



Effects of GA₄₊₇+BA and CPPU on russetting and fruit quality in apple (*Malus × domestica*)

SAJAN SHARMA*, N SHARMA, D P SHARMA and NEENA CHAUHAN

Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh 173 230, India

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ABSTRACT

Apple (*Malus × domestica* Borkh.) production is now being affected by the changing climate which has led to reduction in quality thereby, these fruits command low returns in the market. As it is the most important temperate fruit crop of Himachal Pradesh, it still requires a great improvisation in quality. The present study was conducted in 2017-18 with various plant growth regulator practices on eight year old apple trees cv. 'Scarlet Spur II'. Application of GA₄₊₇+BA at 2.5 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 petal fall stage recorded higher fruit diameter (70.89 mm), fruit weight (155.56 g), fruit volume (102.94 cc), TSS (10.72 °Brix), total sugars (9.11%) and reducing sugars (4.87%).

Key words: Apple, CPPU, GA₄₊₇+BA, Russet, Quality

Apple (*Malus × domestica* Borkh.) is one of the important temperate fruit crops of world. It is rich in phytonutrients, antioxidants, vitamin-C and β-carotene. Due to quality fruit production, Himachal Pradesh has been recognised as “Apple State of India”. In the state, apple is grown mainly in the districts of Shimla, Kinnaur, Kullu, Mandi, Chamba, some parts of Sirmaur and Lahaul-Spiti in an area of about 111896 ha with a production of 468134 MT and productivity of 4.18 MT/ha (Anonymous 2017). “Scarlet Spur II” is a new variety under Red Delicious group. Originally, its parent variety Scarlet Spur was developed as a sport of Oregon Spur in Washington and Scarlet Spurt II is a mutant of Scarlet Spur. It has all the superior characteristics of Red Delicious and Scarlet Spur with added advantage of earliness of fruit maturity and higher level of antioxidant. However, Scarlet Spur II is highly susceptible to ‘Russetting’ which reduces its market value. Russetting on apples is a particular type of skin, slightly rough, usually with a greenish-brown to yellowish-brown colour. It may appear on only a small portion of each fruit, or may cover its surface. In functional terms, russetting restores control of water loss through the skin by the formation of a waterproofing periderm just beneath the microcracked primary fruit skin.

Plant growth regulators have become the major contributors in the improvement of apple production owing

to their desirable effects on shape and quality of fruit. Many commercial formulations of gibberellins and cytokinin such as GA₄₊₇ and BA have been reported in developed countries to increase the size and improve shape of apple fruit through elongation and development of more prominent calyx lobes (Greene 1984). A synthetic cytokinin, CPPU (N-(2-chloro-4-pyridyl)-N-phenylurea) has been found effective in stimulating fruit growth in apples, grapes and cranberry (Devlin and Kiszanski 1988). Keeping this in view, the present investigation was carried out to evaluate the influence of plant growth regulators on russet control in apple cv. Scarlet Spur II.

MATERIALS AND METHODS

The present investigation was carried out at the experimental orchard of Regional Horticultural Research and Training Station, Mashobra, Dr Y S Parmar University of Horticulture and Forestry, Nauni-Solan, Himachal Pradesh during 2017-18. Thirty trees apple cultivar Scarlet Spur II/MM 106 rootstocks which were eight-year old trees having uniform vigour and size, planted at a spacing of 2.5 m × 2.5 m were selected for the study. All the trees were maintained under uniform cultural practices during the course of investigation.

Experimental trees were subjected to 10 treatments, viz. T₁: GA₄₊₇+BA at 1 ppm (2 sprays: PF+ 10 days later), T₂: GA₄₊₇+BA at 1 ppm (3 sprays: PF+ later at 10 days intervals), T₃: GA₄₊₇+BA at 2.5 ppm (2 sprays), T₄: GA₄₊₇+BA at 2.5 ppm (3 sprays), T₅: GA₄₊₇+BA at 5ppm (2 sprays), T₆: GA₄₊₇+BA at 5ppm (3 sprays), T₇: CPPU at 2.5 ppm (single spray at PF), T₈: CPPU at 5 ppm (spray

*Corresponding author e-mail: bhardwajsajan2534@gmail.com

Table 1 Point scale for Russet formation on Apple fruits.

Range	Ranking
0-10	1
10-20	2
20-30	3
30-40	4
40-50	5
50-60	6
60-70	7
70-80	8
80-90	9
90-100	10

at PF), T₉: CPPU at 10 ppm (spray at PF), and T₁₀: control (no spray). 1 litre of spray/tree was applied with the help of foot-sprayer.

Russet formation on the skin of five randomly selected fruits from each replication was examined visually and russet development on the fruits was determined as per 10 point scale basis.

After harvesting the fruits, both physical and biochemical traits of fruit quality were evaluated. For fruit size five randomly selected fruits from each experimental tree were recorded in terms of length and breadth with the help of digital Vernier Calliper (Mitutoyo, Japan). The average values of fruit length and breadth were expressed in millimetre (mm). Fruit shape index was calculated as the ratio between fruit length and fruit diameter (L/D ratio) (Milosevic *et al.* 2014). For fruit weight, selected fruits taken for recording the fruit size data were weighed on electronic top pan balance and the average fruit weight was expressed in gram per fruit (g/fruit). Volume of fruits was measured by water displacement method and expressed in cubic centimetre per fruit. Fruits were observed visually for colour expression with the help of colour chart of Royal

Horticultural Society, London (Wilson, 1941). The fruit firmness was determined by digital pressure tester (FHP-802) which recorded the pressure necessary for the plunger to penetrate the peeled flesh of apple fruits. Five fruits were tested from each tree and results were expressed in kg/cm². Bio-chemical analysis of fruits for evaluation of quality was done as per standard procedure described by AOAC (1980).

The two years data were pooled and statistically analyzed with the standard procedure as suggested by Gomez and Gomez (1984). The level of significance for different variables was tested at 5% value of significance using computer software OP Stat.

RESULTS AND DISCUSSION

Russet formation: In the study, all the treatments with GA₄₊₇ + BA significantly decreased the incidence of russetting on fruit surface, however, least russet formation (1.17 points) occurred in the treatments with three applications of GA₄₊₇+BA at 2.5 ppm (T₄) and GA₄₊₇+BA at 5 ppm (T₆). These results are in conformity with the findings (Edna *et al.* 2010, Mehraj *et al.* 2017) that GA₄₊₇ reduced the fruit russetting on apples. Single spray of CPPU (T₈) also results in lesser russet formation (1.33 points) on fruits. This result is in agreement with the findings of Sharma and Belsare (2011) who observed that forchlorfenuron (CPPU) improved fruit finish in pomegranate. Significantly higher russet formation occurred on fruits under control (6.00 points) in comparison to all other treatments.

Fruit quality: Interpretation of data (Table 2 and 3) revealed that pre-harvest application of GA₄₊₇+BA and CPPU had a significant effect on all the fruit quality parameters of 'Scarlet Spur II' apple during the course of study.

Physical parameters: Pooled data among different treatments revealed that GA₄₊₇+BA (T₆) recorded maximum fruit length (68.93 mm), fruit shape index (1.07) whereas fruit diameter (70.89 mm), fruit weight (155.56 g) and fruit

Table 2 Effect of GA₄₊₇ +BA and CPPU on russet formation and fruit quality in apple cv. Scarlet Spur II

Treatment	Russet formation (10 point scale basis)	Fruit size		Fruit shape index (L/D ratio)	Fruit weight (g)	Fruit volume (cc)	Fruit firmness
		Fruit length	Fruit breadth				
T ₁	2.67	64.12	62.17	1.03	140.47	158.03	13.4
T ₂	2.14	64.85	62.22	1.04	141.51	161.69	13.3
T ₃	1.67	66.33	63.26	1.05	143.54	165.38	13.6
T ₄	1.17	67.66	64.02	1.06	145.77	167.92	13.6
T ₅	1.33	68.21	64.43	1.06	144.06	166.59	13.8
T ₆	1.17	68.93	64.37	1.07	145.23	166.65	13.8
T ₇	2.33	63.87	68.04	0.94	149.17	176.50	14.1
T ₈	1.33	65.05	68.90	0.94	152.78	178.85	14.1
T ₉	2.33	66.16	70.89	0.93	155.56	182.07	14.0
T ₁₀	6.00	61.12	62.95	0.97	126.70	143.31	13.0
CD _{0.05}	0.81	1.06	1.24	0.03	2.82	2.49	0.3

Table 3 Effect of GA₄₊₇+BA and CPPU on chemical fruit properties in apple cv. Scarlet Spur II

Treatment	TSS (°Brix)	Acidity (%)	Total sugars (%)	Reducing sugars (%)	Ascorbic acid (mg/100g)
T ₁	10.08	0.85	8.31	5.08	7.19
T ₂	10.16	0.82	8.38	5.12	7.26
T ₃	10.28	0.77	8.48	5.21	7.36
T ₄	10.40	0.75	8.58	5.25	7.25
T ₅	10.33	0.81	8.52	5.22	7.38
T ₆	10.38	0.80	8.56	5.24	7.31
T ₇	10.54	0.71	8.95	5.48	7.47
T ₈	10.63	0.68	9.04	5.53	7.60
T ₉	10.72	0.64	9.11	5.57	7.56
T ₁₀	9.76	0.93	7.95	4.87	7.07
CD _{0.05}	0.05	0.02	0.04	0.04	0.07

volume (182.07 cc) were maximum in CPPU (T₉). Fruit firmness was maximum (14.1 kg/cm²) in CPPU (T₇) and (T₈). Minimum fruit diameter (62.17 mm) was recorded in GA₄₊₇+BA (T₁), whereas minimum fruit length (61.12 mm), fruit weight (126.70 g), fruit volume (143.31 cc) and fruit firmness (14.0 kg/cm²) was recorded under control (T₁₀). Fruit shape index (0.93) recorded minimum in CPPU (T₉).

In the present investigation, fruit size, weight and volume were markedly increased by the treatments of CPPU applied at 10 ppm and GA₄₊₇+BA applied at 5 ppm. CPPU has been shown to expand fruit size through cell expansion and division (Williamson and NeSmith, 2007). Patterson *et al.* (1993) reported that CPPU stimulated cell expansion in the pericarp sufficiently to explain the measured increase in total fruit volume. The present results concerning the effect of CPPU on the fruit dimensions are in accordance with those obtained by Sharma and Belsare (2011) in pomegranate and Hota *et al.* (2017) in apricot. GA₄₊₇+BA treatments affected fruit shape by increasing length: diameter ratio. These results confirm the earlier findings that combined application of GA₄₊₇+BA altered fruit shape by stimulating elongation and development of the calyx lobes in apple (Koukourikou-Petridou *et al.* 2007, Watanabe *et al.* 2008). The increase in fruit firmness with different CPPU treatments could be due to the delaying effect of exogenous cytokinin on the senescence process (Arteca, 1990). Plant growth regulators like CPPU may maintain fruit firmness by moderating various physiological activities related to the softening of fruits such as preventing the synthesis of hydrolytic enzymes like cellulase which decompose the cell wall (Davies 1995). Earlier, increased fruit firmness following the application of CPPU has been reported in apple (Curry and Greene, 1993) and sapota (Barkule *et al.* 2018).

Biochemical parameters: Pooled data among different treatments revealed that CPPU (T₉) recorded maximum

fruit TSS (10.72 °Brix), total sugars (9.11 %), reducing sugars (5.57 %) and minimum acidity (0.64%). Maximum ascorbic acid content (7.60 mg/100 g of fruit) was recorded in CPPU (T₈). Under control (T₁₀), there was maximum acidity (0.93%) and minimum value of fruit TSS (9.76 °Brix), total sugars (7.95%), reducing sugars (4.87%) and ascorbic acid content (7.07 mg/100g of fruit).

The present results confirm the earlier findings of Kim *et al.* (2006) that foliar application of Sitofex (forchlorfenuron) increased the fruit TSS content and decreased the level of acidity in kiwifruit. This increase in TSS content with application of CPPU may be attributed to the advanced ripening induced by CPPU, probably due to more ethylene production as reported by Lotter (1991) in kiwifruit. The higher TSS content might be attributed to a higher rate of photosynthate assimilation, as cytokinins are known to influence mobilization of metabolites and nutrients to the cytokinin treated portion of the plant (Leopold and Kriedemann 1975). These results are in accordance with that of Barkule *et al.* (2018) who observed higher TSS content in sapota cv. Kalipati treated with 6 ppm CPPU. It can be inferred that, foliar application of plant growth regulators significantly affected accumulation of total sugars in fruits during the course of study. The highest total sugar content was recorded under the treatment of CPPU when applied at 10 ppm at petal fall stage. Other treatments of CPPU and 'GA₄₊₇+BA' also increased total sugar contents in fruits significantly. The increase in fruit sugar contents with CPPU application might be attributed to early ripening induced by CPPU due to more ethylene production (Costa *et al.* 1997). These results are consistent with earlier findings that CPPU enhanced sugar accumulation in apple (Said 2002), Japanese pear (Kano 2003) and pomegranate (Supe and Marshal 2008, Sharma and Belsare 2011). Fang-XueZhi *et al.* (2006) reported that CPPU applied at 5 ppm increased the sucrose, glucose, fructose contents in kiwifruit. Plant growth regulators had a significant influence on ascorbic acid content during the course of study. The maximum ascorbic acid content was recorded under treatment of CPPU when applied at 5-10 ppm which was significantly higher than control. Similarly, pre-harvest sprays of CPPU significantly improved ascorbic acid contents in kiwifruit (Kim *et al.* 2006) and sapota (Barkule *et al.* 2018).

On the basis of results obtained in the present study, it is inferred that foliar applications of GA₄₊₇+BA at 2.5 and 5 ppm when given at petal fall and two times later at 10 days interval can be useful for the control of russet formation, increasing fruit shape index (L/D ratio), as well as increasing fruit TSS and sugar contents in apple cv. Scarlet Spur II. However, CPPU at 10 ppm when applied at petal fall stage resulted in a positive increase in fruit size, fruit weight and fruit quality. It also significantly increased the fruit firmness, which may prolong storage life of fruits. From this study, it is observed that combination of GA₄₊₇+BA at higher concentration plays an important role in controlling the russet formation as well as improving the fruit shape so in order to minimize the cost of cultivation the lower

doses of GA₄₊₇+BA can be used in future by increasing the number of applications.

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