

Effects of growth regulator foliar spray on daisy mandarin (*Citrus reticulata*) fruit splitting, yield, and quality

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ABSTRACT

In order to investigate the impact of foliar growth regulator treatment on fruit splitting, yield, and quality of Daisy mandarin (*Citrus reticulata* Blanco), the experiment was carried out in 2021 and 2022 at the Fruit Research Station, Jallowal-Lesriwal, Jalandhar (Punjab Agricultural University), Punjab. At various phases of Daisy mandarin growth, various quantities of gibberellic acid (GA3) (10, 20, and 30 ppm), naphthalene acetic acid (NAA) (10, 20, and 30 ppm), ethephon (10, 20, and 30 ppm), and salicylic acid (SA) (100 and 200 ppm) were sprayed in addition to a control. The findings showed that foliar treatment of GA3 at 10 ppm produced the greatest fruit weight, number of fruits, and maximum fruit output, while salicylic acid at 100 ppm successfully reduced the severity of fruit splitting in Daisy mandarin over both seasons. When compared to untreated plants, the treatment of 10 ppm GA3 produced better outcomes for fruit quality parameters such as total soluble solids, ascorbic acid, juice, and flavonoid content. According to the findings, applying 10 ppm GA3 and 100 ppm salicylic was successful in improving fruit quality characteristics and lowering the frequency of fruit splitting in Daisy mandarin.

Keywords: salicylic acid, gibberellic acid, daisy, foliar spray, fruit cracking, and plant growth regulators

Mr. Dowling Young of Young's Nursery in California, USA, created the Daisy mandarin (*Citrus reticulata* Blanco), a mix between Fremont and Fortune mandarins. Given its early maturation and great fruit quality, it was deemed promising (Gill et al., 2017). It was brought to Punjab from the United States to diversify the Kinnow, a popular mandarin that accounts for more than half of the region's total fruit area. In 2021, Punjab produced 1.22 million tonnes of citrus on 50.19 thousand hectares of land (Anonymous 2021). Increasing the mandarin fruit's market time in Punjab from November to February was another important factor in its introduction (Dhillon et al. 2016). Fruit splitting is the main problem that daisy mandarin encounters during its development. A common pre-harvest physiological abnormality that affects a variety of fruit crops is fruit splitting, which lowers fruit crop productivity and quality. Mature fruit's appearance and shelf life are adversely affected when it splits or cracks because it loses water and becomes more vulnerable to infection by microorganisms (Yu et al. 2020). Citrus fruit quality and productivity are negatively impacted by fruit splitting, which happens at a rate of 10–35%.

Optimising growing circumstances, such as better cultural techniques, a sufficient water supply, and foliar growth regulator treatments, will greatly prevent fruit splitting. Salicylic acid (SA), gibberellic acid (GA3), and naphthalene acetic acid (NAA) are examples of plant growth regulators that function as signalling molecules that are essential for controlling development and boosting plant resistance to biotic and abiotic challenges. Growth regulators are crucial in determining the flexibility and peel resistance, which in turn determine the degree of cracking. According to Singh et al. (2006), systematic PGR spraying prior to rind splitting may help prevent cracking by affecting rind thickness. Growth regulators used topically not only reduced the frequency of fruit splitting but also significantly increased Daisy mandarin production and quality. This study's main goal was to evaluate how plant growth regulators affected the Daisy mandarin's ability to reduce fruit splitting, increase production, and enhance quality features.

METHODS AND MATERIALS

The current research was conducted in 2021 and 2022 at the Fruit Research Station, Jallowal-Lesriwal, Jalandhar (31° 29' 38" N, 75° 37' 40" E, and 228 m amsl) (Punjab Agricultural University), Punjab. The plot's soil type was described as sandy loamy. Eight-year-old Daisy mandarin plants that were budded on rough lemon

rootstock and spaced six by three meters apart were used for the experiment. The Punjab Agricultural University's package of procedures for fruit crops was closely followed in all agronomic activities, including irrigation, fertilisation, manuring, and plant protection measures. The following concentrations were included in the treatments: 10, 20, 30 ppm GA3; 10, 20, 30 ppm NAA; 10, 20, 30 ppm Ethephon; 100, 200 ppm SA; and control. At the phases of fruit set, 30 days after fruit set (DAFS), and 60 DAFS, GA3 and NAA were sprayed foliarly, while ethephon was also sprayed at 30 and 60 DAFS. At the beginning of fruit breaking, salicylic acid was applied.

Three replications of each treatment were used in the randomised block design (RBD) experiment. In both 2021 and 2022, the number of fruits on the tree was counted from 90 DAFS until the harvest (210 DAFS). Every month, the quantity of split fruits was counted. Fruit splitting was calculated by dividing the total number of fruits by the number of fruits that were split. An electronic weighing scale with an accuracy of 0.01/g was used to determine the average fruit weight of Daisy mandarin trees (EK6100I A&D, Japan). The average fruit weight was multiplied by the total number of fruits produced per plant to get the yield per plant, which was then represented in kilograms (kg).

A digital hand refractometer (ATAGO, PAL-1, Japan) with a range of 0–53 Brix was used to test the fruit juice's TSS. The AOAC's standard techniques were used to assess acidity, ascorbic acid, and juice content (2005). The amount of flavonoids in the fruit juice of Daisy mandarin trees was measured using the Folin-Ciocalteu reagent technique developed by Malik and Malik (1982). The SAS program from SAS Institute Inc. (version 93, USA) was used to analyse the data. The least significant difference approach was used as a post hoc analysis to examine the differences in treatment means.

OUTCOMES AND TALK

Fruit splitting severity (%): Fruit splitting severity of Daisy mandarin budded on rough lemon rootstock was shown to be significantly impacted by the administration of plant growth regulators. Compared to treated plants, untreated plants showed the highest rate of fruit splitting (13.25%) (Table 1). Among the different growth regulators, foliar application of SA at 100 ppm (3.14%) had the lowest frequency of fruit splitting, followed by SA at 200 ppm (3.41%) and GA3 at 10 ppm (4.87%).

Table 1 Effect of foliar application of growth regulators on fruit splitting severity of Daisy mandarin

Treatment	90 (DAFS)		120 (DAFS)		150 (DAFS)		180 (DAFS)		210 (DAFS)		Total fruit splitting (%)
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	
10 ppm GA3	1.79 ± 0.18b	2.11 ± 0.37bcd	1.14 ± 0.20cd	1.37 ± 0.32c	0.99 ± 0.15b	1.12 ± 0.16 b	0.39 ± 0.16 b	0.48 ± 0.19 bc	0.18 ± 0.07b	0.20 ± 0.08bc	4.87
20 ppm GA3	1.83 ± 0.26b	2.39 ± 0.13bcd	1.34 ± 0.17bc	1.53 ± 0.21bc	1.03 ± 0.17b	1.27 ± 0.01b	0.57 ± 0.02b	0.63 ± 0.01b	0.20 ± 0.08b	0.22 ± 0.09bc	5.51
30 ppm GA3	1.94 ± 0.26b	2.54 ± 0.52bcd	1.43 ± 0.15bc	1.57 ± 0.20bc	1.12 ± 0.18b	1.34 ± 0.01b	0.60 ± 0.01b	0.65 ± 0.01b	0.22 ± 0.09b	0.28 ± 0.11bc	5.84
10 ppm NAA	1.91 ± 0.31b	2.49 ± 0.21bcd	1.34 ± 0.17bc	1.56 ± 0.18bc	1.06 ± 0.18b	1.34 ± 0.01b	0.60 ± 0.02b	0.63 ± 0.00b	0.20 ± 0.08b	0.26 ± 0.11bc	5.69
20 ppm NAA	1.79 ± 0.20b	2.33 ± 0.41bcd	1.31 ± 0.03bc	1.43 ± 0.18bc	1.01 ± 0.15b	1.23 ± 0.01b	0.42 ± 0.17b	0.61 ± 0.00b	0.19 ± 0.08b	0.22 ± 0.09bc	5.27
30 ppm NAA	1.99 ± 0.12b	2.56 ± 0.27bcd	1.60 ± 0.18bc	1.79 ± 0.033bc	1.12 ± 0.19b	1.42 ± 0.18b	0.65 ± 0.02b	0.67 ± 0.00b	0.23 ± 0.09b	0.28 ± 0.12bc	6.16
10 ppm Ethephon	2.04 ± 0.03b	2.67 ± 0.22bc	1.63 ± 0.16bc	1.91 ± 0.023bc	1.25 ± 0.27b	1.47 ± 0.14b	0.67 ± 0.00b	0.69 ± 0.01b	0.25 ± 0.10b	0.30 ± 0.12bc	6.44
20 ppm Ethephon	2.06 ± 0.44b	2.78 ± 0.06b	1.90 ± 0.31bc	2.03 ± 0.16bc	1.31 ± 0.30b	1.53 ± 0.21b	0.68 ± 0.13b	0.80 ± 0.15b	0.32 ± 0.13b	0.38 ± 0.15b	6.89
30 ppm Ethephon	2.12 ± 0.17b	2.83 ± 0.36b	1.91 ± 0.31b	2.11 ± 0.20b	1.36 ± 0.02b	1.59 ± 0.21b	0.71 ± 0.29b	0.88 ± 0.17b	0.36 ± 0.14b	0.42 ± 0.17b	7.15
100 ppm SA	2.49 ± 0.04b	2.56 ± 0.0d	0.68 ± 0.02c	0.55 ± 0.02e	0.0 ± 0.00c	0.0 ± 0.00c	0.0 ± 0.00c	0.0 ± 0.00c	0 ± 0.00b	±0 ±0.00c	±3.14

200 ppm SA	2.60 ± 0.01ab	2.77 ± 0.02b	0.74 ± 0.02d	0.73 ± 0.02de	0.0 ± 0.00c	0.0 ± 0.00c	0.0 ± 0.00c	0.0 ± 0.00c	0 ± 0.00b	±0 ±0.00c	±3.41
Control	3.34 ± 0.27a	4.16 ± 0.33a	3.55 ± 0.48a	3.81 ± 0.27a	2.56 ± 0.22a	2.56 ± 0.22a	2.34 ± 0.02a	1.54 ± 0.38a	1.27 ± 0.32a	1.37 ± 0.28a	13.25
Mean	2.16	2.68	1.55	1.70	1.06	1.24	0.63	0.63	0.28	0.33	6.12
CD (P<0.05)	0.83	1.01	0.76	0.68	0.59	0.51	0.38	0.53	0.39	0.37	

90 DAFS in 2021 and 2022. Compared to previous days following fruit set, the severity of fruit splitting was greatest at 90 DAFS. By effectively preventing the buildup of ROS and oxidative damage, the application of antioxidants like salicylic acid protects plant cells. According to Sharma et al. (2020), SA is a phenolic molecule that affects several facets of plant physiology, including photosynthesis, nutrient intake and transport within the plant, and plant pigment production. When pomegranate trees were treated with salicylic acid, Abdel Aziz et al. (2017) saw a decrease in fruit splitting. Similar outcomes were shown by Karantzi et al. (2021) when SA was applied to figs, increasing the amount of fruits without splitting.

Fruit weight, size, and quantity: During the years 2021 and 2022, the highest fruit weight (206.00 and 206.33 g) was noted when GA3 was applied at a concentration of 10 ppm. This was closely followed by NAA at 20 ppm (199.00 and 205.67 g) and SA at 100 ppm (197.00 and 203.67 g) (Table 2). In the years 2021 and 2022, the untreated plants had the lowest fruit weight (183.67 and 184.67 g, respectively). The hormonal control of photosynthate transportation and accumulation, which results in fruit growth, may be the cause of the increased fruit weight. Hormones may also control cell division, elongation, and expansion. Jain et al. (2014) found that applying GA3 increased fruit weight in Nagpur mandarin, while Debbarma and Hazarika (2016) found comparable effects in acid lime. Because developing fruits serve as a reservoir where organic acids gradually accumulate during fruit development, the application of synthetic auxins raises the level of auxin within the fruits, which encourages the development of various fruit parts and ultimately contributes to an increase in fruit weight. Nawaz et al. (2011) found similar results in Kinnow Mandarin. When PGRs were applied topically, the fruit size considerably increased in comparison to the control. In 2021 and 2022, the application of GA3 10 ppm produced the longest fruits (6.88 and 6.83 cm), followed by NAA 20 ppm (6.84 and 6.83 cm), whereas the control group produced the shortest fruits (6.25 and 6.21 cm) in both years under study. In 2021 and 2022, the control group had the lowest fruit breadth (6.62 and 6.58 cm), whereas the application of 10 ppm GA3 produced the highest fruit width (7.20 and 7.12 cm), followed by 20 ppm NAA (7.08 and 7.03 cm). Growth regulators may be responsible for an increase in fruit size and form since there is an

Table 2 Effect of foliar application of growth regulators on yield attributes of Daisy mandarin

Treatment	Fruit weight (g)		Fruit length (cm)		Fruit breadth (cm)		Number of fruits/ tree		Fruit yield/tree (kg/tree)	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
10 ppm GA3	206.00 ± 2.06a	206.33 ± 1.19a	6.88 ± 0.02a	6.83 ± 0.04a	7.20 ± 0.02a	7.12 ± 0.01a	168.67 ± 1.66a	178.0 ± 2.16a	34.74 ± 0.11a	36.73 ± 0.65a
20 ppm GA3	190.67 ± 2.13bcd	200.67 ± 1.66abc	6.66 ± 0.03bc	6.61 ± 0.02bc	6.82 ± 0.02e	6.80 ± 0.01cd	160.33 ± 1.44b	162.0 ± 2.36bc	30.57 ± 0.57bc	32.50 ± 0.39cd
30 ppm GA3	190.67 ± 1.44bcd	195.00 ± 1.42bcd	6.66 ± 0.02bc	6.60 ± 0.03bc	6.75 ± 0.01f	6.74 ± 0.01de	153.00 ± 2.16c	159.3 ± 2.13bc	29.16 ± 0.35cd	31.08 ± 0.64cde
10 ppm NAA	189.00 ± 2.16cd	193.67 ± 0.72cd	6.65 ± 0.02bc	6.55 ± 0.03bc	6.74 ± 0.02fg	6.72 ± 0.02e	152.00 ± 1.42cd	159.0 ± 2.83bcd	28.72 ± 0.25d	30.80 ± 0.66def
20 ppm NAA	199.00 ± 2.16ab	205.67 ± 3.81a	6.84 ± 0.05a	6.83 ± 0.04a	7.08 ± 0.01b	7.03 ± 0.02b	168.33 ± 1.66a	174.0 ± 2.36a	33.51 ± 0.69a	35.79 ± 0.97ab
30 ppm NAA	188.33 ± 1.44cd	193.00 ± 1.89cde	6.60 ± 0.01bc	6.52 ± 0.03cd	6.72 ± 0.02fgh	6.64 ± 0.01f	152.00 ± 1.42cd	154.3 ± 2.38cde	28.63 ± 0.48d	29.79 ± 0.64ef
10 ppm Ethephon	191.33 ± 1.19bcd	201.00 ± 1.89abc	6.67 ± 0.03b	6.64 ± 0.03b	6.88 ± 0.02d	6.85 ± 0.01c	160.67 ± 1.19b	162.7 ± 1.91bc	30.73 ± 0.04b	32.69 ± 0.39cd
20 ppm Ethephon	187.67 ± 1.44d	192.33 ± 2.38cde	6.57 ± 0.02c	6.51 ± 0.03cd	6.70 ± 0.01fgh	6.63 ± 0.02f	148.00 ± 1.42d	153.0 ± 3.40de	27.77 ± 0.07de	29.45 ± 1.01ef

30	ppm	186.00 ± 191.67 ± 6.48 ± 6.42 ± 6.68 ± 6.62 ± 142.00 ± 149.6 ± 26.41 ± 28.68 ±
Ethephon		2.63d 1.19de 0.02d 0.02de 0.02gh 0.02f 1.42e 2.38ef 0.37ef 0.44ef
100	ppm	197.00 ± 203.67 ± 6.80 ± 6.76 ± 7.02 ± 7.00 ± 161.00 ± 163.6 ± 31.72 ± 33.32 ±
Salicylic acid		2.95abc 2.88ab 0.02a 0.04a 0.02c 0.02b 1.42b 2.38b 0.61b 0.35bc
200	ppm	185.67 ± 189.33 ± 6.48 ± 6.35 ± 6.66 ± 6.60 ± 141.33 ± 149.6 ± 26.24 ± 28.35 ±
Salicylic acid		1.66d 1.66de 0.01d 0.03e 0.01hi 0.01f 0.98e 3.31ef 0.41f 0.88fg
Control		183.67 ± 184.67 ± 6.25 ± 6.21 ± 6.62 ± 6.58 ± 140.67 ± 141.0 ± 25.82 ± 26.05 ±
		5.53d 4.82e 0.02e 0.01f 0.02i 0.02f 1.19e 0.94f 0.56f 0.82g
Mean		191.25 196.42 6.62 6.57 6.82 6.78 154.00 158.86 30.27 31.27
CD (P<0.05)		9.28 8.70 0.09 0.11 0.05 0.06 4.53 8.99 2.36 2.48

expansion of cells at later stages of fruit development and a rise in the number of cells during cell division (Singh et al. 2017). Habibi et al. (2021) found similar outcomes with Thompson navel oranges.

Growth regulators used topically greatly increased fruit production (Table 2). The application of GA3 at 10 ppm produced the highest number of fruits per plant (168.67 and 178.0), followed by NAA at 20 ppm (168.33 and 174.0). In both the 2021 and 2022 seasons, the control plants had the fewest fruits per plant (140.67 and 141.0). Fruit shedding and blossom dropping may have decreased as a result of the application of GA3 and NAA. The usage of growth regulators to make up for the lack of natural auxin may be the cause of this decrease in shedding. This might limit the establishment of an abscission layer by reducing the enzymatic activity at higher temperatures (Sweety et al. 2018). Our findings for Kagzi lime are consistent with those of Jagtap et al. (2013).

In comparison to the other treatments, the fruit yield with GA3 at 10 ppm was found to be significantly higher in 2021 and 2022 (37.74 and 36.73 kg/tree, respectively), while the lowest fruit yield was observed in untreated plants (25.82 and 26.05 kg/tree, respectively) during both of the studied seasons. According to Khalid et al. (2012), the application of GA3 and NAA treatments increased fruit yield because GA3 assimilates were partitioned more toward fruit development and assimilates were better translocated, which further led to yield-related attributes like fruit size and weight. Choudhary et al. (2013) and Abdel Aziz et al. (2017) found similar outcomes in Nagpur pomegranate and mandarin fruits, respectively.

Fruit quality characteristics: Measurements of total soluble solids are crucial indicators of citrus fruit quality. The application of GA3 at 10 ppm (11.28 and 11.23°Brix) resulted in the highest TSS, followed by NAA at 20 ppm (11.25 and 11.09°Brix) in 2021 and 2022, respectively (Table 3). In 2021 and 2022, the TSS in control plants was found to be much lower (10.46 and 10.43°Brix). Enzymatic conversion of complex carbohydrates into simple sugars may be the cause of the rise in TSS concentration in juice after foliar application of GA3 and NAA (Rub et al. 2010).

Table 3 Effect of foliar application of growth regulators on TSS, titratable acidity and ascorbic acid, juice content and flavonoids content of Daisy mandarin

Treatment	TSS (°Brix)		Titratable acidity (%)		Ascorbic acid (mg/100 ml)		Juice content (%)		Flavonoid content (mg RE/g FW)	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
10 ppm GA3	11.28 ± 0.02a	11.23 ± 0.02a	0.65 ± 0.01c	0.66 ± 0.00e	26.06 ± 0.03a	25.83 ± 0.04a	50.58 ± 0.43a	49.66 ± 2.02a	3.93 ± 0.02a	3.91 ± 0.18a
20 ppm GA3	11.03 ± 0.02cd	11.03 ± 0.02b	0.68 ± 0.00ab	0.67 ± 0.00bcde	25.71 ± 0.04bc	24.74 ± 0.02c	47.57 ± 0.45bc	47.19 ± 0.71a	3.79 ± 0.01bcd	3.65 ± 0.15ab
30 ppm GA3	10.99 ± 0.02de	11.01 ± 0.01bc	0.68 ± 0.00bc	0.68 ± 0.00bcde	25.66 ± 0.03bc	24.74 ± 0.02c	47.57 ± 0.38bc	46.95 ± 0.71ab	3.75 ± 0.02cde	3.57 ± 0.42ab
10 ppm NAA	10.99 ± 0.02de	10.99 ± 0.01c	0.69 ± 0.01ab	0.68 ± 0.01bcde	25.65 ± 0.04bc	24.74 ± 0.03c	46.85 ± 0.83bc	46.93 ± 1.89ab	3.74 ± 0.01def	3.52 ± 0.21ab
20 ppm NAA	11.25 ± 0.02ab	11.09 ± 0.02b	0.67 ± 0.01bc	0.66 ± 0.00de	26.03 ± 0.02a	25.78 ± 0.03ab	50.29 ± 1.37a	48.42 ± 3.41a	3.85 ± 0.01b	3.78 ± 0.27ab
30 ppm NAA	10.96 ± 0.03de	10.98 ± 0.04cd	0.69 ± 0.01ab	0.69 ± 0.00bcd	25.64 ± 0.22bc	24.74 ± 0.02c	46.72 ± 0.47bc	45.52 ± 0.98ab	3.69 ± 0.01efg	3.31 ± 0.42ab

10	ppm	11.08 ±	11.05 ±	0.68 ±	0.67 ±	25.82 ±	24.75 ±	47.70 ±	47.66 ±	3.81 ±	3.65 ±
Ethephon		0.02c	0.01a	0.07abc	0.00cde	0.03ab	0.03c	0.35bc	1.33a	0.01bcd	0.18ab
20	ppm	10.94 ±	10.97 ±	0.69 ±	0.69 ±	25.50 ±	24.53 ±	46.65 ±	45.29 ±	3.68 ±	3.31 ±
Ethephon		0.02e	0.04cd	0.00ab	0.00bcd	0.08cd	0.04d	0.56bc	0.70ab	0.04fg	0.33ab
30	ppm	10.82 ±	10.88 ±	0.70 ±	0.69 ±	24.96 ±	23.74 ±	46.27 ±	44.88 ±	3.64 ±	3.27 ±
Ethephon		0.04f	0.04d	0.00ab	0.01bc	0.05e	0.02e	0.51bcd	0.93ab	0.02g	0.27ab
100	ppm	11.18 ±	11.06 ±	0.67 ±	0.67 ±	26.01 ±	25.75 ±	48.50 ±	47.83 ±	3.82 ±	3.70 ±
Salicylic acid		0.02b	0.03bc	0.00bc	0.00cde	0.03a	0.03b	0.51ab	1.79a	0.03bc	0.27ab
200	ppm	10.47 ±	10.54 ±	0.70 ±	0.70 ±	25.27 ±	23.75 ±	45.71 ±	42.07 ±	3.63 ±	3.23 ±
Salicylic acid		0.02g	0.03e	0.00ab	0.00b	0.03d	0.02e	0.19 cd	0.72b	0.02g	0.30ab
Control		10.46 ±	10.43 ±	0.72 ±	0.73 ±	24.80 ±	23.48 ±	44.27 ±	30.68 ±	3.53 ±	2.75 ±
		0.03g	0.03f	0.01a	0.01a	0.02e	0.02f	0.52 d	0.81c	0.02h	0.15b
Mean		10.95	10.93	0.68	0.68	25.59	24.71	47.39	45.26	3.74	3.47
CD (P<0.05)		0.07	0.10	0.03	0.02	0.27	0.06	2.25	5.10	0.06	1.04

and as a result of improved sugar transport from the source to the sink (Ahmed et al. 2008). According to Lakshmi et al. (2014), this leads to an increased mobilisation of carbohydrates from their source to sink inside the plant in acid lime. The breakdown of organic acids kept in cell vacuoles may be made easier by this enhanced permeability, which would raise the total soluble solids. Huang and Huang (2005) in citrus species and Nawaz et al. (2011) in Kinnow mandarin have shown similar outcomes. Control had the highest acidity percentage (0.72 and 0.73%), while GA3 had the lowest acidity percentage (0.65 and 0.66%) at 10 ppm in 2021 and 2022, respectively, followed by NAA at 20 ppm (0.67 and 0.66%). The acceleration of orange maturation, which results in quicker ripening compared to untreated plants, may be the cause of the decrease in fruit acidity. Talat et al. (2020) found similar outcomes in Kinnow Mandarin.

Every citrus species has a distinct concentration of vitamin C. GA3 at 10 ppm had the highest ascorbic acid content (26.06 and 25.83 mg/100 ml), followed by NAA at 20 ppm (26.03 and 25.78 mg/100 ml), while untreated plants had the lowest ascorbic acid content (24.80 and 23.48 mg/100 ml) in 2021 and 2022 (Table 3). The rise in ascorbic acid level after the use of plant growth regulators (PGRs) is explained by an increase in osmotic pressure brought on by cell expansion, which in turn causes organic acids to build up. Depending on the citrus species, the amount of vitamin C in fruits varies and is impacted by the environment, the time of fruit harvesting, plant vigour, plant age, and the usage of PGRs. Hifny et al. (2017) found similar outcomes with Washington Navel oranges and Sandhu and Bal (2013) with lemons. During the growth seasons of 2021 and 2022, the application of GA3 at 10 ppm resulted in the highest juice content (50.58 and 49.66%), followed by NAA at 20 ppm (50.29 and 48.42%), respectively (Table 3). Untreated plants had the lowest juice percentage (44.27 and 30.68%). By affecting many biochemical and physiological processes in plants, foliar application of PGRs increased the juice content of daisy mandarin fruits. Nawaz et al. (2011) found that although the untreated plants showed the lowest juice percentage, the administration of plant growth regulators resulted in a significant increase in juice output. Singh and Kaur (2018) confirmed similar findings, stating that GA3 had the maximum juice content whereas untreated plants had the lowest juice %.

By affecting the look, flavour, and nutritional content of fruits and liquids, flavonoids may improve their quality. GA3 had the highest flavonoid content at 10 ppm (3.93 and 3.91 mg RE/g FW), followed by NAA at 20 ppm (3.85 and 3.78 mg RE/g FW). During the growth seasons of 2021 and 2022, untreated plants had the lowest flavonoid content (3.53 and 2.75 mg RE/g FW). Our findings are consistent with those of Talat et al. (2020), who found that applying GA3 topically improved the total flavonoid content of Kinnow mandarin. When compared to controls, wax apple fruits treated with GA3 had the highest flavonoid content (Moneruzzaman et al. 2011).

In conclusion, it was discovered that applying 100 ppm salicylic acid at the beginning of fruit splitting effectively reduced its intensity, boosting the fruit's quality and the leaves' nutritional content. Fruit quality attributes such as total soluble solids, acidity levels, ascorbic acid content, and flavonoid content in juice, as well as the number of fruits, fruit weight, fruit size, and overall yield, were all significantly improved by applying 10 ppm GA3 at different stages of growth. These results imply that careful use of growth regulators, namely salicylic acid, GA3, and NAA, may be a viable tactic to lessen fruit splitting and improve Daisy mandarin fruit quality.

CITATIONS

- El-Sayed M A, Aly H A, and Abdul Aziz F H. 2017. Manfalouty pomegranate plants' reaction to salicylic acid applied topically. *Agricultural Sciences Assiut Journal* 48: 59–74.
- Official Method of Analysis, AOAC, 2005. Horwitz W. and Latimer J. W. (Eds). Anonymous, Washington, DC: AOAC International Press, 2021. *Fruit Crop Practices Package*, pp. 1-2.
- Punjab Agricultural University is located in Ludhiana.
- Ahmad S, Khan M M, Ahmad W, and Nawaz M A. 2008. Growth regulators' effects on Kinnow mandarin fruit loss, production, and quality before to harvest. *Journal of Botany in Pakistan* 40: 1971–81.
- Jain M C, Sharma M K, Choudhary H D, and Bhatnagar P. (2013). Nagpur mandarin (*Citrus reticulata* Blanco) growth and yield are affected by plant growth regulators. *Asian Journal of Horticulture* 8: 746–50.
- Hazarika B N and Debbarma N. (2016). Effect of plant growth regulators and chemicals on yield and quality of acid lime (*Citrus aurantifolia* Swingle) in foot hill condition of Arunachal Pradesh. *Agricultural, Environment, and Biotechnology International Journal* 9: 231–36.
- In 2016, Dhillon W S, Singh S P, Mahajan B V C, Chahal T S, Kumar M, and Sidhu M K. impact of various packaging films on Daisy Mandarin quality and shelf life under ambient conditions. *Journal of Horticulture in India* 73: 262–66.
- In 2017, Gill M S, Brar J S, Gill P P S, and Khehra S. Daisy Mandarin performance in the subtropics in northwest India on three distinct rootstocks. *Environment, Conservation, and Ecology* 23: 177–83.
- Habibi S, Rayatpanah S, Ladanmoghadam A R, and Ebadi A. 2021. Thompson navel orange fruit splitting is affected by plant growth regulators. *Polonorum Hortorum Cultus Acta Scientiarum* 20: 83–92.
- Abd El-Wahed A N, Hamdy A E, Khalifa S M, and Hifny H A. 2017. GA3 and NAA's effects on Washington navel orange growth, yield, and fruit quality. *Journal of Horticulture in Egypt* 44: 33–43.
- Huang L. and Huang J. H. (2005). citrus groves using GA3. *Fruits of South China* 3: 32–36.
- Jagtap V M, Godage S S, Nehete D S, and Patel H C. 2013. Impact of applying micronutrients and plant growth regulators topically on the production and quality of acid lime cultivar Kagzi (*Citrus aurantifolia* Swingle). *Asian Journal of Horticulture* 6: 253–55.
- Singh Bhim, Jain M C, Sharma M K, and Choudhary H D. 2014. The impact of several plant growth regulators on Nagpur mandarin yield and quality characteristics. *Ecology and the Environment* 32: 1141–45.
- In 2021, Karantzi A D, Kafkaletou M, Tsaniklidis G, Bai J, Christopoulos M V, Fanourakis D, and Tsantili E. Fruit cracking during harvest is lessened by pre-harvest foliar salicylic acid treatments. 11: 11374 in *Applied Sciences*.
- In 2012, Khalid S, Jamil A, Khan A S, and Malik A U. Young Kinnow mandarin (*Citrus nobilis* × *C. Deliciosa*) trees' fruit quality is affected by exogenous applications of plant growth regulators. *Agriculture and Biology International Journal* 14: 229–34.
- Lakshmi M L, Yuvaraj K, Lakshmi T N, Sarada G, Gopal K, Ramana K T V, and Krishna V S. 2014. Research and Reviews on the effects of growth regulators and chemicals on hasta bahar blooming fruit output and quality in acid lime (*Citrus aurantifolia* Swingle) cv. Balaji. Malik C. P. and Singh M. B. *Journal of Agricultural and Applied Sciences* 3: 11–13. 1982. Total phenols are extracted and estimated. *Plant Histochemistry and Enzymology*, Kalyani Publisher, New Delhi, pages. 286.
- Moneruzzaman K M, Boyce A N, Hossain A B M S, and Normaniza O. 2011. The wax apple (*Syzygium samarangense*) responds differently to gibberellic acid (GA3) in terms of growth, yield, and quality. Jambu air madu fruits are cultivated in a field. Nawaz M A, Afzal M, Ahmed W, Ashraf M, Silva J A T D, Akhtar N, Shahzad S M, Ullah H, and Hussain, *African Journal of Biotechnology* 10: 1911–18. 2011. Kinnow mandarin (*Citrus reticulata* Blanco) production and quality are enhanced by exogenous treatment of 2,4-D, GA3, and NAA during blooming. *Plant Science and Biotechnology, Asian Australasian Journal*, 5: 17–21.
- In 2010, Rub A, Haq S, Khalil S A, and Ali S G. Fruit quality and senescence associated variations in sweet orange cultivar blood red unipacked in various packing materials. *Journal of Agriculture Sarhad* 26: 221-27.
- Bal J S and Sandhu S. (2013). Using integrated fruit cracking management, lemon [*Citrus limon* (L.) Burm.] quality is improved. Sharma A, Sidhu G P S, Araniti F, Bali A S, Shahzad B, Tripathi D K, Brestic M, Skalicky M, and Landi M. *African Journal of Agricultural Research* 8: 3552–57. 2020. Salicylic acid's function in plants exposed to heavy metals. *Molecules* 25: 540.
- Singh D B, Jain R K, and Kingsly A R P. 2006. regulating pomegranate fruit shattering. *Indian Horticulture* 5: 31–32.

In 2017, Singh S R, Wangchu L, Singh B, Hazarika B N, and Pandey A K. Impact of PGR combination on Khasi Mandarin (*Citrus reticulata* Blanco) pre-harvest fruit decline. 51: 167–72. Indian Journal of Agriculture and Research.

Kaur A. and Singh J. (2018). impact of foliar sprays on baramasi lemon quality and production. Sweetey, Rana G S, and Reddy G C. International Journal of Advanced Research 6: 293–98. 2018. Growth regulator effects on sweet orange (*Citrus sinensis* L. Osbeck) cv. Jaffa production and quality. Current Microbial and Applied Sciences International Journal 7: 2963–67. Talat H, Shafqat W, Qureshi M A, Sharif N, Raza M K, Uddin S, and Jaskani M J. 2020. Gibberellic acid's impact on Kinnow mandarin fruit quality. Agricultural Sciences Journal of Global Innovation 8: 59–63.

In 2020, Yu J, Zhu M, Bai M, Xu Y, Fan S, and Yang G. Calcium's impact on grape (*Vitis vinifera* L.) Xiangfei berry cracking relief 8. Peer Journal 8: e9896.