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Influence of boron, potassium and prohexadione-calcium on productivity of apple cv. red delicious

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Abstract
To determine the influence of boron, potassium sulphate and prohexadione-calcium on productivity of Red Delicious apple, eighteen year old plants with uniform growth and vigour were selected in a private orchard of district Ganderbal, Jammu and Kashmir during 2016. The experiment comprised of six treatments viz. T_1: control (no spray), T_2: boric acid @ 1.5 g/l, T_3: potassium sulphate @ 7 g/l, T_4: boric acid @ 1.5 g/l + potassium sulphate @ 7 g/l), T_5: prohexadione- Ca @ 100 ppm, T_6: Prohexadione-Ca @ 150 ppm, was laid out in a complete randomized block design with four replication. The results obtained revealed significant effect of the treatments on all the studied characters. Foliar application of boric acid @ 1.5 g/l + potassium sulphate @ 7 g/l (T_4) resulted in maximum increment in trunk girth (2.34 cm), tree volume (3.30 m^3), shoot extension growth (52.53 cm), fruit set (48.50%), fruit yield (115.90 kg/tree), fruit length (7.97 cm), fruit diameter (8.34 cm), fruit weight (207.71 g), fruit colour (8.26), TSS (15.62ºB), reducing sugar (10.88%) and total sugars (13.89%). Trees sprayed with Prohexadione-Ca @ 150 ppm (T_6) resulted in maximum fruit retention (33.67%), yield efficiency (0.37 kg/cm^2), TSS/acidity ratio (81.01), fruit firmness (8.91 kg/cm^2) and calcium content (0.049%). Thus it can be concluded that the treatment T_3 i.e. boric acid @ 1.5 g/l + potassium sulphate @ 7 g/l resulted in better yield of quality Red Delicious apples.

Keywords: Apple, boron, potassium, prohexadione-calcium, red delicious

Introduction
Apple (*Malus* x *domestica* Borkh.) is one of the hardiest temperate fruits grown all over in temperate regions of the world. In India, apple is a dominant crop of the Himalayan region extending from Jammu and Kashmir in West to Arunachal Pradesh in the East and more concentred in North-Western region located between latitude of 28ºN and 30ºN. Red Delicious cultivar of apple has been widely accepted by the growers of Jammu and Kashmir because of its appealing colour and economic gains, contributing to more than 80 per cent of production and area under apple. However, continuous cultivation of 'Red Delicious' cultivar over decades has resulted in tendency towards biennial bearing and genetic degradation in respect of yield and fruit quality (Jindal, 2001) [7]. Inadequate diversification and proportion of pollinizers and pollinators, declining population of pollinators and non-synchronization of flowering period, inadequate nutrition and above all poor orchard management practices adversely affect fruit set, fruit quality and yield of our apple orchards. Thus decreased fruit productivity and poor fruit quality of apple orchards has become serious concern for the fruit growers of the valley and challenge for the researchers and horticultural scientists to evolve the production technology for the sustainability of temperate fruit industry. Therefore, for getting higher yields and better quality fruits the present study was conducted to ascertain the influence of Prohexadione-calcium, boron and potassium on Red Delicious apple.

Material and Methods
Experimental site and material involved
The present study was conducted on eighteen year old on apple cv. Red Delicious raised on seedling rootstock at private orchard in district Ganderbal, Jammu and Kashmir during 2016. The experimental orchard was situated at an altitude of 1585 amsl, the orchard had proper soil drainage and good fertility status. Trees of similar vigor and size were selected, marked and maintained under uniform cultural practices and trained as modified leader system at spacing of 6 x 6 meter. Most of the precipitation received from the month of October to April and rest

is erratically distributed. Winters are severe extending from December to March and temperature often goes below freezing point during this period.

Treatment details

The experiment was laid out in a completely randomized block design (RCBD) with four trees representing a treatment. There are twenty four healthy trees grouped into four replications and six treatments including a control (water spray), were marked as per the treatments. Different concentrations of boric acid, potassium sulphate and Prohexadione-Calcium were sprayed at different stages of apple (Table 1). Spraying of trees was done on the scheduled day in the morning hours with a foot sprayer pump equipped with long handle and microfine nozzle to ensure mist spray. Each experimental tree was sprayed with about 15 litres of solution.

Table 1: Treatment details

Treatment	Chemical applied	Time of spray
T_1	Control	Water spray
T_2	Boric acid @ 1.5 g/l (2 sprays)	Pink bud and petal fall stage
T_3	Potassium sulphate @ 7 g/l (2 sprays)	Last week of June and 21 days after
T_4	Boric acid @ 1.5 g/l + Potassium sulphate @ 7 g/l (2 + 2 sprays)	Pink bud, petal fall, last week of June and 21 days after
T_5	Prohexadione- Ca @ 100 ppm (3 sprays)	Petal fall, last week of June and last week of July
T_6	Prohexadione- Ca @ 150 ppm (3 sprays)	Petal fall, last week of June and last week of July

Observations recorded and statistical analysis

The observations were recorded on trunk girth (cm) (initial and after completion of experiment), tree volume (m^3) was calculated by formula suggested by Westwood (1993), shoot extension growth (cm), fruit set (%), fruit drop (%), fruit retention (%) and yield (kg/tree). Yield efficiency and trunk cross sectional area was calculated as per Westwood (1993).

$$\text{Yield efficiency (kg/cm}^2\text{)} = \frac{\text{Yield (kg/tree)}}{\text{Trunk cross sectional area}}$$

Trunk cross sectional area (TCSA) was calculated as per method given by Westwood (1993) as TCSA is equal to πr^2, where, r is equal to radius of trunk. For physical characters of fruits, ten randomly fruits from each replication were taken. Fruit weight of ten randomly fruits were recorded with the help of top pan balance and the average value was expressed in grams. Fruit length and fruit diameter was measured with the help of vernier caliper. Fruit length was measured between calyx and styler end and fruit diameter between cheeks and expressed in cm. L/D ratio of the fruit was calculated by dividing the length with the diameter of the fruit. Fruit firmness was determined by a pressure tester (Magness-Taylor) and was expressed in Kg/cm^2. Total soluble solids of the fruit were recorded on hand refractometer as per the procedure given by Rangana (1997). Per cent titrable acidity (as per cent maleic acid) was determined by titrating known volume of fruit juice against 0.1 N NaOH solution, using phenolphthalein as an indicator (AOAC, 2000). TSS/acid ratio was calculated by dividing total soluble solids by acidity, whereas reducing sugars and total sugars were estimated by Lane and Eynon's method as suggested by Ranganna (1997) [15].

For estimation of calcium content, one gram of crushed sample (fruit as well as leaves) was taken in 100 ml conical flask and 20 ml of di-caid (HNO_3+ perchloric acid in the ratio of 9:4) was added to it. Then the flask was placed on hot plate using gas stove till sample changed to clear solution. 10-15 ml of distilled water was added after cooling down and it was filtrated, the filtrate was diluted to 50 ml (stock sample) with distilled water. Calcium were analysed with the help of atomic absorption spectrophotometer (Fazli and Fazli, 2014) [4]. Data recorded on different parameters was analyzed by standard procedure as described by Panse and Sukhatme, (1995) [14].

Results and Discussion

Growth characters

Significant results were observed with respect to all the growth characters among different treatments presented in Table 1. Maximum increment in trunk girth was obtained in the treatment T_4 i.e. boric acid @ 1.5 g/l + potassium sulphate @ 7 g/l (2.34 cm) which was statistically higher among all the other treatments. Treatment T_6 i.e. Prohexadione-Ca @ 150 ppm (1.01 cm) recorded minimum increment in trunk girth. Perusal of data presented in Table 1 reveal that maximum increment in tree volume was recorded in treatment T_4 i.e. boric acid @ 1.5 g/l + potassium sulphate @ 7 g/l (3.30 m^3) which was statistically at par with T_3 (3.18 m^3) and T_2 (3.11 m^3) treatment, however minimum increment in tree volume was recorded in treatment T_6 (2.20 m^3). Shoot extension growth was markedly influenced by different foliar sprays. Maximum shoot extension growth was recorded in treatment T_4 (52.53 cm) which was statistically at par with treatment T_1 (51.46 cm) and treatment T_2 (52.18 cm). Minimum shoot extension growth was obtained under treatment T_5 (39.62 cm). Significant increase in tree growth characters with potassium and boron applications have also been reported by Kilany and Kilany (1991) [11] and Wojcik and Mika (1996) [19].

Maximum fruit set was recorded in the treatment T_2 i.e. boric acid @ 1.5 g/l (48.62%) which was statistically at par with the treatment T_4 i.e. boric acid @ 1.5 g/l + potassium sulphate @ 7 g/l (48.50%) whereas minimum fruit set was recorded in T_1 i.e. control (43.50%) which was statistically at par with T_3 i.e. potassium sulphate @ 7 g/l (43.51%), T_5 i.e. prohexadione-Ca @ 100 ppm (43.71%) and T_6 i.e. prohexadione-Ca @ 150 ppm (43.75%). Boron plays an important role as an activator for many enzymes that promotes pollen germination and pollen tube growth for successful fruit set and in formation of feeder roots, thereby increased fruit setting (Donald *et al*., 1998) [3]. Similar findings have also been reported by Wojcik *et al.* (1999) [20]. Treatment T_6 (33.67%) recorded maximum fruit retention which was significantly higher than all other treatments whereas treatment T_1 (25.21%) recorded minimum fruit retention. Highest fruit drop was recorded in trees receiving no treatment (control) i.e. T_1 treatment (74.79%) which was significantly higher than all other treatments, however lowest fruit drop was recorded in trees sprayed with treatment T_6 i.e. prohexadione-calcium @ 150 ppm (66.33%) which was statistically at par with the treatment T_5 i.e. prohexadione-calcium @ 100 ppm (67.90%). Prohexadione-

calcium inhibit ethylene biosynthesis thus prevent the abscission of fruits. Furthermore, prohexadione-calcium increases light interception to the inner canopies of plants which promotes fruit growth thus reducing fruit drop (Greene, 2008; Mouco *et al*., 2010) [5, 12].

Data presented in Table 2 indicate a significant influence of boric acid, potassium sulphate and proexadione-calcium on fruit physical characters of Red Delicious apple. Maximum fruit length (7.97 cm) and fruit diameter (8.34 cm) was recorded in the treatment T_4 i.e. boric acid @ 1.5 g/l + potassium sulphate @ 7 g/l which was significantly higher among all other treatments in case of fruit length while treatment T_4 was statistically at par with T_3 treatment for fruit diameter. Minimum fruit length (6.19 cm) and fruit diameter (6.76 cm) was observed in the treatment T_6 i.e. prohexadione-calcium @ 150 ppm. Maximum and minimum L/D ratio was observed in the treatment T_3 (0.95) and T_1 (0.91), respectively. Fruit weight was recorded maximum in treatment T_4 i.e. boric acid @ 1.5 g/l + potassium sulphate @ 7 g/l (207.71 g) which was significantly higher among all the treatments whereas minimum fruit weight was recorded in the treatment T_6 i.e. prohexadione-calcium @ 150 ppm (174.49 g). Application of potassium sulphate and boric acid facilitate the efflux of sucrose to apoplast, which increases sugar translocation to sink tissues and promotes fruit growth (Taiz and Zeiger, 2004) [17]. However, Greene (2008) [5] also observed that application of prohexadione-calcium reduced fruit size in apple.

Fruits of treatments T_4 (8.26) attained maximum fruit colour which was statistically at par with T_3 (8.16) and T_6 (7.82) treatment, however treatment T_1 i.e. control (6.28) scored minimum values for fruit colour. Potassium is involved in colour development in fruits which is evident from the fact that it acts as a cofactor in activation of specific enzymes that are required for anthocyanin formation in anthocyanin pathway (Ju *et al*., 1999) [8]. Boron sprays have also been found to improve fruit colour of apple (Kassem *et al*., 2010) [9]. Perusal of data presented in Table 2 reveals that maximum fruit firmness was recorded in treatment T_6 i.e. prohexadione-calcium @ 150 ppm (8.91 kg/cm^2) which was statistically at par with T_5 i.e. (8.77 kg/cm^2) treatment. Lowest fruit firmness was recorded in fruits harvested from trees sprayed with the treatment T_4 (7.75 kg/cm^2). The present results are in confirmity with the findings of Kazemi *et al.* (2011) [10] in Jonagold apple.

Fruit chemical characters presented in Table 3 also exhibited a significant variation among all the treatments except acidity. Maximum total sugars content was recorded in the treatment T_4 i.e. boric acid @ 1.5 g/l + potassium sulphate @ 7 g/l (15.62ºB) which was statistically at par with treatment T_6 i.e. prohexadione-calcium @ 150 ppm (15.55ºB), T_5 i.e. prohexadione-calcium @ 100 ppm (15.40ºB) and T_3 i.e. potassium sulphate @ 7 g/l (15.38ºB) whereas minimum total soluble solids content was recorded in the treatment T_1 i.e. control (14.60ºB). Minimum and maximum acidity was recorded in the treatment T_6 (0.19%) and T_1 (0.24%), respectively. Maximum TSS/acid ratio was recorded in the treatment T_6 (81.01) which was statistically at par with T_4 (78.05) treatment however minimum TSS/acid ratio was registered in the T_1 (60.83) treatment. Treatment T_4 recorded maximum reducing sugar (10.88%) and total sugars (13.89%) where treatment T_4 was statistically at par with treatment T_5 (10.66%) for reducing sugar and with treatment T_6 (13.72%) for total sugars. Minimum reducing sugar (9.43%) and total sugar (12.32%) was recorded in treatment T_1 i.e. control. Rashid *et al*., (2009) [16] and Nava and Dechen (2011) [13] had recorded significant improvement in total soluble solids with potassium application, however, boron spray increased total soluble solids but decreased total acidity (Canesin *et al*., 2010) [2].

Figure 1 depicts the significant variations for trunk cross sectional area, fruit yield, yield efficiency and calcium content. Treatment T_4 (335.69 cm^2) recorded maximum trunk cross sectional area which was significantly higher among all the treatments. Minimum trunk cross sectional area was recorded under the treatment T_6 (270.09 cm^2). Treatment T_1 i.e. control recorded trunk cross sectional area value as 305.55 cm^2. Significantly higher and maximum values was recorded in the treatment T_4 (115.90 kg/tree) for fruit yield while minimum fruit yield was recorded in the treatment T_1 (90.78 kg/tree). Increase in fruit yield with combined application of potassium sulphate and boric acid might be attributed to the fact that potassium is involved in protein and carbohydrate synthesis and their translocation, water relations in plant and transpiration and boron facilitates transport of carbohydrates through cell membrane (Donald *et al*., 1998) [3]. Maximum yield efficiency was recorded in the treatment T_6 i.e. prohexadione-calcium @ 150 ppm (0.31 kg/cm^2) which was significantly higher among all the treatments whereas minimum yield efficiency was recorded in the treatment T_1 i.e. control (0.29 kg/cm^2). No doubt, prohexadione-calcium recorded low fruit yield per tree but the proportion of decrease in trunk cross section area with prohexadione-calcium application was more than decrease in yield thereby increasing yield efficiency.

Maximum calcium content was recorded in fruits harvested from trees sprayed with the treatment T_6 i.e. prohexadione-calcium @ 150 ppm (0.049%) which was significantly higher than all other treatments, whereas minimum calcium content was recorded in the fruits harvested from trees sprayed with the treatment T_3 i.e. (0.030%). Maximum fruit calcium content as a result of prohexadione-calcium may be attributed to the fact that the prohexadione-calcium reduces shoot growth as a result of which relatively more nutrients are translocated to fruits. Guak (2013) [6] also observed that application of prohexadione-calcium increased calcium content in fruits Golden Delicious apple.

Table 1: Influence of boron, potassium & prohexadione-calcium on growth and fruiting characters of Red Delicious apple

Treatments	Increment in trunk girth (cm)	Increment in tree volume (m^3)	Shoot extension growth (cm)	Fruit set (%)	Fruit retention (%)	Fruit drop (%)
T_1	1.96	2.86	48.54	43.50	25.21	74.79
T_2	2.07	3.11	51.46	48.62	31.37	68.63
T_3	2.14	3.18	52.18	43.51	28.22	71.78
T_4	2.34	3.30	52.53	48.50	31.50	68.50
T_5	1.20	2.31	41.63	43.71	32.10	67.90
T_6	1.01	2.20	39.62	43.75	33.67	66.33
$CD_{0.05}$	0.15	0.28	1.32	1.47	0.68	1.81

Table 2: Influence of boron, potassium & prohexadione-calcium on fruit physical characters of Red Delicious apple

Treatments	Fruit length (cm)	Fruit diameter (cm)	L/D ratio	Fruit weight (g)	Fruit colour (score 1-10)	Firmness (kg/cm^2)
T_1	6.54	7.05	0.91	183.54	6.28	7.87
T_2	7.13	7.66	0.92	194.76	6.72	7.85
T_3	7.72	8.21	0.95	198.25	8.16	7.80
T_4	7.97	8.34	0.94	207.71	8.26	7.75
T_5	6.32	6.86	0.93	177.25	7.50	8.77
T_6	6.19	6.76	0.92	174.49	7.82	8.91
$CD_{0.05}$	0.19	0.13	NS	1.56	0.45	0.26

Table 3: Influence of boron, potassium & prohexadione-calcium on fruit chemical characters of Red Delicious apple

Treatments	TSS (°B)	Acidity (%)	TSS/ acid ratio	Reducing sugar (%)	Total sugar (%)
T_1	14.60	0.24	60.83	9.43	12.32
T_2	15.21	0.22	69.13	10.09	13.02
T_3	15.38	0.21	72.29	10.42	13.34
T_4	15.62	0.20	78.05	10.88	13.89
T_5	15.40	0.21	73.59	10.66	13.30
T_6	15.55	0.19	81.01	10.39	13.72
$CD_{0.05}$	0.26	NS	3.27	0.47	0.32

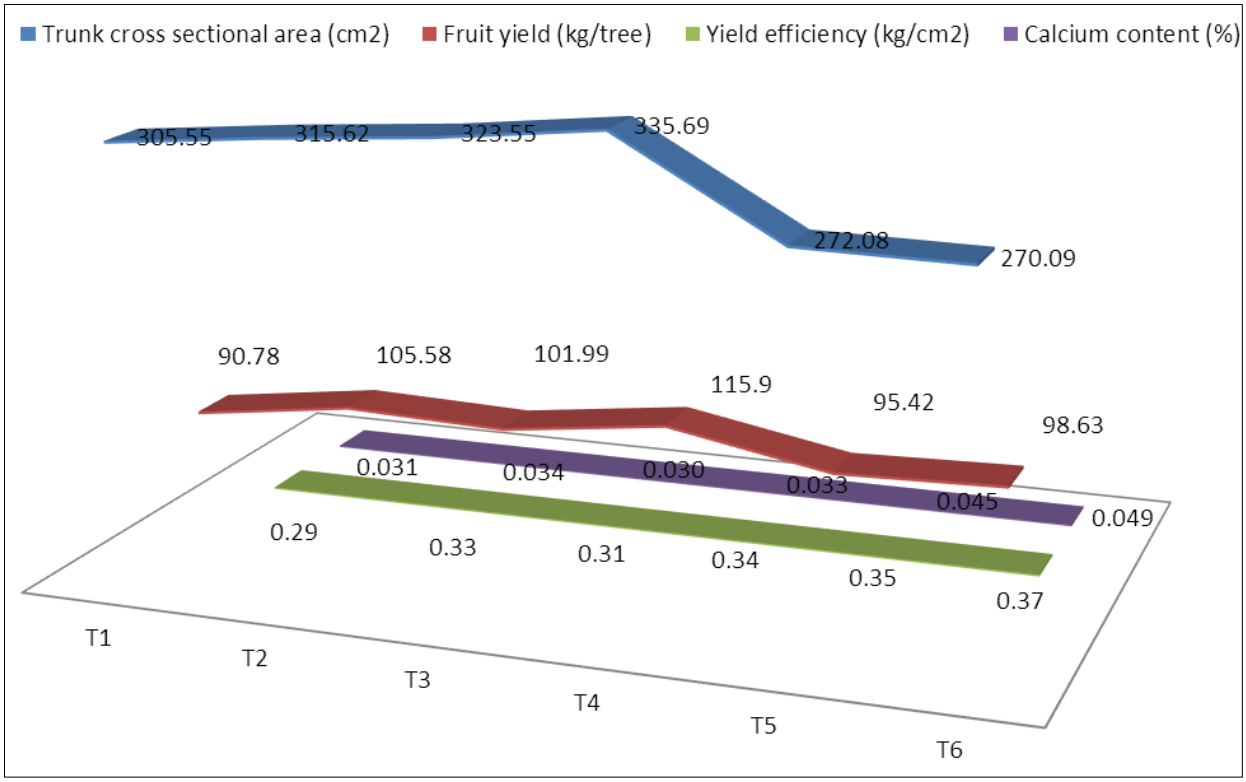

Fig 1: Influence of boron, potassium & prohexadione-calcium on TCSA, yield characters and calcium content

Conclusion

Among different treatments, prohexadione-Ca @ 150 ppm applied at petal fall stage proved effective in controlling the vegetative growth characters. Boron and potassium played an important role in fruit set, fruit retention and development and resulted in higher yield and quality improvement. Hence, it can be concluded that the trees sprayed with boric acid @ 1.5 + potassium sulphate @ 7 g/l (T_4) resulted in higher fruit set, fruit retention, and fruit physical as well as chemical characters.

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