

Paclobutrazol and Summer Pruning Influences Fruit Quality of Red Delicious Apple

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ABSTRACT

Paclobutrazol and summer pruning can restrict vegetative growth and improve productivity and fruit quality in apple. The present experiment was carried out during two successive seasons on Red Delicious cultivar of apple. The study was carried out in a randomized block design with sixteen treatments and three replications. The trees were > 15 years old grown in experimental orchard of Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, Jammu and Kashmir, spaced at 5.49 × 5.49 metre distance. The study was aimed to show the effect of different concentrations of paclobutrazol along with different levels of pruning on fruit quality. With increase in paclobutrazol concentration and pruning levels, an increase in TSS, TSS/acid ratio, anthocyanin, sugars, fruit calcium and improvement in fruit grade was observed with decrease in fruit acidity.

Highlights

- 750 ppm Paclobutrazol 4 weeks after full bloom + Summer Pruning I eight weeks after full bloom + Summer Pruning II 12 weeks after full bloom was found to be effective for maximum TSS, sugars, anthocyanin, fruit calcium and better fruit grades.
- 750 ppm Paclobutrazol 4 weeks after full bloom + Summer Pruning I eight weeks after full bloom + Summer Pruning II 12 weeks after full bloom was found to be effective in relation to fruit acidity.

Keywords: Anthocyanin, summer pruning, calcium, paclobutrazol, apple, sugars

Apple (*Malus domestica* Borkh) is a very important temperate fruit and its cultivation sites fall geographically between 25-52° latitude. 17,26,834 M.T. over an acreage of 1,62,971 ha. The apple productivity depends on canopy management, scion and rootstock behavior, fertilization, disease control measures and nutrification. Among all, canopy management techniques play very vital role in production function. Paclobutrazol and summer pruning can restrict vegetative growth, improve productivity and fruit quality in apple. The plant

growth regulator, [(2RS,3RS)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl)-pentan-3-ol] (paclobutrazol; PP333), is a triazole derivative and has been shown to inhibit shoot growth on apple trees (Steffens *et al.*, 1985). The ancymidol blocks the oxidative steps with high specificity leading from ent-kaurene to ent-kaurenoic acid in the pathway of GA' biosynthesis. The same oxidative steps are thought to be inhibited by the active triazol derivatives (Graebe, 1982). Paclobutrazol has been reported to inhibit GA biosynthesis in



plants by inhibiting kaurene oxidase, a Cyt P-450 oxidase, thus blocking the oxidation of kaurene to kaurenoic acid (Dalziel and Lawrence, 1984). The inhibitory activity of paclobutrazol can be reversed by GA (Steffens *et al.*, 1985). Paclobutrazol was also shown to shift assimilate partitioning from leaves to roots, increase carbohydrates in all parts of apple seedlings, increase chlorophyll content, soluble protein and mineral element concentration in leaf tissue, increase root respiration and reduce water use (Wang and Steffens, 1985). Summer pruning has been reported to reduce vegetative growth, improve canopy light penetration, re-exposes spur leaves and fruits of the interior canopy of apple trees, enhance fruit quality, concentrate fruit maturation and increase the number of flower buds (Rom and Ferree, 1984). The relationship between vegetative and reproductive growth influences the amount and quality of fruits produced by an apple tree. The woody tissue of the tree competes with the fruits for the products of leaves and excessive vegetative growth is made at the expense of the fruits. Excessive tree vigour can reduce flower bud formation, fruit set and result in reduced fruit quality. Pruning intensity, time and method have varying effects on apple quality at harvest and during storage (Wertheim, 2005). The objective of this study was to test the effect of paclobutrazol and summer pruning on quality of apple (*Malus × domestica* Borkh).

MATERIAL METHODS

The main trial was established in the experimental orchard of Division of Fruit Science, SKUAST-K, Shalimar during the years 2011 and 2012. Forty-eight trees, matched for uniform growth and appearance, were selected from the site for the study. Paclobutrazol was used as a source. The quantity was calculated on the basis of active ingredient and spray material required was worked out on the basis of tree age and size. Three concentrations of paclobutrazol 4 weeks after full bloom (250ppm, 500ppm and 750ppm) each with control were used and control plants were sprayed with water only. Two intensities of summer pruning were performed: summer pruning I (thinning out water sprouts and unwanted branches eight weeks after full bloom) and summer pruning II (heading back from upper, middle and lower canopy area to the extent of 25%

only of current season's growth 12 weeks after full bloom). The experiment was laid in a completely Randomized Block Design. The total soluble solids content was determined from fresh strained, thoroughly stirred juice of fruits on each sampling date with the help of a digital hand refractometer and the readings were expressed as percent soluble solids (AOAC, 1980). The acidity was determined by diluting the known volume of apple juice and titrating the same against 1N sodium hydroxide solution using phenolphthalein as an indicator. It was expressed in terms of per cent malic acid. Total soluble solids/acid ratio was obtained by dividing the value of total soluble solids of fruit sample by the acidity value of the same sample. Total anthocyanin was extracted by using 95 per cent ethanol-1.5 N HCl (85:15) and estimations were made by calorimetric procedure as suggested by Ranganna (1986). The concentration of the reducing sugars was determined by Fehlings solution method of Lane and Eynon (1923) using methylene blue as an indicator. Total sugar content was estimated after acid hydrolysis (AOAC, 1990). The amount of non-reducing sugars was estimated by subtracting the value obtained for reducing sugars from total sugars and multiplying the same by a factor of 0.95. Fruit calcium content on the date of harvesting of fruits was determined with flame photometry (Jackson, 1975) and the results were expressed in parts per million (ppm) on dry weight basis.

At the time of harvesting, the fruits were graded on the basis of size, colour and following grades were allotted: A -Super large: Size of fruit 70 mm and above with colour development >65%, B -Super medium: Size of fruit 60-69 mm with colour development 65% and C -Super small: Size of fruit <60 mm with colour development <65%. Two years data was recorded, pooled and analyzed using data analyzing statistical software. The final data is being presented in the table for interpretation of the results.

RESULTS AND DISCUSSION

Total soluble solids (TSS) and sugars

Highest total soluble solids (14.43 °B and 14.51 °B) were recorded in treatment 750 ppm PP333 + SP I + SP II which was significantly superior to all other treatments. The trees under control recorded lowest



Table 1: Effect of paclobutrazol and summer pruning on chemical characteristics of apple cv. Red Delicious

Treatments	TSS (°Brix)			Acidity (%)		
	2011	2012	Pooled	2011	2012	Pooled
T ₀ Control	11.85	11.86	11.85	0.39	0.40	0.39
T ₁ 250 ppm PP333	13.21	12.83	13.02	0.36	0.35	0.35
T ₂ 500 ppm PP333	13.28	12.60	12.94	0.35	0.34	0.34
T ₃ 750 ppm PP333	13.31	13.40	13.35	0.33	0.32	0.32
T ₄ SP I	13.27	13.40	13.33	0.36	0.35	0.35
T ₅ 250 ppm PP333+ SP I	13.39	13.34	13.36	0.32	0.31	0.31
T ₆ 500 ppm PP333 + SP I	13.46	13.49	13.47	0.30	0.28	0.29
T ₇ 750 ppm PP333 + SP I	13.53	13.66	13.59	0.28	0.26	0.27
T ₈ SP II	13.34	13.42	13.38	0.34	0.32	0.33
T ₉ 250 ppm PP333 + SP II	13.44	13.52	13.48	0.31	0.30	0.30
T ₁₀ 500 ppm PP333 + SP II	13.49	13.65	13.57	0.29	0.27	0.28
T ₁₁ 750 ppm PP333 + SP II	13.75	13.78	13.76	0.27	0.25	0.26
T ₁₂ SP I + SP II	13.75	13.94	13.84	0.30	0.28	0.29
T ₁₃ 250 ppm PP333 + SP I + SP II	13.93	14.18	14.05	0.27	0.25	0.26
T ₁₄ 500 ppm PP333 + SP I + SP II	14.25	14.32	14.28	0.26	0.23	0.24
T ₁₅ 750 ppm PP333 + SP I + SP II	14.43	14.51	14.47	0.24	0.22	0.23
CD (p≤0.05)	0.17	0.13	0.15	0.02	0.01	0.01

SP I = summer pruning I, SP II = summer pruning II

Table 2: Effect of paclobutrazol and summer pruning on chemical characteristics of apple cv. Red Delicious

Treatments	TSS/acid ratio			Anthocyanin (mg/100g)		
	2011	2012	Pooled	2011	2012	Pooled
T ₀ Control	30.38	29.65	30.01	6.19	6.23	6.21
T ₁ 250 ppm PP333	36.69	36.66	36.67	8.41	8.76	8.58
T ₂ 500 ppm PP333	37.94	37.06	37.50	8.47	8.87	8.67
T ₃ 750 ppm PP333	40.33	41.88	41.10	8.55	9.03	8.79
T ₄ SP I	36.86	38.29	37.57	8.45	8.84	8.64
T ₅ 250 ppm PP333+ SP I	41.84	43.03	42.43	8.12	9.15	8.63
T ₆ 500 ppm PP333 + SP I	44.87	48.18	46.52	8.81	9.33	9.07
T ₇ 750 ppm PP333 + SP I	48.32	52.54	50.43	9.03	9.54	9.28
T ₈ SP II	39.24	41.94	40.59	8.52	8.97	8.74
T ₉ 250 ppm PP333 + SP II	43.35	45.07	44.21	8.73	9.24	8.98
T ₁₀ 500 ppm PP333 + SP II	46.52	50.56	48.54	8.92	9.43	9.17
T ₁₁ 750 ppm PP333 + SP II	50.93	55.12	53.02	9.11	9.61	9.36
T ₁₂ SP I + SP II	45.83	49.79	47.81	8.86	9.38	9.12
T ₁₃ 250 ppm PP333 + SP I + SP II	51.59	56.72	54.15	9.19	9.75	9.47
T ₁₄ 500 ppm PP333 + SP I + SP II	54.81	62.26	58.53	9.30	9.87	9.58
T ₁₅ 750 ppm PP333 + SP I + SP II	60.13	65.95	63.04	9.42	10.03	9.72
CD (p≤0.05)	2.23	2.21	2.22	0.10	0.06	0.08

SP I = summer pruning I, SP II = summer pruning II

**Table 3 :** Effect of paclobutrazol and summer pruning on chemical characteristics of apple cv. Red Delicious

Treatments	Total sugars (%)			Reducing sugars (%)		
	2011	2012	Pooled	2011	2012	Pooled
T ₀ Control	8.60	8.59	8.59	6.41	6.39	6.40
T ₁ 250 ppm PP333	9.42	9.67	9.54	7.32	7.51	7.41
T ₂ 500 ppm PP333	9.48	9.82	9.65	7.40	7.72	7.56
T ₃ 750 ppm PP333	9.57	9.94	9.75	7.48	7.81	7.64
T ₄ SP I	9.46	9.73	9.59	7.37	7.68	7.52
T ₅ 250 ppm PP333+ SP I	9.65	10.07	9.86	7.59	7.89	7.74
T ₆ 500 ppm PP333 + SP I	9.81	10.36	10.08	7.76	7.97	7.86
T ₇ 750 ppm PP333 + SP I	10.14	10.43	10.28	7.98	8.09	8.03
T ₈ SP II	9.55	9.91	9.73	7.46	7.76	7.61
T ₉ 250 ppm PP333 + SP II	9.72	10.21	9.96	7.68	7.93	7.80
T ₁₀ 500 ppm PP333 + SP II	10.06	10.39	10.22	7.91	8.02	7.96
T ₁₁ 750 ppm PP333 + SP II	10.19	10.47	10.33	8.04	8.14	8.09
T ₁₂ SP I + SP II	10.03	10.41	10.22	7.87	7.98	7.92
T ₁₃ 250 ppm PP333 + SP I + SP II	10.28	10.52	10.4	8.09	8.27	8.18
T ₁₄ 500 ppm PP333 + SP I + SP II	10.51	10.71	10.61	8.26	8.32	8.29
T ₁₅ 750 ppm PP333 + SP I + SP II	10.72	10.88	10.80	8.37	8.39	8.38
CD (p<0.05)	0.10	0.13	0.12	0.07	0.10	0.09

SP I = summer pruning I, SP II = summer pruning II

Table 4 : Effect of paclobutrazol and summer pruning on chemical characteristics of apple cv. Red Delicious

Treatments	Non-reducing sugars (%)			Fruit calcium (ppm)		
	2011	2012	Pooled	2011	2012	Pooled
T ₀ Control	2.19	2.20	2.19	230	220	220
T ₁ 250 ppm PP333	2.10	2.16	2.13	250	260	250
T ₂ 500 ppm PP333	2.08	2.10	2.09	260	280	270
T ₃ 750 ppm PP333	2.09	2.13	2.11	280	290	280
T ₄ SP I	2.09	2.05	2.07	240	260	250
T ₅ 250 ppm PP333+ SP I	2.06	2.18	2.12	290	300	290
T ₆ 500 ppm PP333 + SP I	2.05	2.39	2.22	310	350	330
T ₇ 750 ppm PP333 + SP I	2.16	2.34	2.25	330	410	370
T ₈ SP II	2.09	2.15	2.12	270	280	270
T ₉ 250 ppm PP333 + SP II	2.04	2.28	2.16	300	330	310
T ₁₀ 500 ppm PP333 + SP II	2.15	2.37	2.26	320	380	350
T ₁₁ 750 ppm PP333 + SP II	2.15	2.33	2.24	340	430	380
T ₁₂ SP I + SP II	2.16	2.43	2.29	310	330	320
T ₁₃ 250 ppm PP333 + SP I + SP II	2.19	2.25	2.22	360	440	400
T ₁₄ 500 ppm PP333 + SP I + SP II	2.25	2.39	2.32	380	470	420
T ₁₅ 750 ppm PP333 + SP I + SP II	2.35	2.49	2.42	400	490	440
CD (p<0.05)	0.02	0.03	0.02	10.30	20.0	16.70

SP I = summer pruning I, SP II = summer pruning II

Table 5 : Effect of paclobutrazol and summer pruning on quality parameters of apple cv. Red Delicious

	Treatments	Grades	
		2011	2012
T ₀	Control	8.60	8.59
T ₁	250 ppm PP333	9.42	9.67
T ₂	500 ppm PP333	9.48	9.82
T ₃	750 ppm PP333	9.57	9.94
T ₄	SP I	9.46	9.73
T ₅	250 ppm PP333+ SP I	9.65	10.07
T ₆	500 ppm PP333 + SP I	9.81	10.36
T ₇	750 ppm PP333 + SP I	10.14	10.43
T ₈	SP II	9.55	9.91
T ₉	250 ppm PP333 + SP II	9.72	10.21
T ₁₀	500 ppm PP333 + SP II	10.06	10.39
T ₁₁	750 ppm PP333 + SP II	10.19	10.47
T ₁₂	SP I + SP II	10.03	10.41
T ₁₃	250 ppm PP333 + SP I + SP II	10.28	10.52
T ₁₄	500 ppm PP333 + SP I + SP II	10.51	10.71
T ₁₅	750 ppm PP333 + SP I + SP II	10.72	10.88
	CD (p≤0.05)	0.10	0.13

SP I = summer pruning I, SP II = summer pruning II

total soluble solids (11.85°B and 11.86°B) during 2011 and 2012. Pooled data recorded highest total soluble solids (14.47 °B) in treatment 750 ppm PP333 + SP I + SP II (Table 1) which was significantly different from rest of the treatments whereas, lowest total soluble solids (11.85 °B) were observed in control. The total sugar content was significantly increased by all the treatments of paclobutrazol and summer pruning during both the years of study (Table 3). Pooled data recorded maximum total sugar content (10.80%) under the treatment 750 ppm PP333 + SP I + SP II and minimum total sugar content was noticed in control (8.59%). The highest reducing sugars (8.38%) was noticed under treatment 750 ppm PP333 + SP I + SP II and lowest reducing sugars was observed under control (6.40%) in pooled data (Table 3). The non reducing sugars were significantly influenced by all the treatments of paclobutrazol and summer pruning during both the years of study. Pooled data (Table 4) recorded maximum non reducing sugars (2.42%) in treatment 750 ppm PP333 + SP I + SP II which was significantly higher and minimum non reducing sugar content of (2.19%) was recorded in control. Foliar application of paclobutrazol at 750 ppm + summer pruning I + summer pruning

II significantly improved total soluble solids and sugars in fruits. This can be explained on the basis of increased sucrose, starch and sugar levels due to reduced vegetative growth and thus the absence of other potentially competitive actively growing sinks which resulted in more nutrient partitioning to fruits (Abdel Rahim *et al.*, 2011). Our findings are in conformity with the findings of Wani *et al.* (2007) in Red Delicious apple, Andres *et al.* (2008) and Sarker *et al.* (2016) in mango. The increased rate of photosynthesis led by more light penetration into the interior tree canopy, increased the soluble solids in fruits harvested from pruned trees. The significant increase in non reducing sugars by summer pruning could be due to active translocation of sucrose from leaves to fruits (Daulta and Singh, 1986). These results are supported by Rather (2006) in ‘Red Delicious’ apple and Porika *et al.* in grapes cv. Red Globe (2015).

Acidity

It is inferred from the data that lowest acidity (0.24% and 0.22%) was observed in the treatment 750 ppm PP333 + SP I + SP II whereas, highest acidity (0.39%



and 0.40%) was noticed in control during 2011 and 2012 which was significantly higher than rest of the treatments. Pooled data also recorded lowest acidity (0.23%) under the treatment 750 ppm PP333 + SP I + SP II whereas, highest acidity (0.39%) was noticed in control which was significantly higher than all other treatments (Table 1). Different treatments of paclobutrazol and summer pruning had significant effect on TSS/acid ratio of fruits. Maximum TSS/acid ratio (60.13 and 65.95) was noticed in treatment 750 ppm PP333 + SP I + SP II which was significantly higher than all other treatments whereas, minimum TSS/acid ratio of (30.38 and 29.65) was observed in control during 2011 and 2012. Pooled data also recorded maximum TSS/acid ratio of (63.04) in treatment 750 ppm PP333 + SP I + SP II and minimum TSS/acid ratio of fruits (30.01) in control (Table 2) which was significantly lower than all other treatments. These results find the support of Andres *et al.* (2008) who observed that the acidity content of fruits diminished as a result of the ripening process in mango by paclobutrazol application which resulted in lowest values for acidity. Similar reports were found by Wani *et al.* (2007) in Red Delicious apples. Fruit acidity was reduced by summer pruning. This may be attributed to the reason that fruit maturation was accelerated in summer pruned trees which resulted in higher soluble solid content and lower titratable acidity in the peach (Hossain *et al.*, 2006). Similar results were obtained by Senthilkumar *et al.* (2016).

Anthocyanin

Paclobutrazol and summer pruning significantly improved the anthocyanin content of fruits during both the years of study. Highest anthocyanin content of (9.42 mg/100 gm and 10.03 mg/100 gm) was observed in treatment 750 ppm PP333 + SP I + SP II which was significantly superior to all other treatments whereas, the lowest anthocyanin content of (6.19 mg/100 g and 6.23 mg/100 g) was recorded in control during 2011 and 2012. Pooled data recorded highest anthocyanin content (9.72 mg/100 g) in treatment 750 ppm PP333 + SP I + SP II and the lowest anthocyanin content (6.21 mg/100 g) was observed in control (Table 2). Continuous application of paclobutrazol significantly reduced vegetative growth characters of the trees, thereby exposing fruits to direct sunlight which may have

significantly increased red colouration of the fruits. These results are in accordance with Stover and Fargione (2003) in apple and Wani (2004) in sweet cherry. Increased fruit colour by summer pruning is attributed to the reason that by conducting summer pruning, the canopy size can be controlled and light availability to fruit for red colour development can be improved without undesirable post pruning regrowth by summer pruning (Dusi *et al.*, 2004). The results are in accordance with Rather (2006) in Red Delicious apple and Marini (2014) in apple.

Fruit calcium

Highest fruit calcium content (400 ppm and 490 ppm) was recorded in treatment 750 ppm PP333 + SP I + SP II whereas, lowest fruit calcium content (230 ppm and 220 ppm) was observed in control in 2011 and 2012. Pooled data recorded highest fruit calcium content (440 ppm) in treatment 750 ppm PP333 + SP I + SP II which was significantly higher than all other treatments whereas, lowest fruit calcium content (220 ppm) was observed in control (Table 4). This is due to the reason that the number of shoots were reduced, transforming trees into a more desirable, spur type growth habit and as the vegetative sink was reduced, transport of nutrients including calcium towards fruits was enhanced (Greene, 1991).

These results are in accordance with Luo *et al.* (1989) who found increased calcium, phosphorus and potassium in apple fruits treated with paclobutrazol. Fruit calcium is increased for 2 to 3 years due to carry over effect. Higher uptake of Ca and its relocation to fruits could be attributed to significantly reduced rate of leaf transpiration, thus could favour the supply of Ca towards the fruit (Burondkar *et al.*, 2009). Our findings are in conformity with the findings of Wani *et al.* (2007) in 'Red Delicious' apple.

Summer pruning significantly enhanced fruit calcium which resulted in decrease in incidence of calcium related disorders like bitter pit, cork spot thereby, extending the shelf life of fruits. This may be due to the fact that summer pruning has the potential to reduce the competition between shoot growth and fruit for available calcium which increased calcium levels in fruits. Singh (1992) in peach also reported the same findings.



Effect of paclobutrazol and summer pruning on quality parameters

Grades

Paclobutrazol and summer pruning had significant influence on fruit grades (Table 5). During the year 2011, treatment 750 ppm PP₃₃₃ to treatment 750 ppm PP₃₃₃ + SP I + SP II recorded fruits of grade A (with > 70 mm fruit breadth) whereas, fruits of grade B (with 60-69 mm fruit breadth) were noticed in treatment 250 ppm PP₃₃₃ and treatment 500 ppm PP₃₃₃ and fruits of grade C (with < 60 mm fruit breadth) were observed in control, respectively. During 2012, fruits of grade A were recorded in treatment 500 ppm PP₃₃₃ to treatment 750 ppm PP₃₃₃ + SP I + SP II whereas, fruits of grade B were noticed in treatment 250 ppm PP₃₃₃ and fruits of grade C were observed in control, respectively. This increase in fruit size was due to the reason that application of paclobutrazol reduced vegetative growth (sinks) which in turn, increased the partitioning of nutrients and dry matter towards fruits and thereby, increased the fruit size and weight (Wolstenholme *et al.*, 1990). Similar results were obtained by Pant and Ratan (2004) in apple and Burondkar *et al.* (2009) in Alphonso mango. Pruning decreased the fruit load and as the number of fruits were less, the available food material reached the individual fruit in sufficient quantity which thereby, increased the fruit size. These findings are in conformity with the findings of Bussi *et al.* (2005) in peach.

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