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Improving fruit size and quality of sweet orange (*Citrus sinensis*) cv. Pineapple through auxin sprays

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ABSTRACT

A field study was undertaken to investigate the effect of auxin sprays on fruit size and quality of sweet orange (*Citrus sinensis* L.) cv. Pineapple during the year 2015–16 at the experimental orchard of the University. Exogenous application of 2,4-D @ 20 ppm and NAA @ 50 ppm at the end of April and July increased the percentage of medium size fruits, average fruit weight, number of fruits per plant and fruit physical quality with respect to peel thickness and peel content. However, chemical quality in terms of TSS, acidity and ascorbic acid was not affected by any treatment and spray schedule. The foliar application of 2,4-D 20 ppm at the end of April and July gave highest additional income over control.

Key words: Auxin, Foliar spray, Fruit size, NAA, Sweet orange

Citrus (*Citrus sinensis* L.) fruits are rich source of dietary fiber and therefore, recognized as important components in human healthy life (Sanofer 2014). They are grown under varying agro-climatic regions of India except high hilly regions (Vijay *et al.* 2016). Citrus possesses a share of 12.5% in fruit production of the country with 1.08 million ha area under cultivation with 11.15 mt production and productivity of 10.3 t/ha (Saxena and Gandhi 2014). The cultivation of citrus crop is gaining momentum in north-western states of India like Punjab, Haryana and Rajasthan. Among the various production problems in citrus, variable fruit size is of very economical importance, not even in orchard but even on single plant, fruits of various size are produced which fetches very low price in the market. Fruit size and quality are affected by many factors including soil type, irrigation management, plant age, cultivar and weather variables as reported by Guardiola (1997). PGR play a significant role in growth and development of fruits (Klee and Giovannoni 2011, Seymour *et al.* 2013). Exogenous spray of auxin is effective in increasing size of citrus fruit (Amiri *et al*. 2012, Wheaton 1982). However results of growth regulator are not so consistent and vary with climatic conditions, from crop to crop, variety to variety, and location to location and with stage as well as dose of application**.** Exogenous auxins applied during cell division stage of fruit development reduce the number of fruits and increase the final fruit size by minimizing the competition for metabolites between fruitlets (Agusti *et al*. 1995). Synthetic auxins like 2,4-Dichlorophenoxy acetic acid and naphthalene acetic acid are commonly used to increase the final size of citrus fruit (Agusti *et al*. 1994). Keeping in view the above facts, the investigation was conducted with the objective to standardize the time and dose of auxin spray for improving fruit size and quality of sweet orange cv. pineapple under the semi-arid irrigated agroecosystem of Haryana , so that farmer may fetch better price by increasing the value of their produce.

MATERIALS AND METHODS

The present investigation was carried out at experimental orchard of Haryana Agricultural University, Hisar situated at 215.2 m amsl with coordinates of 29º 10′ N latitude and 75º 46′ E longitudes. Hisar has a typical semi-arid climate with hot and dry summer and extremely cold winter. The mean monthly maximum and minimum temperature show a wide range of fluctuations both in summer and winter. The maximum temperature goes to 45ºC during summer. In winters temperature is as low as 4°C and sometimes frost occurrs in the region. The total rainfall as well as its distribution in the region is subjected to large variations. About 80% the annual rainfall (about 450 mm) is received during rainy months. The rainfall is highly erratic with 20-30% annual and 30-50% seasonal variations.

Two sources of auxin, i.e. 2,4-D (10 ppm and 20 ppm) and NAA (25 ppm and 50 ppm) compared with control (water spray) were used as foliar spray with two spray

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schedule (S_1: at the end of April and July; S_2: at the end of May and July) during 2014-15 and 2015-16 on 10-year-old fruit trees of sweet orange cv. Pineapple. Spray solution of 2,4-D and NAA was prepared by dissolving in alcohol and spray was done in evening by completely wetting the sweet orange trees. All the treatments were replicated thrice taking one plant as single unit in randomized block design. Uniform cultural practices and plant protection measures were followed for these trees throughout the study period as per package of practices (Anonymous 2018).

At the time of harvesting grading of fruits was done on the basis of diameter and categorized as; large: (>7.5 cm); medium: (6.0-7.5 cm); small: (<6.0 cm) diameter and expressed in percent on number basis. Total number of fruits per tree was counted at the time of harvesting and expressed as number of fruits per plant. Total yield per plant was recorded at harvest by taking weight on weighing balance and has been expressed in kg tree. Five randomly selected fruits were peeled manually. The peel thickness was measured with the help of Digital Vernier's Calipers at the equator of fruit and the average value was calculated and expressed in millimeter (mm). The average fruit weight was calculated by dividing the total fruit weight by total number of fruits/tree/replication and expressed in g. The above selected fruits were used for analyzing the peel and juice content. Peel was weighed with electronic balance and percentage of peel was worked out on the basis of total weight of the fruit and weight of the peel. The percent peel content was calculated by using the formula. (Peel weight × 100/ Fruit weight)

The fruits were cut into equal halves and juice was extracted with simple juice extractor. The juice was weighed with electronic balance and percentage of juice was worked out on the basis of total weight of fruit and the weight of juice. The percent juice content was calculated by using the formula. (Juice weight × 100/ Fruit weight)

The total soluble solids (TSS) of five randomly selected fruits was determined at room temperature by using Hand Refractometer having a range of 0 to 32 ^{0}Brix, by placing a drop of juice and taking the readings. The Refractrometer was calibrated with distilled water with every use and the values were expressed in degree brix. The acidity and ascorbic acid was determined by the method described by AOAC (2000). The data for 2015 and 2016 was pooled and analyzed in factorial RBD for evaluating the different parameters.

RESULTS AND DISCUSSION

All the treatments were effective in increasing the percent of medium size grade fruits and decreasing the small size grade fruits over control (Table 1). Spray schedule showed positive effect on grading of fruits. Spray schedule S_1 was more effective in improving the fruit size over S_2. Maximum percentage of medium size fruits (68.18) was found with foliar spray of 2,4-D 20 ppm treatment (T_2) followed by NAA 50 ppm application (T_4). Minimum percentage of medium size fruits (53.14) was recorded in control (T_5) closely followed by T_1 *i.e.* 2,4-D 10 ppm treatment. Auxin sprays in the end of April and July (S_1) recorded higher percentage of medium sized fruits (63.09) as compared with auxin sprays in the end of May and July (S_2). Maximum percentage of medium sized fruits (72.97) were recorded with the interactive effect of 2,4-D 20 ppm sprayed in the end of April and July ($T_2 \times S_1$). Minimum percentage of small sized fruits (23.49) was observed with foliar spray of 2,4-D 20 ppm treatment (T_2) followed by NAA 50 ppm application (T_4), whereas maximum small sized fruits were obtained in control. Between spray schedules S_1, i.e. foliar spray in the end of April and July resulted in lower per cent of small sized fruits (28.48). The interaction effect was also found significant and minimum percentage of small sized fruits (18.48) was obtained with foliar spray 2,4-D @ 20 ppm in the end of April and July ($T_2 \times S_1$) closely followed by $T_4 \times S_1$. The increase in fruit size due to exogenous auxin sprays could be attributed to accelerate fruit growth and subsequently fruit size by increasing cell enlargement. Auxins are known to affect the permeability of the cell wall leading to uptake of water and expansion of cells resulting in cell elongation. The

Table 1 Effect of growth regulator on percent of different grade fruits in sweet orange (cv. Pineapple)

Treatment	Fruit diameter								
	Large (>7.5 cm)			Medium (6.0-7.5 cm)			Small (<6.0 cm)		
	Pooled			Pooled			Pooled		
	S1	S2	Mean	S1	S2	Mean	S1	S2	Mean
T1: 2,4-D @ 10ppm	7.97	8.25	8.11	52.71	53.69	53.20	39.01	37.81	38.41
T2: 2,4-D @ 20ppm	8.80	8.05	8.43	72.97	63.40	68.18	18.48	28.49	23.49
T3: NAA @ 25ppm	8.23	7.62	7.92	66.28	59.08	62.68	25.20	33.31	29.25
T4: NAA @ 50ppm	8.28	8.06	8.17	70.06	61.58	65.82	21.49	30.24	25.86
T5: Control	8.42	8.02	8.22	53.43	52.85	53.14	38.22	38.98	38.60
Mean	8.34	8.00		63.09	58.12		28.48	33.76	
CD (P=0.05)	Treatment (T)-NS, Spray (S)-NS, T×S- NS			Treatment (T)-5.34, Spray (S)-3.41, T×S- 8.74			Treatment (T)-5.67, Spray (S)-3.14, T×S- 8.82		

S1: Spray at the end of April and July; S2: Spray at the end of May and July.

Table 2 Effect of growth regulator on yield parameters of sweet orange (cv. Pineapple)

Treatment	Average fruit weight (g)			No. of fruits/plant			Yield (kg/plant)		
	Pooled			Pooled			Pooled		
	S1	S2	Mean	S1	S2	Mean	S1	S2	Mean
T1: 2,4-D @ 10ppm	130.18	135.03	132.61	470.17	453.67	461.92	62.49	60.50	61.50
T2: 2,4-D @ 20ppm	153.82	146.40	150.11	409.02	443.65	426.33	60.06	62.35	61.21
T3: NAA @ 25ppm	142.08	138.51	140.29	448.34	439.15	443.74	62.46	59.66	61.06
T4: NAA @ 50ppm	153.92	144.75	149.33	410.67	443.17	426.92	59.23	61.56	60.40
T5: Control	134.53	134.49	134.51	444.32	450.85	447.58	59.36	59.93	59.64
Mean	142.90	139.84		436.50	446.10		60.72	60.80	
CD (P=0.05)	Treatment (T)- 8.65, Spray (S)- 1.46, T×S- 8.13			Treatment (T)- 24.46, Spray (S)- NS, T×S- 39.20			Treatment (T)- NS, Spray (S)- NS, T×S- NS		

S1: Spray at the end of April and July; S2: Spray at the end of May and July.

effect of auxins on fruit development is based on greater cell expansion rather than cell division (Mir and Itoo 2017, El-Otmani *et al.* 1993).

This expansion is probably due to an increase in cell vacuolization that, in turn, increases vesicle size, locule dimensions and final fruit size (Agusti *et al.* 1992). Erner *et al.* (1992) reported increase in fruit size by 8-25% in Valencia orange with spraying of 2,4-D @ 20 ppm, 6-8 weeks after flowering. Fruits harvested from trees treated with auxin were significantly larger than that of the control trees reported by Agusti *et al*. (1995) Koch *et al*. (1996), Van-Rensburg *et al.* (1996) and in Clementine mandarin; Agusti *et al.* (1994) Amiri *et al.* (2012) and in Satsuma mandarin; Greenberg *et al.* (1996) Fang *et al.* (2008) in Murcott mandarin; and Yildirim *et al.* (2011) in Valencia orange; Garcia-Lidon *et al.* (1992) in Fino lemons; Gravina *et al*. (1997) in Ellendale tangor.

More pronounced effect of early spray of auxin (S_1) in increasing the percentage of medium sized fruits might be due to the fact that the fruit size was considerably smaller during April as compared with May spray during which the fruit had already attained 2/3rd of fruit size sustaining lower growth and development rate.

Among the different treatments, foliar application of 2,4-D @ 20 ppm (T_2) and NAA @ 50 ppm (T_4) were found significantly effective in increasing the average fruit weight over other treatments (Table 2). 2,4-D @ 20 ppm (T_2) recorded maximum fruit weight (150.11g) closely followed by T_4 (149.33g) and minimum (132.61g) in T_1. Treatment T_1, T_3 and T_5 were found at par with each other. Between spray schedules, S_1 (auxin sprays in the end of April and July) was found significantly effective in increasing fruit weight (142.90g) over S_2 (139.84g). Interaction of treatments and spray schedule was also found significant. Maximum fruit weight (153.92 g) was observed in treatment combination ($T_4 \times S_1$) followed by (153.82 g) in treatment combination ($T_2 \times S_1$) and minimum (130.18g) in treatment combination ($T_1 \times S_1$).

Improvement in fruit weight with exogenous application of auxins can be attributed to accelerated fruit growth and subsequently fruit size by increasing cell enlargement. The results were also in agreement with Saraswathi *et al.* (2003) who observed that growth regulators 2,4-D and GA_3 and their combinations significantly influenced the fruit weight of mandarins. Similarly, Nawaz *et al.* (2008) and Mir and Itoo (2017) in Kinnow mandarin; Greenberg *et al*. (1996) and Yildrim *et al.* (2011) in Valencia oranges; Duarte *et al.* (1996) in Esbal Clementine; Ronca *et al.* (1998) in Lisbon lemon reported maximum fruit weight with foliar application of auxin.

Irrespective of spray schedule, number of fruits per plant was affected significantly by different auxin sprays. The maximum number of fruits (461.92) was observed in T_1, i.e. 2,4-D @ 10 ppm and minimum number of fruits (426.33) was observed in T_2 *i.e* 2,4-D 20 ppm closely followed by T_4 *i.e.* NAA 50 ppm. Spray schedule was found nonsignificant with respect to number of fruits per plant when considered irrespective of auxin treatments. Number of fruits was significantly more in treatment T_1 over T_2 and T_4. Whereas, T_2, T_3, T_4 and T_5 were on par. The interaction effect of auxin treatments and spray schedule was also found significant in enhancing the number of fruits per plant. Maximum number of fruits per plant (470.17) was found with foliar application of 2,4-D @ 10 ppm in the end of April and July ($T_1 \times S_1$), whereas minimum number of fruits per plant (409.02) was obtained with 2,4-D 20 ppm application in the end of April and July. The increased number of fruits per plant by auxin application might be attributed to its role in reducing the pre-harvest fruit drop. The findings are in agreement with Modise *et al.* (2009) who observed foliar application of 2,4-D at 20 mg/l reduced the rate of fall in Navel oranges as compared to control. The present results are also in agreement with Davies and Zalman (2006), Kaur *et al*. (2016), Mollapur *et al*. (2016) who reported that application of 2,4-D and other plant growth regulators significantly reduced the pre harvest fruit drop in citrus species.

Yield was not affected significantly by any of the treatment and spray schedule. However, the maximum yield (61.50 kg/plant) was observed in T_1 and minimum (59.64 kg/

Table 3: Effect of growth regulator on fruit physical quality of sweet orange (cv. Pineapple)

Treatment	Peel thickness (mm)			Peel content (%)			Juice content (%)		
	Pooled			Pooled			Pooled		
	S1	S2	Mean	S1	S2	Mean	S1	S2	Mean
T1: 2,4-D @ 10ppm	4.41	4.38	4.39	26.14	26.20	26.17	36.28	36.79	36.53
T2: 2,4-D @ 20ppm	4.60	4.48	4.54	27.59	26.86	27.22	35.31	35.79	35.55
T3: NAA @ 25ppm	4.47	4.42	4.44	26.56	26.21	26.38	35.97	36.76	36.36
T4: NAA @ 50ppm	4.57	4.46	4.51	27.42	26.69	27.05	35.33	36.04	35.68
T5: Control	4.33	4.36	4.34	25.87	25.96	25.91	36.41	36.60	36.50
Mean	4.47	4.42		26.71	26.38		35.86	36.39	
CD (P=0.05)	Treatment (T)- 0.11, Spray (S)- NS, T×S- NS			Treatment (T)- 0.90, Spray (S)- NS, T×S- NS			Treatment (T)- NS, Spray (S)- NS, T×S- NS		

S_1: Spary at the end of April and July; S_2: Spray at the end of May and July.

Table 4 Effect of growth regulator on chemical quality of sweet orange (cv. Pineapple)

Treatment	TSS (°Brix)			Acidity (%)			Ascorbic acid (mg/100 ml juice)		
	Pooled			Pooled			Pooled		
	S1	S2	Mean	S1	S2	Mean	S1	S2	Mean
T1: 2,4-D @ 10ppm	8.64	8.42	8.53	1.05	0.96	1.00	53.26	53.27	53.26
T2: 2,4-D @ 20ppm	8.92	8.53	8.73	1.11	1.01	1.06	54.44	53.99	54.21
T3: NAA @ 25ppm	8.53	8.37	8.45	1.02	1.03	1.03	54.27	53.99	54.13
T4: NAA @ 50ppm	8.75	8.57	8.66	1.07	1.05	1.06	55.01	54.79	54.89
T5: Control	8.52	8.53	8.52	1.01	1.01	1.01	53.64	53.30	53.47
Mean	8.67	8.48		1.05	1.01		54.12	53.87	
CD (P=0.05)	Treatment (T)- NS, Spray (S)- NS, T×S- NS			Treatment (T)- NS, Spray (S)- NS, T×S- NS			Treatment (T)- NS, Spray (S)- NS, T×S- NS		

plant) in control. Fruit quality in respect of peel thickness, peel content was affected significantly by all the treatment. Maximum peel thickness (4.54) and peel content (27.22%) was observed in foliar application of 2,4-D 20 ppm (T_2) closely followed by T_4 Table 3. However, minimum peel thickness (4.34) and peel content (25.91%) were resulted in control (T_5) which was found at par with T_1. Juice content was found nonsignificant with respect to auxin treatment and spray schedule. The spray schedules did not affect the fruit quality parameters.

The peel thickness and peel content showed a slight increase with higher dose of auxin as evident from present study however; with lower doses the effect was not pronounced. The improved fruit quality by auxin application might be due to its role in delaying fruit maturity and providing a longer period to fruits to remain on tree during which they accumulate more food reserves and water within them (Mir and Itoo 2017). Lima and Davies (1984) reported that spray applications of 2,4-D, GA or their combination did not affect the peel and juice content of Washington Navel orange.

Fruit quality in terms of TSS, acidity and ascorbic acid was not affected significantly by any of the treatments and spray schedules Table 4. The results are in accordance with the findings of Stewart and Klotz (1947). They reported no effect of 2,4-D on TSS and acidity of oranges.

Highest additional income over control (₹ 47886.20) was recorded with foliar application of 2,4-D 20 ppm at the end of April and July, closely followed by foliar spray of NAA 50 ppm at the end of April and July (Table 5).

The present study infers that the foliar application of 2,4-D @ 20 ppm or NAA @ 50 ppm at the end of April and

Table 5 Effect of foliar application of different auxin treatment on economics of sweet orange cv. Pineapple

Treatment combination	Yield (t/ha)	Gross income (₹/ha)	Additional cost over control (₹/ha)	Additional income over control (₹/ha)
T_1S_1	17.18	240586.50	3240.9	7693.10
T_1S_2	16.64	237916.25	3240.9	5022.85
T_2S_1	16.52	280780.50	3241.8	47886.20
T_2S_2	17.15	265766.88	3241.8	32872.58
T_3S_1	17.18	274824.00	3285	41886.50
T_3S_2	16.41	254300.75	3285	21363.25
T_4S_1	16.29	276900.25	3330	43917.75
T_4S_2	16.93	262399.50	3330	29417.00
Control	16.40	229652.50		

July significantly improved the final fruit size, average fruit weight, peel thickness, peel content and juice content without affecting the yield and chemical quality and overall increased the value of Pineapple sweet orange crop by improving the fruit grades which fetch higher prices in market.

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