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Studies on the effect of metabolite elicitors on growth and yield aspects in turmeric (*Curcuma longa* L.) at coastal plains of Andhra Pradesh

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Abstract

The present investigation entitled “Studies on the effect of metabolite elicitors on growth and yield aspects in turmeric (*Curcuma longa* L.) at coastal plains of Andhra Pradesh” is carried out at College of Horticulture, Dr. Y.S.R. Horticultural University, venkataramannagudem during *Kharif* 2017 and 2018. Two varieties viz., Mydukur and Roma were applied with the metabolite elicitors chitosan and salicylic acid in the form of seed treatment and foliar spray. Growth parameters were recorded at 180 days after transplanting (DAT) and yield was recorded at harvest *i.e.* 250 DAT in the variety Roma and 270 DAT in the variety Mydukur. Pooled data over two years (2017-18 & 2018-19) on growth parameters and yield revealed significant effect of varieties, application of metabolite elicitors through seed treatment and foliar application as well as their interactions at coastal plains of venkataramannagudem. The highest plant height (77.62 cm), number of leaves plant⁻¹ (12.94), leaf length (41.68 cm), leaf width (11.42 cm), fresh weight plant⁻¹ (327.22 g) and yield plot⁻¹ (7.10 kg) were recorded in the variety Mydukur. Significantly superior plant height (77.38 cm), number of leaves plant⁻¹ (13.41), leaf length (44.93 cm), leaf width (12.13 cm), number of tillers plant⁻¹ (1.55), fresh weight plant⁻¹ (329.22 g) and yield plot⁻¹ (7.83 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 Mydukur + chitosan @ 100 ppm (st), Mydukur + chitosan @ 100 ppm (fs) and chitosan @ 100 ppm (st) + chitosan @ 100 ppm (fs) recorded significantly highest growth and yield. The three-way interaction Mydukur + chitosan @ 100 ppm (st) + chitosan @ 100 ppm (fs) recorded maximum fresh weight plant⁻¹ (396.78 g).

Keywords: Turmeric, elicitors, growth, yield, chitosan, salicylic acid, mydukur, roma

Introduction

The golden spice, turmeric (*Curcuma longa* L.), is a perennial rhizomatous herb belonging to Zingiberaceae family. Its subterranean rhizome is appreciated for use as a natural colouring agent in food, cosmetics and colours due to the presence of colouring matter “Curcumin”. Curcumin is the primary active secondary metabolite component (Wu *et al.*, 2015) [31] in turmeric. The biological effects of curcumin are extremely diverse, and they include anti-oxidant, anti-inflammatory, anti-mutagenic, anti-carcinogenic and anti-angiogenic properties which makes great demand in pharmaceutical industry.

Like other crop plants, the physiological mechanisms of turmeric growth are hormonally mediated. Additional supply of plant growth regulators control growth and yield in plants. Elicitors are the chemical substances with a wide range of sources that can cause physiological and morphological reactions and hasten the synthesis of beneficial secondary metabolites (Zhao *et al.*, 2005) [32]. Studying the impact of elicitors on plant growth, development, and production has received very little attention, which is mostly due to the promotion of plants' immunity against microbes (bacteria and fungi) (Gornik *et al.*, 2008) [12]. Recently, some researchers reported that chitosan increased plant growth and development (Chibu *et al.*, 2002 and Gornik *et al.*, 2008) [5, 12]. They claimed that the use of chitosan improved the transportation of nitrogen (N) in the functional leaves and raised essential enzyme activities of nitrogen metabolism (nitrate reductase, glutamine synthetase and protease), which benefited plant growth and development. Salicylic acid acts as a potential non-enzymatic antioxidant, and plant growth regulator imparts tolerance against abiotic stress and plays an important role in the regulation of several plant physiological processes and the production of bioactive compounds (Ghasemzadeh *et al.*, 2012) [11].

Research works of elicitors on growth and yield attributes of turmeric is almost rare. Considering the above facts, the present research work was undertaken to evaluate the seed treatment and foliar applications with the promising metabolite elicitor's viz., chitosan and salicylic acid on growth and yield aspects in turmeric varieties at coastal plains in Andhra Pradesh.

Materials and Methods

The experiment is conducted during 2017-2018 and 2018-2019 at College of Horticulture, Dr. Y.S.R. Horticultural University, Venkataramannagudem. The experimental site falls under the 'Agro-climatic zone of East Coastal Plain and Hills' (Krishna-Godavari zone) with an annual rainfall of 900 mm. It is located at an altitude of 34 m above mean sea level. The experimental site is geographically situated at 16.8° N latitude and 81.5° E longitude. The soil is red sandy loam and has 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 single bud rhizomes and given seed treatment with elicitors for 30 minutes and sown in portraits filled with coco peat and vermicompost (75:25) after shade drying. 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. While the plants in the control plots were sprayed with distilled water.

The recommended dose of NPK at 300: 125: 200 kg ha⁻¹ was applied as per the package of practices given by Dr. YSR Horticultural University for a healthy crop. The data on plant height, number of leaves plant⁻¹, leaf length and width, number of tillers plant⁻¹ and fresh weight plant⁻¹ was 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. The data recorded on various parameters was statistically analysed by adopting Randomized Block Design with factorial concept as suggested by Panse and Sukhatme (1985) [23].

Results and Discussion

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 by the variety Mydukur (77.62 cm). Seed treatment with chitosan @ 100 ppm recorded greater plant height (75.49 cm) which was on par with salicylic acid @ 100 ppm (74.38 cm). The foliar spray of chitosan @ 100 ppm was significantly superior and recorded highest plant height of 77.38 cm. All the interactions exhibited non-significant influence on plant height (Table 1). A perusal of data on the effect of variety and application of elicitors on plant height revealed that plants of turmeric variety Mydukur were taller compared to those of Roma at 180 DAT. An examination of data from 180 DAT suggested that the cultivar Mydukur was vigorous hence it could have recorded significantly higher plant height at the terminal crop stages. Both the application methods like seed treatment and foliar application proved the merit of chitosan followed by salicylic acid. Chitosan was known to induce gibberellin synthesis (El-Bassiony *et al.*, 2014) [7] which may be perhaps the reason for its superior plant height in both the methods and cultivars. Chitosan increased the plant height in *Curcuma aromatica* (Thengumpally, 2019) [28]. Application of salicylic acid by both seed treatment and foliar application followed the chitosan application in enhancing plant height. This can be due the capacity of salicylic acid in promoting cell elongation, cell division and rooting ability as reported by El-Tayeb (2005) [8] and Sherif *et al.* (2022) [27]. From the results obtained, it clearly shows that foliar spray method was significantly better for application of both the elicitors which might be because of the fact that foliar application eliminates the negative effects of barriers in uptake process from soil and as well the foliar method facilitates for absorption of chemical through both the stomatal apertures and cuticle layers.

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)	75.08	83.60	79.34	77.53	87.12	82.32	76.31	85.37	80.84
	Salicylic Acid @ 100 ppm (F ₂)	70.01	79.74	74.87	72.00	83.12	77.56	71.01	81.43	76.22
	Water spray (F ₃)	64.80	71.00	67.90	66.38	75.47	70.93	65.59	73.24	69.42
Mean		69.96	78.11	74.04	71.97	81.90	76.94	70.97	80.01	75.49
Salicylic Acid @ 100 ppm (S ₂)	Chitosan @ 100 ppm (F ₁)	70.20	82.26	76.23	76.1	85.53	80.81	73.16	83.90	78.53
	Salicylic Acid @ 100 ppm (F ₂)	73.84	77.47	75.65	72.37	80.59	76.48	73.11	79.04	76.08
	Water spray (F ₃)	63.20	72.94	68.07	64.62	73.35	68.99	63.91	73.15	68.53
Mean		69.08	77.56	73.32	71.03	79.82	75.43	70.06	78.70	74.38
No seed treatment (S ₃)	Chitosan @ 100 ppm (F ₁)	67.61	75.52	71.56	69.46	78.47	73.96	68.54	77.00	72.77
	Salicylic Acid @ 100 ppm (F ₂)	65.72	73.74	69.73	67.33	76.34	71.83	66.53	75.04	70.79
	Water spray (F ₃)	60.68	69.30	64.99	62.03	71.44	66.73	61.36	70.37	65.87

Mean	64.67	72.85	68.76	66.27	75.41	70.84	65.48	74.14	69.81
For comparison between means of Varieties (V) x Foliar spray (F)									
Chitosan @ 100 ppm (F ₁)	70.96	80.46	75.71	74.36	83.70	79.03	72.67	82.09	77.38
Salicylic Acid @ 100 ppm (F ₂)	69.86	76.98	73.42	70.57	80.02	75.29	70.22	78.50	74.36
Water spray (F ₃)	62.89	71.08	66.99	64.34	73.42	68.88	63.62	72.25	67.94
Mean	67.90	76.17		69.76	79.05		68.84	77.62	
Source of variation	SE m±	CD in 5%		SE m±	CD in 5%		SE m±	CD in 5%	
Varieties (V)	0.03	0.10		0.75	2.16		0.38	1.08	
Seed treatment (S)	0.04	0.12		0.92	2.65		0.46	1.33	
Foliar spray (F)	0.04	0.12		0.92	2.65		0.46	1.33	
V × S	0.06	0.17		-	NS		-	NS	
S × F	0.07	0.21		-	NS		-	NS	
V × F	0.06	0.17		-	NS		-	NS	
V × S × F	0.10	0.30		-	NS		-	NS	

Number of leaves plant⁻¹

Number of leaves per plant differed significantly between the varieties. Mydukur recorded significantly higher number of leaves plant⁻¹ (12.94) compared to Roma at 180 DAT. In methods of application of metabolite elicitors, the seed treatment with chitosan @ 100 ppm exhibited significantly greater number of leaves plant⁻¹ (12.66). Foliar application of metabolite elicitor chitosan @ 100 ppm was significantly superior and recorded the maximum number of leaves plant⁻¹ (13.41).

The interaction of the variety Mydukur + chitosan @ 100 ppm (st) recorded significantly maximum number of leaves plant⁻¹ (14.10) and Roma + no seed treatment recorded minimum number of leaves plant⁻¹ (9.34). The combination of the variety Mydukur + chitosan @ 100 ppm (fs) was significant and recorded maximum number of leaves plant⁻¹ (14.54) and Roma + water spray recorded minimum number of leaves

plant⁻¹ (8.40). Application of chitosan @ 100 ppm (st) + chitosan @ 100 ppm (fs) recorded significantly greater number of leaves plant⁻¹ (14.88) whereas, no seed treatment + water spray recorded minimum number of leaves plant⁻¹ (8.75 and 8.90). Three-way interaction showed non-significant effect on number of leaves plant⁻¹ (Table 2).

In the present investigation, chitosan was observed to increase the number of leaves per plant. The stimulating effect of chitosan on number of leaves may be attributed due to increase in the availability of uptake of essential nutrients by pressuring cell osmotic pressure, pre radical scavenger's enzyme activity (Guian *et al.* 2009) [13]. Chitosan increases number of leaves in rice and soya bean by efficient management of stomatal conductance (Khan *et al.* 2002) [17]. Ibraheim and Mohsen (2015) [15] reported an increase in number of leaves per plant in summer squash by the application of chitosan.

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)	12.13	15.33	13.73	14.80	17.26	16.03	13.46	16.30	14.88
	Salicylic Acid @ 100 ppm (F ₂)	9.93	12.73	11.33	12.53	15.86	14.20	11.23	14.30	12.76
	Water spray (F ₃)	8.07	10.27	9.17	9.93	13.13	11.53	9.00	11.70	10.35
Mean		10.04	12.77	11.41	12.42	15.42	13.92	11.23	14.10	12.66
Salicylic Acid @ 100 ppm (S ₂)	Chitosan @ 100 ppm (F ₁)	11.87	12.87	12.37	13.46	16.6	15.03	12.67	14.73	13.70
	Salicylic Acid @ 100 ppm (F ₂)	8.67	12.53	10.60	11.8	15.06	13.43	10.23	13.80	12.02
	Water spray (F ₃)	7.80	9.13	8.46	8.93	12.06	10.50	8.37	10.60	9.48
Mean		9.44	11.51	10.48	11.4	14.57	12.98	10.42	13.04	11.73
No seed treatment (S ₃)	Chitosan @ 100 ppm (F ₁)	10.60	10.40	10.50	10.73	14.8	12.76	10.67	12.60	11.64
	Salicylic Acid @ 100 ppm (F ₂)	9.47	11.67	10.57	9.53	13.8	11.66	9.50	12.73	11.12
	Water spray (F ₃)	7.20	8.07	7.63	8.46	11.26	9.86	7.84	9.67	8.75
Mean		9.09	10.04	9.57	9.57	13.28	11.43	9.34	11.67	10.50
For comparison between means of Varieties (V) x Foliar spray (F)										
Chitosan @ 100 ppm (F ₁)		11.53	12.86	12.20	13.00	16.22	14.61	12.27	14.54	13.41
Salicylic Acid @ 100 ppm (F ₂)		9.35	12.31	10.83	11.28	14.91	13.10	10.32	13.61	11.97
Water spray (F ₃)		7.69	9.15	8.42	9.11	12.15	10.63	8.40	10.65	9.53
Mean		9.52	11.44		11.13	14.43		10.33	12.94	
Source of variation		SE m±	CD in 5%		SE m±	CD in 5%		SE m±	CD in 5%	
Varieties (V)		0.02	0.06		0.11	0.32		0.06	0.17	
Seed treatment (S)		0.03	0.08		0.14	0.40		0.07	0.20	
Foliar spray (F)		0.03	0.08		0.14	0.40		0.07	0.20	
V × S		0.04	0.11		-	NS		0.10	0.29	
S × F		0.05	0.13		0.24	0.69		0.12	0.35	
V × F		0.02	0.06		-	NS		0.10	0.29	
V × S × F		0.03	0.08		-	NS		-	NS	

Leaf length (cm)

The pooled data pertaining to leaf length exhibits that at 180 DAT, the variety Mydukur recorded maximum leaf length (41.68 cm). Seed treatment with chitosan @ 100 ppm recorded significantly highest leaf length (43.06 cm) and foliar spray with chitosan @ 100 ppm significantly recorded superior leaf length (44.93 cm). The varietal interaction with methods of elicitor application showed non-significant influence on leaf length whereas, the interaction between methods of application of metabolite elicitors exhibited

significant influence on leaf length.

The combination of chitosan @ 100 ppm (st) + chitosan @ 100 ppm (fs) recorded significantly maximum leaf length (47.68 cm) which was on par (46.35 cm) with the combined application of salicylic acid @ 100 ppm (st) + chitosan @ 100 ppm (fs). Minimum leaf length was recorded in the interaction no seed treatment + water spray (37.17 cm) at 180 DAT. Three-way interaction exhibited non-significant influence on leaf length (Table 3).

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)	44.78	48.29	46.54	47.15	50.51	48.83	45.96	49.40	47.68
	Salicylic Acid @ 100 ppm (F ₂)	42.16	43.71	42.94	43.19	46.45	44.82	42.67	45.08	43.88
	Water spray (F ₃)	35.72	36.54	36.13	38.74	39.43	39.09	37.23	37.99	37.61
Mean		40.89	42.85	41.87	43.02	45.46	44.24	41.96	44.16	43.06
Salicylic Acid @ 100 ppm (S ₂)	Chitosan @ 100 ppm (F ₁)	43.80	46.15	44.98	45.58	49.86	47.72	44.69	48.01	46.35
	Salicylic Acid @ 100 ppm (F ₂)	41.45	41.28	41.37	42.66	44.30	43.48	42.06	42.79	42.43
	Water spray (F ₃)	33.76	34.32	34.04	36.51	38.44	37.48	35.14	36.38	35.76
Mean		39.67	40.58	40.13	41.58	44.20	42.89	40.63	42.39	41.51
No seed treatment (S ₃)	Chitosan @ 100 ppm (F ₁)	39.18	40.06	39.62	41.49	42.28	41.89	40.34	41.17	40.76
	Salicylic Acid @ 100 ppm (F ₂)	38.56	38.39	38.48	39.19	41.93	40.56	38.88	40.16	39.52
	Water spray (F ₃)	31.34	32.87	32.11	33.25	35.38	34.31	32.29	34.13	33.21
Mean		36.36	37.11	36.73	37.98	39.86	38.92	37.17	38.49	37.83
For comparison between means of Varieties (V) x Foliar spray (F)										
Chitosan @ 100 ppm (F ₁)		42.59	44.83	43.71	44.74	47.55	46.14	43.66	46.19	44.93
Salicylic Acid @ 100 ppm (F ₂)		40.72	41.13	40.93	41.68	44.23	42.95	41.20	42.68	41.94
Water spray (F ₃)		33.61	34.58	34.09	36.17	37.75	36.96	34.89	36.17	35.53
Mean		38.97	40.18		40.86	43.18		39.92	41.68	
Source of variation		SE m±	CD in 5%		SE m±	CD in 5%		SE m±	CD in 5%	
Varieties (V)		0.02	0.07		0.49	1.41		0.24	0.70	
Seed treatment (S)		0.03	0.09		0.60	1.72		0.30	0.85	
Foliar spray (F)		0.03	0.09		0.60	1.72		0.30	0.85	
V x S		0.04	0.12		-	NS		-	NS	
S x F		0.05	0.15		-	NS		0.51	1.48	
V x F		0.01	0.02		-	NS		-	NS	
V x S x F		0.01	0.04		-	NS		-	NS	

Leaf width (cm)

From the pooled data obtained, it can be reported that at 180 DAT, the variety Mydukur recorded maximum leaf width (11.42 cm). Seed treatment with chitosan @ 100 ppm recorded significantly greater leaf width (11.72 cm) and foliar spray with metabolite elicitor chitosan @ 100 ppm significantly recorded highest leaf width of 12.13 cm. Among two-way interactions, the varietal interaction with methods of elicitor application showed a non-significant influence on leaf width whereas the interaction of methods of application of metabolite elicitors *i.e.* chitosan @ 100 ppm (st) + chitosan @ 100 ppm (fs) recorded significantly maximum leaf width (13.20 cm). Minimum leaf width (8.94 cm) was recorded in the combination of no seed treatment + water spray. The three-way interaction effect of the variety with seed treatment and foliar spray of metabolite elicitors was found non-significant (Table 4).

As evident in case of plant height, irrespective of method of application, chitosan could significantly improve all the above leaf parameters as compared to salicylic acid and no application of elicitors. The significant and positive effect of chitosan on promoting differentiation of more leaves and enlargement of leaf tissue in both length and width

dimensions could be ascribed due to its involvement in uptake of water and essential nutrient elements through fine adjustment of osmotic pressure and reducing the accumulation of harmful free radicals (Guian *et al.*, 2009) [13]. Application of chitosan on soil mix application improved leaf length and width of ornamental *Eustoma grandiflorum* (Ohta *et al.* 2001). Chitosan enhanced leaf area of chili pepper (Mahmut *et al.* 2013) [19]. Similar findings were also reported by Ibraheim and Mohsen (2015) [15] in summer squash, Anusuya and Sathiyabama (2016) [2] and Thengumpally (2019) [28] in turmeric, Ullah *et al.* (2020) [29] in tomato. Similarly salicylic acid application through both seed treatment and foliar spray could have resulted in cell elongation and cell differentiation (Sherif *et al.*, 2022) [27] as compared to no treatment of elicitors in both the turmeric varieties. Arfan *et al.* (2007) [3] reported that salicylic acid had direct involvement in plant growth and thermogenesis. Further it has significant role in chlorophyll and carotenoid pigments, photosynthetic rate and modify important enzymes activities. Due to this cumulative effect salicylic acid could increase the number of leaves, leaf length and width significantly. These findings were in accordance with Manoj (2017) [20] in turmeric.

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)	12.13	12.92	12.53	13.16	14.57	13.87	12.65	13.75	13.20
	Salicylic Acid @ 100 ppm (F ₂)	10.61	10.96	10.79	11.40	13.44	12.42	11.01	12.20	11.61
	Water spray (F ₃)	8.41	9.68	9.05	11.18	12.14	11.66	9.80	10.91	10.36
Mean		10.38	11.19	10.79	11.92	13.38	12.65	11.15	12.29	11.72
Salicylic Acid @ 100 ppm (S ₂)	Chitosan @ 100 ppm (F ₁)	10.93	11.02	10.98	12.78	13.63	13.21	11.86	12.33	12.09
	Salicylic Acid @ 100 ppm (F ₂)	9.72	10.44	10.08	11.01	12.83	11.92	10.37	11.63	11.00
	Water spray (F ₃)	7.90	9.04	8.47	10.66	11.63	11.14	9.28	10.33	9.81
Mean		9.52	10.17	9.84	11.48	12.70	12.09	10.50	11.43	10.97
No seed treatment (S ₃)	Chitosan @ 100 ppm (F ₁)	10.19	10.09	10.14	11.62	12.43	12.02	10.91	11.26	11.09
	Salicylic Acid @ 100 ppm (F ₂)	8.84	9.73	9.29	11.27	12.17	11.72	10.06	10.96	10.51
	Water spray (F ₃)	7.28	8.42	7.85	9.67	10.37	10.02	8.48	9.40	8.94
Mean		8.77	9.41	9.09	10.85	11.66	11.26	9.81	10.54	10.18
For comparison between means of Varieties (V) x Foliar spray (F)										
Chitosan @ 100 ppm (F ₁)		11.08	11.34	11.21	12.52	13.54	13.03	11.81	12.45	12.13
Salicylic Acid @ 100 ppm (F ₂)		9.72	10.38	10.05	11.23	12.81	12.02	10.48	11.60	11.04
Water spray (F ₃)		7.86	9.05	8.46	10.50	11.38	10.94	9.19	10.21	9.70
Mean		9.56	10.26		11.42	12.58		10.49	11.42	
Source of variation		SE m±	CD in 5%		SE m±	CD in 5%		SE m±	CD in 5%	
Varieties (V)		0.02	0.05		0.15	0.43		0.08	0.22	
Seed treatment (S)		0.02	0.06		0.18	0.52		0.09	0.26	
Foliar spray (F)		0.02	0.06		0.18	0.52		0.09	0.26	
V x S		0.03	0.08		-	NS		-	NS	
S x F		0.03	0.10		-	NS		0.16	0.46	
V x F		0.03	0.08		-	NS		-	NS	
V x S x F		0.05	0.14		-	NS		-	NS	

Number of tillers plant⁻¹

From the pooled data obtained it was evident that varieties exhibited non-significant effect on number of tillers plant⁻¹ at 180 DAT. As regards to the methods of application of metabolite elicitors, seed treatment with chitosan @ 100 ppm recorded significantly highest number of tillers plant⁻¹ (1.46) and was on par with salicylic acid @ 100 ppm (1.31). Foliar application of metabolite elicitor chitosan @ 100 ppm recorded significantly greater number of tillers plant⁻¹ (1.55) and was on par with salicylic acid @ 100 ppm (1.34) (Table 5). All the interactions showed non-significant effect on number of tillers plant⁻¹.

As evident from the above results on number of tillers per plant it can be inferred that the cultivar Mydukur had significantly more tillers under venkataramannagudem conditions. This could be attributed to the suitability of respective climate to the above turmeric variety. Wherein the

prevailing temperatures ranged from 43.14 °C to 19.94 °C; relative humidity from 82.65% to 41.68%; 43 rainy days during the period of investigation. The number of tillers was significantly superior by the application of chitosan through both seed treatment and foliar spray indicating the capacity of chitosan in inducing higher differentiation of vegetative buds to give rise to tillers. The chitosan functions like induction of gibberellin and auxin synthesis; maintenance of osmotic pressure through promotive regulation of water and nutrient uptake, might be responsible for the above improvement. These findings were similar with Thengumpally (2019) [28] in turmeric.

Further, the positive influence of salicylic acid on cell differentiation and increase in node number as reported by Sherif *et al.* (2022) [27], might be responsible for more number of tillers as observed in the present study. Similar results were observed by Manoj (2017) [20] in turmeric.

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)	1.470	1.670	1.570	1.867	2.067	1.967	1.673	1.870	1.772
	Salicylic Acid @ 100 ppm (F ₂)	1.200	1.470	1.335	1.667	1.667	1.667	1.433	1.570	1.502
	Water spray (F ₃)	0.870	1.000	0.935	1.267	1.267	1.267	1.073	1.137	1.105
Mean		1.180	1.380	1.280	1.600	1.667	1.633	1.393	1.526	1.459
Salicylic Acid @ 100 ppm (S ₂)	Chitosan @ 100 ppm (F ₁)	1.330	1.530	1.430	1.733	1.867	1.800	1.537	1.700	1.618
	Salicylic Acid @ 100 ppm (F ₂)	1.070	1.330	1.200	1.533	1.533	1.533	1.303	1.433	1.368
	Water spray (F ₃)	0.730	0.930	0.830	1.133	1.000	1.067	0.933	0.967	0.950
Mean		1.043	1.263	1.153	1.467	1.467	1.467	1.258	1.367	1.312
No seed treatment (S ₃)	Chitosan @ 100 ppm (F ₁)	0.930	1.200	1.065	1.467	1.400	1.433	1.200	1.303	1.252
	Salicylic Acid @ 100 ppm (F ₂)	0.800	1.130	0.965	1.333	1.333	1.333	1.070	1.233	1.152
	Water spray (F ₃)	0.670	0.800	0.735	1.067	0.933	1.000	0.870	0.870	0.870
Mean		0.800	1.043	0.922	1.289	1.222	1.256	1.047	1.136	1.091

For comparison between means of Varieties (V) x Foliar spray (F)									
Chitosan @ 100 ppm (F ₁)	1.243	1.467	1.355	1.689	1.778	1.733	1.470	1.624	1.547
Salicylic Acid @ 100 ppm (F ₂)	1.023	1.310	1.167	1.511	1.511	1.511	1.269	1.412	1.341
Water spray (F ₃)	0.757	0.910	0.833	1.156	1.067	1.111	0.959	0.991	0.975
Mean	1.008	1.229		1.452	1.452		1.233	1.343	
Source of variation	SE m±	CD in 5%		SE m±	CD in 5%		SE m±	CD in 5%	
Varieties (V)	0.004	0.012		0.116	0.334		0.059	NS	
Seed treatment (S)	0.005	0.014		0.142	NS		0.072	0.206	
Foliar spray (F)	0.005	0.014		0.142	0.409		0.072	0.206	
V × S	0.007	0.020		0.201	NS		0.101	NS	
S × F	0.009	0.025		0.247	NS		0.124	NS	
V × F	0.007	0.020		0.201	NS		0.101	NS	
V × S × F	0.012	0.035		0.349	NS		0.176	NS	

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 Mydukur recorded highest fresh weight plant⁻¹ (327.22 g) when compared to Roma (Table 6). Seed treatment with metabolite elicitor chitosan @ 100 ppm recorded significantly superior fresh weight plant⁻¹ (318.94 g) and foliar spray with metabolite elicitor chitosan @ 100 ppm significantly recorded maximum fresh weight plant⁻¹ *i.e.* 329.22 g (Table 6).

Interactions exhibited significant influence on fresh weight plant⁻¹ at 180 DAT. The combination of Mydukur + chitosan @ 100 ppm (st) recorded maximum fresh weight plant⁻¹ (349.44 g) and minimum fresh weight plant⁻¹ (251.38 g) was recorded in Roma + no seed treatment. The variety Mydukur + chitosan @ 100 ppm (fs) recorded significantly highest fresh weight plant⁻¹ (363.47 g) and lowest fresh weight plant⁻¹ (242.24 g) was recorded in Roma + 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 (357.02 g) and minimum fresh weight plant⁻¹ (250.69 g) was recorded with no seed treatment + water spray. Highest fresh weight plant⁻¹ (396.78 g) was recorded in the combination of Mydukur + chitosan @ 100 ppm (st) + chitosan @ 100 ppm (fs) whereas lowest fresh weight plant⁻¹ (227.65 g) was recorded in Roma + no seed treatment + water spray. Taller plants, stouter stems, higher tiller numbers coupled with a higher leafiness in those plants at respective location as

justified in the previous parameters were responsible for the respective superiority in the fresh weight of plant in the variety Mydukur. Chitosan recorded significantly higher fresh weight per plant which might be because of the reason that it recorded significantly taller and stouter plants with a higher number of tillers and superior leaf production, thus contributing to the corresponding superiority in case of fresh weight per plant. The improvement in plant biomass might be due to the increased photosynthetic activity as stated by Khan *et al.* (2002) [17]. Chitin or chitosan treatments accelerated nitrogen and potassium uptake, suggesting that chitin and its derivatives modulate the absorption of inorganic nutrients through plant roots from environment, which was responsible for promotion of plant growth (Jin *et al.* 2004) [16]. Chitosan application enhanced the shoot and root weight in kasturi turmeric (Thengumpally, 2019) [28].

Salicylic acid registered relatively more plant height, number of tillers per plant and number of leaves duly contributing to higher fresh weight per plant in the above varieties thus justifying its positive action next to chitosan in enhancing fresh weight per plant as compared to no application of elicitors. Salicylic acid treatments were reported to increase the level of cell division by stimulating the mitotic system of the apical meristem of roots eventually leading to better plant growth (Sakhabutdinova *et al.*, 2001). These findings are in accordance with Mahmoud *et al.* (2017) [18] in *Ocimum basilicum* L. and Sherif *et al.* (2022) [27] in turmeric.

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)	310.42	387.29	348.86	324.10	406.26	365.18	317.26	396.78	357.02
	Salicylic Acid @ 100 ppm (F ₂)	283.17	348.56	315.87	301.31	367.83	334.57	292.24	358.20	325.22
	Water spray (F ₃)	246.91	285.05	265.98	264.69	301.64	283.16	255.80	293.35	274.57
Mean		280.17	340.30	310.23	296.70	358.57	327.64	288.44	349.44	318.94
Salicylic Acid @ 100 ppm (S ₂)	Chitosan @ 100 ppm (F ₁)	292.73	366.95	329.84	311.19	385.32	348.25	301.96	376.13	339.05
	Salicylic Acid @ 100 ppm (F ₂)	276.21	327.34	301.78	297.30	342.78	320.04	286.76	335.07	310.91
	Water spray (F ₃)	234.11	277.30	255.71	252.43	292.93	272.68	243.27	285.12	264.20
Mean		267.68	323.86	295.77	286.97	340.34	313.66	277.33	332.11	304.72
No seed treatment (S ₃)	Chitosan @ 100 ppm (F ₁)	256.87	308.67	282.77	274.47	326.34	300.40	265.67	317.51	291.59
	Salicylic Acid @ 100 ppm (F ₂)	252.63	299.09	275.86	269.03	319.14	294.09	260.83	309.12	284.98
	Water spray (F ₃)	217.31	259.37	238.34	237.98	288.09	263.04	227.65	273.73	250.69
Mean		242.27	289.04	265.66	260.49	311.19	285.84	251.38	300.12	275.75
For comparison between means of Varieties (V) x Foliar spray (F)										
Chitosan @ 100 ppm (F ₁)		286.67	354.30	320.49	303.25	372.64	337.95	294.97	363.47	329.22
Salicylic Acid @ 100 ppm (F ₂)		270.67	325.00	297.83	289.21	343.25	316.23	279.95	334.13	307.04
Water spray (F ₃)		232.78	273.91	253.34	251.70	294.22	272.96	242.24	284.07	263.15
Mean		263.37	317.74		281.39	336.70		272.38	327.22	
Source of variation		SE m±	CD in 5%		SE m±	CD in 5%		SE m±	CD in 5%	

Varieties (V)	0.33	0.94	1.82	5.23	0.92	2.65
Seed treatment (S)	0.40	1.15	2.23	6.40	1.13	3.24
Foliar spray (F)	0.40	1.15	2.23	6.40	1.13	3.24
V × S	0.57	1.63	-	NS	1.60	4.59
S × F	0.69	2.00	3.86	11.08	1.95	5.62
V × F	0.57	1.63	3.15	9.05	1.60	4.59
V × S × F	0.98	2.82	-	NS	2.76	7.94

Yield plot⁻¹ (kg)

The pooled data relevant to yield plot⁻¹ at harvest in response to varieties, methods of application of metabolite elicitors as seed treatment and foliar spray and their interactions are presented in table 7.

Varieties and methods of application of elicitors exhibited significant influence on yield plot⁻¹. The variety Mydukur recorded significantly highest yield plot⁻¹ (7.10 kg). Seed treatment with metabolite elicitor chitosan @ 100 ppm recorded significantly highest yield plot⁻¹ (7.31 kg) and foliar spray with metabolite elicitor chitosan @ 100 ppm recorded significantly highest yield plot⁻¹ (7.83 kg).

Interaction between methods of application of metabolite elicitors exhibited significant influence on yield plot⁻¹ however remaining interactions exhibited non-significant influence. The combined application of chitosan @ 100 ppm (st) + chitosan @ 100 ppm (fs) recorded highest yield plot⁻¹ (8.82 kg) and no seed treatment + water spray recorded minimum yield plot⁻¹ (4.56 kg).

As evident from the above results on the weight of rhizomes and rhizome yield, it can be concluded that the variety Mydukur was superior under coastal plains, when compared to the variety Roma. Genetic variables may be responsible for

the variations in growth, yield, and quality characteristics across cultivars produced under the same agro-ecological conditions (Nirmal and Yamgar, 1998) [21]. The impact of chitosan on physiological functions that promote vegetative growth might be the cause for the significant superiority in rhizome yield. Improved uptake of nutrients, chlorophyll content and photosynthetic activity due to chitosan application could be responsible for increase in yield (Farouk and Amany, 2012) [9]. The results obtained in our study were in conformity with Van *et al.* (2013) [30] on coffee, Anusuya and Sathiyabama (2016) [2] and Thengumpally (2019) [28] on turmeric, Ullah *et al.* (2020) [29] on tomato and Rahman *et al.* (2021) [25] on carrot.

These results are in line with earlier results that stated increasing cell length and division as well as the levels of photosynthetic pigment, SA encourages plant development. Both processes are linked to an increase in nutrient uptake (Hayat *et al.*, 2012, Pedroso *et al.*, 2019 and Bagautdinova *et al.*, 2022) [24, 4]. Similar results were also reported by Manoj (2017) [20] and Sherif *et al.* (2022) [27] in turmeric, Garcia-Pastor *et al.* (2020) [10] in pomegranate, Dobon-Suarez *et al.* (2021) [6] in pepper and Al-Zyadi (2021) [1] in coriander.

Table 7: Effect of metabolite elicitors on yield (kg plot⁻¹) in turmeric

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)	7.84	8.97	8.41	8.65	9.83	9.24	8.24	9.40	8.82
	Salicylic Acid @ 100 ppm (F ₂)	6.71	7.93	7.32	7.29	8.45	7.87	7.00	8.19	7.60
	Water spray (F ₃)	4.65	5.81	5.23	5.43	6.09	5.76	5.04	5.95	5.50
Mean		6.40	7.57	6.99	7.12	8.13	7.62	6.76	7.85	7.31
Salicylic Acid @ 100 ppm (S ₂)	Chitosan @ 100 ppm (F ₁)	7.37	8.54	7.96	8.03	9.18	8.61	7.71	8.86	8.29
	Salicylic Acid @ 100 ppm (F ₂)	5.96	7.28	6.62	6.86	7.60	7.23	6.41	7.44	6.93
	Water spray (F ₃)	4.04	5.43	4.74	4.68	5.72	5.20	4.36	5.57	4.97
Mean		5.79	7.08	6.44	6.52	7.50	7.01	6.16	7.29	6.73
No seed treatment (S ₃)	Chitosan @ 100 ppm (F ₁)	5.52	6.60	6.06	6.21	7.15	6.68	5.87	6.88	6.37
	Salicylic Acid @ 100 ppm (F ₂)	5.13	6.15	5.64	5.81	6.83	6.32	5.48	6.49	5.99
	Water spray (F ₃)	3.79	4.90	4.35	4.28	5.27	4.77	4.04	5.08	4.56
Mean		4.81	5.88	5.35	5.44	6.42	5.93	5.13	6.15	5.64
For comparison between means of Varieties (V) x Foliar spray (F)										
Chitosan @ 100 ppm (F ₁)		6.91	8.04	7.47	7.63	8.72	8.18	7.27	8.38	7.83
Salicylic Acid @ 100 ppm (F ₂)		5.93	7.12	6.53	6.66	7.63	7.14	6.30	7.38	6.84
Water spray (F ₃)		4.16	5.38	4.77	4.80	5.69	5.24	4.48	5.54	5.01
Mean		5.67	6.85		6.36	7.35		6.02	7.10	
Source of variation		SE m±	CD in 5%		SE m±	CD in 5%		SE m±	CD in 5%	
Varieties (V)		0.01	0.02		0.07	0.21		0.04	0.11	
Seed treatment (S)		0.01	0.03		0.09	0.26		0.05	0.13	
Foliar spray (F)		0.01	0.03		0.09	0.26		0.05	0.13	
V × S		0.01	0.04		-	NS		-	NS	
S × F		0.02	0.05		0.16	0.45		0.08	0.22	
V × F		0.01	0.04		-	NS		-	NS	
V × S × F		0.02	0.07		-	NS		-	NS	

Conclusions

The present study represents the positive response of metabolite elicitors to increase the growth and yield in

turmeric. From the results obtained it can be concluded that the variety Mydukur responded well to the applied metabolite elicitors at coastal plains of Andhra Pradesh. The effect of

chitosan is proved to be superior in increasing the growth and yield of turmeric through foliar application and in combination of seed treatment with foliar spray followed by salicylic acid treatment.

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