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Original Research Paper

Influence of plant growth substances on reproductive growth, yield and fruit quality of pear (*Pyrus communis* L.) cv. Punjab Beauty

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ABSTRACT

Under sub-tropical region, poor fruit set is a major constraint in semi-soft pears resulting in lower fruit yield. To study the effect of plant growth substances on fruit production and quality, the plants of pear cv. Punjab Beauty were sprayed with the plant growth substances *viz.*, boric acid (200, 300 ppm), CPPU (5, 10 ppm), NAA (10, 20 ppm) and P-Ca (150, 300 ppm) at full bloom stage. Among all the applied treatments, boric acid @ 200 ppm proved to be most effective with maximum fruit set (6.91 %), fruit retention (59.9 %) and yield (57.8 kg/plant), while, maximum fruit weight (162.3 g) was observed with NAA (20 ppm). The highest internal fruit quality in terms of maximum TSS (12.4º Brix), TSS/acid ratio (53.4) and ascorbic acid (12.8 mg kg^{-1}) was observed in 200 ppm boric acid. However, the total phenol (30.9 mg GAE/100 pulp) and flavonoid (36.1 mg CE/100 pulp) content was significantly higher with NAA (20 ppm). The plant growth substances reduced the polyphenol oxidase activity in fruits. Overall, the application of boric acid (200 ppm) resulted in improved fruit set, yield and quality in pear cv. Punjab Beauty.

Key words: Fruit set, fruit quality, fruit yield, pear, phenols

INTRODUCTION

Under north-western conditions of India, pear cultivation is dominated by hard pear cv. Patharnakh due to very high yield potential. However, its fruit quality is average owing to very gritty fruit texture which has led to release of several semi-soft pear varieties. Among these, the cultivar Punjab Beauty became popular due to its commendable fruit quality and adaptability to regional sub-tropical climatic conditions. Although pear plants of this cultivar exhibit abundant flowering in spring but due to low fruit set, the fruit yields often remain below par. The shy behaviour of this cultivar may be either due to ovule abortion, defective flowers, poor pollen germinability, premature or delayed pollination, competition among flowers, excessive flower abscission and low fruit retention leading to reduced fruit set (Gill et al., 2012). Hence, there is a need to improve fruit set in pear cv. Punjab Beauty by reducing flower drop and pistil drop with the application of plant growth substances (Mostafa et al., 2001).

The action of various plant growth substances such as naphthalene acetic acid (NAA), boric acid (BA), N-(2-Chloro-4-pyridyl)-N'- phenylurea (CPPU) or Sitofex and Prohexadione-calcium play a crucial role in the regulation of fruit set, fruit quality and biochemical parameters in many fruit crops. Foliar spray of 400 ppm prohexadione calcium (P-Ca) at 10 days after full bloom stage on 'Patharnakh' pear resulted in an increase in fruit number, size, TSS content, and fruit firmness (Kaur et al., 2021). Likewise, 'Gola' pear plants applied with CPPU [N-(2-Chloro-4-pyridyl)-N2 -phenylurea] @ 5 ppm recorded maximum fruit retention and fruit yield along with better quality fruits in terms of TSS and TA (Nimbolkar et al., 2015; Nimbolkar et al., 2016).

The exogenous application of plant growth substance and boric acid enhances the pollination and promotes pollen germination. It acts as an essential trace element for pollen germination and is responsible for reducing percentage of flower drop and enhances the percentage of fertile flowers which led to increased fruit set and yield of apple, almond and olive (Hegazi, 2001). The post bloom application of NAA improved fruit set, fruit retention and ultimately fruit yield in many fruits (Ghosh et al., 2012). The increased fruit set may be due to higher availability of carbohydrates and C:N ratio because of improved photosynthesis.

Over the past few years, extensive research conducted on the assessment, training, propagation and use of chemicals to improve the quality and output of fruit crops. But very few reports are available on the efficacy of PGSs on improving the fruit yield concomitant with the maintenance of quality attributes. Thus, a study was undertaken to evaluate the impact of plant growth substances (boric acid, CPPU, NAA, and P-Ca) on enhancing the fruit set per cent, yield and fruit quality in pear cv. Punjab Beauty.

MATERIALS AND METHODS

The present investigations were carried out at the Fruit Research Farm, Department of Fruit Science, Punjab Agricultural University. Twelve-year-old plants of pear cv. Punjab Beauty plants were sprayed with different growth substances *viz.*, T_1-boric acid 200 ppm, T_2-boric acid 300 ppm, T_3 -CPPU 5 ppm, T_4 -CPPU 10 ppm, T_5-NAA 10 ppm, T_6-NAA 20 ppm T_7-P-Ca 150 ppm, T_8 P-Ca 300 ppm, and T_9-control with water sprayed only, at full bloom stage for two consecutive years from 2018 to 2019.

Fruit set on tagged branches was recorded from the time of onset of flower bud formation till the completion of fruit set and calculated by dividing number of developing fruitlets with total number of flowers. The fruit retention was computed by dividing number of fruits at harvest with number of fruitlets at peanut stage and both were expressed in percentage. Total fruit yield was calculated by counting total number of fruits retained on each plant at the time of harvest and was expressed in kg/plant.

To record the physical quality parameters, fruits from each experimental plant were picked during the third week of July. The fruit size was recorded with digital vernier calipers (Mitutoyo, Japan) and fruit weight with an electronic precision balance (Model: EK6100i, A&D, Japan). The total soluble solids (TSS) content was determined with a digital refractometer (ATAGO, PAL-1, Model 3810, Japan) at room temperature by making subsequent corrections at 20°C. Titratable acidity (TA) in terms of malic acid was determined by neutralization with 0.1N NaOH. Fruit firmness was determined using a penetrometer (model noFT-327, USA) after peeling thin slice of peel from surface of fruit at three separate sites but equidistant from the equator and values were expressed as Newton (N) force. Ascorbic acid content of pear fruits was estimated as per Ranganna (2000) and expressed as mg/kg. The phenolic content was determined by the method suggested by Sethi et al. (2013) and calculated in terms of gallic acid equivalent (mg/100g). The flavonoid content was determined by the method given by Sethi et al., (2013) and expressed as catechin mg/g. PPO activity was measured by using the spectrophotometric method based on an initial rate of increase in absorbance at 410 nm up to three minutes (Garcia-Palazon et al., 2004) and was expressed as unit min^{-1} g^{-1} fresh weight (FW). The experiment was laid out in a randomized block design with four

Table 1 : Effect of plant growth substances on fruit set, retention and yield of pear cv. Punjab Beauty

Treatment	Fruits set (%)		Fruit retention (%)		Yield (kg/plant)	
	2018	2019	2018	2019	2018	2019
T_1: Boric acid 200 ppm	6.66^{a}	7.16^{a}	59.1^{a}	60.8^{b}	56.1^{a}	59.6^{a}
T_2: Boric acid 300 ppm	6.13^{c}	6.32^{bc}	533^{c}	59.4^{c}	53.4^{ab}	57.1^{ab}
T_3: CPPU 5 ppm	6.12^{c}	6.27^{bc}	53.5^{c}	58.3^{d}	51.6^{ab}	54.2^{bc}
T_4: CPPU 10 ppm	6.06^{c}	6.12^{c}	51.3^{cd}	59.4^{c}	50.4^{bc}	50.5^{cd}
T_5: NAA 10 ppm	6.43^{b}	6.77^{ab}	56.4^{b}	58.3^{d}	47.7^{c}	53.0^{bcd}
T_6: NAA 20 ppm	6.52^{ab}	6.99^{a}	54.5^{bc}	64.1^{a}	50.5^{bc}	57.6^{ab}
T_7: P-Ca 150 ppm	5.84^{cd}	6.09^{c}	50.6^{d}	57.7^{de}	50.0^{d}	51.9^{cd}
T_8: P-Ca 300 ppm	5.43^{d}	6.04^{c}	49.3^{e}	55.0^{e}	45.3^{e}	48.8^{d}
T_9: Control	4.16^{e}	4.63^{d}	44.4^{f}	48.4^{f}	41.2^{f}	47.0^{e}
C.D. (P=0.05)	0.60	0.32	4.11	0.32	7.45	0.30

Different letters in the column represent significant difference at $P < 0.05$ level by Tukey's HSD test

replications. The data of the two years were subjected to analysis of variance (ANOVA) using statistical analysis software SAS (Version 9.3 for Windows). Differences in means were compared by Tukey's HSD test at a significance level of 0.05.

RESULTS AND DISCUSSION

The effect of different PGSs on fruit set, retention and yield during 2018 and 2019 are presented in Table 1. Among the different treatments, boric acid (200 ppm) resulted maximum fruit set and fruit retention during the years 2018 (6.66% and 59.1%) and 2019 (7.16% and 60.8%). Significantly higher fruit yield during the year 2018 (56.1 kg/ plant) and 2019 (59.6 kg/ plant) was recorded with boric acid (200 ppm) as compared to the untreated plants. An increase in fruit set, retention and yield in the plants sprayed with boric acid might be related to stimulatory effect of boric acid on pollen germination and tube growth (Yehia & Hassan, 2005). While, increased fruit retention in NAA treated plants may be due to the delay in the abscission by auxins through preservation of loss of pectin material in middle lamella (Kachave & Bhosle, 2007). NAA sprays also improved fruit set and yield in Gola pear plants (Nimbolkar et al., 2016) which might be related to improvement in the carbohydrate availability to the fruits (Mostafa et al., 2020).

The fruit size (length x breadth) varied significantly in response to the different plant growth substance treatments (Table 2). The application of CPPU (5 ppm) significantly increased the fruit length as compared to other treatments during 2018. During the following year, both doses of CPPU were effective in increasing fruit length. However, varied trend was followed for fruit breadth, where, NAA (20 ppm) and NAA (10 ppm) exhibited highest fruit breadth in 2018 (63.9 mm) and 2019 (61.2 mm), respectively. The maximum fruit weight in 2018 (160.8 g) and 2019 (163.8 g) was observed with NAA (20 ppm), while, fruit size was recorded minimum in P-Ca (300 ppm). Similar increase in mango fruit length with CPPU was also reported (Kulkarni et al., 2017). Increase in fruit weight with CPPU is mainly due to its effect on cell division and enlargement, and strengthening of sink carbohydrate (Mostafa et al., 2020). CPPU also improves the movement of simple sugars which are involved in the cell expansion and cell elongation and therefore results in the greater fruit length (Mostafa et al., 2020). Increased fruit breadth and weight with NAA may be associated to increase in cell division and cell expansion by auxins (Kaseem et al., 2011).

A significant higher fruit firmness was recorded with boric acid (200 ppm) as compared to control during both the years (Table 2), minimum fruit firmness was attained with the CPPU treatment which was, however, at par with control. Boric acid improves the mobility of calcium which is involved with the firmness of fruits (Ganai et al., 2018). Khalaj et al. (2017) also reported that boric acid increased the fruit firmness in pear.

Table 2 : Effect of plant growth substances on fruit size (length and breadth), fruit weight and firmness of pear cv. Punjab Beauty

Treatment	Fruit length (mm)		Fruit breadth (mm)		Fruit weight (g)		Fruit firmness (N)	
	2018	2019	2018	2019	2018	2019	2018	2019
T_1: Boric acid 200 ppm	78.7^c	74.9^c	61.6^b	56.1^d	133.2^e	138.4^e	62.6^a	54.8^a
T_2: Boric acid 300 ppm	73.8^d	75.8^b	54.8^{bc}	57.3^c	125.9^f	131.5^f	60.7^b	54.6^{ab}
T_3: CPPU 5 ppm	84.6^a	76.3^a	54.5^d	52.5^g	137.4^c	142.9^c	50.4^{de}	47.2^e
T_4: CPPU 10 ppm	81.9^b	76.4^a	53.4^{de}	55.7^e	133.8^d	138.6^d	50.0^{ab}	46.9^e
T_5: NAA 10 ppm	72.3^e	68.9^f	62.1^{ab}	61.2^a	158.0^b	162.0^b	62.0^{ab}	50.8^d
T_6: NAA 20 ppm	69.5^f	64.8^g	63.9^a	60.5^b	160.8^a	163.8^a	61.3^{ab}	55.0^a
T_7: P-Ca 150 ppm	69.6^f	70.3^d	57.8^c	53.7^g	121.9^h	127.3^{gh}	49.3^e	52.6^c
T_8: P-Ca 300 ppm	68.8^g	69.2^e	52.4^e	54.8^f	121.1^h	125.7^h	56.4^c	53.1^{bc}
T_9: Control	67.1^h	63.6^h	49.1^f	50.0^h	123.0^g	127.3^g	51.5^d	47.9^e
C.D. (P=0.05)	5.59	0.16	3.90	0.34	3.94	0.56	2.05	0.20

Different letters in the column represent significant difference at $P < 0.05$ level by Tukey's HSD test

Different plant growth substance treatments influenced internal pear fruit quality attributes. The application of boric acid (200 ppm) resulted in significantly high TSS in 2018 (12.3º Brix) and in 2019 (12.5º Brix), respectively as compared to control and other treatments, while, minimum TSS was observed in control plants. Various treatments educed TA content than the control fruit. The minimum TA content during 2018 (0.24%) and 2019 (0.21 %) was recorded with boric acid (200 ppm), which was significantly lower than all other treatments including control. The fruit maturity index defining TSS/acid ratio differed significantly among different treatments during 2018 and 2019, being maximum (50.20 and 56.50, respectively) with boric acid (200 ppm) followed by NAA (20 ppm) (47.9 and 52.9, respectively) and minimum was noted in control (29.9 and 32.1, respectively). Similar results of increased TSS and decreased titratable acidity with boric acid were registered in apple (Ganai et al., 2018) and pear (Gill et al., 2012). The increase in total sugar content may be due to a breakdown of complex polymers into simple substances by hydrolytic enzymes. Boric acid facilitates sugar transport within a plant, and it is reported that boric acid reacts with sugars to form a complex that is more easily available to the transverse membrane (Ganai et al., 2018).

The foliar application of boric acid (200 ppm) resulted in maximum accumulation of ascorbic acid content in fruits during 2018 (12.6 mg/kg), and 2019 (13.0 mg/kg) as compared to other treatments (Table 3). NAA, boric acid, and CPPU treatments recorded significantly higher ascorbic acid contents as compared to control. There was no significant difference in ascorbic acid content for P-Ca treatments and control. The increased ascorbic acid content in NAA treatments may be linked to auxin induced galactose-1-phosphate which is involved in the biosynthesis of ascorbic acid (Li et al., 2017).

A significant highest phenol content during 2018 (30.9 mg GAE/100g pulp) and 2019 (31.1 mg GAE/100g pulp) was recorded with boric acid (200 ppm) than rest of the treatments and was closely followed by NAA (20 ppm) (Table 4.). Likewise, boric acid (200 ppm) recorded significantly high flavonoid content during 2018 (36.4 mg GAE/100g pulp) and 2019 (36.8 mg GAE/100g pulp). The various PGSs reduced the PPO activity in pear fruits as compared to control, minimum was recorded during 2018 (20.2-unit min^{-1} g^{-1} fresh mass) and 2019 (22.5-unit min^{-1} g^{-1} fresh mass) in boric acid (200 ppm).

Khandaker et al. (2012) also reported that NAA (5 ppm) increased phenol, flavonoid and anthocyanin of wax apple fruits. The maximum reduction in the PPO activity was observed in fruits sprayed with NAA treatments. This inhibitory effect of NAA on PPO activity might be related to its interference with ethylene action or reduced sensitivity of the abscission zone of fruit to the hormone (Masia et al., 1998). Auxins are believed to regulate the metabolism of

Table 3 : Effect of plant growth substances on total soluble solids (TSS), titratable acidity, TSS: acid and ascorbic acid of pear cultivar Punjab Beauty

Treatment	TSS (ºBrix)		Titratable acidity (%)		TSS: acid		Ascorbic acid (mg/kg)	
	2018	2019	2018	2019	2018	2019	2018	2019
T_1: Boric acid 200 ppm	12.31^{a}	12.58^{a}	0.24^{d}	0.21^{e}	50.24^{a}	56.57^{a}	12.55^{a}	12.95^{a}
T_2: Boric acid 300 ppm	11.82^{abc}	11.93^{bcd}	0.26^{bcd}	0.25^{c}	44.74^{ab}	46.78^{d}	9.92^{c}	10.04^{c}
T_3: CPPU 5 ppm	11.88^{bc}	11.87^{cde}	0.27^{cd}	0.25^{c}	42.97^{ab}	47.13^{cd}	9.63^{c}	9.89^{c}
T_4: CPPU 10 ppm	11.54^{c}	11.72^{de}	0.30^{bc}	0.26^{c}	43.31^{ab}	45.69^{de}	7.72^{d}	8.04^{d}
T_5: NAA 10 ppm	11.96^{abc}	12.17^{abc}	0.25^{bcd}	0.24^{d}	46.95^{ab}	49.24^{c}	10.17^{bc}	10.33^{bc}
T_6: NAA 20 ppm	12.21^{ab}	12.38^{ab}	0.26^{bcd}	0.23^{d}	47.93^{a}	52.93^{b}	10.32^{b}	10.71^{b}
T_7: P-Ca 150 ppm	11.46^{c}	11.64^{de}	0.27^{cd}	0.26^{c}	41.68^{ab}	43.58^{e}	7.64^{de}	7.72^{de}
T_8: P-Ca 300 ppm	11.29^{d}	11.47^{e}	0.31^{b}	0.28^{b}	37.82^{bc}	40.51^{f}	7.60^{de}	7.74^{de}
T_9: Control	11.20^{e}	11.45^{e}	0.38^{a}	0.35^{a}	29.98^{c}	32.18^{g}	7.44^{e}	7.56^{e}
C.D. (P=0.05)	0.24	0.26	0.04	0.007	0.06	0.27	1.83	0.26

Different letters in the column represent significant difference at $P < 0.05$ level by Tukey's HSD test

Table 4 : Effect of plant growth substances on total phenols, flavonoids and polyphenol oxidase of pear cv. Punjab Beauty

Treatment	Phenols (mg GAE/100 pulp)		Flavonoids (mg CE/100 pulp)		PPO (unit min^{-1} g^{-1} fresh mass)	
	2018	2019	2018	2019	2018	2019
T_1: Boric acid 200 ppm	29.61^{bc}	30.81^{a}	35.66^{ab}	36.22^{b}	22.11^{f}	23.41^{f}
T_2: Boric acid 300 ppm	29.88^{ab}	30.07^{bc}	35.73^{bc}	36.67^{ab}	25.92^{de}	26.15^{d}
T_3: CPPU 5 ppm	28.61^{c}	29.23^{d}	35.12^{cd}	35.51^{c}	26.18^{de}	26.33^{d}
T_4: CPPU 10 ppm	27.44^{d}	29.98^{c}	35.05^{de}	35.29^{bc}	28.52^{cd}	30.25^{c}
T_5: NAA 10 ppm	29.73^{bc}	30.52^{ab}	34.58^{e}	35.92^{b}	23.36^{ef}	24.62^{e}
T_6: NAA 20 ppm	30.91^{a}	31.15^{a}	36.42^{a}	36.88^{a}	20.22^{f}	22.57^{g}
T_7: P-Ca 150 ppm	27.65^{d}	27.72^{e}	34.68^{e}	35.01^{d}	30.38^{bc}	30.53^{c}
T_8: P-Ca 300 ppm	23.12^{e}	26.17^{f}	33.51^{f}	33.64^{e}	33.03^{ab}	32.46^{b}
T_9: Control	22.78^{f}	23.71^{g}	29.78^{g}	29.72^{f}	33.87^{a}	33.08^{a}
C.D. (P=0.05)	0.44	0.31	0.32	0.34	0.28	0.41

Different letters in the column represent significant difference at P < 0.05 level by Tukey's HSD test

phenolics and flavonoids by elevating the activities of chalcone synthase and phenyl alanine ammonia lyase activity which plays crucial role in their biosynthesis (Khandaker et al., 2012).

CONCLUSION

The foliar application of boric acid (200 ppm) at full bloom stage was found most effective for increasing fruit set, yield parameters, fruit quality characters such as fruit weight, fruit firmness, TSS: acid, antioxidants, total phenols and flavonoids in cv. Punjab Beauty.

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