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Effect of Plant Growth Regulators on Tree Growth and Yield of Pomegranate (*Punica granatum* L.) cv. Kandhari

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A B S T R A C T

Pomegranate (*Punica granatum* L.) belongs to the family Punicaceae and it is one of the favourite table fruits in the world, due to its refreshing juice with nutritional and medicinal properties. It is obvious that changes in the level of endogenous hormones due to biotic and abiotic stress alter the crop growth and any sort of manipulation including exogenous application of growth substances would help for yield improvement. So, an investigation was carried out in the Pomegranate Block of Model farm of Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (H.P), India during the year 2016 and 2017. The pomegranate trees cv. Kandhari under investigation were subjected to foliar spray of plant growth regulators viz. NAA, GA_3, 6-BA, their combination and control at different concentrations. The study was conducted to determine the effect of plant growth regulators on tree growth and yield. On the basis of results obtained in the present investigation it is concluded that plant growth regulators and nutrients application revealed that NAA 30ppm (May) followed by GA_3 75ppm (June) and 6-BA (May) was proved to be most effective as it improved the growth and increased yield of pomegranate. While from economic point of view also NAA was superior to GA_3 and 6-BA because of its higher net returns and lower cost when compared with other two growth regulators.

Introduction

Pomegranate (*Punica granatum* L.) is one of the oldest known edible fruits and is capable of growing in different agro-climatic conditions ranging from the tropical to sub-tropical (Levin, 2006; Jalikop, 2007). Pomegranate belongs to family Punicaceae and is native to Persia (Iran), Afganistan and Baluchistan (De Candole, 1967). It is one of the esteemed dessert fruit and is very much liked by people for its cool refreshing juice, taste and being highly valued for its nutritional and medicinal properties. Kandhari is a large fruited variety with deep red skin and sub-acidic taste (Singh, 2004). Trees are deciduous, vigorous and upright growing. It is regular bearer with good yield per tree. It bears only ambe bahar (April-May flowering). Despite this fact, pomegranate culture has always been restricted and generally considered as a minor crop. In Himachal Pradesh, pomegranate is mainly cultivated under rainfed conditions, therefore, its yield and quality is adversely affected during drought and rainfall conditions. Plant growth regulators are used to improve fruit size and quality, extend the storage life and to increase the profitability in some fruits (Lawes and Woolley, 2001). They have a key role in different physiological processes related to growth and development of crops. Plant growth regulators have been used for beneficial effects like fruit size, appearance and aril quality i.e. to improve physical characteristics and fruit quality of pomegranate (Anawal *et al.,* 2016).

Materials and Methods

The present investigation on "Studies on effect of plant growth regulators on yield and quality of pomegranate (*Punica granatum* L.) cv. Kandhari." was carried out in the Pomegranate Block of Model farm of Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (H.P), India during the year 2016 and 2017. For the present study, 45 trees were selected on the basis of uniform vigour and were maintained under uniform cultural practices during the entire course of investigation. The experiments were laid out on 7 year old pomegranate cv. Kandhari planted at a spacing of 4m x 2m in the randomized block design having 15 treatments and each treatment replicated thrice. The pomegranate trees cv. Kandhari under investigation were subjected to foliar spray of plant growth regulators viz. NAA, GA_3, 6-BA, their combination and control at different concentrations in mid may and June.

Technical programme of work

Treatments	Chemicals	Concentration	Time of application
T_1	Naphthalene acetic acid (NAA)	20ppm	Mid May
T_2	Naphthalene acetic acid (NAA)	30ppm	Mid May
T_3	Naphthalene acetic acid (NAA)	20ppm	Mid June
T_4	Naphthalene acetic acid (NAA)	30ppm	Mid June
T_5	Gibberellic acid (GA_3)	50ppm	Mid May
T_6	Gibberellic acid (GA_3)	75ppm	Mid May
T_7	Gibberellic acid (GA_3)	50ppm	Mid June
T_8	Gibberellic acid (GA_3)	75ppm	Mid June
T_9	Benzyl adenine (6-BA)	5ppm	Mid May
T_{10}	Benzyl adenine (6-BA)	10ppm	Mid May
T_{11}	Benzyl adenine (6-BA)	5ppm	Mid June
T_{12}	Benzyl adenine (6-BA)	10ppm	Mid June
T_{13}	NAA+GA_3+BA	20ppm+50ppm+5ppm	Mid May
T_{14}	NAA+GA_3+BA	20ppm+50ppm+5ppm	Mid June
T_{15}	Control	(Water spray)	Mid May/ June

Before spraying, 0.5 ml of wetting agent (Indtron-AE) per litre of solution was added as surfactant to reduce surface tension and to facilitate the absorption of solution was sprayed. Ten shoots from the current season's growth were randomly selected from all over the periphery of each tree for annual shoot growth and return bloom. For leaf area and chlorophyll content, fully developed and matured leaves from the current season's were randomly selected from all the four directions of the tree periphery and detached in the first week of July. The mean yield per tree in number of fruits and weight were also recorded. The data were statically analyses and interpreted.

Results and Discussion

The data pertaining to the effect of plant growth regulators on growth, yield and return bloom are presented in Tables 1 to 3.

Annual shoot growth

The perusal of data (Table 1) indicates that the application of NAA, GA_3, 6-BA and their combination at different concentrations exerted the significant effect on annual shoot growth, which varied from 23.78 to 31.92 cm.

The significantly maximum shoot growth (31.92 cm) was recorded with treatment GA_3 75ppm (T_8), which was found to be statistically at par with the treatments NAA 20ppm (T_3), GA_3 50ppm (T_7), NAA+GA_3+BA 20ppm+50ppm+5ppm (T_{13}), NAA 20ppm (T_1) and control (T_{15}) producing annual shoot growth of 31.59 cm, 31.43 cm, 31.09 cm, 29.80 cm and 28.99 cm, respectively. However, the minimum shoot growth (23.78 cm) was registered in the treatment 6-BA 5ppm (T_9), when applied in the month of May.

Canopy volume

It is evident from data (Table 1) that application of NAA, GA_3, 6-BA and their combination at different concentrations significantly affected the canopy volume, which varied from 2.44 to 3.44 m^3.

The maximum canopy volume (3.44 m^3) was also recorded with the treatment GA_3 75ppm (T_8), when applied in the month of June, closely followed and statistically at par with the treatments GA_3 75ppm (T_7), GA_3 50ppm (T_5), NAA+GA_3+BA 20ppm+50ppm+5ppm (T_{14}) and NAA 20ppm (T_1) resulting in canopy volume of 3.43 m^3, 3.40 m^3, 3.12 m^3 and 3.11 m^3, respectively. The minimum canopy volume (2.44 m^3) was recorded in the treatment 6-BA 10ppm (T_{12}), which was found at par with control (T_{15}).

Leaf area

The perusal of data (Table 2) on the effect of plant growth regulators on leaf area in pomegranate clearly reveals that applications of NAA, GA_3, 6-BA and their combination at different concentrations significantly influenced the leaf area, which ranged from 13.63 to 18.34 cm^2.

The maximum leaf area (18.34 cm^2) was recorded with the treatment 6-BA 10ppm (T_{10}), when applied in the month of May, which was statistically at par with treatments NAA 20ppm (T_3), 6-BA 10ppm (T_{12}), NAA 20ppm (T_1) and 6-BA 5ppm (T_9) having leaf area 16.82 cm^2, 16.51 cm^2, 16.50 cm^2 and 16.47 cm^2, respectively.

However, the minimum leaf area (13.63 cm^2) was registered with the treatment GA_3 75ppm (T_6), when applied in the month of May.

Chlorophyll content

The data pertaining to the effect of plant growth regulators on chlorophyll content in pomegranate cv. Kandhari are presented in Table 2. It is evident from data that applications of NAA, GA_3, 6-BA and their combination at different concentrations exhibited non-significant effect on chlorophyll content.

However, the maximum chlorophyll content was recorded with treatment 6-BA 10ppm (T_{10}), when applied in the month of May and minimum chlorophyll content was registered in the treatment GA_3 50ppm (T_5), when applied in the month of May.

Table.1 Effect of plant growth regulators on annual shoot growth and canopy volume of pomegranate cv. Kandhari

Treatments		Time of application	Annual shoot growth (cm)	Canopy volume (m^3)
T_1	NAA(20ppm)	Mid May	29.80	3.11
T_2	NAA(30ppm)	Mid May	27.50	2.84
T_3	NAA(20ppm)	Mid June	31.59	2.51
T_4	NAA(30ppm)	Mid June	24.46	2.54
T_5	GA_3(50ppm)	Mid May	29.16	3.40
T_6	GA_3(75ppm)	Mid May	26.31	2.46
T_7	GA_3(50ppm)	Mid June	31.43	3.43
T_8	GA_3(75ppm)	Mid June	31.92	3.44
T_9	6-BA(5ppm)	Mid May	23.78	2.67
T_{10}	6-BA(10ppm)	Mid May	28.61	2.84
T_{11}	6-BA(5ppm)	Mid June	25.60	2.85
T_{12}	6-BA(10ppm)	Mid June	24.70	2.44
T_{13}	NAA+GA_3+BA(20ppm+50ppm+5ppm)	Mid May	31.09	2.92
T_{14}	NAA+GA_3+BA(20ppm+50ppm+5ppm)	Mid June	24.58	3.12
T_{15}	Control	Mid May/ June	28.99	2.49
$CD_{0.05}$			3.13	0.42

Table.2 Effect of plant growth regulators on leaf area and chlorophyll content of pomegranate cv. Kandhari

Treatments		Time of application	Leaf area (cm^2)	Chlorophyll content (mg g^{-1})
T_1	NAA(20ppm)	Mid May	16.50	2.90
T_2	NAA(30ppm)	Mid May	14.85	2.57
T_3	NAA(20ppm)	Mid June	16.82	2.61
T_4	NAA(30ppm)	Mid June	15.43	2.91
T_5	GA_3(50ppm)	Mid May	14.71	1.95
T_6	GA_3(75ppm)	Mid May	13.63	2.66
T_7	GA_3(50ppm)	Mid June	14.34	2.32
T_8	GA_3(75ppm)	Mid June	14.58	2.72
T_9	6-BA(5ppm)	Mid May	16.47	3.14
T_{10}	6-BA(10ppm)	Mid May	18.34	3.34
T_{11}	6-BA(5ppm)	Mid June	15.84	3.02
T_{12}	6-BA(10ppm)	Mid June	16.51	2.75
T_{13}	NAA+GA_3+BA(20ppm+50ppm+5ppm)	Mid May	14.32	2.76
T_{14}	NAA+GA_3+BA(20ppm+50ppm+5ppm)	Mid June	15.46	2.98
T_{15}	Control	Mid May/ June	15.50	2.61
$CD_{0.05}$			1.95	NS

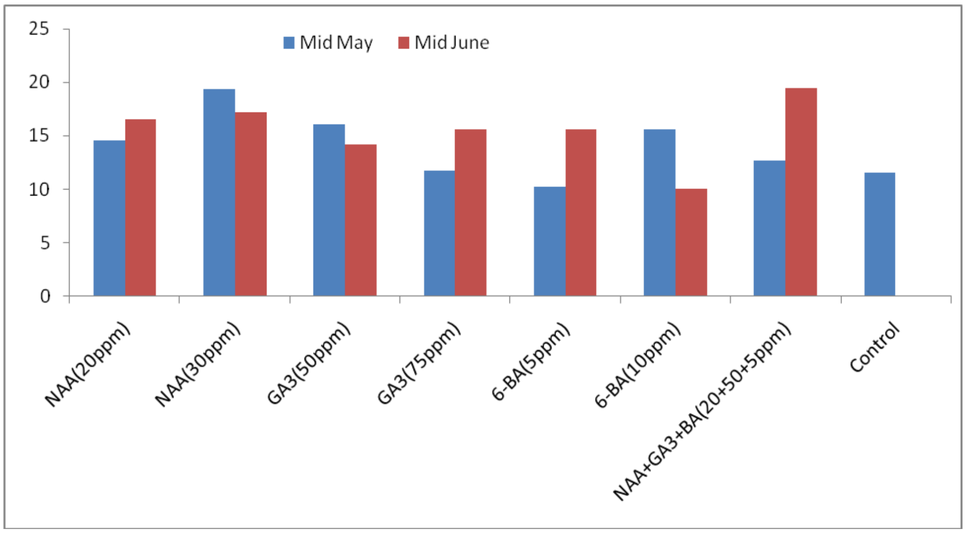
Table.3 Effect of plant growth regulators on flowering and yield of pomegranate cv. Kandhari

Treatments		**Time of application**	**Fruit yield (kg $plant^{-1}$)**	**Return bloom (%)**
T_1	NAA(20ppm)	Mid May	14.57	119.81 (10.97)
T_2	NAA(30ppm)	Mid May	19.93	118.89 (10.94)
T_3	NAA(20ppm)	Mid June	16.57	122.61 (11.11)
T_4	NAA(30ppm)	Mid June	17.19	120.67 (11.03)
T_5	GA_3(50ppm)	Mid May	16.05	112.53 (10.63)
T_6	GA_3(75ppm)	Mid May	11.76	122.34 (11.10)
T_7	GA_3(50ppm)	Mid June	14.21	120.62 (11.04)
T_8	GA_3(75ppm)	Mid June	15.57	132.02 (11.53)
T_9	6-BA(5ppm)	Mid May	10.20	120.24 (11.00)
T_{10}	6-BA(10ppm)	Mid May	10.74	118.24 (10.91)
T_{11}	6-BA(5ppm)	Mid June	15.57	136.56 (11.72)
T_{12}	6-BA(10ppm)	Mid June	10.06	128.80 (11.39)
T_{13}	NAA+GA_3+BA(20ppm+50ppm+5ppm)	Mid May	12.70	119.62 (10.98)
T_{14}	NAA+GA_3+BA(20ppm+50ppm+5ppm)	Mid June	19.43	124.02 (11.17)
T_{15}	Control	Mid May/ June	11.55	111.57 (10.79)
$CD_{0.05}$			6.40	0.54

*Figures in the parentheses are square root transformed value

Table.4 Per hectare cost benefit ratio of pomegranate (value in □)

Treatments	Total cost	Gross return	Net return	C: B ratio
NAA (20ppm)	3,00,534	9,50,000	6,49,466	1:2.16
NAA (30ppm)	3,00,701	11,12,500	8,11,799	1:2.69
GA_3 (50ppm)	3,03,525	9,25,000	6,21,475	1:2.05
GA_3 (75ppm)	3,05,163	10,50,000	7,44,837	1:2.44
6-BA (5ppm)	3,02,075	10,12,500	7,10,425	1:2.35
6-BA (10ppm)	3,03,900	9,75,000	6,71,100	1:2.20
NAA+GA_3+BA (20ppm+50ppm+5ppm)	3,05,684	10,12,500	7,06,816	1:2.31
Control	3,00,200	8,25,000	5,24,800	1:1.74



In the present studies the application of GA_3 75ppm, when applied in the month of June resulted into maximum increase in shoot extension growth and canopy volume. The increase in vegetative growth with the application of GA_3 may be attributed to the effect of GA_3 on cell elongation (Mitchell *et al.*, 1951). Xin *et al.*, (1994) also found that foliar application of GA_3 increased the shoot growth by promoting the protein synthesis and increasing transpirational area of apple trees. The effectiveness of GA_3 might be due to its role in promoting growth and stimulated the rapid cell elongation in meristematic zone of vegetative plant organs. Due to cell elongation and division, the length and spread of branches might have increased, hence GA_3 played an important role in enhancing the height and spread of the plant. Gibberellic acid promote the growth by increasing the plasticity of the cell wall followed by the hydrolysis of the starch into sugars, which reduces the cell water potential, resulting in the entry of water into the cell and causing elongation (Richard, 2006). The significant increase in vegetative growth with the application of GA_3 has also been reported by Dalal *et al.*, (2002), Jadhav *et al.*, (2006) in Rangpur lime and by Singh (2008) and Digrase *et al.*, (2016) in pomegranate. Maximum leaf area and chlorophyll content was recorded in the treatment 6-BA 10ppm. It might be due to the reason that cytokinins increased the cell division resulting into larger leaf area. Gardner *et al.*, (1985) also reported that GA_3 and BA promote the cell division in plant tissue. Cytokinins also brought down the rate of respiration and retarded the degradation of chlorophyll and enhances the rate of chlorophyll synthesis. Gintare *et al.*, (2008) observed that benzyladenine increased leaf chlorophyll content by a strong retardation of the leaf senescence by retarding the terminal changes in chlorophyll or by preserving much of the chlorophyll.

Fruit yield

The data presented in Table 3 and Figure 3 indicate that the applications of NAA, GA_3, 6-BA and their combination at different concentrations induced significant effect on fruit yield, which varied from 10.06 to 19.93 kg $plant^{-1}$. The significantly higher fruit yield (19.93 kg $plant^{-1}$) was recorded with treatment NAA 30ppm (T_2), when applied in the month of May, closely followed by NAA+GA_3+BA (20ppm+50ppm+5ppm) (T_{14}) which yielded 19.43 kg $plant^{-1}$ as compared to control (11.55 kg $plant^{-1}$). However, treatments T_1, T_3, T_4, T_5, T_7, T_8 and T_{11} were also found to be statistically at par with the treatments NAA 30ppm (T_2) and NAA+GA_3+BA (20ppm+ 50ppm+5ppm) (T_{14}). The minimum fruit yield (10.06 kg $plant^{-1}$) was registered in the treatment 6-BA 10ppm (T_{12}), when applied in the month of June.

Return bloom

The data regarding the effect of plant growth regulators on return bloom in pomegranate cv. Kandhari presented in Table 3. It is pertinent from the data that application of NAA, GA_3, 6-BA and their combination at different concentrations had significant effect on return bloom, varying between 136.56 per cent and 111.57 per cent.

The significantly higher return bloom (136.56%) was recorded with treatment 6-BA 5ppm (T_{11}) applied in the month of June, over the control treatment (T_{15}) accounting for 111.57 per cent. However, treatments GA_3 5ppm (T_8) and 6-BA 10ppm (T_{12}) were found to be at par with 6-BA 5ppm (T_{11}) contributing to 132.02 and 128.80 per cent return bloom. The minimum return bloom (111.57%) was registered in the treatment Control (T_{15}).

In the present study, the maximum yield was observed in the plants treated with the application of NAA 30ppm. This may be due to the better physiology of developing fruits in terms of better supply of water, nutrients and other compounds vital for their proper growth and development, which resulted in improved size and ultimately greater yield as compared to other treatments.

Beneficial effects of NAA were recorded by Ghosh *et al.*, (2009) in cv. Ruby, Adi and Prasad (2012) in cv. Ganesh, Goswami *et al.*, (2013) in cv. Sindhuri and Anawal *et al.*, (2015) in cv. Bhagwa of pomegranate. In our studies 6-BA resulted the higher return bloom. It may be due to the fact that cytokinins conserved the higher amounts of carbohydrates and other metabolites in comparison to other treatments, which promoted the flowering in the following year. Mclaughlin and Greene (1984) had also observed that return bloom was increased by BA application in some apple cultivars.

Economics

Gross return

The data on gross return under different treatments in this experiment were given in Table 4. From the results, it was seen that NAA 30ppm gave highest gross return per hectare (Rs. 11,12,500) followed by GA_3 75ppm (Rs. 10,50,000) and the lowest with control (Rs. 8,25,000). 6-BA gave good returns but recorded lower net returns than the other two growth regulators due to its higher cost.

Net return

The data on net return under different treatments in this experiment were given in Table 4. The data reveals that NAA 30ppm gave highest net return per hectare (□ 8, 11, 799) followed by GA_3 75ppm (□ 7,44,837) and the lowest with Control (□ 5,24,800).

Cost: benefit ratio

The data on benefit cost ratio of different treatments was presented in Table 4. From the results, it was seen that NAA 30ppm recorded highest benefit cost ratio (2.69) followed by GA_3 75ppm (2.44) and the lowest with control (1.74). NAA recorded higher cost benefit ratio due to its higher net returns and lower cost than the other two growth regulator. 6-BA gave good returns but recorded lesser cost benefit ratio than the other two growth regulators due to its higher cost.

In conclusions on the basis of the results obtained during the present investigation, it is concluded that among various plant growth regulators, NAA 30ppm (May) followed by GA_3 75ppm (June) and 6-BA (May) was proved to be most effective as it improved the growth and increased yield of pomegranate. Also from the economic point of view, NAA was superior to GA_3 and 6-BA because of its higher net returns and lower cost when compared with other two growth regulators.

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