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Response of foliar application of ascorbic acid and salicylic acid on African marigold

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Abstract
The present study on "Response of foliar application of ascorbic acid and salicylic acid on African marigold" was undertaken at Floriculture Research Farm, ASPEE College of Horticulture, Navsari Agricultural University, Navsari, Gujarat, India during June to December, 2024. The experiment comprised of ten treatments of ascorbic acid (AA) and salicylic acid (SA) along with control *viz.,* T_1: AA @ 50 mg/l + SA @ 50 mg/l, T_2: AA @ 50 mg/l + SA @ 150 mg/l, T_3: AA @ 50 mg/l + SA @ 300 mg/l, T_4: AA @ 100 mg/l + SA @ 50 mg/l, T_5: AA @ 100 mg/l + SA @ 150 mg/l, T_6: AA @ 100 mg/l + SA @ 300 mg/l, T_7: AA @ 200 mg/l + SA @ 50 mg/l, T_8: AA @ 200 mg/l + SA @ 150 mg/l, T_9: AA @ 200 mg/l + SA @ 300 mg/l and T_{10}: Control (no spray). The experiment was laid out in Randomized Block Design (RBD) with three replications and the treatments were applied as foliar spray to the plants at 30 and 50 days after transplanting.
Among the different treatments, AA @ 200 mg/l + SA @ 150 mg/l (T_8) greatly influenced the vegetative, flowering and yield parameters as compared to other treatments which registered the maximum plant height, number of primary branches per plant, stem diameter, plant spread in both N-S and E-W directions and maximum leaf chlorophyll content. The same treatment also resulted in earliness to first flower bud appearance, longest duration of flowering, diameter of flower, fresh weight of flower, number of flowers per plant, flower yield per plant as well as per plot and hectare, flower longevity and shelf life.
Based on results obtained from the present investigation, it can be concluded that foliar application of ascorbic acid @ 200 mg/l + salicylic acid @ 150 mg/l at 30 and 50 days after transplanting found better for growth, flowering, quality and yield of African marigold.

Keywords: African marigold, ascorbic acid, salicylic acid and foliar application

Introduction
African marigold (*Tagetes erecta* L.) is a widely cultivated, versatile flower crop, prized for its vibrant blooms that adds beauty to gardens and arrangements. As a member of the Asteraceae family, with a chromosome number of 2n=24, this plant has thrived in various agro-climatic regions of India. It has gained popularity amongst gardeners and flower dealers on account of its easy cultivation and wide acceptability. Its profuse flowering habit, short duration to produce marketable flowers, wide spectrum of attractive colours, shape, size and good keeping quality attracted the attention of producers and traders most. Crop production relies on several key factors, among which the growth hormones or stimulants also play a vital role in regulating plant growth, development, enhancing yields and improving stress tolerance. By combining these factors and leveraging growth hormones, farmers can optimize crop growth, increase productivity and achieve better agricultural outcomes. The most abundant vitamins found in plants are ascorbic acid, citric acid and thiamine, which are also known as antioxidants due to their strong antioxidant properties.
Ascorbic acid is a powerful antioxidant that is involved in regulating photosynthesis (Blokhina *et al*., 2003) [3], also considered to be growth bioregulators and foliar application in low concentrations may strongly affect metabolic pathways, plant growth regulation and physiological processes, including the biosynthesis of enzymes and co-enzymes (Hathout, 1995) [8]. It is an abundant component in plants, function as an antioxidant and an enzyme cofactor. It participates in a variety of processes including photosynthesis, cell wall growth, cell expansion, resistance to environmental stresses and synthesis of ethylene, gibberellins, anthocyanin and hydroxyl proline.

It is a pivotal component in plant physiology, boasting antioxidant, cellular reductant and other properties that play diverse roles in plant development and stress regulation.

Salicylic acid on other hand is a phenolic compound of hormonal nature produced by plants and plays an important role in responses to several abiotic stresses and to pathogen attack (Noreen *et al*., 2009) [16]. It has also been studied for its effects on various physiological processes related to growth and development of plants under normal or no stress conditions and among these effects, are the induction of flowering (Hegazi and El-Shrayi, 2007) [9], stimulation of root development, stomatal closure and reduced transpiration (Singh and Usha, 2003) [21], reversal of the effects of abscisic acid (Davies, 2004) [5], regulation of gravitropism (Hussein *et al*., 2007) [10]. It acts as an antioxidant and plays a significant role in regulating certain physiological processes in plants such as growth, germination, photosynthesis and ion absorption and also a signalling molecule to various environmental stresses. It affects ethylene biosynthesis, stomatal movement and also reverses the effects of ABA on leaf abscission.

In view of considering the above facts, the present investigation was carried out to study the response of foliar application of ascorbic acid and salicylic acid on African marigold.

Materials and Methods

The experiment was carried out at Floriculture Research Farm, ASPEE College of Horticulture, Navsari Agricultural University, Navsari. The experiment was laid out in Randomized Block Design (RBD) with three replication and ten treatments of ascorbic acid (AA) and salicylic acid (SA) along with control *viz.,* T_1: AA @ 50 mg/l + SA @ 50 mg/l, T_2: AA @ 50 mg/l + SA @ 150 mg/l, T_3: AA @ 50 mg/l + SA @ 300 mg/l, T_4: AA @ 100 mg/l + SA @ 50 mg/l, T_5: AA @ 100 mg/l + SA @ 150 mg/l, T_6: AA @ 100 mg/l + SA @ 300 mg/l, T_7: AA @ 200 mg/l + SA @ 50 mg/l, T_8: AA @ 200 mg/l + SA @ 150 mg/l, T_9: AA @ 200 mg/l + SA @ 300 mg/l and T_{10}: Control (no spray).The treatments were applied as foliar spray to the plants at 30 and 50 days after transplanting.

Good quality seedlings of African marigold var. Punjab Gainda1 were sown on the raised nursery beds with a size of 3.0 m length, 1.0 m wide and 15 cm in height by line sowing at 1-2 cm deep in the soil with proper care to ensure quick germination. After sowing, beds were watered with a fine shower for first week and thereafter it was done at alternate days till the germination was completed. The nursery area was kept free from weeds by regular weeding, thus proper care was taken throughout the period of raising the nursery. The entire experimental plot was thoroughly ploughed and brought to a fine tilth after removing the roots of weeds and stubbles before planting. FYM @ 10 t ha^{-1} was applied and mixed well with the soil.

The experimental plot was divided into 3 blocks with 30 plots as per experimental design. The healthy and disease-free seedlings with uniform size and vigour @ 3-4 leaf stage were selected and transplanted on well prepared and irrigated ridges in open field during the evening time at a spacing of 60 cm × 40 cm. Immediately after transplanting, a light irrigation was given for better establishment of seedling in the field. The field was regularly inspected for optimum plant population and gap filling was done up to one week after transplanting to maintain required plant population in each plot. Fertilizers were applied at the rate of 150:100:100 kg NPK/ha where nitrogen was applied in two equal split doses (half dose as a basal and remaining half dose was given at 30 DAT), whereas phosphorus and potash were applied as basal dose only. Plants were irrigated as and when it required and weeds were removed manually and pre-emergence weedicide *like* pendimethalin @ 60 ml/ 10 litre water was sprayed after transplanting.

Pinching which is very important practice in African marigold was done by removing 1 to 1.5 cm growing tip portion of the plants at 20 days after transplanting. No serious pest and disease incidence were seen during entire course of an investigation period. While, harvesting of flowers was done in cool hours at fully opened stage from different treatments for observations. Five plants were selected randomly from net plot and were tagged for recording the observations from all the treatments under each replication and the vegetative parameters were recorded at 45 and 90 DAT.

Results

Effect on Growth Parameters

It is evident from the data as presented in Table-1 that the highest plant height (35.60 and 87.23 cm, respectively at 45 and 90 DAT) was observed in the treatment of foliar application of AA @ 200 mg/l + SA @ 150 mg/l (T_8) while the lowest was recorded in T_{10} control treatment (22.63 and 65.87 cm, respectively). The same treatment also resulted in maximum number of primary branches per plant (8.61 and 14.18), maximum stem diameter (1.07 and 1.36 cm) and plant spread in both the directions (N-S: 18.50 and 41.76 cm and E-W: 21.50 and 37.36 cm) at 45and 90 DAT, respectively. Whereas, the control treatment (T_{10}) registered lowest number of primary branches per plant (5.14 and 9.09), minimum stem diameter (0.79 and 1.14 cm), plant spread (N-S: 11.67 and 29.91 cm and E-W: 12.63 and 28.74 cm) at 45 and 90 DAT, respectively. Moreover, aamong the different treatments, the total leaf chlorophyll content was significantly highest (1.45 mg/g) in treatment T_8 and lowest value (1.24 mg/g) was found in control treatment at 55 DAT.

The increase in plant height with ascorbic acid and salicylic acid application might be attributed to synthesis of tryptophan which promotes intensity of auxins leading to more cell division, cell elongation, meristematic activity of the tissue and expansion of cells (Martin, 1966) [14], also enhanced the availability of macro nutrients (Chattopadhyay, 1994; Keram *et al.*, 2014) [4, 12] and increased number of internodes (Jaiwal and Bhambie, 1989) [11]. The salicylic acid could be attributed to its bio regulator effects on physiological and bio chemical processes in plant and increased the number of nodes in plant (El-Tayeb, 2005) [7]. The combination of SA and AA might enhance plant growth and increase plant height by promoting cell division, photosynthesis and stress tolerance.

The increased in number of primary branches per plant may be due to the involvement of ascorbic acid in synthesis of protein and tryptophan (a precursor of auxin) which helps the plant to maintain polarity growth and enhance the availability of macro nutrients (Chattopadhyay, 1994) [4]. Likewise, the salicylic acid is involved in enhancing some physiological and biochemical processes of plants such as ion uptake, cell elongation, cell division, cell differentiation,

enzymatic activities, protein synthesis and photosynthetic activity (Raskin, 1992) [18].

The salicylic acid improves root system, synthesis of auxins and cytokinin's and it is also responsible for increment in lignin of cell wall which could be a factor for increase in stem diameter of plant. Ascorbic acid can enhance stem growth and diameter by promoting cell division and expansion, improving photosynthesis, nutrient uptake, reducing oxidative stress and may also play a role in plant hormone regulation influencing stem growth. Similar results of ascorbic acid with its higher concentrations were also obtained by Sawy *et al*. (2021) [20] in lilium and likewise that of salicylic acid by Basit *et al*. (2018) [2] and Moradian *et al*. (2023) [15] in marigold.

Salicylic acid can promote branching and plant spread by stimulating axillary bud growth, regulating hormonal balances, may also influence plant defence responses, potentially affecting plant spread. Ascorbic acid can enhance spread by promoting cell division and expansion, may also play a role in plant hormone regulation thus influencing plant architecture. SA and AA might synergistically promote branching, leading to a more extensive plant spread and could enhance plant growth and vigour. Kumar *et al*. (2024) [13] in marigold also reported similar results with application of salicylic acid.

Both the compounds found to increase chlorophyll content in leaves by enhancing various physiological processes. Ascorbic acid acts as an antioxidant and cofactor in enzyme reactions, while salicylic acid regulates stress responses and improves photosynthetic efficiency. These actions collectively lead to increased chlorophyll synthesis and protection from damage, thus boosting overall chlorophyll levels. Abbass and Aziz (2013) [1] in marigold also reported similar results with application of ascorbic acid.

Effect on Flowering, Quality and Yield Parameters

Different flowering, quality and yield attributes were also affected significantly by different ascorbic acid and salicylic acid treatments and the data is presented in Table 2. In present experiment, treatment T_8 (AA @ 200 mg/l + SA @ 150 mg/l) recorded minimum days to first bud appearance (37.87 days), longest flowering duration (96.94 days), greater flower diameter (8.03 cm), average weight of flower (9.53 g), highest number of flowers per plant (58.76), flower yield (355.56 g/plant, 7.44 kg/plot and 15.52 t/ha) along with better flower longevity (28.70) and shelf life (5.93 days) in African marigold. In contrast, the control treatment (T_{10}) showed the lowest values with respect to all the flowering, quality and yield parameters under study.

Ascorbic acid and salicylic acid promote early flower bud appearance by modulating signaling pathways of hormones especially influencing gibberellins and auxin in plants for regulating flower promoting genes, reducing oxidative stress and stimulating cell division and elongation, which accelerates flower initiation and emergence leading to early flower bud appearance. Ascorbic acid increases flowering duration by acting as an antioxidant, scavenging reactive oxygen species (ROS) that can damage flower tissues and trigger senescence. By reducing oxidative stress, ascorbic acid delays flower senescence, thereby extending the flowering period and maintaining flower quality. (Sardoei *et al.,* 2014 in gazania) [19]. The application of salicylic acid is effective on a wide range of physiological processes having synergistic effect with auxin and gibberellins (Zaghlool *et al.,* 2006) [22] and also influences hormone signaling pathways, potentially modulating ethylene production and senescence that results in increased duration of flowering. Both compounds enhance antioxidant defences, reducing damage to flower tissues and promoting overall flower growth and development, resulting in increased flower diameter and weight, similar results were also obtained by Basit *et al*., 2018 [2] and Moradian *et al*., 2023 [15] in marigold.

AA and SA increase flower yield in plants by regulating hormone balances, promoting plant growth and development, enhancing photosynthesis and nutrient uptake and reducing oxidative stress. These mechanisms synergistically contribute to increased flower initiation, development and biomass accumulation, ultimately leading to higher flower yields. By modulating plant physiological processes, AA and SA support optimal flower production and plant productivity. Similar results were also obtained by Abbass and Aziz, 2013 [1] and Poudel and Subedi (2020) [17] in marigold, Elsadek, 2018 in dahlia. They might also extend the shelf life and longevity of flowers by reducing oxidative stress and senescence, inhibiting microbial growth, maintaining water balance and flower freshness, regulating ethylene production which can impact flower senescence, Sawy *et al*. (2021) [20] in lilium and Moradian *et al.* (2023) [15] in marigold flowers.

Table 1: Effect of ascorbic acid and salicylic acid on growth of African marigold

Treatments	Plant height (cm)		Number of branches per plant		Stem Diameter (cm)		Plant spread (N-S) (cm)		Plant spread (E-W) (cm)		Leaf chlorophyll content (mg/g)
	45 DAT	90 DAT	45 DAT	90 DAT	45 DAT	90 DAT	45 DAT	90 DAT	45 DAT	90 DAT	55 DAT
T_1: AA @ 50 mg/l + SA @ 50 mg/l	27.33	69.45	6.77	11.17	0.79	1.24	13.90	31.53	15.20	30.07	1.26
T_2: AA @ 50 mg/l + SA @ 150 mg/l	25.73	72.30	7.22	11.56	0.82	1.23	14.90	31.01	14.46	30.44	1.25
T_3: AA @ 50 mg/l + SA @ 300 mg/l	28.23	74.69	7.13	11.50	0.84	1.22	15.06	35.07	15.53	33.83	1.28
T_4: AA @ 100 mg/l + SA @ 50 mg/l	28.70	68.94	6.74	11.78	0.84	1.21	15.80	34.57	15.67	32.27	1.31
T_5: AA @ 100 mg/l + SA @ 150 mg/l	31.30	78.71	8.13	12.77	0.90	1.25	15.33	34.26	16.10	35.23	1.36
T_6: AA @ 100 mg/l + SA @ 300 mg/l	31.96	76.34	8.07	12.18	0.88	1.27	15.73	36.13	16.06	34.73	1.36
T_7: AA @ 200 mg/l + SA @ 50 mg/l	30.60	79.58	7.87	11.80	0.90	1.28	16.80	37.57	14.90	34.70	1.42
T_8: AA @ 200 mg/l + SA @ 150 mg/l	35.60	87.23	8.61	14.18	1.07	1.36	18.50	41.76	21.50	37.36	1.45
T_9: AA @ 200 mg/l + SA @ 300 mg/l	32.83	83.83	8.18	12.14	0.96	1.31	16.30	38.50	18.10	36.20	1.44
T_{10}: Control (No spray)	22.63	65.87	5.14	9.09	0.79	1.14	11.67	29.91	12.63	28.74	1.24
S.Em. ±	1.25	3.61	0.42	0.51	0.05	0.03	1.08	1.46	0.93	1.03	0.02
C.D. at 5%	3.74	10.83	1.27	1.55	0.16	0.11	3.24	4.38	2.78	3.04	0.07
C.V.	7.35	8.27	9.98	7.59	10.51	5.15	12.17	7.23	10.05	5.36	3.31

Note: DAT means days after transplanting.

Table 2: Effect of ascorbic acid and salicylic acid on flowering, quality and yield of African marigold

Treatments	Days to first flower bud appearance	Duration of flowering (days)	Flower diameter (cm)	Average flower weight (g)	No. of flowers per plant	Flower yield/plant (g)	Flower yield/plot (kg)	Flower yield/ha (t)	Longevity of flowers (days)	Shelf life of flowers (days)
T_1: AA @ 50 mg/l + SA @ 50 mg/l	46.03	82.05	4.20	7.25	45.10	231.31	5.65	11.79	21.63	4.46
T_2: AA @ 50 mg/l + SA @ 150 mg/l	45.17	84.39	4.93	7.65	47.77	225.01	5.54	11.56	22.36	5.06
T_3: AA @ 50 mg/l + SA @ 300 mg/l	43.01	86.38	5.63	7.86	50.23	260.15	6.23	13.01	22.70	4.53
T_4: AA @ 100 mg/l + SA @ 50 mg/l	42.00	88.39	5.90	8.53	51.03	245.74	5.85	12.21	22.06	5.13
T_5: AA @ 100 mg/l + SA @ 150 mg/l	40.97	90.58	6.10	7.20	52.59	270.07	6.42	13.39	24.83	5.33
T_6: AA @ 100 mg/l + SA @ 300 mg/l	42.14	89.40	5.06	7.60	51.46	294.11	6.50	13.53	22.03	4.90
T_7: AA @ 200 mg/l + SA @ 50 mg/l	42.46	91.06	7.06	8.86	52.09	322.30	6.89	14.38	24.43	4.50
T_8: AA @ 200 mg/l + SA @ 150 mg/l	37.87	96.94	8.03	9.53	58.76	355.56	7.44	15.52	28.70	5.93
T_9: AA @ 200 mg/l + SA @ 300 mg/l	39.75	93.27	7.03	8.13	56.43	338.03	6.93	14.60	27.43	5.00
T_{10}: Control (No spray)	49.84	81.31	3.70	7.05	38.80	228.36	5.23	10.91	17.66	3.46
S.Em. ±	2.14	3.08	0.29	0.48	1.82	11.22	0.28	0.60	1.33	0.19
C.D. at 5%	6.42	9.24	0.87	1.46	5.45	33.61	0.86	1.80	3.98	0.59
C.V.	8.66	6.05	8.79	10.60	6.26	7.01	7.94	7.94	9.85	7.10

Conclusion

On the basis of results obtained during the investigation, it can be concluded that foliar application of ascorbic acid @ 200 mg/l along with salicylic acid @ 150 mg/l twice at 30 and 50 DAT alternately at 2 days interval was found best for enhancing overall growth, flowering, quality and yield parameters in African marigold var. 'Punjab Gainda 1'.

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