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Fruit Physical Attributes as Affected by Russet Management Chemicals in cvs. Red Velox and Golden Clone-B

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ABSTRACT: **The present investigation was conducted in the Experimental fields of Division of Fruit Science, SKUAST-K, Shalimar during the year 2022-23. Five year old trees of exotic apple cvs. "Red Velox" and "Golden Clone-B" grafted on M-9 T337 rootstock, planted at a distance of 3m × 1m were selected for experimentation. The experiment was laid out in Randomized Block Design (two factorial). The first factor was the russet management chemicals which include Control, Gibberellic acid$_{4+7}$ + 6-Benzyladenine (@ 5.5 ppm, 11 ppm and 21ppm), Gibberellic acid$_3$ + 6- Benzyladenine (@ 5.5 ppm, 11 ppm and 21ppm) and Chlorogenic acid (88.5 ppm, 177 ppm and 354 ppm). Timing of the spray was at 80% petal fall and 15 days after the first spray for Gibberellic acid$_{4+7}$ + 6-Benzyladenine (@ 5.5 ppm, 11 ppm and 21ppm) and Gibberellic acid$_3$ + 6-Benzyladenine (@ 5.5 ppm, 11 ppm and 21ppm). However, it was 30 days after the full bloom for Chlorogenic acid (88.5 ppm, 177 ppm and 354 ppm). The second factor was the varieties *i.e.,* Red Velox and Golden Clone-B. Timing of the spray was @ 80% petal fall and 15 days after the first spray for G0-G3 and G7-G9. It was 30 days after the full bloom for G4-G6. Among all the applied chemicals, best results for the physical characters were recorded in G3: GA$_{4+7}$ + 6-BA @ 21 ppm in which maximum fruit length (71.98 mm; 79.89 mm), maximum fruit diameter (77.08 mm; 79.65 mm), maximum length/diameter ratio (0.94; 1.00) and maximum fruit weight (205.03 gms; 221.95 gmswas recorded in the two varieties *i.e.,* Red Velox and Golden Clone-B respectively. Chlorogenic acid @ 177 ppm was also found to be statistically at par with G3: GA$_{4+7}$ + 6-BA @ 21 ppm for the above mentioned parameters when it was applied at 30 DAFB. The present investigation concludes that GA$_{4+7}$ + 6-BA @ 21 ppm can be recommended for controlling the russet apart from improving the physical attributes of the cvs. Red Velox and Golden Clone-B. At the same time, Chlorogenic acid should be considered for further research and shouldn't be recommended to the farmers as of now because of its costly nature.**

Keywords: russet management, GA$_3$+ 6-BA, GA$_{4+7}$ +6-BA, physical characters, chlorogenic acid, Red Velox, Golden Clone-B.

INTRODUCTION

Apple with its appealing nature has appeals enchanted the human minds for thousands of years. This fruit still fits the age-old parable that "An apple a day keeps the doctor away". In the world, apple is grown over an area of 47, 17, 384 hectares with an annual production of 8, 72, 36, 221 metric tonnes (Anonymous, 2019a). At the international level, China is leading in the production of apples followed by India and Brazil. In India, it is grown over an area of 3, 08, 000 hectares with an annual production of 23, 16, 000 metric tonnes (Anonymous, 2019b). In India, even though the three leading states in the production of apples are J&K, Himachal Pradesh and Uttarakhand, the majority of the crop comes from Jammu and Kashmir. Apple industry

is one of the direct sources controlling the economy of the state because of its comparative advantage. Jammu & Kashmir accounts for 67.7% of the total apple production and the production per hectare is 10.0 metric tons, which is higher than the national average (Bhat *et al*., 2019). Jammu & Kashmir occupies an area of about 1, 64, 742 hectares while the production is 17, 19, 415.69 MT (Anonymous, 2021). One of the economically important disorders that is experienced by many fruit crop species including apples is russeting (Knoche and Lang 2017). Russet is known to impair the shiny appearance of the fruit skin even though it doesn't change its nutritional value. Plant growth hormones have found their use in the fruit production industry for various purposes and at different stages of plant growth. Gibberellic acid (GA_{4+7}) has shown its effect in reducing the russet of the fruit and improving its skin finish (Leite *et al*., 2005). The use of cytokinin 6-benzyl adenine (6-BA) at the petal fall stage and four weeks after the petal fall has shown improvement in the typiness of the Red Delicious apples (Cline, 2017). The research conducted on chlorogenic acid has revealed that the upregulated genes associated with it are linked to the biosynthesis of flavonoids while those which are down-regulated are involved in lignin biosynthesis which could be the reason why it stops russeting (Wang *et al*., 2014). Thus, the current investigation on the two cvs. Red Velox and Golden Clone-B was conducted with an aim to standardize the chemical and its concentration in order to manage russet in the two varieties apart from studying its impact on the fruit physical attributes.

REVIEW OF LITERATURE

A lot of studies have been conducted on the russeting incidence, characteristics and fruit quality as well. A few of them are as follows: Sanchez *et al.* (2001) carried out a study on the chemical treatments in "Golden Delicious Spur" fruits in relation to russeting using ProVide, Packhard, Microthiol Special and Dithane which were applied to the apple trees at the onset of flowering, at petal drop, and at the beginning of fruit development. The results reduced the damaged fruit area as well as the percentage of damaged fruits in comparison to control. The application of calcium nitrate and Dithane increased the percentage of the damaged area whereas Packhard resulted in the increase of the fruits with russeting. McArtney *et al*. (2007) undertook a series of four experiments to evaluate the effects of prohexadione-Ca and GA_{4+7} mainly on the fruit russet but also on the fruit set, fruit weight, early season shoot growth and fruit maturity of "Golden Delicious" apples. A single application of P-Ca at petal fall reduced the fruit severity of russet in three of the four experiments conducted, however continuous applications of 20 ppm GA_{4+7} at 10 days intervals resulted in effective russet control. The data led to the conclusion that whereas P-Ca leads to decrease in russet severity, it can have an additive effect when used in combination with $GA_{4+7.}$ Chitu *et al.* (2009) conducted a study on the apple cultivar Goldspur (grafted on M-26) using Promalin. The treatments were applied four times between June and September, beginning at flowering and continuing at 14 days interval for three treatments. Carbosulf was sprayed three times before harvest at 0.5% concentration. The results showed that the foliar clay application increased the percentage of russeting free fruit from 17% (control) to 23-28%. Carbosulf performed better than the clays (average 38% fruits russeting free), but worse than Promalin, which averaged close to 59% russeted free fruits. Pesteanu (2015) conducted a study on the effect of GA_{4+7} on the russeting of "Golden Delicious" apples. The treatments given were 4 ppm and 5 ppm which were applied 4 times starting from the petal fall stage and after 7-10 days for the other sprays. It was seen that almost 74% and 61% of fruits sprayed with GA_{4+7} @ 5 ppm and 4 ppm respectively showed no russet formation. Cline (2017) studied the interactive effects of 6-BA and GA_{4+7} in a two-year-old experiment on Royal Gala/Bud9 apple trees during bloom and fruit set to reduce russeting and improve their typiness. Four treatments were used which included untreated control and three different concentrations of GA_{4+7} and 6-BA *i.e.,* 5.5 mg/L, 11 mg /L and 21 mg/L. It was observed that GA_{4+7}/6-BA decreased soluble solids and fruit firmness in the first year, suggesting a delay in fruit maturity. While gibberellic acid was used to reduce skin russet and improve the skin finish, the cytokinin 6-benzyladenine (6-BA) was used at petal fall and four week after that to improve the typiness of the Red delicious apples. The russet rating which was obtained by a spray of GA_{4+7} + 6-BA in three concentrations *i.e.,* 5.5 ppm, 11 ppm and 21 ppm was 1.9-2.0 on a scale of 0-3. GA_{4+7} + 6-BA was found to increase fruit typiness and length to diameter ratios. Sharma *et al*. (2020) conducted a study with various plant growth regulator practices on eight year old apple trees cv. 'Scarlet Spur II'. Application of GA_{4+7} +BA at 2.5 ppm and 5 ppm when given at petal fall and two times later at 10 days interval recorded minimum russet formation (Score:1.17), increased fruit length (68.93 mm) as well as increased L/D ratio (1.07), TSS and sugar content in apple. however, CPPU at 10 ppm when applied at the petal fall stage recorded higher fruit diameter (70.89 mm), fruit weight (155.56 g), fruit volume (102.94 cc), TSS (10.72 ºBrix), total sugars (9.11%) and reducing sugars (4.87%). Kuchay *et al*. (2022) carried out a study to know the effect of Applin (gibberellin andcytokinin) on the growth, yield and quality of Royal Delicious apple. The fruits showed maximum fruit length, fruit diameter, fruit weight, yieldand ascorbic acid in those plants that were treated with 0.5 mL/l of Applin and with 1.0 mL/l of Wetcit. The results showed that the application of PGRs at different concentrations greatly affects the fruit size, quality and shelf life of apples during the year of high crop load. Bhat *et al.* (2022) carried out a study to determine the response of Promalin on the growth of apple cv. Red Delicious. The study shows that the growth of apple fruit was significantly influenced by Promalin (GA_{4+7} and 6-BA). The results showed that the longest fruit length of 71.06

mm was recorded with 60 ppm Promalin which was at par with 30 ppm, 90 ppm and 100 ppm whereas the control (Water spray) had a fruit length of 60.52 mm and was found to be a significantly different from all the treatments. The results also showed a fruit breadth of 70.70 mm with 90 ppm Promalin application and it was found to be at par with 60 ppm Promalin application. The least breadth was however shown by the control (Water spray) where it was 61.34 mm. Fruit colour was found to be maximum where the concentrations of the chemical were low and in untreated fruits as compared to high concentrations. Apart from that, with the increase in the concentration of Promalin, the fruits developed a long conical shape. In those fruits where the concentration of Promalin was phytotoxic, around 12.67% russetting in treated fruits was found. Pramanick *et al.* (2022) carried out a research on the effect of Promalin on growth and yield parameters of the apple cultivars "Royal delicious" in humid subtemperate zones of Himachal Pradesh, and they concluded that "Promalin" @ 60 ppm as foliar spray at full bloom stage on apple cultivar "Royal Delicious" has a significant impact on the fruit size, shape, fruit yield and other yield contributing traits and had no phytotoxicity in apple. Promalin @ 60 ppm and its double dose @ 90 ppm applied as a foliar spray showed no phytotoxic effect on apple trees at all the intervals of observations. Ates *et al.* (2023) carried out a study to determine the physical properties, biochemical and bioactive compounds of different apple cultivars including 'Scarlet Spur', 'Starking Delicious', 'Starkrimson Delicious', 'Golden Delicious', and 'Super Chief. The results showed the highest fruit weight (289.96 gm) and fruit length (32.61 mm) from "Scarlet Spur". The highest fruit diameter (34.86 mm) was seen in 'Scarlet Spur' and 'Starkrimson Delicious'.

MATERIAL AND METHODS

Five year old trees of exotic apple *cv*s. "Red Velox" and "Golden Clone-B" grafted on M-9 T337 rootstock, introduced by SKUAST-Kashmir from Holland in March 2017 were selected for experimental studies. The experiment was laid out in Randomized Block Design (two factorial) and was conducted in the year 2022-2023 respectively. The first factor was the russet management chemicals which include G0: Control, G1: GA_{4+7} +6-BA @ 5.5 ppm, G2: GA_{4+7}+6-BA @ 11 ppm, G3: GA4+7 + 6-BA @ 21 ppm, G4: Chlorogenic acid @ 88.5 ppm, G5: Chlorogenic acid @ 177 ppm, G6: Chlorogenic acid @ 354 ppm, G7: GA_3+ 6-BA @ 5.5 ppm, G8: GA_3+ 6-BA @ 11 ppm and G9: GA_3+ 6-BA @ 21 ppm. The second factor was the varieties i.e., Red Velox and Golden Clone-B. Timing of the spray was @ 80% petal fall and 15 days after the first spray for all the treatments comprising of GA_{4+7} +6-BA and GA_3 + 6-BA. It was 30 days after the full bloom for Chlorogenic acid.

For calculating the fruit length and fruit diameter, random samples from the experimental units of both the varieties were measured separately with a digital vernier caliper in millimeters (mm) and the fruit length and fruit diameter was averaged and analyzed statistically. The L/D ratio was estimated by dividing the length of the fruit by the diameter of the corresponding fruit. For measuring the fruit weight, the random samples from the experimental units of both varieties were weighed on a sensitive monopan electronic balance, averaged and recorded in grams (g). Fruit firmness was measured using the Effegi penetrometer model: 53205 having 7/16 diameter of the head with penetration of 5/6. In each replication, fruits were punched at three different places on their surface after removing about one square inch of peel and firmness was recorded as kg/cm^2. The observations recorded during the investigation were subjected to statistical analysis according to the method of 'Analysis of Variance' (Gomez and Gomez 1984). The significance and non-significance of treatment effects were judged with the help of the software CPCS. The effects of the treatments were tested at a 5 percent level of significance.

Table 1: Effect of various russet management chemicals on fruit length (mm) of apple cvs. Red Velox and Golden Clone-B.

Varieties / Treatments	2022			2023			Pooled		
	Red Velox	Golden Clone-B	Mean	Red Velox	Golden Clone-B	Mean	Red Velox	Golden Clone-B	Mean
G0: Control	62.61	71.65	67.13	62.13	72.61	67.37	63.11	72.17	67.64
G1: GA_{4+7}+ 6-BA @ 5.5 ppm	66.51	74.63	70.57	68.28	75.53	71.90	67.39	75.08	71.23
G2: GA_{4+7} + 6-BA @ 11 ppm	69.24	77.55	73.39	70.31	78.46	74.39	69.77	78.07	73.89
G3: GA_{4+7} + 6-BA @ 21 ppm	71.55	79.46	75.51	72.42	80.33	76.37	71.98	79.89	75.94
G4: Chlorogenic acid @ 88.5ppm	62.63	71.66	67.15	62.38	72.64	67.65	63.13	72.21	67.67
G5: Chlorogenic acid @ 177 ppm	62.66	71.70	67.18	63.66	72.61	67.99	63.18	72.20	67.69
G6: Chlorogenic acid @ 354 ppm	62.83	71.89	67.36	63.73	72.79	68.26	63.28	72.24	67.76
G7: GA_3 + 6-BA @ 5.5 ppm	65.48	73.64	69.56	67.42	74.58	71.00	66.45	74.11	70.28
G8: GA_3 + 6-BA @ 11 ppm	68.64	75.60	72.12	69.50	76.79	73.14	69.06	76.19	72.63
G9: GA_3 + 6-BA @ 21 ppm	71.15	78.79	74.97	71.48	79.66	74.57	69.81	79.23	74.52
Mean	66.33	74.65		67.13	75.60		66.71	75.13	
C.D.(< 0.05)	**C.D. (2022)**			**C.D. (2023)**			**Pooled**		
Russet management chemicals (G)	0.250			0.199			0.194		
Varieties (V)	0.112			0.089			0.087		
G x V	0.354			0.281			0.274		

Table 2: Effect of various russet management chemicals on fruit diameter (mm) of apple cvs. Red Velox and Golden Clone-B.

Varieties / Treatments	2022			2023			Pooled		
	Red Velox	Golden Clone-B	Mean	Red Velox	Golden Clone-B	Mean	Red Velox	Golden Clone-B	Mean
G0: Control	70.03	74.62	72.32	70.46	74.68	72.57	70.24	74.27	72.25
G1: GA_{4+7}+ 6-BA @ 5.5 ppm	74.05	76.07	75.06	74.94	75.46	75.20	74.20	76.26	75.23
G2: GA_{4+7} + 6-BA @ 11 ppm	74.85	78.25	76.55	75.52	78.75	77.14	75.18	78.50	76.84
G3: GA_{4+7} + 6-BA @ 21 ppm	76.85	79.54	78.19	77.31	79.78	78.54	77.08	79.65	78.36
G4: Chlorogenic acid @ 88.5ppm	70.06	74.63	72.35	70.46	74.90	72.69	70.26	74.77	72.25
G5: Chlorogenic acid @ 177 ppm	70.06	74.68	72.37	70.51	74.93	72.72	70.27	74.78	72.52
G6: Chlorogenic acid @ 354 ppm	70.22	74.80	72.51	70.72	74.94	72.81	70.47	74.98	72.72
G7: GA_3 + 6-BA @ 5.5 ppm	73.81	75.29	74.55	74.29	75.18	74.73	74.05	75.51	74.78
G8: GA_3 + 6-BA @ 11 ppm	74.35	77.15	75.75	75.24	76.46	75.85	74.93	76.80	75.86
G9: GA_3 + 6-BA @ 21 ppm	75.57	79.02	77.29	76.09	79.48	77.78	75.82	79.25	77.53
Mean	72.98	76.40		73.55	76.45		73.25	76.47	
C.D.(< 0.05)	**C.D. (2022)**			**C.D. (2023)**			**Pooled**		
Russet management chemicals (G)	0.236			0.276			0.221		
Varieties (V)	0.105			0.123			0.099		
G x V	0.333			0.390			0.312		

Table 3: Effect of various russet management chemicals on fruit length/diameter ratio of apple cvs. Red Velox and Golden Clone-B

Varieties / Treatments	2022			2023			Pooled		
	Red Velox	Golden Clone-B	Mean	Red Velox	Golden Clone-B	Mean	Red Velox	Golden Clone-B	Mean
G0: Control	0.893	0.959	0.927	0.881	0.972	0.928	0.897	0.963	0.931
G1: GA_{4+7}+ 6-BA @ 5.5 ppm	0.898	0.981	0.940	0.911	1.000	0.956	0.908	0.984	0.946
G2: GA_{4+7} + 6-BA @ 11 ppm	0.925	0.991	0.958	0.931	0.996	0.964	0.928	0.994	0.961
G3: GA_{4+7} + 6-BA @ 21 ppm	0.931	0.998	0.965	0.936	1.006	0.972	0.933	1.003	0.969
G4: Chlorogenic acid @ 88.5ppm	0.890	0.959	0.928	0.888	0.969	0.930	0.898	0.964	0.931
G5: Chlorogenic acid @ 177 ppm	0.894	0.961	0.930	0.899	0.969	0.935	0.899	0.965	0.931
G6: Chlorogenic acid @ 354 ppm	0.894	0.960	0.931	0.901	0.971	0.937	0.898	0.966	0.932
G7: GA_3 + 6-BA @ 5.5 ppm	0.887	0.978	0.933	0.907	0.992	0.950	0.897	0.981	0.939
G8: GA_3 + 6-BA @ 11 ppm	0.923	0.979	0.952	0.923	1.004	0.964	0.921	0.992	0.957
G9: GA_3 + 6-BA @ 21 ppm	0.941	0.997	0.969	0.939	1.002	0.958	0.920	0.999	0.961
Mean	0.908	0.976		0.912	0.988		0.910	0.982	
C.D.(< 0.05)	**C.D. (2022)**			**C.D. (2023)**			**Pooled**		
Russet management chemicals (G)	0.004			0.003			0.003		
Varieties (V)	0.002			0.001			0.001		
G x V	0.005			0.004			0.004		

Table 4: Effect of various russet management chemicals on fruit weight (g) of apple cvs. Red Velox and Golden Clone-B.

Varieties / Treatments	2022			2023			Pooled		
	Red Velox	Golden Clone-B	Mean	Red Velox	Golden Clone-B	Mean	Red Velox	Golden Clone-B	Mean
G0: Control	179.75	204.19	191.97	176.79	199.27	188.03	178.27	201.77	190.02
G1: GA_{4+7}+ 6-BA @ 5.5 ppm	195.12	211.15	203.13	189.46	206.24	197.85	192.38	208.75	200.56
G2: GA_{4+7} + 6-BA @ 11 ppm	201.24	217.44	209.34	197.55	213.25	205.40	199.39	215.36	207.37
G3: GA_{4+7} + 6-BA @ 21 ppm	204.87	223.51	214.29	205.32	220.46	212.89	205.04	222.12	213.58
G4: Chlorogenic acid @ 88.5ppm	180.58	204.12	192.35	176.73	200.43	188.58	178.61	202.25	190.43
G5: Chlorogenic acid @ 177 ppm	180.39	205.63	193.01	177.41	199.52	188.46	178.87	202.54	190.70
G6: Chlorogenic acid @ 354 ppm	181.56	204.86	193.21	178.44	200.51	189.47	179.95	202.77	191.36
G7: GA_3 + 6-BA @ 5.5 ppm	192.85	210.15	201.50	183.57	203.20	193.38	188.26	206.68	197.47
G8: GA_3 + 6-BA @ 11 ppm	198.74	213.64	206.19	193.78	209.21	201.49	196.23	211.49	203.86
G9: GA_3 + 6-BA @ 21 ppm	203.02	221.17	212.09	200.04	217.42	208.73	201.54	219.33	210.43
Mean	191.81	211.58		187.90	206.95		189.85	209.30	
C.D.(< 0.05)	**C.D. (2022)**			**C.D. (2023)**			**Pooled**		
Russet management chemicals (G)	1.783			2.405			2.001		
Varieties (V)	0.797			1.887			1.217		
G x V	2.522			2.678			3.850		

Table 5: Effect of various russet management chemicals on fruit firmness (kg/cm^2) of apple cvs. Red Velox and Golden Clone-B.

Varieties / Treatments	2022			2023			Pooled		
	Red Velox	Golden Clone-B	Mean	Red Velox	Golden Clone-B	Mean	Red Velox	Golden Clone-B	Mean
G0: Control	8.21	7.21	7.71	8.42	7.42	7.92	8.31	6.81	7.56
G1: GA_{4+7}+ 6-BA @ 5.5 ppm	7.93	6.92	7.42	8.14	7.12	7.63	8.01	7.01	7.51
G2: GA_{4+7} + 6-BA @ 11 ppm	7.73	6.71	7.22	8.00	6.95	7.48	7.82	6.81	7.31
G3: GA_{4+7} + 6-BA @ 21 ppm	7.53	6.52	7.02	7.72	6.72	7.22	7.61	6.6	7.11
G4: Chlorogenic acid @ 88.5ppm	8.14	7.14	7.64	8.35	7.32	7.83	8.21	7.21	7.71
G5: Chlorogenic acid @ 177 ppm	7.53	6.52	7.02	7.72	6.72	7.22	7.61	6.61	7.11
G6: Chlorogenic acid @ 354 ppm	8.33	7.32	7.82	8.52	7.52	8.02	8.41	7.41	7.91
G7: GA_3 + 6-BA @ 5.5 ppm	8.04	7.13	7.58	8.27	7.22	7.74	8.11	7.16	7.64
G8: GA_3 + 6-BA @ 11 ppm	7.84	6.83	7.33	8.02	7.02	7.52	7.91	6.91	7.41
G9: GA_3 + 6-BA @ 21 ppm	7.62	6.63	7.12	7.81	6.83	7.32	7.71	6.71	7.21
Mean	7.89	6.89		8.09	7.08		7.97	6.92	
C.D.(< 0.05)	**C.D. (2022)**			**C.D. (2023)**			**Pooled**		
Russet management chemicals (G)	0.007			0.007			0.006		
Varieties (V)	0.003			0.003			0.003		
G x V	0.009			0.010			0.009		

RESULTS AND DISCUSSION

Russet represents the incorporation of suberin (which has suberized secondary skin which is linked to a triterpenoid *i.e.,* betulinic acid) (Falginella *et al*., 2021) into the cell walls of phellem, which are formed by the division of phellogen, which inturn forms the source of the periderm. It starts with the formation of microcracks in the cuticle which if shallow get filled up by the wax, or otherwise travel through its thickness and affect the osmotic potential of the cuticle. The cracks that get deep enter into the epidermis and begin to form in the hypodermis. Subsequently, the epidermis dries away exposing the periderm at the fruit surface. This series of events is known as russeting and is highly susceptible during the early stages of fruit development (Khanal *et al.,* 2020). Whereas exposure to longer periods of surface wetness/high humidity amounts to russet in the susceptible cultivars, the application of GA_{4+7} reduces the incidence of it (Ginzberg and Stern 2016).

Firstly, it is responsible for reducing the size of epidermal cells and making them more uniform (Curry, 2012). The skin that contains smaller epidermal cells is mechanically more sound, which provides structural support to the cuticle. This also decreases the stress concentrations which otherwise result in microcracking. Also, GA has been known to reduce moisture-induced microcracking in russet-susceptible "Golden Delicious" varieties. However, its spray doesn't have an impact on the cuticle mass, wax content or mechanical strength of the isolated apple fruit cuticle (Knoche *et al*., 2011). In some sprays, it has been seen that often GA is sprayed in combination with cytokinin, benzyl adenine (BA) which is believed to be responsible for offsetting certain adverse effects that GA may have on flowering (McLaughlin and Greene 1984).

Chlorogenic acid, meanwhile is known to affect the enzyme activities and regulate the expression of the phenylpropanoid pathway. Similarly, it has been seen to affect the secondary metabolism of apple peels which is related with the russet formation (Wang *et al*., 2014). As reported by Wang *et al*. (2014), chlorogenic acid increases the levels of chlorogenic acid and total flavonoids, but inhibits the lignin accumulation in the apple peels. This suggests that its treatment results in an up-regulation of the whole metabolism of phenylpropanoids, but results in the down-regulation of lignin biosynthesis.

A significant effect of the russet management chemicals was seen on the fruit length, fruit diameter, l/d ratio and fruit weight (Tables 2-5). A significant impact of the russet management chemicals was found on the fruit length (mm) as well and the varietal impact was found to be significant. Maximum fruit length (75.94 mm) was obtained in G3: GA_{4+7} + 6-BA @ 21 ppm which was followed by G9: GA_3+6-BA @ 21 ppm (74.52 mm). Minimum fruit length (67.64 mm) was obtained in G0: Control during the years 2022 and 2023 respectively. It was found to be statistically at par with G4: Chlorogenic acid @ 88.5 ppm (67.67 mm), G5: Chlorogenic acid @ 177 ppm (67.69 mm) and G6: Chlorogenic acid @ 354 ppm (67.76 mm) in both the years. With respect to the varietal impact which was also found to be significant, maximum fruit length was recorded in Golden Clone-B (75.13 mm) while as minimum fruit length was recorded in Red Velox (66.71 mm). Similarly, maximum fruit diameter (78.36 mm) was obtained in G3: GA_{4+7} + 6-BA @ 21 ppm which was followed by G9: GA_3+6-BA @ 21 ppm (77.53 mm). Minimum fruit diameter (72.25 mm) was obtained in G0: Control during the years 2022 and 2023 respectively. It was found to be statistically at par with G4: Chlorogenic acid @ 88.5 ppm (72.25mm), G5: Chlorogenic acid @ 177 ppm (72.52 mm) and G6: Chlorogenic acid @ 354 ppm (72.72mm) in both the years. With respect to the varietal impact which was also found to be significant, maximum fruit diameter was recorded in Golden Clone-B (76.47 mm) while as minimum fruit diameter was recorded in Red Velox (73.25 mm).

Similarly, maximum fruit L/D ratio (0.969) was obtained in G3: GA_{4+7} + 6-BA @ 21 ppm which was followed by G9: GA_3+6-BA @ 21 ppm (0.961).

Minimum fruit L/D ratio (0.931) was obtained in G0: Control during the years 2022 and 2023 respectively. It was found to be statistically at par with G4: Chlorogenic acid @ 88.5 ppm (0.931), G5: Chlorogenic acid @ 177 ppm (0.931) and G6: Chlorogenic acid @ 354 ppm (0.932) in both the years. With respect to the varietal impact which was also found to be significant, maximum fruit L/D ratio was recorded in Golden Clone-B (0.982) while as minimum fruit L/D ratio was recorded in Red Velox (0.910). With respect to the fruit weight, maximum fruit weight ratio (213.58 gm) was obtained in G3: GA_{4+7} + 6-BA @ 21 ppm which was followed by G9: GA_3+6-BA @ 21 ppm (210.43 gm). Minimum fruit weight (190.02 gm) was obtained in G0: Control during the years 2022 and 2023 respectively. It was found to be statistically at par with G4: Chlorogenic acid @ 88.5 ppm (190.43 gm), G5: Chlorogenic acid @ 177 ppm (190.70 gm) and G6: Chlorogenic acid @ 354 ppm (191.36 gm) in both the years.With respect to the varietal impact which was also found to be significant, maximum fruit weight was recorded in Golden Clone-B (209.30 gm) while as minimum fruit weight was recorded in Red Velox (189.85 gm). Increase in fruit length, fruit diameter, l/d ratio and fruit weight can be attributed to the application of gibberellin. This is because, $GA_{4+7,}$ increases the fruit size and results in changing the shape of the fruit. The length/width ratio gets increased particularly in the calyx region, due to which the fruit gets extended calyx lobes. On the other hand, if BA is applied alone, it causes an increase in russeting for which there is no specified reason. Also, as reported by (Greene, 2012), the amount of russet reduction due to GA_{4+7} + 6-BA decreases the russet only to the same amount as that of GA_{4+7} itself (Greene, 2012). Similar results were suggested by Sharma *et al*. (2018) in which the authors concluded that GA_{4+7} + 6-BA when applied thrice is responsible not only for increasing the fruit shape index (L/D ratio) but is also effective in reducing the russet formation. Kuchay *et al*. (2021) also showed that the increase in fruit length, fruit diameter and fruit weight with the application of Applin (combination of gibberellin and cytokinin). Benzyladenine, which is a cytokinin, also increases fruit weight and size independently by increasing the cell division. These results were in coordination with Link (2000) who found that BA causes an increase in the fruit size even in the absence of fruit thinning. Liu *et al*. (2022), who carried out a study on self-pollinated "Hanfu" apples, found that the external application of gibberellic acid not only increased the fruit weight but also lowered the proportion of asymmetrical fruit, at the same time increasing the wax layer thickness and reducing the fruit water loss rate. Also, a reason for the difference in Golden Clone-B having more fruit length, diameter and l/d ratio than Red Velox would be because of these being their varietal characters. Similar results were recorded by Karsi and Aslantas (2016).

A significant impact of the russet management chemicals was found on fruit firmness as well as the varietal impact was found to be significant. Maximum fruit firmness (7.11 kg/cm^2) was obtained in G3: GA_{4+7} + 6-BA @ 21 ppm which was followed by G9: GA_3+6-BA @ 21 ppm (7.21 kg/cm^2). Minimum fruit firmness (7.56 kg/cm^2) was obtained in G0: Control during the years 2022 and 2023 respectively. It was found to be statistically at par with G4: Chlorogenic acid @ 88.5 ppm (7.71 kg/cm^2), G5: Chlorogenic acid @ 177 ppm (7.11 kg/cm^2) and G6: Chlorogenic acid @ 354 ppm (7.91 kg/cm^2) in both the years. With respect to the varietal impact which was also found to be significant, maximum fruit firmness was recorded in Red Velox (7.97 kg/cm^2) while as minimum fruit firmness was recorded in Golden Clone-B (6.92 kg/cm^2).

The reason for the highest fruit firmness in G6: Chlorogenic acid @ 354 ppm and G0: Control, would have been probably because of the reason that the water vapour permeance of the russeted area/skin of the fruit is higher than that of the non russeted area. This higher water vapour permeance results in increase in the water loss from the apple skin resulting in a higher mass loss and a more shrivelled appearance (Winkler *et al.,* 2022). This in turn means, that more the russeted surface of the fruit, more will be the water loss, and hence, more will be the firmness and less will be the fruit weight (Marchioretto *et al*., 2018). Considering the varietal impact of fruit firmness, maximum fruit firmness was recorded for Red Velox while as minimum fruit firmness was recorded for Golden Clone-B. This might be because of Red Velox being stronger and more firm than Golden Clone-B as its varietal character. Another factor which contributes to the fruit firmness is calcium pectate which maintains the membrane integrity of the cell walls and it has also a role in the binding the complex polysaccharides and proteins which in turn form the cell wall (Sadiq *et al*., 2023). It was found to be maximum in G6: Chlorogenic acid @ 354 ppm and G0: Control. Also, as much as the size of the cells increases, there is a decrease in the firmness as well. This is mostly brought about by an increase in the size of the vacuole during the cell enlargement phase which occupies a large portion of the cell space (Din, 2019). Marchioretto *et al*. (2018) observed that flesh firmness is negatively correlated with mean fruit weight. This might be the reason that minimum fruit firmness was found in G0: Control while maximum fruit firmness was found in G6: Chlorogenic acid. Similar results were recorded by Jemric *et al*. (2003); Ali *et al*. (2023).

CONCLUSION

From the present research findings, it can be concluded that treatment G3 *i.e.,* GA_{4+7} + 6-BA applied at a concentration of 21 ppm at 15% petal fall (15 DAFB) and at 30 DAFB proved to be the best for controlling russet in both varieties, *i.e.*, Red Velox and Golden Clone-B apart from improving the physical attributes of the fruit, *i.e.*, fruit length, fruit diameter, L/D ratio, fruit weight and fruit firmness.

FUTURE SCOPE

The study reveals that the spray of the russet

management chemicals can be used as a recommendation to the farmers to improve the fruit physical characteristics, at the same time improving the fruit finish and its typiness.

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