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Studies on combined influence of pruning and exogenous application of growth regulators on vegetative growth and flowering of sweet orange (*Citrus sinensis* Swingle.) cv. Sathgudi

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Abstract
A field investigation entitled "Studies on combined influence of pruning and exogenous application of growth regulators on flowering and fruiting behaviour of Sweet Orange (*Citrus sinensis* Swingle.) cv. Sathgudi" was conducted at Fruit science block, sweet orange orchard, College of Horticulture, Anantharajupeta, Dr. Y.S.R.H.U. during the year of 2018-19. The experiment was laid out in factorial randomized block design with twelve treatments with single control and replicated thrice. A single tree was taken as treatment unit. Vegetative growth and flowering behaviors of the treated trees were studied to evaluate the combined influence of pruning and growth regulators. Among the different interaction treatments tested, to initiate flowering, in sweet orange (*Citrus sinensis* Swingle) cv. Sathgudi, Maximum shoot length was recorded in T_4 (P1C4- Pruning 10 cm + GA_3 @ 100 ppm) whereasT_2 (P_1C_2 – Pruning 10 cm + NAA @ 100 ppm) recorded less number of days taken for flowering, more number of flowers per shoot, maximum flowering percentage and highest flower retention percentage.

Keywords: Pruning, growth regulators, sweet orange

Introduction
The sweet orange (*Citrus sinensis* Swingle.) occupies the first position among all the commercial citrus species grown in the world. It prefers dry, sub-tropical climate for good growth yield and for producing quality fruits. It produces a well-spread canopy with well-developed leaders, laterals and sub-laterals. Sweet orange plants are generally planted at a spacing of 5 x 5 meters, and economical orchard life varies from 15 to 25 years depending upon the rootstock used, management practices followed and the prevailing agro-climatic conditions in a particular area. It is observed that on attaining the age of seven to eight years, the canopy of the sweet orange plant becomes dense and overcrowded, besides, excessive growth of the leaders and laterals may result in shade which may result in reduced pollination and decreases in yield.

Singh *et al*. (2004) [24] observed that citrus trees which were begun to decline invigour, yield and size of fruit, need pruning to help the restore their condition. Pruning is done to restrict excessive vegetative growth and to maintain a balance between leaf/fruit ratio, fruit size, fruit colour and other quality attributes. Flowering in sweet orange is recurrent under tropical and sub-tropical conditions unless synchronized into well-defined period of extreme stress. Since the demand for the fruit remains very high during summer it is very essential to regulate flowering that gives fruiting in the months of April and May which fetches higher returns to the grower compared to the income receive during other seasons. There is difficulty in fruit set because of incomplete pollination, hence plant growth regulators may be effectively used to increase fruit set.

Hasta-bahar (September - October) management through the use of plant growth regulators and chemicals play an important role to get maximum fruit yields during summer (Lakshmi *et al.* 2014) [11]. Hence there is a need to test the plant growth through the use of plant growth regulators and chemicals for their role inducing flowering for the *Hasta bahar* crop.

Material and Methods

The experiment was carried out to find out the combined influence of pruningand growth regulators at sweet orange orchard, College of Horticulture, Anantharajupeta, YSR Kadapa Dist., which was located in southern agro-climatic zone of Andhra Pradesh at an elevation of 184 m (606 feet) above mean sea level between 13^0 99'North latitude and 79^0 33' East longitudes. The experiment was laid out in Factorial Randomized Block Design with single control with three replications and one tree per replication. Two factors were taken, the first factor is pruning and the second one is growth regulators. Pruning was done in two levels i.e. 10 cm pruning from the terminal portion of the shoot and 15 cm pruning from the terminal portion of the shoot done in each tree under each replication. The growth regulators were applied @ two concentrations each growth regulator i.e. NAA @ 50 ppm and 100 ppm, GA_3 @50 ppm and 100 ppm, KNO_3 @ 2% and 3%. Combination of pruning and growth regulators having 12 treatments and one control were taken. They are as follows. T_1 - Pruning 10 cm + NAA @ 50 ppm, T_2- Pruning 10 cm + NAA @ 100 ppm, T_3- Pruning 10 cm + GA_3 @ 50 ppm, T_4- Pruning 10 cm + GA_3 @ 100 ppm, T_5- Pruning 10 cm + 2% KNO_3, T_6 - Pruning 10 cm + 3% KNO_3, T_7- Pruning 15 cm + NAA @ 50 ppm, T_8- Pruning 15 cm + NAA @ 100 ppm, T_9- Pruning 15 cm + GA_3 @ 50 ppm, T_{10}- Pruning 15 cm + GA_3 @ 100 ppm, T_{11}- Pruning 15 cm + 2% KNO_3, T_{12} - Pruning 15 cm + 3% KNO_3, T_{13}- Control. Pruning of the trees was done in the orchard by following two levels. They were Pruning (Heading back) was done in the second week of September. Spraying of plant growth regulators is done during the October, at fortnightly intervals.

Results and Discussion

The data obtained from the present study was subjected to statistical analysis and the results obtained on various aspects of the investigation are presented under the following sub heads with appropriate discussion.

Morpho-metric observations

Shoot length (cm)

The effect of different treatments on shoot length was measured and presented in Table 1 which revealed that the effect of pruning, growth regulators and their combinations significantly increased shoot length.

With regard to the effect of pruning, the highest shoot length (18.22 cm) was noticed under pruning treatment P_2 (Pruning 15 cm), which was showed superiority over other pruning treatments (17.72 cm) in P_1 (Pruning 10 cm). The highest shoot length (20.50 cm) was observed under treatment C_3 (GA_3 @ 50 ppm) which was best as compared to control and all other treatments whereas, lowest (16.17 cm) was observed under C_5 (2% KNO_3).

In the combined effect of pruning and growth regulators, the maximum shoot length (25.67 cm) was measured under treatment combination T_4 (Pruning 10 cm + GA_3 @ 100 ppm), since it was found to be significantly high among all other treatments, followed by T_9 (21.33 cm), T_2 (20.00 cm), T_3 (19.67 cm) and minimum (11.33 cm) was recorded under T_{13} (Control) is on par with T_1 (13.33 cm).

Maximum shoot length might be attributed to the reserve food material in the main scaffolds or branches due to which new growth was put forth just after the heading back. Increase in shoot length was observed with increase in pruning level. The increase in shoot length may be due to the effect of gibberellic acid as promotes the cell elongation in plants. Similar results were reported by Saini *et al.* (2016) [23] in guava hybrid Hissar Safeda, Lakra *et al.* (2018) [10] in phalsa, Mohammed *et al.* (2006) [15] in guava and Mosa *et al.* (2015) [16] in pear cv. Le Conte.

Number of shoots per tree

Observations onthe number of shoots per tree was recorded and presented in Table 1. Data revealed that the effect of pruning and exogenous application of growth regulators was not showed significant effect on number of shoots per tree.

The increased number of shoots per tree (25.89) was observed under pruning treatment P_2 (Pruning 15 cm) whereas the minimum (25.21) was recorded under pruning treatment P_1 (Pruning 10 cm). The maximum number of shoots per tree (33.17) was noticed under growth regulators treatment C_4 (GA_3 @ 100 ppm) whereas the minimum (19.33) was observed under growth regulators treatment C_6 (3% KNO_3).

The interaction effect of pruning and growth regulators has not showed significant effect on number of shoots per tree. The maximum number of shoots per tree (31.57) was recorded under treatment T_{10} (Pruning 15 cm + GA_3 @ 100 ppm) whereas the minimum (24.33) was noticed under treatment T_5 (Pruning 10 cm + 2% KNO_3).

Similarly number of shoots developed after head back was also increased with the intensity of pruning. In unheaded treatments only terminal shoot was developed and large number of spurs was formed and vegetative growth was greatly checked. The results are in line with the findings of Dhaliwal *et al.* (2014) [3] in mandarin cv. Kinnow, Lakra *et al.* (2018) [10] in phalsa and Kumar and Thakur (2012) [9] in plum cv. Santarosa.

Table 1: Shoot length (cm), number of shoots per tree and number of days taken for flowering as influenced by pruning and exogenous application of plant growth regulators in sweet orange cv. Sathgudi

Pruning	Shoot length (cm)	Number of shoots per tree	Number of days taken for flowering
P_1- Pruning 10 cm	17.72	25.21	38.28
P_2- Pruning 15 cm	18.22	25.89	38.56
SE m(±)	0.90	0.27	0.71
CD @ 0.05	NS	NS	NS
Growth regulators			
C_1- NAA @ 50 ppm	16.33	23.33	37.17
C_2- NAA @ 100 ppm	18.50	24.33	33.50
C_3- GA_3 @ 50 ppm	20.50	30.83	37.67
C_4- GA_3 @ 100 ppm	20.00	33.17	42.67
C_5- 2% KNO_3	16.17	21.83	34.83
C_6- 3% KNO_3	16.33	19.33	44.67
SE m(±)	0.52	0.16	0.41
CD @ 0.05	NS	0.46	1.20
Interaction			

T_1 (P_1C_1) - Pruning 10 cm + NAA @ 50 ppm	13.33	27.00	36.00
T_2 (P_1C_2) - Pruning 10 cm + NAA @ 100 ppm	20.00	26.33	32.00
T_3 (P_1C_3) - Pruning 10 cm + GA_3 @ 50 ppm	19.67	30.00	35.68
T_4 (P_1C_4) - Pruning 10 cm + GA_3 @ 100 ppm	25.67	31.00	38.67
T_5 (P_1C_5) - Pruning 10 cm + 2% KNO_3	16.00	24.33	35.12
T_6 (P_1C_6) - Pruning 10 cm + 3% KNO_3	15.33	28.66	55.33
T_7 (P_2C_1) - Pruning 15 cm + NAA @ 50 ppm	19.33	27.66	38.33
T_8 (P_2C_2) - Pruning 15 cm + NAA @ 100 ppm	17.00	27.33	35.82
T_9 (P_2C_3) - Pruning 15 cm + GA_3 @ 50 ppm	21.33	30.66	40.67
T_{10} (P_2C_4) - Pruning 15 cm + GA_3 @ 100 ppm	18.00	31.57	46.67
T_{11} (P_2C_5) - Pruning 15 cm + 2% KNO_3	16.33	29.33	36.67
T_{12} (P_2C_6) -Pruning 15 cm + 3% KNO_3	17.33	28.00	35.37
T_{13} (P_0C_0) –Control	11.33	28.66	62.33
SE m(±)	1.28	0.38	1.01
CD @ 0.05	3.73	NS	2.94

* NS = Non significant

Flowering and yield observations

Number of days taken for flowering

The effect of different treatments on number of days taken for floweringis presented in Table 1 which revealed that the effect of pruning, growth regulators and their combinations significantly decreased number of days taken for flowering.

The effect of pruning on the minimum number of days taken for flowering (38.28) was recorded under pruning treatment P_1 (Pruning 10 cm), which was showed significant superiority over pruning treatment (38.56) in P_2 (Pruning 15 cm). The minimum number of days taken for flowering (33.50) was observed under treatment C_2 (NAA @ 100 ppm) which was significantly superior as whereas, maximum (44.67) number of days taken for floweringwas noticed under C_6 (3% KNO_3).

The combined effect of pruning and growth regulators on the minimum number of days taken for flowering (32.00) was noticed under treatment combination T_2 (Pruning 10 cm + NAA @ 100 ppm) showed significant effect among other treatments, followed by T_5 (35.12), T_{12} (35.37) and T_3 (35.68) while, maximum number of days taken for flowering (62.33) was recorded under T_{13} (Control) was followed by T_6 (55.33).

The decreased number of days taken for flowering may be due to the juvenility was considered to be more at the base of a tree or branch and gets gradually reduced in acropetal manner towards the distal end as per Leopold & Kriedmann, 1982. NAA promotes the formation and translocation of flowering stimuli as hormones from the leaf to the axils of the leaves and thus produces early flowering compared with other treatments. Similar findings were reported by Dahapute *et al.* (2018) [2] in custard apple, Adhikari *et al.* (2015) [1] in guava, Lakra *et al.* (2018) [10] in phalsa, Somwanshi *et al.* (2017) [24] in sweet orange, Pawar *et al.* (1994) [19] in pomegranate and Hazarika *et al.* (2016) [4] in papaya cv. Red Lady, Leopold and Kriedmann (1982).

Number of flowers per shoot

The effect of different treatments on number of flowers per shoot was presented in Table 2 which revealed that the effect of pruning, growth regulators and their combinations significantly increased number of flowers per shoot**.**

As regards the effect of pruning, the maximum number of flowers per shoot (34.33) was computed under pruning treatment P_2 (Pruning 15 cm), which has shown superiority over pruning treatment (33.89) in P_1 (Pruning 10 cm). The maximum number of flowers per shoot (40.50) was observed under treatment C_2 (NAA @ 100 ppm) which was significantly superior as compared to control and all other treatments whereas, minimum (26.00) was noticed under C_6 (3% KNO_3).

The interaction effect of pruning and growth regulators on the maximum number of flowers per shoot (48.33) was noticed under treatment T_2 (Pruning 10 cm + NAA @ 100 ppm) had significant effect, followed by T_{11} (40.00), T_9 (37.33) and T_7 (37.00) while, minimum (21.53) was observed under T_{13} (Control) followed by T_{12} (24.33).

The increase in number of flowers per shoot might be due to the effect of NAA in accelerating the differentiation of inflorescence and rapid elongation of peduncle, leading to full development of flower buds having functional reproductive parts. It seems to have helped to increase the fruit set either by improving pollen germination or by helping the growth of pollen tubes and thus facilitate in timely fertilization before the stigma loses its receptivity or the style becomes non-functional. The results are in approval to the same extent with Dahapute *et al.* (2018) [2] in custard apple, Mohamed *et al.* (2010) [14] in custard apple, Lamo *et al.* (2017) [12] in phalsa cv. Purple round and Sahu *et al.* (2018) [21] in sapota cv. Cricket ball, Parouissi *et al.*, 2002 [17].

Flowering (%)

The flowering percentage was recorded and presented in Table 2. Data revealed that the effect of pruning and exogenous application of growth regulators was not showed any significant effect on flowering percentage.

The increased flowering percentage (72.16%) was observed under pruning treatment P_1 (Pruning 10 cm) whereas the decreased flowering percentage (71.87%) was recorded under pruning treatment P_2 (Pruning 15 cm). The maximum flowering percentage (74.51%) was noticed under growth regulators treatment C_1 (NAA @ 50 ppm) whereas the minimum (68.79%) was observed under growth regulators treatment C_4 (GA_3 @ 100 ppm).

The combined effect of pruning and growth regulators on the maximum flowering percentage (76.88%) was recorded under treatment T_2 (Pruning 10 cm + NAA @ 100 ppm) whereas the minimum (64.14%) was observed under treatment T_{13} (Control).

The increase in flowering intensity with pinching as compared to the unpinched trees indicates that pinching resulted in production of new growing points on the pinched trees. More flowering percentage expressing panicle emergence may be attributed to suppression of vegetative growth which resulted into the fast maturation of twigs and stress due to application of potassium that led to more accumulation of photosynthates in twigs and leaves. Similar results were reported by Saini *et al.* (2018) in guava hybrid Hisar Safeda, Kumar *et al.* (2017) [8] in litchi cv. Shahi, Krishna *et al.* (2016) [7] in mango cv. Banganpalli, Mohammed *et al.* (2006) [15] in guava and

Patoliya *et al.* (2017) [18] in mango cv. Dashehari. However, these results of present study were in contradiction with the earlier findings of Jadhav *et al.* (2002) [5].

Percentage of flower retention (%)

The effect of different treatments on percentage of flower retention was presented in Table 2 has revealed that the effect of pruning, growth regulators and their combinations significantly increased percentage of flower retention.

The effect of pruning on the maximum percentage of flower retention (79.94%) was recorded under pruning treatment P_1 (Pruning 10 cm), which was showed significant superiority over pruning treatment (75.21%) in P_2 (Pruning 15 cm). The maximum percentage of flower retention (83.99%) was noticed under treatment C_2 (NAA @ 100 ppm), was significantly superior as compared to control and all other treatments whereas, minimum (69.81%) was observed under C_4 (GA_3 @ 100 ppm).

Table 2: Number of flowers per shoot, flowering percentage and percentage of flower retention as influenced by pruning and exogenous application of plant growth regulators in sweet orange cv. Sathgudi

Pruning	Number of flowers per shoot	Flowering (%)	Flower retention (%)
P_1- Pruning 10 cm	33.89	72.16	79.94
P_2- Pruning 15 cm	34.33	71.87	75.21
SE m(±)	0.91	0.16	0.11
CD @ 0.05	NS	NS	0.33
Growth regulators			
C_1- NAA @ 50 ppm	31.33	74.51	78.52
C_2- NAA @ 100 ppm	40.50	74.28	83.99
C_3- GA_3 @ 50 ppm	36.17	71.85	80.64
C_4- GA_3 @ 100 ppm	33.83	68.79	69.81
C_5- 2% KNO_3	36.83	72.50	80.04
C_6- 3% KNO_3	26.00	70.16	72.44
SE m(±)	0.52	0.09	0.06
CD @ 0.05	1.53	NS	0.19
Interaction			
T_1 (P_1C_1) - Pruning 10 cm + NAA @ 50 ppm	25.67	76.32	75.58
T_2 (P_1C_2) - Pruning 10 cm + NAA @ 100 ppm	48.33	76.88	88.09
T_3 (P_1C_3) - Pruning 10 cm + GA_3 @ 50 ppm	35.00	72.81	85.06
T_4 (P_1C_4) - Pruning 10 cm + GA_3 @ 100 ppm	33.00	69.38	78.20
T_5 (P_1C_5) - Pruning 10 cm + 2% KNO_3	33.67	72.53	77.22
T_6 (P_1C_6) - Pruning 10 cm + 3% KNO_3	27.67	66.15	75.48
T_7 (P_2C_1) - Pruning 15 cm + NAA @ 50 ppm	37.00	73.81	81.46
T_8 (P_2C_2) - Pruning 15 cm + NAA @ 100 ppm	32.67	71.69	79.89
T_9 (P_2C_3) - Pruning 15 cm + GA_3 @ 50 ppm	37.33	70.88	76.22
T_{10} (P_2C_4) - Pruning 15 cm + GA_3 @ 100 ppm	34.67	68.19	61.41
T_{11} (P_2C_5) - Pruning 15 cm + 2% KNO_3	40.00	72.47	82.86
T_{12} (P_2C_6) -Pruning 15 cm + 3% KNO_3	24.33	74.17	69.40
T_{13} (P_0C_0) –Control	21.53	64.14	50.27
SE m(±)	1.28	0.22	0.16
CD @ 0.05	3.74	NS	0.46

* NS = Non significant

The interaction effect of pruning and growth regulators on the maximum percentage of flower retention (88.09%) was noted under treatment combination T_2 (Pruning 10 cm + NAA @ 100 ppm) found significantly high among all other treatments, followed by T_3 (85.06%), T_{11} (82.86%) and T_7 (81.46%) while, minimum (50.27%) was recorded under T_{13} (Control) followed by T_{10} (61.41%).

The plant growth regulators play a paramount role in citrus biology and effect several processes connected with flowering, fruit setting and fruit development. The results are in accordance with the findings of Thirugnanavel *et al.*, (2007) [25], Khan *et al.* (2014) [6] in sweet orange cv. Blood red and Ranganna *et al.* (2017) [20] in acid lime cv. Balaji.

Conclusion

From the investigation it is clear that pruning and exogenous application of growth regulators are responsible for manipulating the vegetative growth and flowering behavior in sweet orange. The vegetative parameters like shoot length and number of shoots per tree had some influence by the application of these treatments. Shoot length was maximum (25.67 cm) at flowering in the treatment T_4 (Pruning 10 cm + GA_3 @ 100 ppm), found to be significantly higher among all other treatments, followed by T_9 (21.33 cm), T_2 (20.00 cm).More number of shoots per tree (31.57) was recorded under T_{10} (Pruning 15 cm + GA_3 @ 100 ppm). With regard to the flowering observations revealed that the minimum number of days taken for flowering (32.00) was noticed under treatment combination T_2 (Pruning 10 cm + NAA @ 100 ppm) which was significant effect among other treatments, followed by T_5 (35.12), T_{12} (35.37). More number of flowers per shoot (48.33) was recorded with the T_2 (Pruning 10 cm + NAA @ 100 ppm) had significant effect, followed by T_{11} (40.00), T_9 (37.33). Under treatment T_2 (Pruning 10 cm + NAA @ 100 ppm) the highest flowering percentage (76.88%) was recorded. The interaction effect of pruning and growth regulators on the maximum percentage of flower retention (88.09%) was noted under treatment combination T_2 (Pruning 10 cm + NAA @ 100 ppm) found significantly high among all other treatments, followed by T_3 (85.06%), T_{11} (82.86%).

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