Biological Forum – An International Journal **15(3): 212-220(2023)**

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

Impact of Metabolite Elicitors on Growth and Yield Characteristics in Turmeric (*Curcuma longa* L.) at High Altitude Zone of Andhra Pradesh

D. Manjusha[1*], S. Suryakumari[2], K. Giridhar[3], A.V.D. Dorajeerao[4], D.R. Salomi Suneetha[5], P. Subbaramamma[6] and V. Sivakumar[7]

[1]Ph.D. Scholar, Horticulture, Department of PSMA, COH, Dr. YSRHU, Venkataramannagudem (Andhra Pradesh), India.
[2]Dean of PG Studies, Dr. YSRHU, Venkataramannagudem (Andhra Pradesh), India.
[3]Principal Scientist & Head (Hort.), Horticultural Research Station, Lam (Andhra Pradesh), India.
[4]Professor (Hort.), College of Horticulture, Dr. YSRHU, Venkataramannagudem (Andhra Pradesh), India.
[5]Dean of Student Affairs, Dr. YSRHU, Venkataramannagudem (Andhra Pradesh), India.
[6]Associate Professor, Plant Physiology, College of Horticulture, Dr. YSRHU, Venkataramannagudem (Andhra Pradesh), India.
[7]Scientist & Head (Hort.), Horticultural Research Station, Chintapalli (Andhra Pradesh), India.

(Corresponding author: D. Manjusha)*
(Received: 14 January 2023; Revised: 17 February 2023; Accepted: 21 February 2023; Published: 22 March 2023)
(Published by Research Trend)

ABSTRACT: The present investigation entitled "Impact of metabolite elicitors on growth and yield characteristics in turmeric (*Curcuma longa* L.) at high altitude zone of Andhra Pradesh" is carried out at HRS, Chintapalli, Dr. Y.S.R. Horticultural University, during *Kharif* 2017 and 2018. The metabolite elicitors chitosan and salicylic acid were administered to two varieties, Mydukur and Roma, in the form of seed treatment and foliar spray. At 180 days after transplanting (DAT), growth characteristics were noted. At harvest, yield was noted at 250 DAT for the variety Roma and 270 DAT for the variety Mydukur. Pooled data over two years (2017-18 & 2018-19) on growth parameters and yield revealed significant effect on plant height (103.21 cm), number of leaves plant^{-1} (11.49), leaf length (44.48 cm), leaf width (11.56 cm), number of tillers plant^{-1} (1.68), fresh weight plant^{-1} (439.52 g) and yield plot^{-1} (8.38 kg) were recorded in the variety Roma. Significantly superior plant height (96.32 cm), number of leaves plant^{-1} (12.15), leaf length (44.97 cm), leaf width (12.09 cm), number of tillers plant^{-1} (1.75), fresh weight plant^{-1} (419.98 g) and yield plot^{-1} (7.67 kg) were recorded in the foliar application of chitosan @ 100 ppm as the effect of metabolite elicitors through foliar application is observed superior to seed treatment. The combinations of variety Roma + chitosan @ 100 ppm (S), Roma + chitosan @ 100 ppm (F) and chitosan @ 100 ppm (S) + chitosan @ 100 ppm (F) recorded significantly highest growth and yield characteristics. The three-way interaction Roma + chitosan @ 100 ppm (S) + chitosan @ 100 ppm (F)recorded superior plant height (113.80 cm), number of leaves plant^{-1} (13.74), leaf length (50.76 cm), leaf width (13.34 cm), number of tillers plant^{-1} (2.24), fresh weight plant^{-1} (527.74 g) and yield plot^{-1} (10.87 kg) and lowest was recorded with Mydukur + no seed treatment + water spray.

Keywords: Turmeric, Elicitors, Growth, Yield, Chitosan, Salicylic Acid, Mydukur, Roma, High altitude zone of Andhra Pradesh.

INTRODUCTION

One essential spice that is used frequently for flavour is turmeric (*Curcuma longa* L.). In Andhra Pradesh, districts like Cuddapah, Guntur, Krishna, Kurnool, and Vishakhapatnam record major contribution in both area and production of turmeric. Turmeric rhizomes are rich in essential oils (5%) and curcuminoid pigments (6%) in addition to having significant amounts of proteins (6.3%), lipids (5.1%), carbs (69.4%), and fibre (2.6%) (Ojikpong, 2018). According to a recent survey, more people are using Indian turmeric for both food and non-food purposes, which has increased both its export and demand (Ray *et al.*, 2016). Curcumin, the primary biologically active secondary metabolite of turmeric, has a wide range of biological qualities, including those that are anti-inflammatory, anti-mutagenic, anti-carcinogenic, and anti-angiogenic (Kunnumakkara *et al.*, 2007; Lan *et al.*, 2019).

Due to the widespread acceptance of turmeric's use and the value-added goods it produces, more turmeric must be produced to satisfy its demand. Elicitors are chemical substances with a wide range of sources that can cause physiological and morphological reactions that lessen stress and hasten the synthesis of beneficial

secondary metabolites. Along with their effects on plant components, chitosan and salicylic acid as metabolite elicitors are considered crucial for enhancing vegetative and generative growth. Chitin can be converted into chitosan by removing the acetyl group and changing it to an amino group, which is a natural biopolymer. Numerous studies revealed that adding chitosan to many crops boosted their vegetative growth and output including Castro *et al*. (2016) on coriander; Mahdavi, (2013) on isabgol; Yin *et al*. (2012) on Greek oregan; Lei *et al*. (2011) on artemisia and Kim *et al*. (2005) on basil. Chitosan has also gained recognition as a product to improve crop production because of its bioactivities, which include biodegradability, seed germination and growth stimulation, and increased nutrient uptake (Hadrami *et al*., 2010; Hadwiger, 2013). Salicylic acid, a phenol found in plants, controls seed germination and vegetative growth, contributing to the growth and development of plants. The activation of metabolic pathways linked to plants' tolerance mechanisms is regulated by salicylic acid. Salicylic acid's role in nutrient intake, membrane stability, water relations, stomatal regulation, photosynthesis, and growth have all been linked to its potential to reduce the effects of abiotic stress on plant growth. (Khan *et al*., 2003 and Stevens *et al*., 2006).

Hence, the study was undertaken with an objective to evaluate the effect of metabolite elicitors on growth and yield in turmeric at high altitude zone of Andhra Pradesh.

MATERIALS AND METHODS

The experiment is conducted during *Kharif* 2017-2018 and 2018-2019 at Horticultural Research Station, Chintapalli. The location comes under the high-altitude tribal zone of Andhra Pradesh and is situated at an altitude of 839 m above mean sea level with 17.86 ° N latitude and 82.35° E longitude. The soil is an alluvial type having a good drainage facility and moderate water holding capacity. The experiment was conducted in factorial concept with three factors *viz.,* varieties, seed treatment and foliar application of chitosan and salicylic acid with no use of elicitor in both the methods. There were two levels of varieties (Mydukur and Roma), three levels each in seed treatment and foliar spray (chitosan @ 100 ppm, salicylic acid @ 100 ppm and no use of elicitor), thus making eighteen treatment combinations replicated thrice.

Seed material (rhizomes) of variety Mydukur was obtained from farmers' field near Thumuluru village of Guntur District and variety Roma was collected from HRS, Chintapalli. Healthy rhizomes were cut into 5 g single bud rhizome pieces and the rhizome pieces of individual treatments were dipped in chitosan and salicylic acid solutions, respectively for 30 minutes and were shade dried before sowing in protrays which were filled with coco peat, vermiculite and perlite (2:1:1). Irrigation was given with rose can and sprinklers. The land was thoroughly ploughed for 2-3 times with mould board plough and brought into a fine tilth by harrowing. The entire experimental area was levelled and raised beds with ridges were made. Transplanting was done after 40 days of sowing at the three to four-leaf stage. The seedlings were planted at a spacing of 45 cm between the rows and 20 cm between the plants. The plants of individual treatments were sprayed with respective metabolite elicitors solutions at 60, 90, and 120 DAT using hand-held sprayer. While the plants in the control plots were sprayed with distilled water.

The data on plant height, number of leaves plant^{-1}, leaf length and width, number of tillers plant^{-1} and fresh weight plant^{-1} were recorded from five randomly selected plants from each treatment in each replication at 180 DAT and yield plot^{-1} at the time of harvest *i.e.* 250 DAT in the variety Roma and 270 DAT in the variety Mydukur.

RESULTS

Observations on growth parameters *viz.,* plant height, number of leaves plant^{-1}, leaf length and width, number of tillers plant^{-1}, fresh and dry weight plant^{-1} and were recorded at 180 DAT (60 days after the third spray).

Plant height (cm). The pooled data on plant height clearly shows that plant height varied significantly among the varieties and methods of application of metabolite elicitors at 180 DAT. At 180 DAT, the highest plant height was recorded in the variety Roma (103.21 cm). The highest plant height (93.63 cm) was recorded in seed treatment (S) with chitosan @ 100 ppm. The foliar spray (F) of chitosan @ 100 ppm was significantly superior and recorded highest plant height of 96.32 cm. The combination of variety Roma + chitosan @ 100 ppm (S) recorded significantly highest plant height (106.82 cm) and the variety Mydukur + no seed treatment recorded lowest plant height (75.90 cm). In the varietal interaction with foliar spray, the variety Roma + chitosan @ 100 ppm (F) recorded significantly highest plant height (109.30 cm) and Mydukur + water spray recorded lowest plant height (73.02 cm).In the interaction of seed treatment with foliar spray, chitosan @ 100 ppm as both seed treatment and foliar spray exhibited significantly highest plant height (99.83 cm) and lowest plant height was recorded with no seed treatment + water spray (82.99 cm).The three-way interaction effect of the variety with seed treatment and foliar spray of elicitors on plant height was found significant. Highest plant height (113.80 cm) was recorded in the variety Roma + chitosan @ 100 ppm (S) + chitosan @ 100 ppm (F) and lowest plant height (71.17 cm) was observed in the variety Mydukur + no seed treatment + water spray (Table 1).

Number of leaves plant^{-1}. From the pooled data obtained it was found that number of leaves plant^{-1} differed significantly between the varieties. Roma recorded significantly higher number of leaves (11.49) in the high-altitude zone of Chintapalli at 180 DAT. In methods of application of metabolite elicitors, seed treatment with chitosan @ 100 ppm exhibited significantly maximum number of leaves plant^{-1} (11.72). Chitosan @ 100 ppm as foliar spray was significantly superior and recorded the maximum number of leaves plant^{-1} (12.15). The combination of variety Roma + chitosan @ 100 ppm (F) recorded significantly maximum number of leaves plant^{-1} (12.64)

and Mydukur + water spray recorded minimum number of leaves plant^{-1} (8.60). Application of chitosan @ 100 ppm (S) + chitosan @ 100 ppm (F) recorded significantly greater number of leaves plant^{-1} (13.19) whereas, no seed treatment + water spray recorded minimum number of leaves plant^{-1} (8.90). Higher number of leaves plant^{-1} (13.74) was recorded in the three-way interaction of variety Roma + chitosan @ 100 ppm (S) + chitosan @ 100 ppm (F) and lesser number of leaves plant^{-1} (8.03) were recorded in the variety Mydukur + no seed treatment + water spray (Table 2).

Leaf length (cm). The pooled data referring to leaf length in response to varieties, methods of application of metabolite elicitors as seed treatment and foliar application and their interactions was presented in Table 3.

At 180 DAT, the variety Roma recorded maximum leaf length (44.48 cm). Seed treatment with chitosan @ 100 ppm recorded significantly highest leaf length *i.e*. 43.26 cm. Foliar spray with chitosan @ 100 ppm recorded significantly greater leaf length of 44.97 cm. All the interactions exhibited significant influence onleaf length. The interaction of the variety Roma + chitosan @ 100 ppm (S) recorded superior leaf length (46.19 cm) and minimum leaf length was recorded with the combination of variety Mydukur + no seed treatment (31.64 cm). Interaction between the variety Roma + chitosan @ 100 ppm (F) recorded maximum leaf length (48.23 cm) and minimum leaf length was recorded with the interaction Mydukur + water spray (33.32 cm). Seed treatment and foliar spray both with chitosan @ 100 ppm recorded significantly maximum leaf length (47.68 cm) and the minimum leaf length was recorded in the combination of no seed treatment + water spray (35.97 cm). Significantly highest leaf length (50.76 cm) was recorded in the variety Roma + chitosan @ 100 ppm (S) + chitosan @ 100 ppm (F) and the lowest leaf length (31.64 cm) was observed in the variety Mydukur + no seed treatment + water spray.

Leaf width (cm). The pooled data relevant to leaf width in response to varieties, method of application of metabolite elicitors as seed treatment and foliar application and their interactions are presented in Table 4. At 180 DAT, the variety Roma (11.56 cm) outperformed well. Seed treatment with metabolite elicitor chitosan @ 100 ppm recorded significantly maximum leaf width (11.72 cm). Foliar spray with metabolite elicitor chitosan @ 100 ppm recorded significantly highest leaf width 12.09 cm. All the two-way interactions exhibited significant influence on leaf width except for the varietal interaction with seed treatment. The combination of variety Roma + chitosan @ 100 ppm (F) recorded maximum leaf width (12.58 cm) and the minimum leaf width was recorded with Mydukur + water spray (9.55 cm). Application of chitosan @ 100 ppm as both seed treatment and foliar spray recorded significantly maximum leaf width (12.14 cm) and minimum leaf width (10.11 cm) was recorded with no seed treatment + water spray. The three-way interaction effect of the variety with seed treatment and foliar spray of metabolite elicitors exhibited significant effect on leaf width. Roma + chitosan @ 100 ppm (S) + chitosan @ 100 ppm (F) recorded maximum leaf width (13.34 cm) and minimum leaf width (9.04 cm) was observed with Mydukur + no seed treatment + water spray.

Number of tillers plant^{-1}. The pooled data referring to number of tillers plant^{-1} in response to varieties, method of application of metabolite elicitors as seed treatment and foliar application and their interactions at 180 DAT are presented in Table 5. The mean number of tillers plant^{-1} in the variety Roma is 1.68. As regards to the methods of application of metabolite elicitors, seed treatment with chitosan @ 100 ppm recorded significantly highest number of tillers plant^{-1} (1.63). Foliar application of chitosan @ 100 ppm exhibited greater number of tillers plant^{-1} (1.75). The varietal interaction with methods of elicitor application exhibited significant influence on number of tillers plant^{-1} except for varietal interaction with seed treatment. The variety Roma + chitosan @ 100 ppm (F) recorded significantly maximum number of tillers plant^{-1} (1.75) and Mydukur + water spray recorded minimum number of tillers plant^{-1} (1.05). The combined application of chitosan @ 100 ppm (S) + chitosan @ 100 ppm (F) recorded significantly maximum number of tillers plant^{-1} (1.99) and minimum number of tillers plant^{-1} was recorded with no seed treatment + water spray (1.22). The interaction effect of the variety with seed treatment and foliar spray of metabolite elicitors exhibited significant on number of tillers plant^{-1}. Greater number of tillers plant^{-1} (2.24) was recorded with Roma + chitosan @ 100 ppm (S) + chitosan @ 100 ppm (F) and minimum number of tillers plant^{-1} (0.70) was observed in the interaction of variety Mydukur + no seed treatment + water spray.

Fresh weight plant^{-1} (g). At 180 DAT, varieties and methods of application of elicitors showed significant effect on fresh weight plant^{-1}. The variety Roma recorded maximum fresh weight plant^{-1} (439.52 g). Seed treatment with chitosan @ 100 ppm recorded significantly maximum fresh weight plant^{-1} (398.44 g). Foliar spray with metabolite elicitor chitosan @ 100 ppm recorded significantly highest fresh weight plant^{-1} (419.98 g). Interactions exhibited significant influence on fresh weight plant^{-1}. The combination of Roma + chitosan @ 100 ppm (S) recorded maximum fresh weight plant^{-1}(459.40 g) and minimum fresh weight plant^{-1}(274.64 g) was recorded in Mydukur + no seed treatment. Variety Roma + chitosan @ 100 ppm (F) recorded significantly maximum fresh weight plant^{-1} (492.82 g) and minimum fresh weight plant^{-1} (257.28 g) was recorded in Mydukur + water spray. Interaction of methods of application of metabolite elicitors *i.e*. seed treatment and foliar spray both with chitosan @ 100 ppm recorded significantly maximum fresh weight plant^{-1} (453.72 g) whereas minimum fresh weight plant^{-1} (294.54 g) was recorded with no seed treatment + water spray. Significantly highest fresh weight plant^{-1} (527.74 g) was recorded in the combination of variety Roma + chitosan @ 100 ppm (S) + chitosan @ 100 ppm (F) whereas, lowest fresh weight plant^{-1} (237.68 g)

was recorded in Mydukur + no seed treatment + water spray.

Yield plot^{-1} (kg). Varieties and methods of application of elicitors exhibited significant influence on yield plot^{-1}. The variety Roma at Chintapalli recorded superior yield plot^{-1} (8.38 kg). Seed treatment with metabolite elicitor chitosan @ 100 ppm recorded significantly highest yield plot^{-1} (7.06 kg). Foliar spray with metabolite elicitor chitosan @ 100 ppm recorded significantly maximum yield plot^{-1} (7.67 kg). All the interactions exhibited significant influence on yield plot^{-1}. The varietal interaction of Roma + chitosan @ 100 ppm (S) recorded maximum yield plot^{-1} (9.07 kg) and the variety Mydukur + no seed treatment recorded minimum yield plot^{-1} (4.02 kg). Significantly highest yield plot^{-1} (9.98 kg) was recorded in the combination of variety Roma + chitosan @ 100 ppm (F) and minimum yield plot^{-1} (3.74 kg) was recorded in the variety Mydukur + water spray. Seed treatment and foliar spray both with the metabolite elicitor chitosan @ 100 ppm recorded highest yield plot^{-1} (8.39 kg) and was on par with combined application of salicylic acid @ 100 ppm (S) + chitosan @ 100 ppm (F) (8.12 kg) whereas, lowest yield plot^{-1} (4.69 kg) was recorded with no seed treatment + water spray. The combination of variety Roma + chitosan @ 100 ppm (S) + chitosan @ 100 ppm (F) recorded superior yield plot^{-1} (10.87 kg) and was on par (10.52 kg) with Roma + salicylic acid @ 100 ppm (S) and chitosan @ 100 ppm (F). The variety Mydukur + no seed treatment + water spray recorded minimum yield plot^{-1} (3.35 kg).

DISCUSSION

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 (Sofy *et al*., 2020). Chitosan increases the plant height of radish, cucumber, and sweet pepper plants (Farouk *et al*., 2008). Also, then gumpally (2019) reported that treatment of chitosan on turmeric increased plant growth. Chitosan significantly boosted the number of leaves plant^{-1}, which may be related to its ability to help plants absorb more phosphorus and potash, which in turn leads to an increase in cell size, chloroplast growth, and chlorophyll synthesis (Latif and Mohamed 2016).

Chitosan has significantly increased leaf length and width, which may be related to an increase in the availability and consumption of water and vital nutrients, leading to an increase in the activities of key enzymes involved in nitrogen metabolism and improved nitrogen transport, which has accelerated photosynthesis, growth and plant development (Guan *et al*., 2009). These results are similar to Sofy *et al*. (2020) who 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 (Ibraheim and Mohsen 2015). 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. Anusuya and Sathiyabama (2016) reported that chitosan (0.1%, w/v) increased plant height, leaf number and fresh weight per plant in turmeric.

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.

Salicylic acid promotes plant development by increasing cell division and elongation as well as photosynthetic pigment levels, both of which are connected to increased nutrient intake (Hayat *et al*., 2012 ; Pedroso *et al*., 2019; Bagautdinova *et al*., 2022) The bioregulatory effects of salicylic acid on physiological and biochemical processes in plants, such as ion uptake, cell elongation, cell division, cell differentiation, sink/source regulation, enzymatic activities, protein synthesis, and photosynthetic activity, as well as an increase in plant antioxidant capacity, could be responsible for the substance's stimulatory effect on vegetative growth (El-Tayeb, 2005). Moreover, the increase in plant height was due to increase in number of internodes, while the increase in the fresh weight of turmeric might be attributed to an increase in number of branches and leaves as well as leaf area. Our results are in harmony with those of Manoj (2017); Gharib (2006) on sweet basil and marjoram. Along with its role in enhancing vegetative development, salicylic acid also has a good impact on yield. Similar results were obtained by Manoj (2017) in turmeric, Hesami *et al*. (2012) on coriander and Rahimi *et al*. (2013) on cumin. They reported that there was an improvement in yield as a result to foliar application of salicylic acid.

Table 1: Effect of metabolite elicitors on plant height (cm) in turmeric at 180 DAT.

Seed treatment (S)	Foliar spray (F)	2017-18			2018-19			Pooled		
		Roma (V_1)	Mydukur (V_2)	Mean	Roma (V_1)	Mydukur (V_2)	Mean	Roma (V_1)	Mydukur (V_2)	Mean
Chitosan @ 100 ppm (S_1)	Chitosan @ 100 ppm (F_1)	111.99	79.62	**95.81**	115.60	92.09	**103.84**	113.80	85.86	**99.83**
	Salicylic Acid @ 100 ppm (F_2)	106.86	75.42	**91.14**	110.84	88.46	**99.65**	108.85	81.94	**95.40**
	Water spray (F_3)	95.37	66.31	**80.84**	100.26	80.70	**90.48**	97.82	73.51	**85.66**
Mean		**104.74**	**73.78**	***89.26***	**108.90**	**87.08**	***97.99***	**106.82**	**80.44**	***93.63***
Salicylic Acid @ 100 ppm (S_2)	Chitosan @ 100 ppm (F_1)	108.35	79.27	**93.81**	113.87	90.53	**102.2**	111.11	84.90	**98.01**
	Salicylic Acid @ 100 ppm (F_2)	102.65	74.19	**88.42**	106.35	87.67	**97.01**	104.50	80.93	**92.72**
	Water spray (F_3)	93.52	70.60	**82.06**	97.52	78.15	**87.83**	95.52	74.38	**84.95**
Mean		**101.51**	**74.69**	***88.10***	**105.91**	**85.45**	***95.68***	**103.71**	**80.07**	***91.89***
No seed treatment(S_3)	Chitosan @ 100 ppm (F_1)	100.68	72.74	**86.71**	105.28	85.78	**95.53**	102.98	79.26	**91.12**
	Salicylic Acid @ 100 ppm (F_2)	96.91	71.00	**83.96**	102.11	83.51	**92.81**	99.51	77.26	**88.39**
	Water spray (F_3)	93.00	66.05	**79.53**	96.60	76.29	**86.44**	94.80	71.17	**82.99**
Mean		**96.86**	**69.93**	***83.40***	**101.33**	**81.86**	***91.59***	**99.10**	**75.90**	***87.50***
for comparison between means of Varieties (V) x Foliar spray (F)										
Chitosan @ 100 ppm (F_1)		**107.01**	**77.21**	***92.11***	**111.58**	**89.46**	***100.52***	**109.30**	**83.34**	***96.32***
Salicylic Acid @ 100 ppm (F_2)		**102.14**	**73.54**	***87.84***	**106.43**	**86.54**	***96.49***	**104.29**	**80.04**	***92.17***
Water spray (F_3)		**93.96**	**67.65**	***80.81***	**98.12**	**78.38**	***88.25***	**96.05**	**73.02**	***84.53***
Mean		***101.04***	***72.80***		***105.38***	***84.79***		***103.21***	***78.80***	
Source of variation		**SE m±**	**CD at 5%**		**SE m±**	**CD at 5%**		**SE m±**	**CD at 5%**	
Varieties (V)		0.02	0.07		0.06	0.16		0.04	0.12	
Seed treatment (S)		0.03	0.08		0.07	0.20		0.05	0.15	
Foliar spray (F)		0.03	0.08		0.07	0.20		0.05	0.15	
V × S		0.04	0.11		0.10	0.28		0.07	0.21	
S × F		0.05	0.14		0.12	0.35		0.09	0.26	
V × F		0.04	0.11		0.10	0.28		0.07	0.21	
V × S × F		0.07	0.20		0.17	0.49		0.13	0.37	

Table 2: Effect of metabolite elicitors on number of leaves plant^{-1} in turmeric at 180 DAT.

Seed treatment (S)	Foliar spray (F)	2017-18			2018-19			Pooled		
		Roma (V_1)	Mydukur (V_2)	Mean	Roma (V_1)	Mydukur (V_2)	Mean	Roma (V_1)	Mydukur (V_2)	Mean
Chitosan @ 100 ppm (S_1)	Chitosan @ 100 ppm (F_1)	13.07	12.13	**12.60**	13.79	12.62	**13.21**	13.74	12.63	**13.19**
	Salicylic Acid @ 100 ppm (F_2)	12.00	11.20	**11.60**	13.28	12.03	**12.66**	12.84	12.00	**12.42**
	Water spray (F_3)	9.33	8.40	**8.87**	11.40	10.53	**10.97**	10.16	8.97	**9.56**
Mean		**11.47**	**10.58**	***11.03***	**12.83**	**11.73**	***12.28***	**12.25**	**11.20**	***11.72***
Salicylic Acid @ 100 ppm (S_2)	Chitosan @ 100 ppm (F_1)	12.53	11.60	**12.07**	13.55	12.31	**12.93**	13.27	11.84	**12.55**
	Salicylic Acid @ 100 ppm (F_2)	11.13	10.73	**10.93**	12.77	11.75	**12.26**	11.60	11.20	**11.40**
	Water spray (F_3)	9.47	8.07	**8.77**	10.99	10.16	**10.57**	10.04	8.54	**9.29**
Mean		**11.05**	**10.14**	***10.59***	**12.44**	**11.41**	***11.92***	**11.64**	**10.53**	***11.08***
No seed treatment(S_3)	Chitosan @ 100 ppm (F_1)	10.53	10.13	**10.33**	12.45	11.21	**11.83**	10.90	10.53	**10.72**
	Salicylic Acid @ 100 ppm (F_2)	10.80	9.33	**10.07**	12.06	10.82	**11.44**	11.37	9.77	**10.57**
	Water spray (F_3)	9.00	7.80	**8.40**	10.88	9.82	**10.35**	9.50	8.30	**8.90**
Mean		**10.11**	**9.09**	***9.60***	**11.80**	**10.61**	***11.21***	**10.59**	**9.53**	***10.06***
for comparison between means of Varieties (V) x Foliar spray (F)										
Chitosan @ 100 ppm (F_1)		**12.05**	**11.29**	***11.67***	**13.27**	**12.05**	***12.66***	**12.64**	**11.67**	***12.15***
Salicylic Acid @ 100 ppm (F_2)		**11.31**	**10.42**	***10.87***	**12.71**	**11.53**	***12.12***	**11.94**	**10.99**	***11.46***
Water spray (F_3)		**9.27**	**8.09**	***8.68***	**11.09**	**10.17**	***10.63***	**9.90**	**8.60**	***9.25***
Mean		***10.88***	***9.94***		***12.35***	***11.25***		***11.49***	***10.42***	
Source of variation		**SE m±**	**CD at 5%**		**SE m±**	**CD at 5%**		**SE m±**	**CD at 5%**	
Varieties (V)		0.01	0.04		0.01	0.03		0.02	0.04	
Seed treatment (S)		0.02	0.05		0.01	0.04		0.02	0.05	
Foliar spray (F)		0.02	0.05		0.01	0.04		0.02	0.05	
V × S		0.02	0.06		0.02	0.06		-	NS	
S × F		0.03	0.08		0.02	0.07		0.03	0.09	
V × F		0.02	0.06		0.02	0.06		0.03	0.07	
V × S × F		0.04	0.11		0.01	0.03		0.04	0.13	

Table 3: Effect of metabolite elicitors on leaf length (cm) in turmeric at 180 DAT.

Seed treatment (S)	Foliar spray (F)	2017-18			2018-19			Pooled		
		Roma (V_1)	Mydukur (V_2)	Mean	Roma (V_1)	Mydukur (V_2)	Mean	Roma (V_1)	Mydukur (V_2)	Mean
Chitosan @ 100 ppm (S_1)	Chitosan @ 100 ppm (F_1)	48.11	42.26	**45.19**	53.40	45.37	**49.39**	50.76	43.82	**47.29**
	Salicylic Acid @ 100 ppm (F_2)	45.04	40.08	**42.56**	46.09	42.79	**44.44**	45.57	41.44	**43.51**
	Water spray (F_3)	41.81	35.69	**38.75**	42.67	35.75	**39.21**	42.24	35.72	**38.98**
Mean		**44.99**	**39.34**	***42.17***	**47.39**	**41.31**	***44.35***	**46.19**	**40.33**	***43.26***
Salicylic Acid @ 100 ppm (S_2)	Chitosan @ 100 ppm (F_1)	47.11	41.71	**44.41**	50.93	43.13	**47.03**	49.02	42.42	**45.72**
	Salicylic Acid @ 100 ppm (F_2)	44.32	39.58	**41.95**	47.14	41.10	**44.12**	45.73	40.34	**43.04**
	Water spray (F_3)	39.53	31.91	**35.72**	41.28	33.28	**37.28**	40.41	32.60	**36.51**
Mean		**43.65**	**37.73**	***40.69***	**46.45**	**39.17**	***42.81***	**45.06**	**38.46**	***41.76***
No seed treatment(S_3)	Chitosan @ 100 ppm (F_1)	43.74	37.28	**40.51**	46.06	40.46	**43.26**	44.90	38.87	**41.89**
	Salicylic Acid @ 100 ppm (F_2)	42.17	36.32	**39.25**	45.50	38.44	**41.97**	43.84	37.38	**40.61**
	Water spray (F_3)	35.89	30.66	**33.28**	39.81	32.61	**36.21**	37.85	31.64	**34.75**
Mean		**40.60**	**34.75**	***37.68***	**43.79**	**37.17**	***40.48***	**42.20**	**35.97**	***39.08***
for comparison between means of Varieties (V) x Foliar spray (F)										
Chitosan @ 100 ppm (F_1)		**46.32**	**40.42**	***43.37***	**50.13**	**42.99**	***46.56***	**48.23**	**41.71**	***44.97***
Salicylic Acid @ 100 ppm (F_2)		**43.84**	**38.66**	***41.25***	**46.24**	**40.78**	***43.51***	**45.05**	**39.72**	***42.39***
Water spray (F_3)		**39.08**	**32.75**	***35.92***	**41.25**	**33.88**	***37.57***	**40.17**	**33.32**	***36.75***
Mean		***43.08***	***37.28***		***45.87***	***39.22***		***44.48***	***38.25***	
Source of variation		**SE m±**	**CD at 5%**		**SE m±**	**CD at 5%**		**SE m±**	**CD at 5%**	
Varieties (V)		0.03	0.08		0.07	0.20		0.02	0.07	
Seed treatment (S)		0.03	0.10		0.08	0.24		0.03	0.08	
Foliar spray (F)		0.03	0.10		0.08	0.24		0.03	0.08	
V × S		0.05	0.14		0.12	0.34		0.04	0.12	
S × F		0.06	0.17		0.14	0.42		0.05	0.14	
V × F		0.05	0.14		0.12	0.34		0.04	0.12	
V × S × F		0.08	0.24		0.20	0.59		0.07	0.20	

Table 4: Effect of metabolite elicitors on leaf width (cm) in turmeric at 180 DAT.

Seed treatment (S)	Foliar spray (F)	2017-18			2018-19			Pooled		
		Roma (V_1)	Mydukur (V_2)	Mean	Roma (V_1)	Mydukur (V_2)	Mean	Roma (V_1)	Mydukur (V_2)	Mean
Chitosan @ 100 ppm (S_1)	Chitosan @ 100 ppm (F_1)	12.88	11.77	**12.33**	13.79	12.62	**13.21**	13.34	12.20	**12.77**
	Salicylic Acid @ 100 ppm (F_2)	11.54	10.86	**11.20**	13.28	12.03	**12.66**	12.41	11.45	**11.93**
	Water spray (F_3)	9.89	9.91	**9.90**	11.40	10.53	**10.97**	10.65	10.22	**10.44**
Mean		**11.44**	**10.85**	***11.14***	**12.83**	**11.73**	***12.28***	**12.14**	**11.29**	***11.72***
Salicylic Acid @ 100 ppm (S_2)	Chitosan @ 100 ppm (F_1)	12.06	11.21	**11.64**	13.55	12.31	**12.93**	12.81	11.76	**12.29**
	Salicylic Acid @ 100 ppm (F_2)	11.16	10.55	**10.86**	12.77	11.75	**12.26**	11.97	11.15	**11.56**
	Water spray (F_3)	9.32	8.63	**8.98**	10.99	10.16	**10.57**	10.16	9.40	**9.78**
Mean		**10.85**	**10.13**	***10.49***	**12.44**	**11.41**	***11.92***	**11.65**	**10.77**	***11.21***
No seed treatment(S_3)	Chitosan @ 100 ppm (F_1)	10.72	10.38	**10.55**	12.45	11.21	**11.83**	11.59	10.80	**11.20**
	Salicylic Acid @ 100 ppm (F_2)	10.25	10.16	**10.21**	12.06	10.82	**11.44**	11.16	10.49	**10.83**
	Water spray (F_3)	8.99	8.25	**8.62**	10.88	9.82	**10.35**	9.94	9.04	**9.49**
Mean		**9.99**	**9.60**	***9.79***	**11.80**	**10.61**	***11.21***	**10.90**	**10.11**	***10.50***
for comparison between means of Varieties (V) x Foliar spray (F)										
Chitosan @ 100 ppm (F_1)		**11.89**	**11.12**	***11.50***	**13.27**	**12.05**	***12.66***	**12.58**	**11.59**	***12.09***
Salicylic Acid @ 100 ppm (F_2)		**10.98**	**10.52**	***10.75***	**12.71**	**11.53**	***12.12***	**11.85**	**11.03**	***11.44***
Water spray (F_3)		**9.40**	**8.93**	***9.17***	**11.09**	**10.17**	***10.63***	**10.25**	**9.55**	***9.90***
Mean		***10.76***	***10.19***		***12.35***	***11.25***		***11.56***	***10.72***	
Source of variation		**SE m±**	**CD at 5%**		**SE m±**	**CD at 5%**		**SE m±**	**CD at 5%**	
Varieties (V)		0.03	0.08		0.01	0.03		0.01	0.04	
Seed treatment (S)		0.03	0.10		0.01	0.04		0.02	0.04	
Foliar spray (F)		0.03	0.10		0.01	0.04		0.02	0.04	
V × S		0.05	0.14		0.02	0.06		-	NS	
S × F		0.06	0.17		0.02	0.07		0.03	0.08	
V × F		0.05	0.14		0.02	0.06		0.02	0.06	
V × S × F		0.08	0.24		0.03	0.10		0.04	0.11	

Table 5: Effect of metabolite elicitors on number of tillers plant^{-1} in turmeric at 180 DAT.

Seed treatment (S)	Foliar spray (F)	2017-18			2018-19			Pooled		
		Roma (V_1)	Mydukur (V_2)	Mean	Roma (V_1)	Mydukur (V_2)	Mean	Roma (V_1)	Mydukur (V_2)	Mean
Chitosan @ 100 ppm (S_1)	Chitosan @ 100 ppm (F_1)	1.87	1.60	**1.73**	2.60	1.87	**2.23**	2.24	1.74	**1.99**
	Salicylic Acid @ 100 ppm (F_2)	1.53	1.33	**1.43**	2.33	1.53	**1.93**	1.93	1.43	**1.68**
	Water spray (F_3)	1.13	0.93	**1.03**	1.73	1.07	**1.40**	1.43	1.00	**1.22**
Mean		**1.51**	**1.28**	***1.40***	**2.22**	**1.49**	***1.85***	**1.87**	**1.39**	***1.63***
Salicylic Acid @ 100 ppm (S_2)	Chitosan @ 100 ppm (F_1)	1.60	1.53	**1.56**	2.46	1.73	**2.09**	2.03	1.63	**1.83**
	Salicylic Acid @ 100 ppm (F_2)	1.40	1.20	**1.30**	2.20	1.47	**1.83**	1.80	1.34	**1.57**
	Water spray (F_3)	0.87	0.73	**0.80**	1.60	0.93	**1.26**	1.24	0.83	**1.03**
Mean		**1.29**	**1.15**	***1.22***	**2.09**	**1.38**	***1.73***	**1.69**	**1.27**	***1.48***
No seed treatment(S_3)	Chitosan @ 100 ppm (F_1)	1.33	1.07	**1.20**	2.13	1.20	**1.66**	1.73	1.14	**1.44**
	Salicylic Acid @ 100 ppm (F_2)	1.20	0.87	**1.03**	1.93	1.33	**1.63**	1.57	1.10	**1.33**
	Water spray (F_3)	0.73	0.60	**0.66**	1.47	0.80	**1.13**	1.10	0.70	**0.90**
Mean		**1.08**	**0.84**	***0.96***	**1.84**	**1.11**	***1.48***	**1.47**	**0.98**	***1.22***
for comparison between means of Varieties (V) x Foliar spray (F)										
Chitosan @ 100 ppm (F_1)		**1.60**	**1.40**	***1.50***	**2.40**	**1.60**	***2.00***	**2.00**	**1.50**	***1.75***
Salicylic Acid @ 100 ppm (F_2)		**1.37**	**1.13**	***1.25***	**2.15**	**1.44**	***1.80***	**1.77**	**1.29**	***1.53***
Water spray (F_3)		**0.91**	**0.75**	***0.83***	**1.60**	**0.93**	***1.27***	**1.26**	**0.84**	***1.05***
Mean		***1.29***	***1.09***		***2.05***	***1.32***		***1.68***	***1.21***	
Source of variation		**SE m±**	**CD at 5%**		**SE m±**	**CD at 5%**		**SE m±**	**CD at 5%**	
Varieties (V)		0.01	0.03		0.01	0.04		0.01	0.01	
Seed treatment (S)		0.02	0.04		0.02	0.04		0.01	0.02	
Foliar spray (F)		0.02	0.04		0.02	0.04		0.01	0.02	
V × S		0.02	0.06		-	NS		-	NS	
S × F		0.03	0.07		0.03	0.08		0.01	0.03	
V × F		-	NS		0.02	0.06		0.01	0.02	
V × S × F		0.01	0.03		0.04	0.11		0.01	0.04	

Table 6: Effect of metabolite elicitors on fresh weight plant^{-1} (g) in turmeric at 180 DAT.

Seed treatment (S)	Foliar spray (F)	2017-18			2018-19			Pooled		
		Roma (V_1)	Mydukur (V_2)	Mean	Roma (V_1)	Mydukur (V_2)	Mean	Roma (V_1)	Mydukur (V_2)	Mean
Chitosan @ 100 ppm (S_1)	Chitosan @ 100 ppm (F_1)	519.27	371.79	**445.53**	536.19	387.61	**461.90**	527.74	379.71	**453.72**
	Salicylic Acid @ 100 ppm (F_2)	449.06	347.19	**398.13**	465.59	362.04	**413.82**	457.33	354.62	**405.98**
	Water spray (F_3)	385.86	269.41	**327.64**	400.39	286.77	**343.58**	393.13	278.10	**335.61**
Mean		**451.40**	**329.46**	***390.43***	**467.39**	**345.48**	***406.43***	**459.40**	**337.48**	***398.44***
Salicylic Acid @ 100 ppm (S_2)	Chitosan @ 100 ppm (F_1)	499.32	353.04	**426.18**	517.79	370.51	**444.15**	508.56	361.78	**435.17**
	Salicylic Acid @ 100 ppm (F_2)	469.11	319.22	**394.17**	484.39	337.27	**410.83**	476.76	328.25	**402.50**
	Water spray (F_3)	369.56	248.63	**309.10**	380.39	263.48	**321.94**	374.98	256.06	**315.52**
Mean		**446.00**	**306.96**	***376.48***	**460.86**	**323.76**	***392.31***	**453.43**	**315.36**	***384.40***
No seed treatment(S_3)	Chitosan @ 100 ppm (F_1)	433.94	290.89	**362.42**	450.39	309.00	**379.70**	442.17	299.95	**371.06**
	Salicylic Acid @ 100 ppm (F_2)	415.28	278.09	**346.69**	431.99	294.49	**363.24**	423.64	286.30	**354.97**
	Water spray (F_3)	342.60	229.03	**285.82**	360.19	246.31	**303.25**	351.40	237.68	**294.54**
Mean		**397.27**	**266.00**	***331.64***	**414.19**	**283.27**	***348.73***	**405.74**	**274.64**	***340.19***
for comparison between means of Varieties (V) x Foliar spray (F)										
Chitosan @ 100 ppm (F_1)		**484.18**	**338.57**	***411.38***	**501.46**	**355.71**	***428.58***	**492.82**	**347.15**	***419.98***
Salicylic Acid @ 100 ppm (F_2)		**444.48**	**314.83**	***379.66***	**460.66**	**331.27**	***395.96***	**452.58**	**323.06**	***387.82***
Water spray (F_3)		**366.01**	**249.02**	***307.52***	**380.33**	**265.52**	***322.92***	**373.17**	**257.28**	***315.22***
Mean		***431.56***	***300.81***		***447.48***	***317.50***		***439.52***	***309.16***	
Source of variation		**SE m±**	**CD at 5%**		**SE m±**	**CD at 5%**		**SE m±**	**CD at 5%**	
Varieties (V)		0.40	1.14		0.74	2.13		0.33	0.95	
Seed treatment (S)		0.48	1.39		0.91	2.61		0.41	1.17	
Foliar spray (F)		0.48	1.39		0.91	2.61		0.41	1.17	
V × S		0.69	1.97		1.28	3.69		0.57	1.65	
S × F		0.84	2.41		1.57	4.52		0.70	2.02	
V × F		0.69	1.97		1.28	3.69		0.57	1.65	
V × S × F		1.19	3.41		2.22	6.39		0.99	2.86	

Table 7: Effect of metabolite elicitors on yield plot^{-1} (kg) in turmeric at harvest.

Seed treatment (S)	Foliar spray (F)	2017-18			2018-19			Pooled		
		Roma (V_1)	Mydukur (V_2)	Mean	Roma (V_1)	Mydukur (V_2)	Mean	Roma (V_1)	Mydukur (V_2)	Mean
Chitosan @ 100 ppm (S_1)	Chitosan @ 100 ppm (F_1)	10.63	5.79	**8.21**	11.10	6.01	**8.55**	10.87	5.90	**8.39**
	Salicylic Acid @ 100 ppm (F_2)	9.46	5.08	**7.27**	9.77	5.44	**7.60**	9.62	5.26	**7.44**
	Water spray (F_3)	6.50	3.73	**5.12**	6.92	4.27	**5.59**	6.71	4.00	**5.36**
Mean		**8.86**	**4.87**	***6.87***	**9.26**	**5.24**	***7.25***	**9.07**	**5.05**	***7.06***
Salicylic Acid @ 100 ppm (S_2)	Chitosan @ 100 ppm (F_1)	10.15	5.56	**7.86**	10.8	5.85	**8.37**	10.52	5.71	**8.12**
	Salicylic Acid @ 100 ppm (F_2)	9.03	4.71	**6.87**	9.57	5.41	**7.49**	9.30	5.06	**7.18**
	Water spray (F_3)	5.92	3.50	**4.71**	6.77	4.24	**5.50**	6.35	3.87	**5.11**
Mean		**8.37**	**4.59**	***6.48***	9.07	5.16	***7.12***	**8.72**	**4.88**	***6.80***
No seed treatment(S_3)	Chitosan @ 100 ppm (F_1)	8.29	4.13	**6.21**	**8.80**	**4.84**	**6.82**	8.55	4.49	**6.52**
	Salicylic Acid @ 100 ppm (F_2)	7.34	3.95	**5.65**	7.57	4.46	**6.01**	7.46	4.21	**5.83**
	Water spray (F_3)	5.38	3.11	**4.25**	6.65	3.59	**5.12**	6.02	3.35	**4.69**
Mean		**7.00**	**3.73**	***5.37***	**7.67**	**4.29**	***5.98***	**7.34**	**4.02**	***5.68***
for comparison between means of Varieties (V) x Foliar spray (F)										
Chitosan @ 100 ppm (F_1)		**9.69**	**5.16**	***7.43***	**10.26**	**5.56**	***7.91***	**9.98**	**5.37**	***7.67***
Salicylic Acid @ 100 ppm (F_2)		**8.61**	**4.58**	***6.60***	**8.97**	**5.10**	***7.03***	**8.79**	**4.84**	***6.82***
Water spray (F_3)		**5.93**	**3.45**	***4.69***	**6.78**	**4.03**	***5.40***	**6.36**	**3.74**	***5.05***
Mean		***8.08***	***4.40***		***8.67***	***4.90***		***8.38***	***4.65***	

Source of variation	SE m±	CD at 5%	SE m±	CD at 5%	SE m±	CD at 5%
Varieties (V)	0.02	0.06	0.03	0.07	0.05	0.13
Seed treatment (S)	0.02	0.07	0.03	0.09	0.06	0.16
Foliar spray (F)	0.02	0.07	0.03	0.09	0.06	0.16
V × S	0.03	0.10	0.05	0.13	0.08	0.22
S × F	0.04	0.12	0.06	0.16	0.10	0.27
V × F	0.03	0.10	0.05	0.13	0.08	0.22
V × S × F	0.06	0.17	0.08	0.22	0.13	0.39

CONCLUSIONS

The response of Roma to metabolite elicitors was proved to be high when compared to Mydukur at high-altitude zones of Andhra Pradesh. This study highlights the significance of chitosan in exhibiting its role on growth and yield characteristics in turmeric at high-altitude zone of Andhra Pradesh. Salicylic acid followed chitosan in registering relatively more growth and yield. Foliar application of elicitors has more impact on the crop grown than seed treatment.

FUTURE SCOPE

1. Studies on the effect of nano scale chitosan and salicylic acid on growth, yield and secondary metabolite production are to be conducted.
2. Metabolite elicitation can be attempted with the combined use of stimulants, by designing different permutations of application methods.

Acknowledgement. The authors are grateful to Dr. YSR Horticultural University, Venkataramannagudem, for providing necessary support and facilities during the course of experiment.
Conflict of Interest. None.

REFERENCES

Anusuya, S. and Sathiyabama, M. (2016). Effect of chitosan on growth, yield and curcumin content in turmeric under field condition. *Biocatalysis and Agricultural Biotechnology*, *6*, 102-106.

Bagautdinova, Z. Z., Omelyanchuk, N., Tyapkin, A. V., Kovrizhnykh, V. V., Lavrekha, V. V. and Zemlyanskaya, E. V. (2022). Salicylic Acid in Root Growth and Development. *International Journal of Molecular Sciences*, *23,* 22-28.

Castro, G. T., Avelelas, F. P. and Leandro, S. (2016). Chitosan seed soaking: germination and growth of *Coriandrum sativum* and *Solanum lycopersicum*. *Frontiers of Marine Science*. Conference Abstract: IMMR, International Meeting on Marine Research.

El-Tantawy, E. M. (2009). Behaviour of tomato plants as affected by spraying with chitosan and aminofort as natural stimulator substances under application of soil organic amendments. *Pakistan Journal of Biological Sciences*, *12,* 1164-1173.

El-Tayeb, M. A. (2005). Response of barley grains to the interactive effects of salinity and salicylic acid. *Plant Growth Regulation*, *45*, 215-224.

Farouk, S., Ghoneem, K. M. and Abeer, A. A. (2008). Induction and expression of systematic resistance to downy mildew disease in cucumber plant by elicitors. *Egypt Journal of Phyto-pathology*, *1*, 95-111.

Gharib, F. A. (2006). Effect of salicylic acid on the growth, metabolic activities and oil content of basil and marjoram. *International Journal of Agriculture Biology*, *4,* 485-492.

Guan, Y. J., Hu, J., Wang, X. J. and Shao, C. X. (2009). Seed priming with chitosan improves maize germination and seedling growth in relation to physiological changes under low temperature stress. *Journal of Zhejiang University Science*, *10*(6), 427-433.

Hadrami, A. E., Adam, L. R., Hadrami, I. E. and Daayf, F. (2010). Chitosan in Plant Protection. *Marine Drugs*, *8*, 968-987.

Hadwiger, L. A. (2013). Multiple effects of chitosan on plant systems: Solid science or hype. *Plant Science Journal*, *208,* 42-49.

Hayat, Q., Hayat, S., Alyemeni, M. N. and Ahmad, A. (2012). Salicylic acid mediated changes in growth, photosynthesis, nitrogen metabolism and antioxidant defense system in *Cicer arietinum* L. *Plant Soil Environment*, *58,* 417-423.

Hesami, S., Nabizadeh, E., Rahimi, A. and Rokhzadi, A. (2012). Effects of salicylic acid levels and irrigation intervals on growth and yield of coriander (*Coriandrum sativum*) in field conditions. *Environmental and Experimental Biology*, *10,* 113-116.

Ibraheim, S. K. A. and Mohsen, A. A. M. (2015). Effect of chitosan and nitrogen rates on growth and productivity of summer squash plants. *Middle East Journal of Agriculture Research*, *4*(4), 673-681.

Khan, W., Prithiviraj, B. and Smith, D. L. (2003). Photosynthetic responses of corn and soybean to foliar application of salicylates. *Journal of Plant Physiology*, *160*(5), 485-492.

Kim, H. J., Chen, F., Wang, X. and Rajapakse, N. C. (2005). Effect of chitosan on the biological properties of sweet basil (*Ocimum basilicum* L.). *Journal of Agricultural and Food Chemistry*, *53*(9), 3696-3701.

Kunnumakkara, A. B., Guha, S., Krishnan, S., Diagaradjane, P., Gelovani, J. and Aggarwal, B. B. (2007). Curcumin potentiates antitumor activity of gemcitabine in an orthotopic model of pancreatic cancer through suppression of proliferation, angiogenesis, and inhibition of nuclear factor-kB-regulated gene products. *Journal of Cancer Research*, *67,* 3853–3861.

Lan, T. T. P., Huy, N. D., Luong, N. N., Quang, H. T., Tan, T. H., Thu, L. T. A., Huy, N. X. and Loc, N. H. (2019). Effect of salicylic acid and yeast extract on curcuminoids biosynthesis gene expression and curcumin accumulation in cells of *Curcuma zedoaria*. *Journal of Plant Biotechnology*, *46*(3), 172-179.

Latif, H. H. and Mohamed, H. I. (2016). Exogenous applications of moringa leaf extract effect on retrotransposon, ultrastructural and biochemical contents of common bean plants under environmental stresses. *South African Journal of Botany*, *106*, 221–231.

Lei, C., Ma, D., Pu, G., Qiu, X., Du, Z., Wang, H., Li, G., Ye, H. and Liu, B. (2011). Foliar application of chitosan activates artemisinin biosynthesis in *Artemisia annua* L. *Industrial Crops and Products*, *33*(1), 176-182.

Mahdavi, B. (2013). Seed germination and growth responses of Isabgol (*Plantago ovata* Forsk) to chitosan and salinity. *International Journal of Agriculture and Crop Sciences*, *5*(10), 1084-1088.

Manoj, M. R. (2017). Effect of metabolite elicitors on curcumin content in Turmeric (*Curcuma longa* L.) Cv. Mydukur. *M.Sc. Thesis*. Dr. YSR Horticultural University, Venkataramannagudem, Andhra Pradesh, India.

Ojikpong, T.O. (2018). Effect of Planting Dates and NPK (15: 15: 15) Fertilizer on the growth and yield of turmeric (*Curcuma longa* Linn). *International Journal of Agriculture & Environmental Science*, *5*(4), 42-46.

Pedroso, R. C. N., Branquinho, N. A. D. A., Hara, A. C. B. D. A. M., Silva, F. G., Kellner Filho, L. C., Silva, M. L. A., Cunha, W. R., Pauletti, P. M. and Januario, A. H. (2019). Effect of salicylic acid and silver nitrate on rutin production by *Hyptis marrubioides* cultured in vitro. *Ciencia Rural*, 49.

Rahimi, A. R., Rokhzadi, A., Amini, S. and Karami, E. (2013). Effect of salicylic acid and methyl jasmonate on growth and secondary metabolites in *Cuminum cyminum* L. *Journal of Biodiversity and Environmental Sciences*, *3*(12), 140-149.

Ray, M., Dash, S., Shahbazi, S., Achary, K. G., Nayak, S. and Singh, S. (2016). Development and validation of ELISA technique for early detection of rhizome rot in golden spice turmeric from different agroclimatic zones. *Food science & Technology*, *66*, 546-552.

Sofy, A. R., Dawoud, R. A., Sofy, M. R., Mohamed, H. I., Hmed, A. A. and El-Dougdoug, N. K. (2020). Improving regulation of enzymatic and non-enzymatic antioxidants and stress-related gene stimulation in *Cucumber mosaic cucumo virus*-infected cucumber plants treated with glycine betaine, chitosan and combination. *Molecules*, *25*, 2341.

Stevens, J., Senaratna, T. and Sivasithamparam, K. (2006). Salicylic acid induces salinity tolerance in tomato (*Lycopersicon esculentum* cv. Roma): associated changes in gas exchange, water relations and membrane stabilisation. *Plant Growth Regulators*, *49*, 77-83.

Thengumpally, N. J. (2019). Chitosan mediated metabolite elicitation and growth responses in kasthuri turmeric (*Curcuma aromatica*). *Ph.D. Thesis*. Kerala Agricultural University, Kerala, India.

Ullah, N., Basit, A., Ahmad, I., Ullah, I., Shah, S. T., Mohamed, H. I. and Javed, S. (2020). Mitigation the adverse effect of salinity stress on the performance of the tomato crop by exogenous application of chitosan. *Bulletin of the National Research Centre, 44,* 1-11.

Yin, H., Frettei, X. C., Christensen, L. and Grevsen, K. (2012). Chitosan oligosaccharides promote the content of polyphenols in Greek oregano (*Origanum vulgare* ssp. hirtum). *Journal of Agriculture and Food Chemistry*, *60*, 136-143.

How to cite this article: D. Manjusha, S. Suryakumari, K. Giridhar, A.V.D. Dorajeerao, D.R. Salomi Suneetha, P. Subbaramamma and V. Sivakumar (2023). Impact of Metabolite Elicitors on Growth and Yield Characteristics in Turmeric (*Curcuma longa* L.) at High Altitude Zone of Andhra Pradesh. *Biological Forum – An International Journal, 15*(3): 212-220.