. Important role in plant development- and physiological processes induces or increases the biosynthesis of many secondary secondary metabolites that play important roles, (Choi *et al*., 2005; Kim *et al*., 2009). Sivaranjani *et al*. (2022) are suggested that foliar spray of chitosan and salicylic acid at rhizome development stage could be employed to elicit the physiological response and improve the quality of turmeric grown under rain fed condition.

The promotive effect of salicylic acid on vegetative growth could be attributed to its bio regulator effects on physiological and biochemical processes in plants such as ion uptake cell elongation, cell division, sink/source regulation, enzymatic activities, protein synthesis and photosynthetic activity as well increase the antioxidant capacity of plants (El-Tayab, 2005) and its role in enhancing rooting of plants (Sandoval - Yapiz, 2004) which play a key role in enhancing the growth and productivity of plants. Our results are in harmony with those of Manoj (2017) in turmeric, Said-Al *et al*. (2014); Hesami *et al*., (2013) on coriander, Rahimi *et al*. (2013) on cumin. Among four elicitors, salicylic acid and chitosan proved better as compared to others.

Table 1: Influence of foliar treatment with metabolite elicitors on growth parameters of turmeric.

Sr. No.	Treatments (ppm)	Plant height (cm)		Number of leaves $plant^{-1}$		Number of tillers $plant^{-1}$	
		150 DAP (Pooled)	180 DAP (Pooled)	150 DAP (Pooled)	180 DAP (Pooled)	150 DAP (Pooled)	180 DAP (Pooled)
1.	Chitosan-250	145.23	155.52	13.70	17.02	1.89	2.74
2.	Chitosan-500	151.24	164.86	15.04	19.35	2.01	3.18
3.	Chitosan-750	156.89	170.65	15.71	19.93	2.18	2.93
4.	Methyl jasmonate-50	149.61	160.11	14.82	17.06	1.54	2.66
5.	Methyl jasmonate-100	158.32	171.02	16.11	19.08	2.28	3.24
6.	Methyl jasmonate-200	149.32	160.14	16.04	18.12	2.13	2.65
7.	Proline-50	127.94	143.68	13.64	16.70	1.27	2.27
8.	Proline-100	140.10	148.79	14.53	17.70	1.39	2.32
9.	Proline-200	128.40	148.18	13.61	16.45	1.20	2.06
10.	Salicylic acid -100	152.47	164.55	14.73	18.36	1.79	2.82
11.	Salicylic acid -200	167.25	175.80	16.75	19.51	2.25	3.47
12.	Salicylic acid -300	162.31	184.72	15.76	20.90	1.81	3.47
13.	Control	124.13	142.06	13.06	16.54	1.36	2.06
14.	S.Em. (±)	2.283	2.582	0.351	0.409	0.049	0.045
15.	C. D. (P=0.05)	6.702	7.580	1.031	1.200	0.144	0.132

Table 2: Influence of foliar treatment with metabolite elicitors on clump and Yield parameters of turmeric.

Sr. No.	Treatments (ppm)	Weight of clump (g)	Length of clump (cm)	Breadth of clump (cm)	Yield per plot (kg 3m^{-2})	Projected yield (t ha^{-1})
		Pooled	Pooled	Pooled	Pooled	Pooled
1.	Chitosan-250	296.76	17.81	15.62	11.28	28.19
2.	Chitosan-500	320.17	18.01	15.69	12.17	30.41
3.	Chitosan-750	341.48	18.88	16.45	12.98	32.45
4.	Methyl jasmonate-50	287.23	16.20	14.78	10.92	27.29
5.	Methyl jasmonate-100	318.09	17.33	15.82	12.09	30.21
6.	Methyl jasmonate-200	283.45	16.30	15.10	10.77	26.93
7.	Proline-50	250.99	15.74	14.09	9.54	23.85
8.	Proline-100	272.31	17.15	15.35	10.35	25.86
9.	Proline-200	234.84	15.46	14.98	8.92	22.30
10.	Salicylic acid -100	306.84	17.21	15.44	11.66	29.15
11.	Salicylic acid -200	348.81	18.66	16.02	13.26	33.14
12.	Salicylic acid -300	327.70	17.70	15.80	12.46	31.14
13.	Control	272.70	14.71	13.85	10.36	25.90
14.	S.Em. (±)	5.379	0.307	0.319	0.205	0.665
15.	C. D. (P=0.05)	15.794	0.903	0.935	0.601	1.952

Table 3: Influence of foliar treatment with metabolite elicitors on primary finger and Secondary finger of turmeric.

Sr. No.	Treatments (ppm)	Primary finger				Secondary finger			
		Number	Weight (g)	Length (cm)	Breadth (cm)	Number	Weight (g)	Length (cm)	Breadth (cm)
		Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
1.	Chitosan-250	9.94	155.28	8.47	1.75	11.21	121.99	3.74	1.36
2.	Chitosan-500	10.20	166.41	9.51	1.90	11.95	133.92	3.98	1.66
3.	Chitosan-750	10.81	171.84	9.54	2.23	14.92	148.18	4.69	1.60
4.	Methyl jasmonate-50	10.10	150.42	7.93	1.79	13.96	149.70	3.25	1.66
5.	Methyl jasmonate-100	11.19	183.90	9.60	2.15	12.78	124.58	3.85	1.66
6.	Methyl jasmonate-200	9.99	156.78	8.55	1.89	12.42	105.54	4.07	1.47
7.	Proline-50	8.85	138.54	7.67	1.61	9.76	92.65	3.17	1.24
8.	Proline-100	9.57	146.18	8.15	1.69	10.52	107.33	3.75	1.41
9.	Proline-200	8.06	121.28	7.61	1.70	10.01	98.25	3.61	1.39
10.	Salicylic acid -100	11.57	173.55	8.40	2.20	15.26	161.45	4.41	1.90

CONCLUSIONS

Considering the yield per plot and projected yield per ha the most effective treatment among different elicitors was salicylic acid 200 ppm followed by salicylic acid 300 ppm and chitosan 750 ppm towards improving the production of turmeric. These two elicitors are proved to be the best when compared to other elicitors on turmeric. at Horticultural Research Station, Mondouri, BCKV, West Bengal. Salicylic acid followed chitosan are affecting more impact on growth and yield parameters. These two elicitors can be suggested to the farmers for higher yields and increasing farmer's income.

FUTURE SCOPE

1. Studies on the effect of elicitors on seed treatment as well as foliar treatment for detailed understanding the impact on yield and quality parameters
2. Combined application of growth substances with bio-inoculants may be tried yield maximization.

Acknowledgement. The authors are grateful to Prof J.K. Hore, Dean P.G. and Dean Faculty of Horticulture, BCKV, for providing necessary support and facilities during the course of experiment.
Conflict of Interest. None.

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How to cite this article: Vamshi Krishna S., Hore J.K., Gowthami D., Luwangshangbam James Singh and Kavya E. (2023). Influence of Foliar Treatment of Metabolite Elicitors on Plant Growth and Yield Parameters of Turmeric (*Curcuma longa* L.). *Biological Forum – An International Journal, 15*(10): 1011-1016.