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Fruit cracking and quality of pomegranate (*Punica granatum* L.) cv. Kandhari as influenced by CPPU and boron

Prativa Sahu and Narender Sharma

Abstract
An investigation on pre-harvest spray of forchlorfenuron (CPPU) and boron along with some in-situ soil moisture conservation techniques was carried out on seven-year old plants of pomegranate cultivar Kandhari trained as four stems grown under Rainfed conditions of Himachal Pradesh. Experimental plants were subjected to 11 treatments, *viz*., mulching, CBOC (crescent bund with open catchment pits), CPPU at 5 or 10 ppm, H 3 BO 3 at 0.2 or 0.4%, mulching + CPPU at 5 ppm or H 3 BO 3 at 0.2%, CBOC + CPPU at 5 ppm or H 3 BO 3 at 0.2% and control. These treatments were applied in mid-March (in-situ soil moisture conservation) and mid-May (CPPU & boron). Growth parameters like plant height, plant spread, trunk girth and annual shoot growth were observed significantly higher under the treatment CBOC + H 3 BO 3 at 0.2%. However, leaf area and leaf chlorophyll content were recorded significantly higher under the treatment CBOC + CPPU at 5 ppm. Physiological characteristics such as photosynthetic rate and transpiration rate were higher in the plant under crescent bund with open catchment pits. The extent of fruit cracking was reduced to the lowest level (2.8%) from 11.67% in control and highest fruit yield (26.8Kg/plant) was recorded when the plants were given foliar application of CPPU at 5 ppm under CBOC. The least russet formation (1.33 on 10 point scale) occurred in fruits from plants given the treatment of CPPU at 5ppm +CBOC. The maximum fruit length (86.2 cm) and fruit breadth (88.3 cm), fruit weight (419.74 g), aril weight (279.21 g), aril percentage (66.52), juice content (67.93 ml/100 g), ascorbic acid content (16.84 mg/100g) were obtained with the treatment of CPPU at 5ppm +CBOC. The lowest titratable acidity (0.49%), highest TSS (15.210 B) and TSS/acid ratio (31.07) was recorded in fruits from plants under the treatment of H 3 BO 3 at 0.2% with mulching. Total sugar, reducing sugar were recorded highest under the treatment H 3 BO 3 at 0.2% + CBOC and lowest in control.

Keywords: Pomegranate, CPPU, boron, fruit cracking, CBOC

Introduction

Pomegranate (*Punica granatum* L.) belongs to family Punicaceae and is native to Persia (Iran), Afghanistan and Baluchistan. Its fruit has wide consumer preference for its attractive, juicy, sweet-acidic and refreshing arils. Though pomegranate was originally adapted to Mediterranean climate, but it has also flourished well under hot dry summers with cool winters. The foot hills of Himachal Pradesh comprise sub-tropical sub-montane and valley areas of Shivalik hills hold tremendous scope for its cultivation. The plants suffer acute moisture stress leading to fruit cracking due to erratic and uneven rains under rainfed conditions. Fruit cracking is a physiological disorder, generally associated with differential rate of growth of fruit skin/rind and fruit aril. It may be due to imbalance soil moisture in mature fruits and boron deficiency in immature fruits. It therefore becomes imperative to conserve every drop of rain water in the field using *in-situ* moisture conservation techniques to enhance soil moisture storage for inducing good vegetative growth and productivity, lowest fruit cracking by improving their morphological and physiological status. Some practices like mulching of tree basins and soil working techniques like, crescent bund with open catchment pits (Sharma and Singh, 2010) [19] have been found to be useful in many crops for conserving soil moisture. Growth regulators like CPPU (Sharma and Belsare, 2009) [18] and nutrients like boron (Bhat *et al*., 2004) also play important role in improving fruit quality in different fruits.

N-(2-chloro-4-pyridinyl)-N-phenylurea (CPPU, forchlorfenuron) possesses strong cytokinin bioactivity and has been shown to stimulate the fruit growth in a number of fruit crops (Ahmed *et al*., 2007; Kim *et al*., 2006; Fang-Xue Zhi *et al*., 2006; Supe and Marshal, 2008; Sharma and Belsare, 2009) [1, 11, 5, 18]. The most important physiological effects of boron in plants are structural role in cell walls, stimulation or inhibition of specific metabolic pathways, involvement in the movement of Ca into the plant, flower production and retention, pollen tube elongation and germination, and seed and fruit development, sugar transport and

hormonal regulation (Alila *et al.*, 2005; Topno *et al.* 2006; Kumar, 2006; Khalifa *et al.*, 2009) [2, 23, 12, 10]. Therefore, the present study was undertaken to ascertain the effect on pre-harvest spray of forchlorfenuron (CPPU) and boron along with some *in-situ* soil moisture conservation techniques like mulching, crescent bund with open catchment pits in pomegranate cv. Kandhari with an objective to evaluate the morphological and physiological status, fruit cracking, yield potentials and quality of pomegranate under rainfed conditions.

Materials and Methods

The present investigation was carried out in the experimental orchard of the Department of Fruit Science, Dr Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India during 2010-2011. For this study, 33 plants of 7-year-old pomegranate trained as four stem system and spaced 4 m x 4 m apart were selected. Soil at the experimental site was silty loam; having 6.81 pH, 1.76% organic carbon content, 8.00% permanent wilting point, 25.50% field capacity and 1.10 g cm^{-3} bulk density. Experimental plants were subjected to 11 treatments, *viz*. mulching (10 cm thick hey), CBOC (crescent bund with open catchment pits), CPPU (forchlorfenuron) at 5 or 10 ppm, H_3BO_3 at 0.2 or 0.4%, Mulching + CPPU at 5 ppm or H_3BO_3 at 0.2%, CBOC + CPPU at 5 ppm or H_3BO_3 at 0.2% and control (no treatment). These treatments were applied in mid-March (*in-situ* soil moisture conservation) and mid-May (CPPU &boron). All the treatments were replicated three times in a randomized block design.

For the preparation of CPPU solutions, the required quantity of its commercial formulation 'Sitofex' procured from M/S Degussa AG; Germany was directly dissolved in 12 litres of water. The required amount of H_3BO_3 was weighed on a digital balance and dissolved in warm water. In order to decrease surface tension and to facilitate absorption of droplets, 0.05 per cent 'Break Thru' (surfactant) was added to each solution prior to use. Soil moisture (%) were taken with the help of AquaPro® soil moisture profiler at 15 day intervals during the growing season from 1st April to 15th July at 15, 30, 45 cm depths. The access tubes fitted 1 m away from the trunk.

The percentage increase in annual shoot growth was observed in the field before the commencement of the growth and after the cessation of growth in autumn. Simultaneously, 20 fully expended leaves were collected at random from the periphery of each plant in the month of August and their area (cm^2) was measured with the help of LI-Cor 3100 leaf area meter. The number of the fruits cracked on each experimental plant were counted periodically during the entire fruiting season and expressed in per cent. Fruit yield (kg/tree) was determined on the basis of total weight of fruits harvested from the each experimental plant. Russet formation on the skin of five randomly selected fruits from each replication was examined visually at the time of harvest and russet development on the fruits was determined on 10 point scale. The total soluble solids of the juice were determined with Erma-hand refractometer (0 to 320B range). Ascorbic acid content of the fruits was determined as per AOAC. (1980) method. The data were subjected to statistical analysis as per the procedure outlined by Panse and Sukhatme.

Results and Discussion

Soil moisture contents under the plant basins fluctuated greatly with dry spells and erratic rainfall cycles (1, 0, 0, 2.7, 48.2, 0, 116.6, 52.2, 280.7, 203.9 mm rainfall in 15th March, 1st April, 15th April, 1st May, 15th May, 1st June, 15th June, 1st July, 15th July, respectively during the course of investigation. However during all the observation dates, maximum soil moisture contents of 18.01% at 0-15 cm soil depth; 18.88% at 15-30 cm soil depth and 19.03% at 30-45 cm soil depth were recorded under the treatment CBOC + CPPU at 5 ppm. Soils under mulching also maintained more moisture level. The interaction effect of treatments with soil moisture levels during different period was also found to be significant.

Table 1: Effect of pre-harvest spray of forchlorfenuron and boron on annual shoot extension growth, average leaf area, Leaf chlorophyll content, fruit set and fruit cracking of pomegranate cv. Kandhari

Treatments	Annual shoot extension growth (cm)	Average leaf area (cm^2)	Leaf chlorophyll Content (mg/g of fresh wt.)	Fruit set (%)	Fruit cracking (%)
T_1:Mulching with hay(10cm)	26.93	9.2	1.92	20.4	5.2
T_2:Crescent bund with open catchment pits(CBOC)	32.7	10.6	1.99	22.7	3.9
T_3:CPPU at 5 ppm	25.15	9.4	2.61	19.8	4.1
T_4:CPPU at 10 ppm	27.27	8.7	2.57	18.6	4.53
T_5:H_3BO_3 at 0.2%	37.43	9.1	2.3	18.97	5.1
T_6:H_3BO_3 at 0.4%	31.13	8.4	2.21	17.89	5.6
T_7:Mulching+ CPPU at 5 ppm	27.37	9.7	2.78	23.6	3.5
T_8: Mulching+ H_3BO_3 at 0.2%	39.57	9.19	2.41	23.2	3.8
T_9: CBOC+ CPPU at 5 ppm	34.29	11.05	2.93	24	2.8
T_{10}: CBOC+ H_3BO_3 at 0.2%	43.15	10.8	2.45	23.5	3.2
T_{11}:Control	17.75	7.07	1.41	13.33	11.67
$CD_{0.05}$	1.817	0.55	0.05	0.55	0.28
SE ±	0.87	0.26	0.022	0.26	0.13

Highest shoot growth (43.15 cm) was recorded in plants under CBOC when sprayed with boric acid at 0.2%. The results can be attributed to the availability of more moisture under CBOC and mulching at all soil depths and role of boron in N metabolism, hormone movement action and cell division (Russel, 1957) [17]. The leaf area (11.05 cm^2), accumulation of chlorophylls (2.93 mg/100 g fresh weight) was significantly higher under the treatment CBOC + CPPU at 5 ppm (Table 1). The present findings are in agreement with those of Iersel and Nemali, 2004 [6], and Jyothi and Raijadhav, 2004 [7], who observed that higher soil moisture level favoured more leaf growth in Rangapur lime. The CPPU is an urea based cytokinin which induced the activity of invertase enzyme in conversion of lipids to glucose, fructose (Notodimedjo, 2000) [14] and as solute concentration increases and OP becomes negative, thus resulting in more uptake of water, leading to better leaf expansion. Cytokinin helps in the retention of chlorophyll and stimulates the nutrient mobilization and thus

might have resulted in the accumulation of more chlorophyll in treated leaves. In the study, the plants grown under the treatment of CBOC+ CPPU at 5 ppm (T_9), and CBOC+ H_3BO_3 at 0.2% (T_{10}) had higher fruit set. These results are in accordance with the findings of Farmahan and Sharma (2005) [18], who observed increased fruit set due to *in-situ* moisture conservation in pomegranate. Boric acid helps in fruit set due to its effect on generative processes on pollen production, germination and pollen tube growth (Chaplin and Westwood, 1980) [3]. Fruit cracking was reduced to the lowest level (2.8%) when the plants grown under CBOC and given foliar application of CPPU at 5 ppm (T9) or H3BO3 at 0.2% (T10). Fruit cracking is a physiological disorder, generally associated with differential rate of growth of fruit skin/rind and fruit aril. As CBOC maintained higher soil moisture level soil during the fruit development, which consequently might have decreased fruit cracking in this study. Kaulgud (2001) [9] reported that moisture stress was one of the reasons for fruit cracking in pomegranate. The growth regulator CPPU might have stimulated overall growth of pomegranate fruits and thereby reduced fruit cracking. The findings are in agreement with those of Singh *et al.* (2003) [3], who observed reduced fruit cracking in pomegranate following the foliar application of boron. The highest fruit yield (26.8 kg/plant) was recorded under T9 (CBOC + CPPU at 5 ppm) over control (14.27 kg/ plant).

Table 2: Effect of pre-harvest spray of forchlorfenuron and boron on russeting, fruit yield, fruit length, fruit dia and fruit L/D ratio of pomegranate cv. Kandhari

Treatments	Russeting (10 point scale)	Fruit yield (kg/tree)	Fruit length (mm)	Fruit diameter (mm)	Fruit L/D ratio
T_1:Mulching with hay (10cm)	2.66	21.2	81.2	83.4	0.97
T_2:Crescent bund with open catchment pits(CBOC)	2.33	22.9	82.1	84.2	0.97
T_3:CPPU at 5 ppm	1.67	22.1	84.5	86.6	0.98
T_4:CPPU at 10 ppm	2	20.6	84	86	0.97
T_5:H_3BO_3 at 0.2%	4	21.9	83.7	85.7	0.98
T_6:H_3BO_3 at 0.4%	4.33	20.2	83.1	85.3	0.97
T_7:Mulching+ CPPU at 5 ppm	2	24.9	85.3	87.4	0.98
T_8: Mulching+ H_3BO_3 at 0.2%	3.33	23.3	83.9	85.9	0.98
T_9: CBOC+ CPPU at 5 ppm	1.33	26.8	86.2	88.3	0.98
T_{10}: CBOC+ H_3BO_3 at 0.2%	3.66	24.02	84.1	86.2	0.97
T_{11}:Control	5	14.27	75.16	76.93	0.97
$CD_{0.05}$	1.45	0.46	0.36	0.30	NS
SE ±	0.69	0.22	0.17	0.14	NS

Table 3: Effect of pre-harvest spray offorchlorfenuron and boron on fruit weight, aril weight, aril percentage, juice content and TSS of pomegranate cv. Kandhari

Treatments	Fruit weight (g)	Aril weight (g)	Aril per cent age	Juice content (ml/100g)	TSS (^{0} B)
T_1:Mulching with hay(10cm)	326.98	192.00	58.73	64	13.3
T_2:Crescent bund with open catchment pits(CBOC)	344.73	203.9	59.15	64.71	13.71
T_3:CPPU at 5 ppm	401.56	260.73	64.93	66.86	14.97
T_4:CPPU at 10 ppm	384.39	246.00	64	66.79	14.52
T_5:H_3BO_3 at 0.2%	363.06	221.79	61.09	65	13.88
T_6:H_3BO_3 at 0.4%	344.91	209.63	60.78	64.56	13.66
T_7:Mulching+ CPPU at 5 ppm	414.52	269.52	65.02	67.31	14.09
T_8: Mulching+ H_3BO_3 at 0.2%	371.25	232.43	62.61	66.72	15.21
T_9: CBOC+ CPPU at 5 ppm	419.74	279.21	66.52	67.93	14.28
T_{10}: CBOC+ H_3BO_3 at 0.2%	376.3	237.85	63.21	66.8	15.03
T_{11}:Control	287.96	154.98	53.82	56.73	12.8
$CD_{0.05}$	8.85	1.13	0.05	0.038	0.02
SE ±	4.24	0.54	0.02	0.018	0.01

In the study, pre-harvest application of CPPU significantly influenced the fruit finish in respect of russet formation on skin (Table 2). It was observed that the least russet formation (1.33 on 10 point scale) occurred in fruits under treatment of CBOC+ CPPU at 5ppm (T_9), which was superior to control (5.00 points).Application of boric acid irrespective of the concentration was not effective in controlling the russeting on fruit skin. Maximum fruit length (86.2 mm), fruit diameter (88.3 mm), fruit weight (419.74 g), aril weight per fruit (279.21g), aril percentage (66.52), juice content (67.93 ml/100 g), ascorbic acid content (16.84 mg/100g)were obtained (Table 2 & 3) with the treatment of CPPU at 5ppm +CBOC, closely followed by the treatment T_7 (Mulching+ CPPU at 5 ppm). The CPPU is an urea based cytokinin (Ranjan *et al*., 2003) [16], and its application at earlier stage of fruit development might have enhanced cell division of different fruit parts and consequently increased fruit size in the present study. Earlier, the synthetic cytokinin CPPU was reported to promote fruit development in apple (Costa *et al.* 2004) [4], grapes (Stern et al. 2002) [21] and kiwi fruit (Kim, 2006) [11].

Table 4: Effect of pre-harvest spray forchlorfenuron and boron on acidity, TSS/acid ratio, ascorbic acid, total sugar and reducing sugar of pomegranate cv. Kandhari

Treatments	Acidity	TSS/Acid ratio	Ascorbic acid (mg/100g)	Total Sugar (%)	Reducing Sugar (%)
T_1:Mulching with hay (10cm)	0.68	19.58	14.64	11.38	9.92
T_2:Crescent bund with open catchment pits(CBOC)	0.63	21.79	15.32	11.74	10.33
T_3:CPPU at 5 ppm	0.53	28.25	16.06	11.66	10.19
T_4:CPPU at 10 ppm	0.55	26.49	15.21	11.69	10.45
T_5:H_3BO_3 at 0.2%	0.60	23.17	16.34	11.71	10.46
T_6:H_3BO_3 at 0.4%	0.65	21.05	15.91	11.61	10.23
T_7:Mulching+ CPPU at 5 ppm	0.59	24.31	16.59	11.67	10.52
T_8: Mulching+ H_3BO_3 at 0.2%	0.49	31.07	16.65	11.83	10.63
T_9: CBOC+ CPPU at 5 ppm	0.56	25.55	16.84	11.76	10.55
T_{10}: CBOC+ H_3BO_3 at 0.2%	0.51	29.35	16.70	11.95	10.67
T_{11}:Control	0.73	17.54	12.83	10.03	9.25
$CD_{0.05}$	0.04	1.74	0.22	0.22	0.19

The lowest titratable acidity (0.49%), highest TSS (15.210 B) and TSS/acid ratio (31.07) was recorded in fruits from plants under the treatment of H_3BO_3 at 0.2% with mulching (Table 4). Total sugar, reducing sugar were recorded highest under the treatment H_3BO_3 at 0.2% + CBOC and lowest in control. These results are in conformity with those of Kano (2003) [8] who reported increase in sugar content with the foliar application of CPPU at 20 ppm on Japanese pear trees. CPPU applied at 5 ppm increased the sucrose, glucose, fructose contents in kiwi Fang-Xue Zhi *et al.* (2006) [11].

From the ongoing study it can be concluded that growth parameters like plant height, plant spread, trunk girth and annual shoot growth were observed significantly higher under the treatment CBOC + H_3BO_3 at 0.2%. However, leaf area and leaf chlorophyll content were recorded significantly higher under the treatment CBOC + CPPU at 5 ppm. Physiological characteristics such as photosynthetic rate and transpiration rate were higher in the plant under crescent bund with open catchment pits. The extent of fruit cracking was reduced to the lowest level (2.8%) from 11.67% in control and highest fruit yield (26.8Kg/plant) was recorded when the plants were given foliar application of CPPU at 5 ppm under CBOC. The least russet formation (1.33 on 10 point scale) occurred in fruits from plants given the treatment of CPPU at 5ppm +CBOC. The maximum fruit length (86.2 cm) and fruit breadth (88.3 cm), fruit weight (419.74 g), aril weight (279.21 g), aril percentage (66.52), juice content (67.93 ml/100 g), ascorbic acid content (16.84 mg/100g) were obtained with the treatment of CPPU at 5ppm +CBOC. The lowest titratable acidity (0.49%), highest TSS (15.210 B) and TSS/acid ratio (31.07) was recorded in fruits from plants under the treatment of H_3BO_3 at 0.2% with mulching. Total sugar, reducing sugar were recorded highest under the treatment H_3BO_3 at 0.2% + CBOC and lowest in control. Hence, pre-harvest spray of forchlorfenuron and boron along with soil working technique-crescent bund with open catchment pit can be employed to conserve more soil moisture, reducing fruit cracking and increase production of pomegranate with improved fruit quality in rain fed conditions.

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