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Effect of Foliar Application of Growth Regulators and Nutrients on Fruit Retention and Yield of acid Lime (*Citrus aurantifolia* Swingle)

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ABSTRACT: Plant growth regulators and nutrients are common in yield, production and quality attributes. In this experiments applying some novel plant growth regulators like, Jasmonic acid (JA) and brassino steroides (BR) are hormones involved in the regulation of many processes in plants and act (when applied as a pre-harvest treatment) to increase fruit bioactive compounds with yield potential. However, there is less literature available regarding the effect of pre-harvest treatment on citrus fruit yield attributes and production, which was the aim of the present study. The detailed knowledge of this novel plant growth regulator (brassino steroids/jasmonic acid) has become extremely important for various researchers, stakeholders and commercial growers. A field study was carried out on the effects of foliar application of growth regulators and nutrients on fruit retention and yield of acid lime (*Citrus aurantifolia* Swingle) on seven years old acid lime trees cv. Phule Sharbati with thirteen treatments involving combinations of Jasmonic Acid (JA) at 1, 2 and 3 ppm, brassinosteroids (BR) at 5, 10 and 15 ppm, GA_3 and 2,4 -D each at 15 ppm and urea, KNO_3 and KH_2PO_4 each at 1% along with untreated control in a randomized block design subjected to three replications sprayed at three consecutive months at monthly interval after anthesis in *Ambia bahar* (spring flowering crop). Results indicated that jasmonic acid at 3 ppm showed better performance in fruit set (20.98%), fruits per plants (1234), yield (62.02 kg/plant), fruit breadth (31.36 mm), fruit juice contents (46.16%), fruit volume (52.65 cc) was significant over untreated control. The treatment GA_3 15 ppm + urea 1% showed notable influence on fruit length (35.20 mm), the maximum number of seeds fruits^{-1} (11.15). The combined application of 2, 4-D 15 ppm + KNO_3 1% recorded maximum fruit retention (62.12 %), minimum fruit drop (37.88 %). However, three spray applications of BR 15 ppm at petal fall, fruit development and fruit maturation stages notably increased the fruit weight (52.36 g) over control (36.97 g). Overall results suggested that plant regulators in combination with nutrients could be a promising tool to increase fruit retention, decrease fruit drop, yield and production improve qualitative and quantitative attributes compare to non treated plants in experimental field.

Keywords: Foliar application, growth regulators, nutrients, fruit retention, yield and physical parameters of acid lime (*Citrus aurantifolia* Swingle)

INTRODUCTION

Acid lime (*Citrus aurantifolia* Swingle) belongs to the family Rutaceae. It originated in India and has a chromosome number of 2n=18. Citrus fruits are one of the most important fruits grown commercially in more than 50 countries of the world. The total area of citrus crop in the world is 9.37 million hectares and the total production 129.17 million tonnes. In India, common citrus fruits grown are mandarins, sweet oranges, limes and lemons comprising 45, 25, 15 and 10% area respectively. From ancient times, citrus fruit has been recognized as a natural source of providing nutrients and medicinal value. The area of acid lime and lemon is 1.26 million hectares and production 13.51 million tonnes and total area of sweet oranges is 4.46 million hectare and production 75.41 million tonnes (FAO, 2018).

Acid lime occupies about 259.17 thousand hectares (28.87%) of the total area under citrus in India is 897.75 thousand hectares and total production of 11040.22

thousand MT and productivity of 12.29 t/ha (NHB, 2018-19) in the country. The area under acid lime cultivation in Maharashtra alone is 29.16 thousand hectares, with a production of 263.01 thousand MT and productivity of 9.01 t/ha (NHB, 2018-19). The citrus fruits are well known for their refreshing fragrance, thirst-quenching ability, and a good source of vitamin C. Therefore, the present investigation was undertaken at ICAR-Central Citrus Research Institute (CCRI), Nagpur (Maharashtra) during 2019-2020.

The plant hormones (or phytohormones) are the naturally producing organic substances in the plant that are produced in minute quantity and regulates the growth and other physiological functions of a plant. The plant growth regulators, also called as biostimulators or bio inhibitors act inside the plant cell. They either stimulate or inhibit the enzymes and enzymatic system and thus regulate plant metabolism. Hence, such chemical substances have proven to be an important component of modern fruit production technology both for improving the quantity as well as quality of fruit crops (Jain and Dashora, 2011). It alters the parameters like vegetative growth, fruit set, fruit drop, yield attributing parameters (Hota *et al.*, 2017; Priyadarshi *et al.*, 2017). Many synthetic substances mimicking properties of plant hormones such as auxins, giberellins, cytokinins, abscisic acid, ethylene, brassinosteroides and jasmonic acid, CCC and maleichydrazide are being used as plant growth regulators for specific purposes in crop production.

Thirugnanavel *et al.*, (2007) studied the effect of plant growth regulators *viz*, GA_3 and cycocel, chemicals *viz*, KNO_3, thiourea and salicylic acid on flowering and fruiting in acid lime. The result revealed that the application of GA_3 50 ppm in June + cycocel 1000 ppm in September + KNO_3 2 % in October significantly enhanced number of flower shoots, fruit set, fruit retention no of fruits and yield. Modise *et al*., (2009) evaluated the effect of 2, 4-dichlorophenoxyacetic acid (2,4-D) on reducing the premature fruit drop. Different concentration levels of the 2,4-D @ 8, 16 and 20 mg/L were applied exogenously to mature fruit trees of sweet orange (*Citrus sinensis* L.). The results indicated that, 2, 4-D 16 and 20 mg/L were effective in controlling the fruit drop by enhanced fruit retention, as well as improving the quality of navel oranges under dry climatic conditions. Omima *et al*., (2014) reported that the effect of growth regulators like ascorbic acid, proline and jasmonic acid on olive. The jasmonic acid at 15 ppm and 25 ppm on olive tree significantly increased the fruit set, yield and quality traits. Thapliyal *et al.*, (2016) evaluated that the effect of plant growth regulators *viz.*, GA_3, BR (brasssinosteroid), GA_3 + BR and water as control on pear (*Pyrus pyrifolia* (Burm.) Nakai). The spray of GA_3 @ 50 ppm improved the length of fruit (6.98 cm), fruit breadth (6.81 cm), fruit weight (175.9 g) and fruit volume (171.16 cc). The increased fruit quality was observed either singly or in the combined application of GA_3 and Br (Brassinosrerids) Garcia-Pastor *et al.*, (2019) studied the effects of methyl jasmonate applied at different concentrations (1, 5 and 10 mmol L^{-1}) on pomegranate. The results revealed that the spraying of methyl jasmonate significantly increased the yield at concentrations of 1 and 5 mmol L.

MATERIALS AND METHODS

Treatments details: The treatments consisted of combinations of chemicals and plant growth regulators and the details are furnished below Table 1.

Table 1.

Treatment No.	Treatments
T_1	Jasmonic acid @ 1 ppm
T_2	Jasmonic acid @ 2 ppm
T_3	Jasmonic acid @ 3 ppm
T_4	Brassinosteroid @ 5 ppm
T_5	Brassinosteroid @ 10 ppm
T_6	Brassinosteroid@ 15 ppm
T_7	GA_3@15 ppm + Urea 1%
T_8	2,4 –D @15 ppm + Urea 1%
T_9	GA_3@15 ppm + KNO_3 1%
T_{10}	2,4 –D @15 ppm + KNO_3 1%
T_{11}	GA_3 @15 ppm + Monopotassium phosphate 1%
T_{12}	2,4 -D@ 15 ppm + Monopotassium phosphate 1%
T_{13}	Control

The experimental field was situated at the experimental farm of ICAR-Central Citrus Research Institute, Nagpur during 2019-2020. The planting material for the present study of the 78 plant acid lime variety Phule Sharbati (released varieties, MPKV, Rahuri MH, in 2008).

Measurements:

Number of flowers/meter shoot length: The total number of flowers (staminate and hermaphrodite) produced per meter length was recorded in five randomly selected shoots from each tree. The mean value was expressed in numbers per meter shoot length.

Number of fruits per meter shoot length: The total number of fruits produced per meter length was recorded in five randomly selected shoots from each tree at the time of harvest. The mean value was expressed in numbers per meter shoot length.

Fruit set percentage: The number of flowers born on each labelled shoots and number of fruits set on the same shoot was counted and the fruit set percentage was calculated as follows and expressed in percentage.

$$\text{Fruit set (\%)} = \frac{\text{No. of initial fruits/shoot}}{\text{No. of flowers/shoot}} \times 100$$

Number of fruit set: The fruit set count of north-south and east-west directions was taken out by tagging four of shoots in each direction of the whole plant.

Fruit drop percentage: The fruit drop of observational plants was measured in percentage by using flowers per shoot, fruit set and final fruit retention on the plant. Naturally, fallen fruits were collected, counted and estimated as fruit drop in percent.

Number of fruits per plant: The number of fruits harvested at each harvest was computed and the total was expressed as a number of fruits per tree.

Yield per plant: The yield of fruits harvested at each harvest was computed and the total was expressed in kg per tree.

Fruit yield: The total yield was calculated by multiplying the single tree yield and total number of plants per hectare and expressed as t ha^{-1}.

Physical parameters: Five mature fruits from all directions were randomly selected from each tree to record the physical parameters and the same fruits were used estimation of fruit quality characters.

Fruit length: The fruit length was recorded from stylar end to the blossom end of the fruit by using verniercalliper and the mean was calculated and expressed as millimetres (mm).

Fruit breadth: The fruit breadth was measured at the central portion of the fruit with the use of verniercalliper and the mean was calculated and expressed as millimetres (mm).

Fruit weight: The five selected fruits taken for recording the fruit size were weighing on an electronic balance and the average fruit weight was expressed in gram (g).

Juice content: The fruit juice was extracted by hand-operated squeezer and the juice percentage was measured from the juice weight and total weight of fruit and expressed as per cent (%).

Fruit volume: The fruit volume was measured by water displacement method and expressed as a cubic centimetre (cc).

Peel thickness: The peel thickness was measured using verniercalliper and expressed as millimetres (mm).

Number of seed per fruit: The seeds extracted from each fruit were counted and the mean was expressed in numbers per fruit.

Seed weight: The seed weight was recorded using an electronic balance, and the mean was calculated and expressed in milligram (mg)

The Statistical analysis was done as suggested by Panse and Sukhatme (1967).

The experiment was laid out Randomized Block Design (RBD) with three replication and thirteen treatments these are of Comprising spraying of T_1 Jasmonic acid @ 1 ppm, T_2 Jasmonic acid @ 2 ppm, T_3 Jasmonic acid @ 3 ppm, T_4 Brassinosteroid @ 5 ppm, T_5 Brassinosteroid @ 10 ppm, T_6 Brassinosteroid@ 15 ppm, T_7 GA_3@15 ppm + Urea 1%, T_8 2,4 –D @15 ppm + Urea 1%, T_9 GA_3@15 ppm + KNO_3 1%, T_{10} 2,4 –D @15 ppm + KNO_3 1%, T_{11} GA_3 @15 ppm + Monopotassium phosphate 1%, T_{12} 2,4 -D@ 15 ppm + Monopotassium phosphate 1% and T_{13} control. The plant growth regulator and nutrients sprayed at three times. First spraying of plant growth regulators and nutrients was carried at petal fall stage in the second week of February and second spraying 21 days after first spray separately in the first week of March and third last after second spray April first week, 2020.

RESULTS AND DISCUSSION

A. Effect of plant growth regulators and nutrients

Fruit set (%): The analysis of data on fruit set percentage revealed the significant variation ($P < 0.05$) as observed in treatments (20.98 %) was observed in treatment T_3-Jasmonic acid @ 3 ppm. These results are on similar (Parthier *et al.*, 1992). The jasmonic acid is considered as anendogenous growth substance identified in many plant species which influence a wide variety of physiological and developmental responses as a response to light, phytochrome and cryptochrome induce transduction signals to influence the jasmonate signaling pathway triggering developmental responses in plants (Kazan and Manners, 2011).

In perennial crops stresses negatively affect growth through stomatal closure, which in turn disrupt photosynthesis as well as water and hormonal movement within the plant, bringing on a hormonal imbalance which leads the slowing of plant growth. Jasmonic acid is usually involved in physiological and molecular responses often including activation of the antioxidant system (superoxide anion radical, peroxidase and NADPH-oxidase) as reported by Karpets *et al.,* (2014), accumulation of amino acids (isoleucine and methionine) and soluble sugars Wasternack *et al*., (2014) and regulation of the stomatal opening and closing (Acharya *et al.*, 2009). Omima *et al*., (2014), also observed that the foliar spray of jasmonic acid@15 ppm and 25 ppm Olive tree significantly increased fruit set, yield and quality traits.

Fruit drop (%): The observed data showed revealed that the application of growth-regulating hormones and nutrients significantly influenced the fruit drop foliar application of T_{10} -2,4 –D @ 15 ppm + KNO_3 1% recorded the lowest fruit drop (37.88 %) over control. However, treatments T_6 - Brassinosteroid @15ppm (43%), T_3 –Jasmonic acid @ 3 ppm (44.81%) and T_9 - GA_3@15 ppm + KNO_3 1% (46.08%) showed moderate fruit drop respectively. This may be because of the contribution of potassiumnitrate along with the growth regulator. The quality improvement in fruits may be due to the proper supply of nutrients and induction of growth hormones, which stimulates cell division, cell elongation, increase in weight of fruits, better translocation of water uptake and deposition of nutrients. These findings are in close conformity with the findings of Modise *et al*., (2009) who observed that the application of 2,4-D 16 and 20 mg/L was effective to control fruit drop by enhanced retention, as well as improving the quality of navel oranges under dry climatic conditions.

Number of fruits per plant: Significantly maximum number of fruits/plants was recorded by treatment T_3-Jasmonic acid@ 3 ppm (1234) followed by treatments T_7 – GA_3@15 ppm + Urea 1%, (1134) and T_6-Brassinosteroid@15 ppm, (1089). However, treatments T_4 - Bassinosteroid@ 5ppm and T_1 - Jasmonic acid @1ppmwere found on par with control (702).

The above findings of Garcia-Pastor *et al.,* (2019) also revealed significantly increased pomegranate crop yield with the application of MeJA at 1 and 5 mmol L^{-1}. Ali and Zayat (2019) recorded that the 4ml/L of jasmine oil is more effective on fruit set, significantly increased no. of fruit /plant and yield per plant in Washington Navel Orange. The obtained results regarding the effect of jasmonic acid on fruit set go line with the findings of Oliva *et al*., (1988); Fujisawa *et al.*, (1997).

Fruit weight (g): A perusal of data presented in Table 2 revealed that different growth regulating treatments significantly influenced the fruit weight. Treatment T_6 – Brassinosteroid @15 ppm (52.36 g) exhibited the maximum fruit weight followed by treatments T_3 - Jasmonic acid 3@ppm (50.26 g), T_5 – Brassinosteroid@ 10 ppm (49.91 g), T_4 – Bassinosteroid@ 5ppm (49.31 g), T_7- GA_3 @ 15 ppm + Urea 1%)(48.35 g), and the treatments T_9 – GA_3 @ 15 ppm + KNO_3 1) T_{10} – 2,4-D@ 15ppm + KNO_3 1%), T_2 - Jasmonic acid @ 2ppm, T_1 – Jasmonic acid @1ppm, T_{12} – 2,4-D @ 15ppm + Monopotassium phosphate 1%), T_8 – 2,4 –D 15 ppm + Urea 1% were found on par with control. The above results might be due to exogenious application brassinosteroid increased fruit weight in sweet cherries fruits Baghe *et al*., (2019).

Table 2: Effect of growth regulators on yield attributes of acid lime.

Treatments	Number of flowers /meter shoot length	Number of fruits/meter shoot length	Fruit set (%)	No. of fruit set in the north-south direction	No. of fruit set in the east-west direction	% fruit drop	No. of fruits per plant	Fruit weight (g)	Fruit yield per plant (kg)	Fruit yield (tonne/ha)	Fruit retention (%)
T_1 –Jasmonicacid @ 1 ppm	126.23	26.22	16.06	412	340	62.66	752	37.69	28.34	7.85	37.34
T_2 – Jasmonic acid @ 2 ppm	142.69	29.18	16.64	548	426	49.74	974	39.69	38.66	10.71	50.26
T_3 – Jasmonic acid @ 3 ppm	151.85	31.11	20.98	740	494	44.81	1234	50.26	62.02	17.18	55.19
T_4 – Brassinosteroid @ 5 ppm	147.69	22.10	13.53	412	309	56.88	721	49.31	35.55	9.85	43.12
T_5 – Brassinosteroid @10 ppm	164.36	29.56	14.81	485	429	50.08	914	49.91	45.62	12.64	49.92
T_6 – Brassinosteroid @15 ppm	152.29	26.12	16.59	617	472	43.10	1089	52.36	57.02	15.79	56.90
T_7 – GA_3@15 ppm + Urea 1%	137.21	24.15	18.83	522	612	47.01	1134	48.35	54.83	15.19	52.99
T_8 – 2,4 –D @15 ppm + Urea 1%	141.36	22.84	13.01	514	458	48.68	972	35.74	34.74	9.62	51.32
T_9 – GA_3@15 ppm + KNO_3 1%	136.84	26.42	11.36	601	411	46.08	1012	41.65	42.15	11.68	53.92
T_{10} -2,4 –D @15 ppm + KNO_3 1%	117.36	34.12	13.10	452	537	37.88	989	39.91	39.47	10.93	62.12
T_{11}– GA $_3$ @15 ppm + KH_2PO_4 1%	137.97	24.26	14.58	631	370	49.85	1001	42.36	42.40	11.75	50.15
T_{12} -2,4 –D @15 ppm + KH_2PO_4 1%	124.78	22.47	12.26	528	406	47.68	934	37.58	35.10	9.72	52.32
T_{13} – Control	142.36	22.54	11.41	413	289	60.65	702	36.97	25.95	7.19	39.35
SE ± (m)	-	-	1.01	-	-	3.20	63.30	2.83	2.87	0.79	3.26
CD at 5%	NS	NS	2.97	NS	NS	9.36	184.78	8.28	8.40	2.32	9.53

Further, Eid *et al.,* (2016) revealed that foliar application of Milagro (0.2% Brassinolide) increased fruit weight of avocado tree cv. Fuerte. Also, Bhat *et al*., (2011) observed that brassinosteroid 0.4 mg /L give the highest bunch and berry weight due to the increased assimilation efficiency of photosynthetic carbon, however, brassinosteroid stimulate greater Co_2 assimilation and increased cell division. BRs exogenous application in an aqueous solution considerably enhanced grape cluster weight and berry weight, (Champa *et al.,* 2015). BR might be involved in initial fruit development by stimulating cell division of strawberry fruits. It was also validated by down regulating the expression of BRs receptors Chai *et al.,* (2013).

Fruit yield per plant (kg): The observed yield per plant (kg) of acid lime was significantly influenced by the foliar application of different treatments as presented in Table 2. The data revealed that the fruit yield per plant was significantly influenced by the growth-regulating treatments. The treatment T_3-Jasmonic acid @ 3 ppm (62.02 kg) was found significant followed by treatmentsT_6-Brassinosteroid @15 ppm (57.02 kg) and T_7 – GA_3 @ 15 ppm + Urea 1% (84.83 kg) respectively, whereas treatment T_1 – Jasmonic acid@ 1 ppm (28.34 kg) was found on par with control T_{13} (25.95). Similar results were observed by Martinez-Espla *et al.*, (2014); Jagtap *et al.*, (2013).

Fruit yield (t ha^{-1}): The data regarding fruit yield (t ha^{-1}) was found statistically significant. It was evident that the application of plant growth regulating treatments significantly affected the yield of acid lime. The maximum yield (17.18 t ha^{-1}) was obtained in (foliar spray of T_3 Jasmonic acid @ 3 ppm in the months of February, March and April) followed by treatments T_6– Brassinosteroid @15 ppm (15.79 t ha^{-1}) and T_7– GA_3@ 15 ppm + Urea 1% (15.19t ha^{-1}) and minimum yield recorded in control (7.19 ha^{-1}). All remaining treatments showed a moderate increase in fruit yield t ha^{-1} over control.

The above findings are found in line with the findings of Garcia-Pastor *et al.*, (2019) revealed that the significantly increased pomegranate crop yield, application of MeJA at 1 and 5 mmol L^{-1}.

Fruit retention (%): A perusal data reveals that different treatments significantly influenced the fruit retention of acid lime. It was evident from the data that treatment T_{10}-2,4–D @ 15 ppm + KNO_3 1% showed maximum percentage of fruit retention (62.12 %). followed by treatments T_6-Brassinosteroid @15 ppm (56.90%), T_3-Jasmonic acid @ 3 ppm (55.19%), T_9– GA_3 @15 ppm + $KNO_3$1% (53.92%) and T_7 - GA_3 @15 ppm + Urea 1% (52.99%) respectively over control (37.34 %). However, the treatments T_1- Jasmonic acid @ 1 ppm (37.34) and T_4-Brassinosteroid @ 5 ppm (43.12) were found on par with control. The above findings are found in line with the result recorded by Patel *et al.*, (2013). Similarly, Thirugnanavel *et al.*, (2007) found that the application of KNO_3 2% significantly enhanced fruit retention and yield in acid lime.

Physical parameters: The results obtained in the present study showed that application of plant growth hormones and nutrients significantly enhanced and improved the physical characters of acid lime in terms of fruit length (mm), fruit breadth (mm), fruit volume (cc), peel thickness (mm), peel percentage, number of seeds fruit $^{-1}$, seed weight (g) as compared to control.

Fruit length (mm): The data regarding fruit length presented in Table 3 differed significantly over control. The maximum fruit length (35.20 mm) was found in T_7 - GA_3 15 ppm + Urea 1% and followed by treatment T_5 – Brassinosteroid @ 10 ppm, (35.18mm). All remaining treatments showed a moderate increase in fruit length over control.

Table 3: Effect of growth regulator on physical parameters of acid lime.

Treatments	Fruit length(mm)	Fruit breadth (mm)	Juice content (%)	Fruit volume (cc)	Peel thickness (mm)	Peel %	Number of seeds fruit $^{-1}$	Seed weight (g)
T_1 – Jasmonic acid @ 1 ppm	31.20	28.36	41.39	39.56	1.58	19.18	9.20	1.25
T_2 - Jasmonic acid @ 2 ppm	30.14	27.86	43.36	42.19	1.63	18.39	8.21	1.26
T_3 - Jasmonic acid @ 3 ppm	32.18	31.36	46.16	52.65	1.76	15.52	8.44	1.27
T_4 - Brassinosteroid @ 5 ppm	32.10	27.12	45.52	46.74	1.54	15.41	9.05	1.26
T_5 – Brassinosteroid@10 ppm	35.18	30.25	42.94	47.25	1.69	15.43	9.23	1.24
T_6 - Brassinosteroid @15 ppm	35	31.23	44.36	50.11	1.67	15.47	10.21	1.28
T_7 - GA_3@15 ppm + Urea 1%	35.20	30.23	45.95	49.47	1.68	15.51	11.15	1.32
T_8 - 2,4 –D@ 15 ppm + Urea 1%	33.84	29.18	42.87	36.31	1.58	19.03	8.45	1.24
T_9 - GA_3@15 ppm + KNO_3 1%	31.20	28.14	40.36	40.20	1.63	17.77	10.47	1.30
T_{10} -2,4 –D @15 ppm + KNO_3 1%	32.26	30.36	43.63	37.51	1.61	18.29	10.74	1.26
T_{11} - GA_3 @15 ppm + KH_2PO_4 1%	30.69	28.01	42.14	43.36	1.64	17.45	7.69	1.32
T_{12} -2,4 –D @15 ppm + KH_2PO_4 1%	33.41	29.37	44.36	37.89	1.59	17.80	10.66	1.28
T_{13} - Control	32.25	29.16	42.17	38.04	1.67	18.42	8.41	1.23
SE ± (m)	1.60	1.09	2.80	2.85	-	-	0.84	-
CD at 5%	4.96	3.18	8.18	8.32	NS	NS	1.73	NS

It is noticeable from the results presented in Table 3 that fruit length was maximum in treatment T_7 – GA_3 @15 ppm + Urea 1% (35.20 mm) as compared to control. Similar results were recorded by Bradford *et al.*, (2003); Bharti *et al.*, (2019) in acid lime. Jasmonic acid (JA) or its derivatives have been found to occur naturally in a wide range of higher plants and considered as elicitors or signaling agents involved in many physiological and biochemical processes Creelman and Mullet, (1997).

Fruit breadth (mm): A perusal of data regarding fruit breath (mm) of acid lime showed that the fruit breadth was significantly influenced by the application of different treatments as summarized in Table 3. The maximum fruit breath (31.36 mm) was found in treatment T_3-Jasmonic acid @ 3ppm followed by treatment T_6- Brassinosteroid @ 15 ppm (31.23mm) over control.

Among the treatments, maximum fruit breath (31.36 mm) was recorded in the application of T_3-Jasmonic acid @ 3ppm and followed by T_6- Brassinosteroid @ 15 ppm (31.23mm) compared to the control. Ali and Zayat (2019) in Washington Navel orange, Thapliyal *et al*., (2016) in pear and Laila and Hatem (2018) in Sugar apple also observed similar results.

Juice content (%): The significantly influenced by the foliar application of crop growth regulation treatments. The maximum juice content (46.16 %) was recorded in T_3 – Jasmonic acid @ 3 ppm and minimum (40.36 %) in T_9 - GA_3@15 ppm + KNO_3 1%.

The above findings are found in line with the findings of Mohammadreza Asghari *et al*., (2019).

Fruit volume (cc): The perusal of data regarding fruit volume (cc) presented in Table 3 was significantly influenced by the foliar application of crop growth regulation treatments. The maximum fruit volume (52.65 cc) was recorded in treatment T_3 – Jasmonic acid @ 3 ppm followed by treatments T_6 – Brassinosteroid @ 15 ppm (50.11 cc), T_7 - GA_3 15 ppm + Urea 1% (49.47 cc), T_5 – Brassinosteroid @ 10 ppm (47.25 cc) and T_4 – Brassinosteroid @ 5ppm(46.74 cc) respectively. However, all remaining treatments were found on par with control (38.04cc) and minimum fruit volume was recorded in T_8 – 2, 4 –D 15 ppm + Urea 1% (36.31 cc).

In line with this Martinez-Espla *et al.,* (2014), reported that fruit volume was significantly affected by MeJA treatments in BS plums with the concentration of 0.5 and 1 mM MeJA led to significantly ($P < 0.05$) higher fruit volume than in the control, the concentrations of 0.5 and 2.0 mM were also effective in significantly increasing the fruit volume at harvest time, the major increases in fruit volume were 8 and 18% in 0.5 and 2.0 mM treated plums for BS and RR, respectively. Yilmaz *et al.,* (2003) reported that foliar feed of Jasmonic acid (0.25, 0.50 and 1 mM) on strawberry, significantly increased berry size in the first two weeks of harvest, and increased total yield per plant.

Number of seeds fruit^{-1}: The number of seeds fruit^{-1} was significantly influenced by different crop regulation treatments. Maximum number of seeds/fruit was found in treatment T_7 – GA_3 @ 15 ppm + Urea 1% (11.15) followed by treatments T_{10} – 2, 4 –D @15 ppm + KNO_3 1% (10.74), T_{12}-GA_3 @15 ppm + KH_2PO_4 1% (10.66), T_9 – GA_3@15 ppm + KNO_3 1% (10.47), T_6 – Brassinosteroid @15 ppm (10.21) respectively. Further, the combination of growth regulation treatment T_7 – GA_3 @15 ppm + Urea 1% exhibited the highest (11.15) number of seeds fruit^{-1} over all the treatments. Bradford *et al.,* (2003) indicated that the regulation of LeSNF4 expression by GA_3 provides a potential link between hormonal and sugars -sensing pathways controlling seed development.

CONCLUSION

Foliar application of T_{10}- 2,4-D @ 15 ppm + KNO_3 1% notably reduced fruit drop and enhanced fruit retention which significantly contributed to final fruit retention and fruit yield.

The foliar spray of T_3-Jasmonicacid @ 3 ppm in February, March and April in acid lime enhanced yield attributing fruit characters such as fruit set%, number of fruits plant^{-1}, fruit breadth, fruit volume and titratable acidity, which ultimately increased yield plant^{-1}. The application of GA_3 @ 15 ppm + urea 1% increased the fruit length, number of seeds/fruit, TSS, ascorbic acid, total sugars, reducing sugars whereas T_6-Brassinosteroid @ 15 ppm recorded maximum fruit weight.

FUTURE SCOPE

Some plant growth regulators are novel generations (jasmonaic acid and brassinosteroides), we find during experiment work, they are very effective in kind of fruit set, yield, production and also quality attributes to compare of another Brassinosteroids play prominent roles in many developmental processes including the increase of cell elongation, pollen tube growth, flowering, senescence, abscission and maturation. The yield induced by brassinosteroids has been related to improvement the efficiency of photosynthesis process of the sprayed trees. Jasmonic acid is usually involved in physiological and molecular responses and regulation of the stomatal opening and closing. Ecomonic evalutions of each treatment the maximum results improves novel plant growth regulators as compare to another.

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