The Pharma Innovation Journal 2023; 12(11): 1917-1921

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(11): 1917-1921

www.thepharmajournal.com
Received: 13-09-2023
Accepted: 22-10-2023

Karakal SP
M.Sc., Department of Horticulture, College of Agriculture Badnapur, V.N.M.K.V., Parbhani, Maharashtra, India

Dr. Patil SG
Office Incharge, Sweet Orange Research Station, Badnapur, V.N.M.K.V., Parbhani, Maharashtra, India

Gaikwad GB
Ph.D., Department of Horticulture, College of Horticulture Dapoli, Dr. B.S.K.K.V., Dapoli, Ratnagiri, Maharashtra, India

Gaikwad RB
M.Sc., Department of Horticulture, College of Agriculture Badnapur, V.N.M.K.V., Parbhani, Maharashtra, India

Gite AS
M.Sc., Department of Horticulture, College of Agriculture Badnapur, V.N.M.K.V., Parbhani, Maharashtra, India

Corresponding Author:
Karakal SP
M.Sc., Department of Horticulture, College of Agriculture Badnapur, V.N.M.K.V., Parbhani, Maharashtra, India

Influence of growth regulators and chemical on growth, yield and quality of acid lime (*Citrus aurantifolia* L.) cv. Sai Sharbati

Karakal SP, Dr. Patil SG, Gaikwad GB, Gaikwad RB and Gite AS

Abstract
The present investigation entitled "Influence of growth regulators and chemical on growth, yield and quality of Acid lime (*Citrus aurantifolia* L.) cv. Sai Sharbati" was carried out at Sweet Orange Research Station, Badnapur, Tal- Badnapur, District- Jalna during 2021-22 An experiment was laid out in Randomized block design (RBD) with eight treatments combination with three replications. Treatments are T_1 (GA3 @ 50 ppm), T_2 (Cycocel @ 1000 ppm), T_3 (KNO_3 @ 1%), T_4 (GA_3 @ 50 ppm + KNO_3 @ 1%), T_5 (Cycocel @ 1000 ppm + KNO_3 @ 1%), T_6 (GA_3 @ 100 ppm + KNO_3 @ 2%), T_5 (Cycocel @ 1500 ppm + KNO_3 @ 2%), T_8 (Control). Among all the treatments, T_6 (GA_3 @ 100 ppm + KNO_3 @ 2%) recorded maximum increase in plant height, East – West Spread, North – South Spread and stem girth. The Maximum number of flowers per shoot (8.10), length of fruit (4.86 cm), diameter of fruit (5.20 cm), volume of fruit (54.86 ml), weight of fruit (55.80 g), no. of fruits per tree (890.00), yield per plant (49.70 kg) and yield per hectare (27.59 tonne) were recorded in treatment T_6 (GA_3 @ 100 ppm + KNO_3 @ 2%). Minimum number of seeds per fruit (6.20) was recorded in treatment T_4. The treatment T_6 (GA_3 @ 100 ppm + KNO_3 @ 2%) showed maximum juice (58.90%), total soluble solids (8.20 ^{0}Brix), reducing sugar (0.88%), non-reducing sugar (0.90%), total sugars (1.80%) and minimum acidity (5.40%) was recorded.

Keywords: Sai Sharbati, KNO_3, plant growth regulators, Cycocel, total soluble solids

Introduction
Acid lime (*Citrus aurantifolia* Swingle), is the third most important species of citrus in India after mandarin and sweet orange. The area under acid lime in India is 322 thousand hectares with production of 3742 thousand MT and productivity 11.62 MT (Anonymous, 2021-22) [1]. In India, acid lime is mainly grown in the states of Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Madhya Pradesh, Bihar, Assam, Jharkhand and Chhattisgarh. Fruits of acid lime possess great medicinal and nutritional value. It is a rich source of vitamin "C". Fruits being acidic in nature, they are largely used for garnishing and flavouring several vegetarian and non-vegetarian dishes. Besides its value-added products like pickle, juice, squash etc., lime peel oil, peel powder are also in great demand in soap and cosmetic industry.
The soil and climatic conditions of semi-arid regions in Marathwada offers suitable condition of acid lime under irrigated and rain-fed conditions as well. However, the production of acid lime fruits is not sufficient enough to meet the local demand and distant markets. It is possible to bridge this gap by growing acid lime in Marathwada region of Maharashtra where there are some stray trees with fairly good performance. In view of the specific problems regarding acid lime productivity in Maharashtra, it were felt necessary to assess the effect of pre harvest application of PGR's, Cycocel and KNO_3 on yield of acid lime.

Materials and Methods
Experiment was laid out in Randomized block design (RBD) with eight treatments combination with three replications. The treatments are T1 (GA3 @ 50 ppm), T2 (Cycocel @ 1000 ppm), T3 (KNO3 @ 1%), T4 (GA3 @ 50 ppm + KNO3 @ 1%), T5 (Cycocel @ 1000 ppm + KNO3 @ 1%), T6 (GA3 @ 100 ppm + KNO3 @ 2%), T5 (Cycocel @ 1500 ppm + KNO3 @ 2%), T8 (Control). One foliar spray of all the treatments were applied before flowering of acid lime. The observation on different parameters *viz.*, plant height, east-west spread, north-south spread, stem girth, number of flowers per shoot, length of fruit, diameter of fruit, volume of fruit, weight of fruit, number of seeds per fruit, no. of fruits per tree, yield per plant, yield per hectare, juice %, total soluble solids, acidity %, reducing sugar, non-reducing

sugar and total sugars were recorded The soil was medium black with uniform in texture, colour and had good drainage. Drip irrigation was made for an easy supply of water.

Results and Discussion

The observations recorded on various parameters during the course of the investigation were statistically analyzed and the results obtained are presented under.

Growth Parameters

Plant height (m)

The data on effect of different growth regulators and chemical on plant height (m) recorded during the course of investigation and analysis are presented in Table 1 for plant height (m) revealed non-significant changes as a result of different treatments. However, there were non-significant differences were recorded in plant height (m). However, the maximum plant height increased (0.23 m) was recorded in the treatment T6 (GA3 @ 100 ppm + KNO3 @ 2%) followed by T4 (0.22 m) (GA3 @ 50 ppm + KNO3 @ 1%). Whereas, the minimum plant height (0.12 m) was recorded in treatment T8 (Control), followed by T2 (Cycocel @ 1000 ppm). It is known that the plant growth regulator GA3 causes fast cell elongation in the meristematic zone of vegetative plant organs. This may be because gibberellins (GA3), which function as a growth promoter and induce rapid cell elongation by activating the intercalary meristematic area of developing shoots, also lengthen internodal distances between branches. Other writers, including, found similar results about the increase in vegetative shoot and plant height by the application of gibberellins (GA3) and stopped vegetative development with Cycocel.

Table 1: Effect of PGR's and Cycocel on plant height, plant spread and stem girth of acid lime cv. Sai Sharbati

Treatment no.	Treatment details	plant height (m)			East-West spread (m)			North-South spread (m)			stem girth (cm)		
		Before Treatment Plant height (m)	After Treatment Plant height (m)	Plant height increased (m)	Before Treatment East-West Spread (m)	After Treatment East-West spread (m)	East-West spread increased (m)	Before Treatment North-South spread (m)	After Treatment North-South spread (m)	North-South spread increased (m)	Before Treatment Stem girth (cm)	After Treatment Stem girth (cm)	Stem girth increased (cm)
T_1	GA_3 50ppm	3.82	3.98	0.19	3.82	4.00	0.18	3.82	4.02	0.20	27.45	34.27	4.15
T_2	Cycocel 1000ppm	3.56	3.71	0.15	3.56	3.69	0.13	3.56	3.69	0.12	32.00	33.22	3.00
T_3	KNO_3 1%	3.99	4.17	0.18	3.99	4.14	0.15	3.99	4.14	0.15	31.23	33.43	2.20
T_4	GA_3 50ppm + KNO_3 1%	4.11	4.33	0.22	4.11	4.31	0.20	4.11	4.34	0.23	33.23	39.05	4.88
T_5	Cycocel 1000ppm + KNO_3 1%	4.03	4.23	0.20	4.32	4.49	0.17	4.32	4.52	0.20	32.14	36.03	3.89
T_6	GA_3 100ppm + KNO_3 2%	3.89	4.12	0.23	3.89	4.12	0.23	3.89	4.14	0.25	28.15	36.00	5.82
T_7	Cycocel 1500 ppm+ KNO_3 2%	4.10	4.30	0.21	4.60	4.75	0.15	4.60	4.82	0.17	29.60	33.00	3.40
T_8	Control	4.10	4.22	0.12	4.63	4.75	0.12	4.07	4.17	0.10	30.12	32.89	1.88
	S.E±	0.23	0.52	0.04	0.34	0.34	0.01	0.24	0.23	0.02	2.34	6.27	0.07
	CD at 5%	NS	NS	NS	NS	NS	0.02	NS	NS	0.07	NS	NS	0.21

East-West spread (m)

The significantly maximum east-west spread (0.23 m) was recorded in the treatment T_6 (GA_3 @ 100 ppm + KNO_3 @ 2%), followed by Treatment T_4 (0.20 m), and T_1 (0.18 m). Whereas, minimum east-west spread (0.12 cm) was observed in treatment T_8 (control). The enormous rise in east-west spread may be related to the boosting impact of GA3 on acid lime's vegetative development, which raises the mean east to east-west spread. Gibberellins (GA3) act as a growth promoter that stimulates rapid cell elongation. These results were in agreement with those of Babu and Lavania (1985) in the lemon

North-South spread (m)

The significantly maximum North-South spread (0.25 m) was recorded in the treatment T6 (GA3 @ 100 ppm + KNO3 @ 2%) which was at par with treatment T4(0.23 m), T1and T5 (0.20 m). Whereas, minimum North-South spread (0.10 m) was observed in treatment T8 (control).

Stem girth (cm)

The information showed that there were significant differences in the stem girth. However, the treatments T6 (GA3 @ 100 ppm + KNO3 @ 2%) showed the largest increase in stem girth (5.82 cm), followed by the treatment T4 (4.88 cm) and T1 (4.15 cm). In contrast, treatment T8 (control) had a low increase in stem girth (1.88 cm). This might be due to the growth promoter's gibberellins (GA3), which hasten cell elongation and increase stem girth. Similar trend was also observed by Canli and Orhan (2009) [3] reported that maximum stem thickness in pear, apple and cherry.

Yield parameters

Number of flowers per shoot

Table 2 provides information on the significant effects that various growth regulators and chemical had on the number of flowers per shoot. The treatment T6 (GA3@ 100 ppm + KNO3 @ 2%) had recorded the significantly largest number

of flowers per shoot (8.10), followed by the treatment T4 (6.90) and T1 (6.00). The significantly lowest flowers were present on each shoot in treatment T8 (4.12) (control).Similar increases in fruit set by GA3 treatment were noted in mandarin by Greenburg *et al.* (2000) [9].

Length of fruit (cm)

The significant effects that various growth regulators and chemical had on the Length of fruit (cm). The treatment T6 (GA3 @ 100 ppm + KNO3 @ 2%) had the significantly maximum Length of fruit (cm) (4.86 cm), followed by the treatment T4 (4.20) and T1 (4.00). However, the minimum Length fruit (3.10 cm) was found in treatment T8 that is control. Similar increases in length of fruit by GA3 treatment were noted by Deshlehra *et al.* (2019) [7], Chutichudet *et al.* (2006) [5] Yadav *et al.* (2011) [30] in guava, Mosa *et al.* (2022) [16] in Pear, Sandhu (2013) [23] in Lemon.

Diameter of fruit (cm)

Table 2 provides information on the significant effects that various growth regulators and chemical had on the Diameter of fruit (cm). The treatment T6 (GA3 @ 100 ppm + KNO3 @ 2%) had the significantly maximum Diameter of fruit (cm) (4.52 cm), followed by the treatment T4 (4.20 cm). However, the minimum fruit diameter (3.50 cm) was found in treatment T8 that is control. Similarly increasing in length of fruit by application of GA3 was noted by Deshlehra *et al.* (2019) [7], Nawaz *et al.* (2008) [17] in Kinnow mandarin, Jagtap *et al.* (2013) [12], Jain *et al.* (2015) [13] in Nagpur mandarin.

Table 2: Effect of PGR's, Cycocel on yield contributing parameters of acid lime cv. Sai Sharbati

Treatment no.	Treatment details	Number of flowers per shoot	Length of fruit (cm)	Diameter of fruit (cm)	Volume of fruit (ml)	Weight of fruit (g)	No. of seeds per fruit	No. of fruit per tree	Yield per plant (kg)	Yield per hectare (tonnes)
T_1	GA_3 50ppm	6.00	4.00	3.80	52.23	52.56	7.10	810.00	42.68	23.69
T_2	Cycocel 1000ppm	4.80	3.24	3.89	45.56	49.59	6.50	750.00	37.24	20.67
T_3	KNO_3 1%	4.60	3.40	4.10	49.78	49.10	8.69	620.00	30.45	16.90
T_4	GA_3 50ppm + KNO_3 1%	6.90	4.20	4.20	52.83	53.56	6.20	850.00	45.22	25.10
T_5	Cycocel 1000ppm + KNO_3 1%	5.50	3.89	4.00	50.89	51.42	6.56	790.00	40.63	22.55
T_6	GA_3 100ppm + KNO_3 2%	8.10	4.86	4.52	54.86	55.80	7.20	890.00	49.70	27.59
T_7	Cycocel 1500 ppm+ KNO_3 2%	5.90	3.50	4.10	51.23	52.10	7.91	800.00	41.72	23.15
T_8	Control	4.12	3.10	3.50	36.56	47.49	9.20	615.00	29.20	16.25
	S.E±	0.10	0.08	0.08	1.01	0.82	0.13	12.29	1.57	0.78
	CD at 5%	0.29	0.24	0.25	3.10	2.52	0.40	37.65	4.81	2.34

Volume of fruit (ml)

Information regarding significant effects of various growth regulators and chemical on the Volume of fruit (ml). The treatment T6 (GA3 @ 100 ppm + KNO3 @ 2%) had the significantly maximum Volume of fruit (54.86 ml), at par with the treatment T4 (52.83 ml) and T1 (52.23 ml), followed by treatment T7 and T5. However, the minimum volume of fruit (36.56 ml) was recorded in treatment T8 that is control. Similar results for increase in fruit volume by application of GA3 were reported by Sharma and Singh (2008) [26], Jagtap *et al.* (2013) [12], Chandra *et al.* (2015) [4], Tagad *et al.* (2018) [29], Kheder *et al.* (2019) [15], Debaje *et al.* (2011) [6] in acid lime

Weight of fruit (g)

Table 2 provides prevailing information on the significant effects that various growth regulators and chemical had on the weight of fruit (g). The treatment T6 (GA3 @ 100 ppm + KNO3 @ 2%) had the significantly maximum weight of fruit (55.80 g), which was at par with the treatment T4 (53.56 g). However, the minimum weight of fruit (47.49 g). was found in treatment T8 that is control. Similar results for increase in fruit volume by application of GA3 and KNO3 were reported by El-Agamy *et al.* (2004) [8], Pawar *et al.* (2005) [18] in mango.

No. of seeds per fruit

Number of seeds per fruit showed that there was significant variation in the number of seeds per fruit. However, the treatment T4 (GA3 @ 50 ppm + KNO3 @ 1%) had the fewest seeds per fruit (6.20), which was at par with treatments T2 (6.50) and T5 (6.56), While the treatment T8 showed the highest level of seeds per fruit (9.20) (control). Application of GA3 reduced the number of seeds per fruit. Present findings are in agreement with the results reported by Debaje *et al.* (2011) [6] acid lime.

No. of fruit per tree

Table 2 provide information on the significant effects that various growth regulators and chemical had on the number of fruits per tree. The treatment T6 (GA3 @ 100 ppm + KNO3 @ 2%) had the significantly maximum number of fruits per tree. (890.00), followed by the treatment T4 (850). The significantly minimum fruits were present on each plant in treatment T8 (615) (control). Similar results were reported by Sudha *et al.* (2012) [28] found that, on application of KNO3 on mango tree gives highest number of fruits per plant resulting in highest yield.

Yield per plant (kg)

The data on effect of different growth regulators and chemical on yield per plant (kg) recorded during course of investigation are presented in Table 2 revealed that significant changes as a result of different treatments. However, there was significant differences were recorded in yield per plant (kg). However, the maximum yield per plant (49.70 kg) was recorded in the treatment T6 (GA3 @ 100 ppm + KNO3 @ 2%), followed by T4 (45.22 kg) (GA3 @ 50 ppm + KNO3 @ 1%) and T1 (42.61 kg). Whereas, the minimum yield per plant (29.20 kg) was recorded in treatment T8 (Control). Similar results were reported by Rattanpal *et al.* (2008) [21] application of KNO3 increase yield. Sudha *et al.* (2012) [28] and Sarker and Rahim (2013) [24] found that, application of KNO3 on mango recorded in highest yield.

Yield per hectare (tonnes)

The maximum yield per hectare (27.59 T) was recorded in the treatment T6 (GA3 @ 100 ppm + KNO3 @ 2%) followed by T4 (25.10 T) (Cycocel @ 1500 ppm + KNO3 @ 2%) and T1 (23.69 T). Whereas, the minimum yield per plant (16.25 T) was recorded in treatment T8 (Control).

Quality parameters

Juice (%)

From the data Table 3 it is revealed that, juice percentage was significantly influenced by various plant growth regulators and chemical. The maximum juice percentage (58.90%) was recorded in the treatment T6 (GA3 @ 100 ppm + KNO3 @ 2%), followed by T4 (53.56) (GA3 @ 50 ppm + KNO3 @ 1%). The minimum juice percentage (32.20%) was recorded in the treatment T8 (control). Similar results were reported by Prabhu *et al.* (2017) [19], Rai and Patil (2020) [20] Application of GA3 and KNO3 increased juice percent of fruit. Application of GA3 increase juice percent of fruit, reported by Khalid *et al.* (2012) [14] in mandarin, Sandhu (2013) [23] in acid lemon, Rokaya *et al.* (2016) [22] in mandarin, Prabhu *et al.* (2017) [19], Bhatt *et al.* (2017) [2] in lemon, Rai and Patil (2020) [20].

TSS (0Brix)

The data regarding TSS is present in Table 3 From the data it is revealed that, TSS (0Brix) was significantly influenced by various plantgrowth regulators and chemical. The maximum TSS (^{0}Brix) (8.20 0Brix) was recorded in the treatment T_6 (GA3 @ 100 ppm + KNO3 @ 2%), at par with T_7 (8.10), T_5 (7.99) and T_4 (7.90). The minimum TSS percentage (5.68 ^{0}Brix) was recorded in the treatment T_8 (control). Foliar application of GA3 increased TSS similar results were reported by Ingle *et al.* (2001) [11] in acid lime.

Table 3: Effect of PGR's, Cycocel on chemical quality contributing parameters of acid lime cv. Sai Sharbati

Treatment no.	Treatment details	Juice (%)	TSS (^{0}Brix)	Acidity (%)	Reducing Sugar (%)	Non-reducing Sugar (%)	Total Sugar (%)
T_1	GA_3 50ppm	49.56	6.99	5.96	0.77	0.79	1.61
T_2	Cycocel 1000ppm	45.20	7.49	6.30	0.55	0.59	1.26
T_3	KNO_3 1%	48.23	7.60	6.15	0.58	0.65	1.29
T_4	GA_3 50ppm + KNO_3 1%	53.56	7.90	5.90	0.79	0.86	1.54
T_5	Cycocel 1000ppm + KNO_3 1%	51.23	7.99	6.09	0.59	0.70	1.39
T_6	GA_3 100ppm + KNO_3 2%	58.90	8.20	5.40	0.88	0.90	1.80
T_7	Cycocel 1500 ppm+ KNO_3 2%	52.10	8.10	6.10	0.68	0.75	1.43
T_8	Control	32.20	5.68	6.56	0.50	0.35	0.94
	S.E±	0.78	0.11	0.10	0.12	0.15	0.12
	CD at 5%	2.39	0.36	0.32	NS	NS	0.37

Acidity (%)

The data regarding to Acidity (%) is presented in 3 The significantly minimum acidity (5.40%) was observed in treatment T6 (GA3 @ 100 ppm and KNO3 @ 2%), followed by T4 (5.90) and T1 (5.96). Maximum Acidity (6.56%) was recorded in the treatment T8 (Control). Whereas, foliar application of KNO3 increased acidity similar results were reported by Singh *et al.* (2005) [27] reported higher acidity content on mango cv. Dashehari

Reducing sugar (%)

From the data Table 3 it is evident that, there was non-significant difference regarding reducing sugar (%). The maximum reducing Sugar (0.88%) was recorded in the treatment T6 (GA3 @ 100 ppm + KNO3 @ 2%). Whereas, the minimum reducing sugar (0.50%) was recorded in the treatment T8 (control). Foliar application of GA3 increased reducing sugar similar results were reported by Sharma *et al.* (1973) [25] in grape.

Non-reducing sugar (%): From the data Table 3 it is evident that, there was non-significant difference regarding reducing sugar (%). The maximum reducing sugar (0.90%) was recorded in the treatment T6 (GA3 @ 100 ppm + KNO3 @ 2%). Whereas, the minimum reducing sugar (0.35%) was recorded in the treatment T8 (control). Foliar application of GA3 increased non-reducing sugar similar results were reported by Rai and Patil (2020) [20].

Total Sugar (%)

The data on total sugar (%) is presented in Table 3 it is evident that, there was significant difference regarding total sugar (%). The maximum total sugar (1.80%) was recorded in the treatment T6 (GA3 @ 100 ppm + KNO3 @ 2%) was at par with T1 (1.61%), T4 (1.54%) and T7 (1.43%). Whereas, the minimum total sugar (0.94%) was recorded in the treatment T8 (control). Foliar application of GA3 increased total reducing sugar similar results were reported by Hari Om *et al.* (1975) [10] in apple.

Conclusions

From the investigation's findings, the following can be concluded GA3, Cycocel, and KNO3 are key factors in the enhancement of acid lime cv. Sai Sharbati's growth, yield, and fruit quality. GA3 was successful in increasing vegetative growth, which decreased the generative shoot and boosted the development of the vegetative shoot. Application of GA3 @ 100 ppm + KNO3 @ 2% was found to be more effective for enhancing acid lime growth, yield, and fruit quality.

Acknowledgements

We acknowledge Sweet Orange Research Station Badnapur affiliated under Vasantrao Naik Marathwada Krishi Vidyapeeth Parbhani, (Maharashtra) India.

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