Effect of gibberellin and brassinosteroid on vegetative and reproductive growth of pear [*Pyrus pyrifolia* (Burm.) Nakai] cv. Gola

VINOD SINGH THAPLIYAL, LOKESH BORA, P N RAI, D. C. DIMRI and MAMTA METWAL

Department of Horticulture, College of Agriculture, G. B. Pant University of Agriculture and Technology, Pantnagar-263145 (U. S. Nagar, Uttarakhand),

ABSTRACT : The present study consists of seventeen year old pear trees subjected to seven treatments *viz.,* GA_3 (50 ppm,100 ppm), BR (0.5 ppm, 1.0 ppm), and GA_3 + BR (50 ppm + 0.5 ppm and 100 ppm + 1 ppm) and water as control, sprayed thrice at 15 days intervals starting from petal fall stage. Each treatment was replicated thrice with one tree served as a treatment unit. The experiment was conducted in RBD. The application of GA_3 had significant effect on tree spread when applied at 50 ppm (T_1), while tree volume, shoot growth, number of leaves and total chlorophyll content at 100 ppm (T_2). Spray of 100 ppm GA_3 + 1 ppm BR (T6) was found effective in enhancing yield and yield attributing characters viz., fruit set (37.68%), fruit retention (62.25%) and yield (82.93 kg $tree^{-1}$). Thus, it can be concluded that the combined application of gibberellin and brassinosteroid either @ GA_3 (100 ppm) + BR (1 ppm) or GA_3 (50 ppm) + BR (0.5 ppm) as pre- harvest sprays at 15 days interval starting from the petal fall stage may be recommended for improvement in fruit yield and quality of Gola pear in *tarai* region.

Key words: 24-epibrassinolide, foliar spray, Gibberellic acid, vegetative and reproductive growth

Pear (*Pyrus pyrifolia* (Burm.)) is one of the important temperate fruit grown in a wide range of climatic conditions, which can tolerate temperature as low as -26°C when dormant and as high as 45°C during the growing period. It requires a chilling period as high as 1200 hours below 7°C during winter to flower and fruit satisfactorily. Pear belongs to the family Rosaceae, tribe Pomoideae and genus *Pyrus*. It ranks second, only next to apple in many respect *viz.,* global importance, existence of diversity, acreage and production. About 23.53 millions MT of pear are produced around the world (FAO STAT, 2013) of which 315,000 MT is produced in India from an area of 42,000 ha (NHB, 2014). The area, production and productivity of pear in the state of Uttarakhand is 5,081 ha; 108,120 MT and 7.16 tonne ha^{-1}, respectively (Anonymous, 2014). The pear cv. 'Gola' is mainly cultivated in *Tarai* region of Uttarakhand and Punjab, which is harvested in the month of July. In comparison to the other low chilled early cultivars, 'Gola' has higher productivity with better quality fruits. Due to non adoption of improved cultivation practices and several other horticultural practices, the growth and development of fruit, yield and quality are generally poor. The cultivar has typical characteristic feature for upright growth, narrow branch angles, excessive flower and fruit drop in subtropical region. It bear small sized fruits with inferior quality, due to which their potential to fetch heavy price in market is hampered. Improving marketable yield of good quality sub-tropical pear fruits has always been a challenge for pear growers. If the control over the excessive fruit drop and increased fruit size is achieved by use of use of growth regulators, the cultivar may have a further improvement in its marketing value.

During recent years a new class of phytohormones has been gaining importance for modification of vegetative growth and boosting yield in various fruit crops. The sixth generation plant growth hormones, which come after auxins, gibberellins, cytokinins, abscissic acid and ethylene, are named as Brassinosteroids (BRs). Brassinosteroids are relatively new endogenous phytohormones (Swamy and Rao, 2010) which was first isolated from pollen grains of Brassica napus, participate with other plant hormones in the regulation of numerous aspects of plant development, including shoot and root growth, vascular differentiation, fertility, and seed germination. Its several analogues and substances with a similar structure to the natural brassinosteroid have been shown to be useful in horticulture (Zullo et al., 2003). Application of brassinosteroids (BRs) affects a broad spectrum of cellular and physiological processes, including cell expansion, vascular differentiation, photosynthesis, seed germination, stem elongation, pollen tube growth, leaf bending, flowering and fruit set and modulation of gene expression in fruit crops. Brassinosteroids (BRs) can be developed to be the new generation agro chemicals, as they do not interfere with the environment, act in natural doses in a natural way and above all they have the ability to improve quantity and quality of horticultural crops and protect plants against several kinds of stresses. For these reasons, they have good prospects for enhancing fruit production and plant protection in the near future. Being natural compounds, they stimulate the plant itself via activation of gene expression in a certain period of development and also they do not allow the development of biotypes or co-evolution of pests. Such an approach, based on a wider use of existing genetic resources looks promising, and may be better accepted by the consumer. So, it is necessary to overcome these problems for improving yield with quality attributes by using different pre-harvest application of plant bio-regulators *viz,* gibberellin and brassinosteroids. Therefore, considering the above facts and constraints, the present study was undertaken to elucidate the effect of gibberellin and brassinosteroids on Gola pear under *Tarai* condition.

MATERIALS AND METHODS

The study was carried out at HRC Patharchatta, GBPUAT, Pantnagar, (Uttarakhand) during the growing season of year 2014. The experiment was laid out on 17 years old bearing pear trees cv. 'Gola' of uniform vigor and size. All the trees were maintained under uniform cultural practices during investigation. The applications of various treatments were given thrice, first spray at petal fall on 3rd March, 2014 and second and third spray after fifteen days interval i.e., 18th March, and 2nd April, 2014, respectively. The trees were subjected to seven treatments *viz.,* GA_3 (50 ppm, 100 ppm), BR (0.5 ppm, 1.0 ppm), and GA_3 + BR (50 ppm + 0.5 ppm and 100 ppm + 1 ppm) and water as control (T_7). Tree height was measured twice with the help of pre-marked bamboo pole (15 m) from the base of the trunk at the collar region to the tip of the terminal extension growth on central leader. The tree canopy volume was calculated as per formula suggested by Westwood (1978).

$$\text{Tree volume } (m^3) = \frac{-4\pi r^2 h}{3}$$

Where, $\pi = 3.14$

r = radius from average canopy spread (m).

h = distance from point of first branch on trunk to the top of tree (m).

The canopy spread of the tree was measured in both directions i.e. North-South and East-West with the help of measuring tape. Tree canopy spread was calculated by the following formula:

$$\textit{Average Plant spread} = \frac{(\textit{Spread from East to West}) + (\textit{Spread form North to South})}{2}$$

The per cent tree spread was computed by subtracting final value from the initial value, dividing it by initial value and multiplied by hundred. The number of fruitlets in tagged portion of four branches in each direction of experimental trees was counted, 30 days after petal fall stage and the percentage of fruit set was calculated.

$$\text{Fruit Set (\%)} = \frac{\text{Total number of fruitlets on fruiting branch}}{\text{Total number of flower on branch}} \times 100$$

Numbers of fruits were counted at 30 days interval on each selected branch during the fruit growing season upto 10th of July, 2014. The data of fruit drop was recorded by observing the retention of the fruits on tree and then subtracting it from initial value of total number of fruits, and then dividing by total number of fruits and multiplied by hundred.

$$\text{Fruit drop (\%)} = \frac{\text{Total number of fruit set - number of fruits at harvest time}}{\text{Total number of fruit set}} \times 100$$

Fruit retention (%)

Total numbers of fruits retained on the marked branches were counted at the time of harvest and the percentage of fruit retention was calculated.

$$\text{Fruit retention (\%)} = \frac{\text{Total number of fruits set retained of fruiting branch}}{\text{Total number of fruit set on fruiting branch}} \times 100$$

Four leaves were collected from each treatment at the end of growing season and leaf area index was measured by using leaf area meter. The leaf area was measured with the help of LI-COR portable leaf area meter LI-3000, attached with a LI-3050 a transparent belt conveyor and area was expressed in square centimeters (cm^2).

The total chlorophyll was measured by the method as described by Hiscox and Isrealstam (1979). Five leaves were taken from apex, middle and base of shoot all around of the tree and chopped into small pieces separately. Hundred milligram samples from these chopped leaves was placed into separate test tubes. After that 10 ml of Dimethyl Sulphoxide (DMSO) was added in each tube. These tubes were then incubated in oven at temperature 65 °C for 3 ½ hours. The chlorophyll content is then determined using spectrophotometer at a wavelength of 663 and 645 nm, against pure DMSO as blank. The amount of chlorophyll a, chlorophyll b and total chlorophyll in terms of mg/100 g on fresh weight basis of leaves was calculated from the equation of Arnon (1949).

$$\text{Chlorophyll 'a' mg /100 g} = \frac{[12.7\ (A663) - 2.69(A645)]}{W \times 1000} \times V$$

$$\text{Chlorophyll 'b' mg /100 g} = \frac{[22.9\ (A645) - 4.68(A663)]}{W \times 1000} \times V$$

$$\text{Total Chlorophyll 'a' mg /100 g} = \frac{[20.2(A645)-8.02(A663)]}{W \times 1000} \times V$$

Where,
A= Absorbance of chlorophyll extract at the specific indicated wavelength,
V = Final volume of the solution and
W = gm of tissue extracted/weight of sample

Number of fruits per tree, yield and yield efficiency

After collection of fruits under individual tree total number of marketable fruits per tree were counted manually. The fruits were harvested at harvest maturity on 12th July, 2014. All the fruits from the individual trees were picked manually and collected under the trees. The exceptionally small, damaged or misshapen fruits were pulled out. Yield efficiency was calculated by dividing yield with tree volume and expressed as kg m^{-3}.

$$\text{Yield efficiency (kg m}^{-3}) = \frac{\text{Total yield (kg)}}{\text{Volume of the tree (m}^3)}$$

Statistical analysis

The experiment was laid out in Randomized Block Design (RBD) consisting of seven treatments. All the treatments were replicated thrice and one tree served as a unit of treatment in each replication. Data were subjected to analysis of variance (ANOVA) by using STPR3 software, G.B.P.U.A&T, Pantnagar, India.

RESULTS AND DISCUSSION

With respect to the data pertaining to the effect of pre-harvest application of gibberellin (GA_3) and brassinosteroid (BRs) on increase in the tree height, trunk diameter, spread and volume (Table 1), it was noticed that per cent increment in tree height was statistically non-significant, under the various application of GA_3 and BRs. Maximum per cent increment in height (8.26%) was observed in foliar application of BR @ 1 ppm (T_4) followed by 100 ppm GA_3 (T_2) i.e., 8.11% in comparison to control (7.48%). A close perusal of data reveals that per cent increment in trunk diameter of different trees by the application of bioregulators did not differ significantly. The increase in trunk diameter over the growing season ranged from 3.15% (control) to 4.18% (T_2) under different treatments.

The increment in tree volume was observed maximum 16.81% in GA_3 at 100 ppm (T_2) followed by 15.47% i.e., BR at 1 ppm (T_4), both statistically at par with each other. The minimum value of 11.31% was observed in control (T_7). The data regarding per cent increase in tree spread indicates that there was significant influence of various treatments. Among the different treatments, 50 ppm GA_3 (T_1) registered maximum increase in tree spread (8.52%) followed by (1.0) ppm BR i.e., T_4 (8.48%). On the other hand, minimum value (7.22%) was observed in control (T_7) which was *at par* with the spray of 0.5 ppm BR (T_3) i.e., 7.94%. Foliar application of gibberellic acid has the ability to stimulate plant growth and development. This may be due to the enhanced photosynthetic rates or due to more efficient

Table 1: Effect of pre-harvest spray of GA_3 and BR on per cent increase in tree height, trunk diameter, volume and spread in pear cv. 'Gola'

Treatments	Per cent increase			
	Tree height	Trunk diameter	Tree volume	Tree spread
GA_3 @ 50 ppm (T_1)	7.83	4.04	13.68	8.52
GA_3 @ 100 ppm (T_2)	8.11	4.18	16.81	8.41
BR @ 0.5 ppm (T_3)	7.91	3.47	12.31	7.94
BR @ 1 ppm (T_4)	8.26	3.61	15.47	8.48
GA_3 @ 50 ppm + BR @ 0.5 ppm (T_5)	7.93	3.84	12.96	8.03
GA_3 @ 100 ppm + BR @ 1 ppm (T_6)	8.02	3.70	13.24	8.35
Control (T_7)	7.48	3.15	11.31	7.22
SEm±	0.26	0.21	0.54	0.24
CD (0.05)	NS	NS	1.66	0.74

utilization of photosynthates. These results are in conformity with the study of Casper and Taylor (1982), who stated that gibberellins at lower concentrations (50 mg L^{-1}) increase the growth in young trees of 'Loring' peach.

The shoot growth was recorded at 30 days interval from 10th April to 10th July. The data presented in the table 2 reflects that all treatments had significant effect on lateral shoot growth and a sigmoidal growth pattern was observed during the entire growing season. During the month of April, maximum increment in shoot growth (7.13 cm) was observed in 50 ppm GA_3 (T_1) which was statistically *at par* with T_2 (6.83 cm) and T_6 (6.17 cm) while minimum (4.98 cm) with control (T_7) followed by treatment T_3 (5.52 cm). During the later part of investigation i.e., July, the increase in shoot growth was found maximum (13.05 cm) in treatment T_2. The minimum shoot growth was recorded in control (8.07 cm) which was found statistically *at par* with T_3, (10.19 cm).

Possible reason for the increment in shoot growth may to due to counteracting effects of the applied gibberellins on autogenous growth inhibitors and aiding the endogenous levels of gibberellins and auxin. The significant increase in shoot growth as observed with the GA_3 application in this study is in line with the earlier findings of Lakshmi *et al.* (2014) in acid lime (*Citrus aurantifolia* Swingle) cv.'Balaji'. Similar results were obtained by Duarte *et al*. (2006) suggesting positive effect of GA_3 on the shoot growth of 'Clausellina Satsuma' mandrain. Several studies have demonstrated the role of brassinosteriods (BRs), alone and in interaction with other plant hormones, in cell elongation.

The maximum number of leaves per meter shoot (46.96) was observed with the application of 100 ppm GA_3 (T_2), while minimum (36.20) with control (T_7) followed by foliar applications of brassinosteroid T_3 (37.17) and T_4 (38.86) which was found to be statistically *at par* with each other (Table 3). The increment in leaf number recorded with higher concentration of GA_3 is due to the increased translocation of photosynthates all around the tree system and being readily available in sufficient quantities at the growing sites in the shoots as described by Duarte *et al*, (2006), who observed a

Table 2: Effect of pre-harvest spray of GA_3 and BR on shoot growth of pear cv. 'Gola''

Treatments	Shoot growth increment (cm)			
	10-April	10-May	10-June	10-July
GA_3 @ 50 ppm (T_1)	7.13	9.84	11.75	12.50
GA_3 @ 100 ppm (T_2)	6.83	9.95	12.48	13.05
BR @ 0.5 ppm (T_3)	5.52	7.63	9.08	10.19
BR @ 1 ppm (T_4)	5.77	8.03	9.74	10.93
GA_3 @ 50 ppm + BR @ 0.5 ppm (T_5)	5.80	7.95	9.88	11.21
GA_3 @ 100 ppm + BR @ 1 ppm (T_6)	6.17	8.76	10.79	12.18
Control (T_7)	4.98	6.86	7.72	8.07
SEm±	0.43	0.60	0.85	0.83
CD (0.05)	1.31	1.85	2.63	2.54

Table 3: Effect of pre-harvest spray of GA_3 and BR on number of leaves per meter of branch and leaf area index in pear cv. 'Gola'

Treatments	No. of leaves per meter of branch	Leaf area (cm^2)
GA_3 @ 50 ppm (T_1)	43.72	73.12
GA_3 @ 100 ppm (T_2)	46.96	74.63
BR @ 0.5 ppm (T3)	37.17	76.23
BR @ 1 ppm (T_4)	38.86	78.50
GA_3 @ 50 ppm + BR @ 0.5 ppm (T_5)	39.39	73.93
GA_3 @ 100 ppm + BR @ 1 ppm (T_6)	41.85	75.86
Control (T_7)	36.20	71.13
SEm±	2.14	1.37
CD (0.05)	6.60	4.23

significant elevation in number of leaves after treating the 'Clausellina Satsuma' trees with GA_3. The value of leaf area ranged from 71.13 cm^2 to 78.50 cm^2. The maximum leaf area was measured with the spray of BR @ 1 ppm (T_4) followed by T_3 (76.23 cm^2). The minimum leaf area was found in control followed by T_1 (73.12 cm^2) and T_5 (73.93 cm^2) which were statistically *at par* with each other.

Increased leaf area might be due to the enhancing effect of brassinosteriods on the activities of meristematic tissues of plant, increasing number and size of cell, which ultimately increases the photosynthetic surface area of the leaves (Munoz *et al*., 1998). Besides, brassinosteriods are known to promote nucleic acid level, nitrogen fixation, soluble protein content, DNA and RNA concentrations (Jeyakumar *et al.,* 2010). These results also elucidate the findings of Anitha and Jeyakumar, (2005) in banana and Gabr *et al*. (2011) in apricot.

The maximum content of chlorophyll 'a' (0.42 mg/100 g) was recorded in the treatment GA_3 at 50 ppm (T_1) followed by T_2 (0.41 mg/100 g) and both were statistically *at par* with each other, while minimum chlorophyll 'a' content in control (0.36 mg/100 g) which was statistically *at par* with T_3 (0.37 mg/100 g). The chlorophyll 'b' content was also found highest (0.23 mg/100 g) in T_1 followed by T_5 (0.21 mg/100 g) similar to T_2 whereas minimum value was recorded in control (0.17). The total chlorophyll was observed maximum (0.65 mg/100 g) in T_1 and minimum (0.53 mg/100 g) in control (Table 4).

The enhancement in chlorophyll contents may be through a positive interaction with phytochrome, since chlorophyll is influenced by phytochrome (Mathis *et al*., 1989). The above findings can be correlated with the research of Moneruzzaman *et al.* (2011), who concluded that leaf composition and chlorophyll synthesis was increased at lower GA_3 concentrations. These findings are also in line with the studies performed by Fathi *et al*. (2011), who reported higher chlorophyll contents in the leaves of "Costata" persimmon after application of GA_3 @ 10 ppm in comparison to 20 ppm.

Data given in Table 5 shows that the flowers counted before the foliar spray did not differ significantly however it ranges from 43.68 to 49.35 in numbers per

Table 4: Effect of pre-harvest spray of GA_3 and BR on chlorophyll content of leaf in pear cv. 'Gola'

Treatments	Chlorophyll 'a' (mg/100 g)	Chlorophyll 'b' (mg/100 g)	Chlorophyll 'a+b' (mg/100 g)
GA_3 @ 50 ppm (T_1)	0.42	0.23	0.65
GA_3 @ 100 ppm (T_2)	0.41	0.22	0.63
BR @ 0.5 ppm (T_3)	0.37	0.18	0.55
BR @ 1 ppm (T_4)	0.38	0.19	0.57
GA_3 @ 50 ppm + BR @ 0.5 ppm (T_5)	0.39	0.22	0.61
GA_3 @ 100 ppm + BR @ 1 ppm (T_6)	0.39	0.21	0.60
Control (T_7)	0.36	0.17	0.53
SEm±	0.005	0.007	0.008
CD (0.05)	0.016	0.022	0.026

Table 5: Effect of pre-harvest spray of GA_3 and BR on number of flowers and fruit set per meter branch of pear cv. 'Gola'

Treatments	No. of flowers per meter branch	Fruit set (%)
GA_3 @ 50 ppm (T_1)	49.35	28.32
GA_3 @ 100 ppm (T_2)	48.15	30.35
BR @ 0.5 ppm (T_3)	47.26	27.53
BR @ 1 ppm (T_4)	46.26	31.95
GA_3 @ 50 ppm + BR @ 0.5 ppm (T_5)	45.45	33.66
GA_3 @ 100 ppm + BR @ 1 ppm(T_6)	43.68	37.68
Control (T_7)	46.40	24.71
SEm±	2.28	1.76
CD (0.05)	NS	5.42

meter of tagged branches. Application of GA_3, BRs and their combinations had significant effect on per cent fruit set. Among the different treatments, the highest fruit set (37.68%) was recorded with the combined spray of GA_3 at 100 ppm + BR at 1ppm (T_6) which was statistically at par with the treatment T_5 (33.66%) respectively. The lowest fruit set was observed in control (24.71%).

The higher number of fruit set could be due to accumulation of more carbohydrates in flowers by combined application of GA_3 and BR. Brassinosteriods are known to facilitate pollen tube growth (Mussig, 2005), enhance photosynthesis and mobilizes the metabolites to the flowers (Bhatia and Kaur, 1997) which resulted in more fruit set. Gibberellins play a significant role at the onset of the fruit development, especially in controlling the expression of the genes involved in fruit setting (Jong *et al.,* 2009). Kassem *et al.* (2010) also stated that GA_3 affects fruit formation. Goldwin (1985) observed that positive relationship exist between the longevity and viability of ovules and the application of exogenous growth regulators. These results are in agreement with some earlier findings where, the combination of two or more growth regulators has been noticed to increase fruit set in various fruit crops. A mix of gibberellin and auxin has been capable of improving fruit set as reported by Jackson (1989). In apple, Watanabe *et al.* (2008) have achieved an increase in the percentage of fruit set through the application of GA_3 and CPPU at bloom. Moreover, enhanced fruit set due to brassinosteroids is in line with the application of GA_3 + BRs + BA in Thompson Seedless grapes (Warusavitharana *et al.,* 2008).

The fruit drop percentage was recorded at monthly interval from 10th April to 10th July, 2014 (Table.6). It is apparent from the data that the per cent fruit drop was influenced significantly by different treatments during the course of study. During the initial part of the investigation (10th April to 10th May), per cent fruit drop was higher as compared to the latter half of the investigation (10th June to 10th July). On 10th April, maximum fruit drop (21.68%) was observed in control which was reduced significantly by the use of growth regulators at different concentrations. On the same date, minimum fruit drop (12.35%) was recorded in plants treated with GA_3 @ 100 ppm + BR @ 1 ppm (T_6). During the last observation recorded on 10th July, maximum per cent fruit drop was observed in control i.e., 4.85%, whereas minimum in combined treatment T_6 (1.06%) and T_5 (1.48%) which were however statistically *at par* with each other. Reduced fruit drop may be due to delay in abscission through preservation of pectin material in middle lamella and promotion of pollen tube growth which may have lead to better fruit set and thus prevented the fruit drop (Kachave and Bhosale, 2007).

The second opinion is the existence of high level of internal auxin like substances which prevent fruit drop. Brassinosteriods and gibberellins both have a synergistic effect on the concentration of auxin in the plants. Exogenous application of growth regulator might help in building up endogenous level of hormone at optimal level favorable for reducing fruit drop. The fruit drop occurs due to the low concentrations of hormones to prevent the formation of abscission zone (Bains *et al.,* 1997). Reduction in fruit drop caused by the application of GA_3 + BR is in agreement with the findings of Akcay and Ozcagiran (1995) in sweet cherry and Singh and Lal (1980) in litchi.

The fruit retention percentage was calculated at the time of harvest (Table 7). The applied GA, BR and combine treatment with different concentrations had

Table 6: Effect of pre-harvest spray of GA3 and BR on fruit drop in pear cv. 'Gola'

Treatments	Fruit drop (%)			
	10-April	10-May	10-June	10-July
GA_3 @ 50 ppm (T_1)	18.55	28.05	7.27	2.59
GA_3 @ 100 ppm (T_2)	16.74	27.45	6.77	1.80
BR @ 0.5 ppm (T_3)	17.38	30.47	8.76	3.13
BR @ 1 ppm (T_4)	15.25	26.12	6.83	1.98
GA_3 @ 50 ppm + BR @ 0.5 ppm (T_5)	13.06	25.56	5.83	1.48
GA_3 @ 100 ppm + BR @ 1 ppm (T_6)	12.35	24.32	5.15	1.06
Control (T_7)	21.68	34.69	10.18	4.85
SEm±	0.31	0.49	0.08	0.03
CD (0.05)	0.97	1.51	0.26	0.09

Table 7: Effect of pre-harvest spray of GA_3 and BR on numbers of fruits, fruit retention yield and efficiency of pear cv. 'Gola'

Treatments	Fruit retention (%)	No. of fruits per tree	Fruit yield (kg $tree^{-1}$)	Yield efficiency (kgm^{-3})
GA_3 @ 50 ppm (T_1)	52.94	410.37	72.46	0.42
GA_3 @ 100 ppm (T_2)	55.30	439.19	77.85	0.47
BR @ 0.5 ppm (T_3)	50.77	422.44	75.17	0.43
BR @ 1 ppm (T_4)	57.18	457.87	78.23	0.48
GA_3 @ 50 ppm + BR @ 0.5 ppm (T_5)	60.04	466.19	80.79	0.49
GA_3 @ 100 ppm + BR @ 1 ppm (T_6)	62.25	487.10	82.93	0.52
Control (T_7)	43.72	405.07	68.44	0.41
SEm±	0.86	6.94	1.12	0.01
CD (0.05)	2.65	21.39	3.45	0.03

significant effect on fruit retention as compared to control. The highest fruit retention (62.25%) was recorded in treatment GA_3 at 100 ppm + BR at 1 ppm (T_6) was statistically *at par* with T_5 (60.04%). The lowest fruit retention (43.72%), which was significantly inferior to all other treatments was observed under control (T_7).

It is well known in many fruit crops including pear that retention of a fruit e.g., the capacity of a fruit to prevent itself from being shed, relates positively with its ability to produce growth promoting hormones (Buban, 2000 and Prakash and Ram, 1984). The experimental results are in close conformity with the findings of Abubakar *et al.* (2013) who reported that the mean value of fruit retention obtained from all the concentrations of Vipul + HBRs was higher than that of control in case of pomegranate cv. 'Kandhari kabuli'. Moreover, enhanced fruit set and fruit retention was recorded with the application of GA_3 + BR + BA in Thompson Seedless grapes (Warusavitharana *et al.,* 2008).

Observations recorded demonstrate that number of fruits per tree at harvest were significantly affected by all treatments over control. Among the various treatments, maximum number of fruits (487.10) was observed in trees with foliar spray of GA_3 at 100 ppm + BR at 1 ppm i.e., T_6. The other superior treatments in respect to this attribute were T_5 (466.19) and T_4 (457.87). However, minimum fruits per tree (405.07) were noticed in control which was statistically *at par* with T_1 (410.37) and T_3 (422.44).

The foremost reason behind the elevated number of fruits in GA_3 at 100 ppm + BR at 1 ppm is due to the correlation between increased fruit set, reduced fruit drop and enhanced fruit retention percentage which ultimately increases the number of fruits per tree. In the present study the synergetic effect of GA_3 along with BR is similar to that of results obtained by Warusavitharan *et al*. (2008) in Thompson Seedless grapes, Bhat *et al*. (2004) in grape cv. Flame Seedless and Abubakar (2013) in pomegranate cv. 'Kandhari Kabuli' where the combined application of different growth regulators resulted in more number of fruits per plant. The highest mean yield was recorded under the spray GA_3 at 100 ppm + BR at 1ppm (T_6) i.e., 82.93 kg $tree^{-1}$ which was statistically *at par* with T_5 (80.79 kg $tree^{-1}$). On the other hand, fruit yield in untreated control was observed to be significantly low (68.44 kg $tree^{-1}$).

As previously discussed, the number of fruits per tree was significantly increased by the spray of GA_3 (100 ppm) + BR (1 ppm) which resulted in improvement in yield. There might be certain changes in the metabolism of fruits for the improvement of sink strength followed by efficient partitioning of assimilates towards the developing sink in response to combined spray of GA_3 + BR. Application of gibberellic acid in combination with brassinosteroids was found effective for increasing the yield of 'Thompson Seedless' grapes (Tambe, 2002). Velu (2001) opined that application of 25 ppm of GA_3 along with 0.5 ppm of BR at flowering and fruit set stage improved the yield of 'Muscat' grapes as compared to control. The combined foliar sprays of 2 per cent SOP and 2 ppm brassinosteroid significantly increased the total bunch yield (29.38 tonnes ha^{-1}) in banana cv. 'Nendran' (Mulagund *et al*., 2015).

A significant variation was found with respect to tree yield efficiency (Table 4.8) in different treatment. The maximum yield efficiency of 0.52 kg m^{-3} was recorded in GA_3 at 100 ppm + BR at 1 ppm (T_6), whereas the minimum (0.41 kg m^{-3}) was found in the control. This is attributed to the reason that the above mentioned treatment enhanced the fruit set and fruit retention thus resulting in more number of fruits per tree despite having small canopy volume as compared to the control.

CONCLUSION

The present study clearly manifests that GA_3 alone has a profound effect on vegetative characteristics while yield parameters GA_3 + BR had a positive effect pear. Thus it can be concluded that the combined application of gibberellin and brassinosteroid either @ GA_3 (100 ppm) + BR (1 ppm) or GA_3 (50 ppm) + BR (0.5 ppm) as pre-harvest sprays at 15 days interval starting from the petal fall stage may be recommended for improvement in fruit yield Gola pear in *tarai* region.

ACKNOWLEDGEMENTS

The author is thankful to the Department of Horticulture, G. B Pant University of Agric. & Tech. Pantnagar for facilitating the conduct of the investigation.

REFERENCES

Akcay, M and Ozcagiran, R. (1995) Research on the effect of some growth regulators on pollen tube growth and fruit setting in sweet cherry. *Ege Universitesi-Ziraat Fakultesi Dergisi Turkey*, 32(2): 241-247.

Anitha, R. and Jeyakumar, P. (2005) Effect of plant growth regulators and chemicals on morphological traits and yield of banana cv. Grand Naine. *Madras Agric. J* 95(1-2): 24-28.

Anonymous. (2014). Indian Horticulture Database. National Horticulture Board, Gurgaon, Haryana.

Bains, K.S., Bajwa, G.S. and Singh, Z. (1997) Abscission of mango fruitlets in relation to endogenous concentrations of IAA, GA and ABA in pedicels and fruitlets. *Fruits*, 52: 159-165.

Bhat, Z.A., Reddy, Y.N., Srihari, D., Bhat, J.A., Rizwan, R. and Rather, J.A. (2011). New generation growth regulators brassinosteroids and CPPU improve bunch and berry characteristics in 'Tas-A-Ganesh' grape". *International Journal of Fruit Science,* 11: 309-315.

Bhatia, D.S and Kaur, J. (1997) Effect of homobrassinolide and humicil on chlorophyll content, hill activity and yield components in mungbean (*Vigna radiata* (L.) Wilczek), *Phytomorpho.,*47: 421-426.

Buban, T. (2000). The use of benzyladenine in orchard fruit growing: a mini review. *Journal of Plant Growth Regulation,* 32(2-3): 381-390.

Casper, J.A. and Taylor, B.H. (1982) Effect of gibberellins on the performance of 'Loring' peach. *Deciduous Fruit Growers.* 47: 172-178.

Duarte, A.M.M., Garcia-Luis, A., Molina, R.V., Monerri, C., Navarro, V., Nebaner, S.G., Perales, M.S. and Guardiola, J.L. (2006) Long-term effect of winter gibberellic acid sprays and auxin applications on crop value of 'Clausellina' satsuma. *J. Amer. Soc. Hortic. Sci.* 131: 586592.

FAOSTAT (2013) FAO Statistical Yearbook. Food and Agriculture Organization of the United Nations, Rome, Italy.

Fathi, M.A., Azza, I. and Abd El-Bary, A. (2011) Effect of Sitofex (CPPU) and GA3 spray on fruit set, fruit quality, yield and monetary value of "Costata" persimmon. *Nature and Science.* 9(8): 40-49.

Gabr, M.A., Faithi, M.A., Azza, I.M. and Mekhaeil, G.B. (2011) Influences of some chemical substances used to induce early harvest of 'Canino' apricot tress. *Nature and Science*. 9(8): 59-65.

Goldwin, G. (1985). The use of plant growth regulators to improve fruit setting, *In*: R. Menhenette, M. Jackson, Growth Regulators in Horticulture, British. *Plant Growth Regulation.* 13: 71-88.

Jackson, J. (1989). The manipulation of fruiting, *In*: Wright, C. Manipulation of Fruiting. Butterworsths, London. pp3-12.

Jeyakumar, P., Amutha, R. and Balamohan, T.N. (2010) Nutrient- Bioregulators Interaction Effects on Banana. *Acta Horticulturae.* 884: 515- 524.

Jong, M.D., Mariani, C. and Vriezen, W. (2009) The role of auxin and giberellin in tomato fruit set. *Journal of Experimental Botany*. 60(5): 1523-1532.

Kachave, D.B. and Bhosale, A.M. (2007) Effect of plant growth regulators and micronutrients on fruiting and yield parameters of Kagzi lime (Citrus aurantifolia Swingle) fruits. *Asian J. Hortic*. 2(2): 75-79.

Kassem, H.A., El-Kobbia, A.M., Marzouk, H.A. and El-Sebaiey, M. (2010) Effect of foliar sprays on fruit on fruit retention, quality and yield of "Costata" persimmon trees. *Emirates J. of Food Agric.,* 22(4): 259-274.

Lakshmi, M., Ramana, K.T.V., Krishna, V.N.P.S., Yuvaraj, K.M., Lakshmi, T.N., Sarada, T., Sankar, T.G., Gopi, V. and Gopal, K. (2014) Effect of growth regulators and chemicals on fruit yield and quality of Hasta

Bahar flowering in acid lime (*Citrus aurantifolia* Swingle) cv. Balaji. *Research and Reviews: J. Agric. Allied Sci.,* 3(3): 11-13.

Marler, T.E., Mickelbart, M.V. (1992) Application of GA_{4+7} to stem enhances the carambola seedling growth. *Hort Sci.*,27 (2): 122-23.

Mathis, J.N., Bradburne, J.A and upree, M.A. (1989) Gibberellic acid effects on greening of pea seedlings. *Plant Physiol.,* 91: 19-22.

Moneruzzaman, K.M., Hossain, A.B.M.S., Normaniza, O. and Boyce, A.N. (2011) Growth, yield and quality responses to gibberellic acid (GA_3) of wax apple *Syzygium samarangense* var. Jambu air madu fruits grown under field conditions. *Afr J Biotechnol* 10(56): 11911-11918.

Mulagund, J., Kumar, S., Soorianathasundaram, K. and Porika, H. (2015) Influence of post-shooting sprays of sulphate of potash and certain growth regulators on bunch characters and fruit yield of banana cv. Nendran (French Plantain Musa AAB). *The Bioscan.,* 10(1): 153-159.

Munoz, F.J., Labrador, E. and Dopico, B. (1998) Brassinolides promote the expression of a new *Cicer arietinum* β-tubulin gene involved in the Epicotyl elongation. *Plant Mol Biol* .,37: 807-817.

Mussig, C. (2005) Brassinosteroid-promoted growth. *Plant Biol.,* 7: 110-117.

Mussig, C. and Altmann, T. (1999) Physiology and molecular mode of action of Brassinosteroids. *Plant Physiol Biochem.,* 37: 363372.

Prakash, S. and Ram.S. 1984. Naturally occurring auxins and inhibitor and their role in fruit growth and drop of mango "Dashehari". *Scientia Horticuturae*,22: 241-48.

Singh, U. and Lal, K. (1980) Influence of growth regulators on setting retention and weight of fruits in two cultivars of Litchi*, Sci. Hortic.,* 12(4): 321-326.

Swamy, K.N. and Rao, S.S.R. (2010). Effect of brassinosteroids on rooting and early vegetative growth of Coleus [*Plectranthus forskohlii* (Willd.) Briq.] stem cuttings. *Indian J. Natural Products Resources,* 1: 68-73.

Tambe, T.B. (2002) Effects of gibberellic acid in combination with Brassinostroid on berry size, yield and quality of Thompson Seedless grape. *J Maharashtra Agric Univ.,* 27(2): 151-153.

Velu, V. (2001) Studies on bud load and certain crop thinning practices on vigour, yield and quality of grapes (*Vitis vinifera* L.) cv. Muscat. Thesis, M.Sc. TNAU, Coimbatore, 88p.

Warusavitharana, A.J., Tambe, T.B.and Kshirsagar, D.B. (2008) Effect of cytokinins and Brassinosteroid with gibberellic acid on yield and quality of Thompson Seedless grapes. *Acta Hortic.,* 785: 217-223.

Watanabe, M., Segawa, H., Murakami, M., Sagawa, S. and Komori, S. (2008) Effects of plant growth regulators on fruit set and fruit shape of parthenocarpic apple fruits*. J. Jap. Soc. Hortic. Sci.,* 77(4): 350-357.

Westwood, M.N. 1963. Temperate Zone Pomology: Physiology and culture. Timber press, Portland Dregon, 521p.

Zullo, M.A.T., Kohout, L. and De-Azevedo, M.B.M. 2003. Some notes on the terminology of brassinosteroids. *Plant Growth Regulation, 39*: 1-11.

Received: September 1, 2015
Accepted: May 10, 2016