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Delayed harvesting and creasing fruit disorder in Nagpur mandarin (*Citrus reticulata* Blanco): Nature and alleviation through GA_3 application

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Abstract
The research was carried out at ICAR-CCRI, Nagpur during 2020 and 2021 to improve fruit yield, quality characteristics and to manage the creasing disorder incidence with delayed harvesting of one month in *Mrig bahar* of Nagpur mandarin (*Citrus reticulata* Blanco) through foliar application of different concentrations of gibberellic acid (10, 15, 20 and 25 ppm). Maximum number of fruits per plant (716), yield per plant (105.60 kg/plant), yield per hectare (29.25 t/ha), fruit weight (147.25 g), fruit length (58.53 mm), fruit breadth (67.60 mm), fruit volume (145.37 cm^3), juice per cent (45.67%), vitamin C (40.73 mg/100 ml) content and minimum per cent of creasing (3.74%) incidence was noted in GA_3 25 ppm + urea 1.5% over the control. Maximum fruit firmness (2.55 kg/cm^2) was noted in GA_3 20 ppm + urea 1.5% followed by GA_3 25 ppm + urea 1.5% (2.36 kg/cm^2) indicates the delayed ripening of fruits, which helps in storage of fruits on tree by controlling the incidence of creasing disorder whereas minimum fruit firmness (1.62 kg/cm^2) was noted in control. Maximum TSS (11.63%) and TSS/Acid ratio (15.11) were recorded in control followed by GA_3 10 ppm + urea 1.5% (10.32% and 13.05, respectively) indicates fruits were more ripened compared to other treatments whereas minimum TSS (9.86%) was noted in GA_3 20 ppm + urea 1.5% and minimum TSS/Acid ratio (12.20) was noted in GA_3 25 ppm + urea 1.5% indicates fruits were firm and less matured compared to other treatments. The foliar spray of GA_3 20 or 25 ppm along with urea 1.5% will slow down the senescence process of cells, and maintains the compactness of albedo tissues, thus reduced creasing incidence with improvement in yield and quality parameters of Nagpur mandarin fruits in delayed harvesting of one month.

Keywords: Creasing fruit disorder, gibberellic acid, *Mrig bahar* and Nagpur mandarin

Introduction
Nagpur mandarin (*Citrus reticulata* Blanco) is the finest variety of mandarin in the world, and is majorly grown in central part of India. To get good market values and profit, some growers of Nagpur mandarin in central India go for the late harvesting, but there will be the incidence of physiological disorder called creasing due to delay in harvesting. These fruits will have the poor post-harvest storage capacity and poor transportability due to decreased firmness. The nature of creasing disorder is presence of cracks in white coloured spongy (albedo) tissue of peel, loss of turgor pressure will cause the occurrence of depressed and bulky areas on fruit peel, and cell wall will collapse, activation of pectin methyl esterase enzyme in albedo tissue and it will leads to pectin degradation [1]. The creased fruits are large in size with high water content; very thin peel; high nitrogen and potassium content; and lower calcium content. Cultural practices like mineral nutrition; climatic factors like light, temperature and humidity; and genetic factors are the cause of creasing disorder [1, 13, 19]. Deficiency of calcium and potassium, higher application of phosphorus; warm and humid climatic conditions; irregular irrigation; and heavy fruit load are the reasons for fruit splitting or albedo breakdown in citrus fruit [4]. The creasing disorder is controlled through foliar spray of GA_3 at the concentration of 25 mg l^{-1} prior to colour break (6-8 weeks before the normal harvest season) delayed the colour change of the flavedo and prevented peel puffing. In GA_3 treated fruits higher fruit firmness, reduced peel thickness and weight, and loss of juice in mature fruits was also retarded. It will be helpful in extending harvesting season without affecting internal fruit quality [15]. Application of GA_3 prior to colour break stage or at 30-40 mm fruit size reduced the creasing incidence. Gibberellic acid slow down the senescence process of albedo tissue, improve and maintains the compactness of albedo tissues [1]. Fruit thinning followed by GA_3 application, optimum nutrition (Ca, K, and P) and regular irrigation of mandarin plants are the practices to reduce fruit creasing incidence [4].

Materials and Methods

The main aim of the experiment was to improve the fruit yield, quality parameters and to delay harvesting of Nagpur mandarin fruits in *Mrig bahar* by avoiding the creasing incidence at ICAR-CCRI, Nagpur during 2020 and 2021. The earmarked orchard was twelve years old, and trees were spaced at the spacing of 6 m x 6 m. The statistical design used for the experiment was randomized block design with four replications. The different concentrations of gibberellic acid (10, 15, 20 and 25 ppm) along with 1.5% of urea were foliar applied to delay the harvesting at monthly intervals from November to December. At harvest (March), yield parameters and fruit physico-chemical characteristics were analysed and recorded. Electronic balance was used to note the average fruit weight of ten selected fruits. Digital vernier calliper was used to note the fruit dimensions *viz.* length; breadth; rind thickness; and core diameter. Electronic citrus juicer used to extract fruit juice, and juice content was calculated on a volume by weight basis, and expressed in per cent. TSS was recorded by using digital refractometer, while titrable acidity was estimated by titration with standard alkali, and calculated in terms of per cent citric acid. The method prescribed by Ranganna (2001) was used to determine the ascorbic acid content.

Results and Discussion

Yield parameters

Maximum number of fruits per plant, yield per plant and yield per hectare were recorded in GA_3 25 ppm + urea 1.5% (716, 105.60 kg/plant and 29.25 t/ha) followed by treatment GA_3 20 ppm + urea 1.5% (699, 101.62 kg/plant and 28.15 t/ha), whereas minimum number of fruits per plant, yield per plant and yield per hectare were recorded in control (628, 83.25 kg/plant and 23.06 t/ha, Table 1). Thus, foliar spray of GA_3 maintains the marketable quality of fruits at delayed harvesting by one month by reducing the creasing disorder incidence, and also improved the yield parameters [2, 6, 8, 10, 11].

Per cent of creasing incidence and fruit firmness

The GA_3 application at different concentrations has positive influence on delaying the ripening of fruits and by this process reduced the creasing incidence. Minimum per cent of creasing (3.74%) was reported in GA_3 25 ppm + urea 1.5%, followed by GA_3 20 ppm + urea 1.5% (5.15%) whereas maximum per cent of creasing (8.85%) was recorded in control. Maximum fruit firmness (2.55 kg/cm^2) was noted in the treatment GA_3 20 ppm + urea 1.5%, followed by GA_3 25 ppm + urea 1.5% (2.36 kg/cm^2) indicates the delayed ripening of fruits, which helps in storage of fruits on tree by controlling the incidence of creasing disorder whereas, minimum fruit firmness (1.62 kg/cm^2) was noted in control (Table 1). Gibberellin application keeps the albedo tissues compact, delays the senescence of tissues, maintains higher protein content in peel, lowers the incorporation of amino acids in to proteins. Thus, gibberellic acid application reduced the per cent of creasing incidence, and maintains the fruit firmness by delayed maturity [1, 3, 7, 14, 15, 17].

Physico-chemical characteristics of fruits at harvesting

The treatment GA_3 25 ppm + urea 1.5% has recorded the maximum fruit weight (147.25 g), length (58.53 mm), breadth (67.60 mm), volume (145.37 cm^3) and juice per cent (45.67%) followed by GA_3 20 ppm + urea 1.5% (144.75 g, 57.56 mm, 66.54 mm, 142.87 cm^3 and 45.14% respectively) whereas minimum fruit weight, length, breadth, volume and juice per cent (132.25 g, 52.21 mm, 61.15 mm, 130.37 cm^3 and 39.72% respectively) were recorded in control. Maximum fruit length to diameter ratio noted in GA_3 10 ppm + urea 1.5% (0.88), followed by GA_3 20 ppm + urea 1.5% and GA_3 25 ppm + urea 1.5% (0.86) whereas, minimum fruit length to diameter ratio noted in GA_3 15 ppm + urea 1.5% (0.80). Maximum rind thickness reported in GA_3 25 ppm + urea 1.5% (2.92 mm) followed by the control (2.83 mm) whereas minimum rind thickness noted in GA_3 15 ppm + urea 1.5% (2.49 mm). The treatments recorded no effects on core diameter**,** number of seeds and number of segments of Nagpur mandarin fruits (Table 1 and 2).

The biochemical parameters *viz.* TSS, titrable acidity, TSS/acid ratio, and Vitamin C shown statistically significant results among the different concentrations of GA_3 application. Maximum TSS (11.63%) was noted in control followed by treatment GA_3 10 ppm + urea 1.5% (10.32%) indicates fruits are more ripened compared to remaining treatments whereas, minimum TSS (9.86%) was noted in GA_3 20 ppm + urea 1.5% indicates fruits were firm and less matured compared to other treatments. No effect of treatments was observed on the acidity content of the fruits. The control has recorded the maximum TSS/Acid ratio (15.11) followed by GA_3 10 ppm + urea 1.5% (13.05) whereas, minimum TSS/Acid ratio (12.20) was noted in GA_3 25 ppm + urea 1.5%. Significantly, the maximum vitamin C (40.73 mg/100ml) content was reported in GA_3 25 ppm + urea 1.5% followed by GA_3 20 ppm + urea 1.5% (38.81 mg/100ml) whereas minimum vitamin C (33.73 mg/100ml) content was recorded in the control (Table 2). The physical and biochemical analysis of Nagpur mandarin fruits during holding of fruits on the tree with pre-harvest application of GA_3 (10, 15 and 20 ppm), delayed fruit colour development, fruit softening and puffiness without any adverse effect on fruit productivity and TSS/acid ratio [12]. Foliar application of GA_3 at the concentration of 25 ppm improved the fruit weight; yield; fruit volume; TSS and ascorbic acid over control in 'Nagpur' mandarin [9]. Similarly, foliar spray of GA_3 has improved the fruit yield and quality characteristics in citrus fruits reported by the earlier studies [5, 10, 11, 18].

Table 1: Effect of different concentrations of GA_3 on fruit yield and yield attributes in *Mrig bahar* of Nagpur mandarin at delayed harvesting of one month

Treatment	No. of fruits harvested per plant	Yield (kg/ plant)	Yield (t/ha)	Per cent of disorder	Fruit firmness (kg/cm^2)	Fruit weight (g)	Fruit length (mm)	Fruit breadth (mm)	Length/ diameter ratio	Fruit volume (cm^3)
$GA_3$10 ppm + Urea 1.5%	669	92.76	25.69	6.53	1.67	138.25	57.28	65.01	0.88	136.37
$GA_3$15 ppm + Urea 1.5%	683	97.70	27.06	5.73	2.22	143.00	52.55	65.22	0.80	141.12
GA_3 20 ppm + Urea 1.5%	699	101.62	28.15	5.15	2.55	144.75	57.56	66.54	0.86	142.87
GA_3 25 ppm + Urea 1.5%	716	105.60	29.25	3.74	2.36	147.25	58.53	67.60	0.86	145.37
Control	628	83.25	23.06	8.85	1.62	132.25	52.21	61.15	0.85	130.37
S.Em±	16.23	3.54	0.98	0.24	0.07	3.18	1.08	1.04	0.01	3.18
CD at 5%	50.58	11.03	3.05	0.76	0.22	9.93	3.38	3.26	0.04	9.93

Table 2: Effect of different concentrations of GA_3 on fruit physico-chemical characteristics in *Mrig bahar* of Nagpur mandarin at delayed harvesting of one month

Treatment	Core diameter (mm)	No. of segments	No. of seeds	Rind thickness (mm)	Juice (%)	TSS (%)	Acidity (%)	TSS/ Acid ratio	Vitamin C (mg/100 ml)
GA_3 10 ppm + Urea 1.5%	15.61	10.37	11.12	2.77	43.95	10.32	0.79	13.05	35.99
GA_3 15 ppm + Urea 1.5%	14.35	10.12	11.50	2.49	44.85	10.17	0.79	12.77	37.23
GA_3 20 ppm + Urea 1.5%	15.00	10.12	11.37	2.53	45.14	9.86	0.80	12.23	38.81
GA_3 25 ppm + Urea 1.5%	13.71	10.25	11.00	2.92	45.67	9.88	0.81	12.20	40.73
Control	14.63	10.25	12.12	2.83	39.72	11.63	0.77	15.11	33.73
S.Em±	0.95	0.11	0.29	0.09	0.87	0.18	0.01	0.32	0.52
CD at 5%	NS	NS	NS	0.29	2.73	0.58	NS	0.99	1.64

Conclusion

The pre-harvest application of GA_3 on Nagpur mandarin fruits at monthly intervals from November to December has the significant effects on delaying the maturity and maintaining fruit firmness. The foliar spray of GA_3 20 or 25 ppm along with urea 1.5% will slow down the senescence process of cells, and maintains the compactness of albedo tissue, thus reduce the albedo breakdown or creasing incidence and helpful in late harvesting of Nagpur mandarin fruits with improved yield and quality characteristics.

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