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Effect of plant growth regulators on physico-chemical parameters of pomegranate (*Punica granatum* L.) cv. Kandhari

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Abstract
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. Plant growth regulators provide effective means for the improvement of productivity as a result of direct influence on the qualitative as well as quantitative aspects of fruit growth. 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 physico-chemical parameters of fruits. On the basis of results obtained in the present investigation it is concluded that plant growth regulators and nutrients application revealed NAA 30ppm (May and June) to be most effective as it improves the quality of pomegranate.

Keywords: Pomegranate, NAA, GA_3, 6-BA, fruit, quality

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) [14, 13]. Pomegranate belongs to family Punicaceae and is native to Persia (Iran), Afganistan and Baluchistan (De Candole, 1967) [7]. 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) [18]. 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. The importance of synthetic plant growth regulators in achieving higher yield and better quality of horticultural crop has been well recognized in recent time. 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) [3].

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. Fruits were collected after attaining maturity and observations were recorded on fruit length, volume, fruit weight, aril weight, aril percent, rind weight, TSS, juice content etc. The data were statically analyses and interpreted.

Results and Discussion

Regarding the effect of plant growth regulators on physico-chemical parameters in pomegranate cv. Kandhari are depicted from Table 1 to Table 7.

Fruit Weight

It is evident from data (Table 1) that application of NAA, GA_3, 6-BA and their combination at different concentrations significantly affected the fruit weight of pomegranate, thus ranging between 446.72 g fruit^{-1} to 257.21 g fruit^{-1}. Significantly higher fruit weight (446.72 g fruit^{-1}) was observed with the treatment NAA 30ppm (T_2), when applied in the month of May in comparison to all other treatments including Control (T_{15}), which weighed 279.63 g fruit^{-1}. However, minimum fruit weight (257.21 g fruit^{-1}) was recorded in the treatment NAA+GA_3+BA @ 20ppm + 50ppm + 5ppm (T_{14}), when applied in the month of June.

Table 1: Effect of plant growth regulators on fruit weight and volume of pomegranate cv. Kandhari

Treatments		Time of application	Fruit weight (g)	Fruit volume (cc)
T_1	NAA(20ppm)	Mid May	270.50	284.44
T_2	NAA(30ppm)	Mid May	446.72	467.77
T_3	NAA(20ppm)	Mid June	299.39	310.00
T_4	NAA(30ppm)	Mid June	260.54	295.55
T_5	GA_3(50ppm)	Mid May	298.46	304.44
T_6	GA_3(75ppm)	Mid May	325.40	357.77
T_7	GA_3(50ppm)	Mid June	272.00	287.78
T_8	GA_3(75ppm)	Mid June	342.19	361.11
T_9	6-BA(5ppm)	Mid May	345.01	353.33
T_{10}	6-BA(10ppm)	Mid May	269.21	277.78
T_{11}	6-BA(5ppm)	Mid June	294.55	306.66
T_{12}	6-BA(10ppm)	Mid June	300.87	330.00
T_{13}	NAA+GA_3+BA(20ppm+50ppm+5ppm)	Mid May	339.89	352.22
T_{14}	NAA+GA_3+BA(20ppm+50ppm+5ppm)	Mid June	257.21	294.43
T_{15}	Control	Mid May/ June	279.63	300.00
$CD_{0.05}$			82.69	71.52

Fruit Volume

The data regarding the effect of different plant growth regulators on the average fruit volume are presented in Table 1. It is pertinent from the data that NAA, GA_3, and their combination at different concentrations significantly affected the fruit volume which from 277.78 cc. to 467.77 cc. Significantly higher mean fruit volume (467.77 cc) was recorded with treatment NAA 30ppm (T_2), when applied in the month of May over all the treatments including Control (T_{15}), which measured the mean fruit volume to 300.33 cc. However, minimum fruit volume (277.78 cc) was recorded with treatment 6-BA 10ppm (T_{10}) applied at the time of mid May.

In the present study the application of NAA 30ppm significantly increased the fruit weight and volume. This may be due to immediate absorption of auxins, which increased the endogenous auxin level that resulted in cell elongation, and further accelerated the development of fruits. Similarly responses in fruit weight was observed by Hussein *et al*. (1994) [12] in pomegranate by using NAA 20ppm. Beneficial effects of NAA 25ppm and GA_3 10ppm on fruit weight and volume were also recorded by Ghosh *et al*. (2009) [9] in pomegranate. Adi and Prasad (2012) [1] studied the positive influence of NAA on fruit length, diameter in pomegranate cv. Ganesh and Anawal *et al*. (2015) [2] in Bhagwa.

Fruit size

Data pertaining to the fruit size i.e. fruit length and diameter is presented in Table 2.

1 Fruit Length

It is evident from the data (Table 2) that the fruit size measured in terms of fruit length was significantly influenced by the plant growth regulator treatments. The data indicates that the mean fruit length values under various treatments ranged between 9.04 cm to 7.29 cm. The maximum fruit length (9.04 cm) was recorded with treatment NAA 30ppm (T_2), when applied in the month of May, which was significantly higher over all the treatments including Control (T_{15}). However, treatments GA_3 75ppm (T_8) and NAA+GA_3+BA @ 20ppm+50ppm+5ppm (T_{13}), applied in mid- May were found to be statistically at par with NAA 30ppm (T_2) resulting into 8.47 cm and 8.46 cm fruit length, respectively. The minimal fruit length (7.29cm) was recorded with 6-BA 10ppm (T_{10}) treatment, when applied in the month of May.

2 Fruit diameter

The perusal of the data in Table 5 depicts that the fruit size measured in terms of fruit diameter was significantly affected by all the plant growth regulator treatments ranging from 9.42 cm to 7.76 cm. The maximum fruit diameter (9.42 cm) was recorded with treatment NAA 30ppm (T_2), when applied in the month of May, which was significantly higher over all the treatments except Control (T_{15}). However, treatments GA_3 75ppm (T_8) and NAA+GA_3+BA @ 20ppm+50ppm+5ppm (T_{13}) and Control (T_{15}) were found to be statistically at par with NAA 30ppm (T_2) resulting into 9.02 cm, 8.97 cm and 8.46 cm fruit diameter, respectively. The minimum fruit diameter (7.76) was also recorded with 6-BA 10ppm (T_{10}) treatment, when applied in the month of May.

Table 2: Effect of plant growth regulators on fruit size and length and diameter ratio of pomegranate cv. Kandhari

Treatments		Time of application	Fruit size (cm)		L: D ratio
			Length	Diameter	
T_1	NAA(20ppm)	Mid May	7.63	8.00	0.95
T_2	NAA(30ppm)	Mid May	9.04	9.42	0.95
T_3	NAA(20ppm)	Mid June	7.78	8.39	0.95
T_4	NAA(30ppm)	Mid June	7.58	7.86	0.96
T_5	GA_3(50ppm)	Mid May	7.75	8.40	0.92
T_6	GA_3(75ppm)	Mid May	7.52	8.07	0.93
T_7	GA_3(50ppm)	Mid June	7.31	7.92	0.92
T_8	GA_3(75ppm)	Mid June	8.47	9.02	0.93
T_9	6-BA(5ppm)	Mid May	8.14	8.49	0.95
T_{10}	6-BA(10ppm)	Mid May	7.29	7.76	0.94
T_{11}	6-BA(5ppm)	Mid June	7.48	8.01	0.93
T_{12}	6-BA(10ppm)	Mid June	8.21	8.66	0.98
T_{13}	NAA+GA_3+BA(20ppm+50ppm+5ppm)	Mid May	8.46	8.97	0.95
T_{14}	NAA+GA_3+BA(20ppm+50ppm+5ppm)	Mid June	7.84	8.24	0.95
T_{15}	Control	Mid May/ June	8.10	8.67	0.93
$CD_{0.05}$			0.71	0.75	NS

Fruit length and diameter ratio

The data pertaining to the effect of plant growth regulators on fruit length and diameter ratio in pomegranate cv. Kandhari are presented in Table 5. It is evident from data that application of NAA, GA_3, 6-BA and their combination at different concentrations could not significantly affect the fruit length and diameter ratio. However, the maximum fruit length and diameter ratio was recorded with treatment 6-BA 10ppm (T_{12}), when applied in the month of June and minimum length and diameter ratio was registered in the treatment GA_3 50ppm (T_5 and T_7), when applied in the mid May and mid June.

In the present study, maximum fruit length and fruit diameter was recorded with foliar spray of 30ppm NAA. The increase in fruit size with the application of NAA could be due to nature of auxins to stimulate cell division and cell enlargement and increase sink strength of the fruits. Increased fruit size is in corroboration with the findings of Hoang *et al.* (2003) [11] and Singh (2008) [19]. However, this may also attributed to immediate absorption of auxins, which increased the endogenous auxin level that resulted in cell elongation, thus accelerated the development of fruits. Beneficial effects of NAA 25ppm and GA_3 10ppm were also recorded by Ghosh *et al.* (2009) [9] for all the parameters in pomegranate. Adi and Prasad (2012) [1] studied the positive influence of NAA on fruit length, diameter in pomegranate cv. Ganesh and Anawal *et al.* (2015) [2] in cv. Bhagwa.

Rind Weight

From the perusal of data in Table 3, it is evident that application of NAA, GA_3, 6-BA and their combination at different concentrations exerted significant effect on mean rind weight. The rind weight under various treatments ranged from 60.33g to 98.00g. Maximum rind weight (98.00g) was recorded with treatment NAA 30ppm (T_2), when applied in the month of May in comparison to all other treatments, except Control (T_{15}) and 6-BA 5ppm (T_9), which were found statistically at par with the treatment NAA 30ppm (T_2). However, minimum rind weight (60.33g) was registered in the treatment GA_3 75ppm (T_6), when applied in the month of May.

Rind thickness

The data (Table 3) reveals that application of NAA, GA_3, 6-BA and their combination at different concentrations exerted significant effect on rind thickness. The rind thickness under various treatments ranged from 2.52mm to 3.08mm. Significantly maximum rind thickness (3.08mm) was recorded with treatment 6-BA 10ppm (T_{12}), when applied in the month of June, which was further found to be statistically at par with the treatments NAA 30ppm (T_2), NAA 30ppm (T_1) and NAA+GA_3+BA @ 20ppm+50ppm+5ppm (T_{14}) attributing to 2.98mm, 2.91mm and 2.91mm, respectively. However, minimum rind thickness (2.52mm) was registered under the treatment GA_3 50ppm (T_5), when applied in the month of May.

Rind Percentage

The data pertaining to the effect of plant growth regulators on rind percentage in pomegranate cv. Kandhari are presented in Table 3. It is evident from data that application of NAA, GA_3, 6-BA and their combination at different concentrations exerted significant effect on rind percentage. The rind percentage under various treatments ranged from 21.39 to 31.48 per cent. Maximum rind percentage (31.48%) was recorded with treatment Control (T_{15}), which was statistically at par with the treatments 6-BA 5ppm (T_9), 6-BA 10ppm (T_{10}), 6-BA 5ppm (T_{11}), NAA+GA_3+BA @ 20ppm + 50ppm + 5ppm (T_{13}) and NAA+GA_3+BA @ 20ppm+50ppm+5ppm (T_{14}). However, minimum rind percentage (21.39%) was registered in the treatment NAA 20ppm (T_3), when applied in the month of June, though found at par with T_5 and T_6.

Table 3: Effect of plant growth regulators on rind weight, rind thickness and rind percentage of pomegranate cv. Kandhari

Treatments		Time of application	Rind weight (g)	Rind thickness (mm)	Rind percentage
T_1	NAA(20ppm)	Mid May	64.63	2.91	22.41(28.25)
T_2	NAA(30ppm)	Mid May	98.00	2.98	22.83(28.53)
T_3	NAA(20ppm)	Mid June	67.66	2.64	21.37(27.53)
T_4	NAA(30ppm)	Mid June	76.83	2.90	24.09(29.36)
T_5	GA_3(50ppm)	Mid May	69.66	2.52	22.67(28.38)
T_6	GA_3(75ppm)	Mid May	60.33	2.62	24.09(29.38)
T_7	GA_3(50ppm)	Mid June	70.00	2.66	25.99(30.63)
T_8	GA_3(75ppm)	Mid June	71.00	2.69	22.97(28.59)
T_9	6-BA(5ppm)	Mid May	96.16	2.71	27.98(31.81)
T_{10}	6-BA(10ppm)	Mid May	72.33	2.72	26.73(31.10)
T_{11}	6-BA(5ppm)	Mid June	85.50	2.85	28.75(32.35)
T_{12}	6-BA(10ppm)	Mid June	71.50	3.08	24.09(28.38)
T_{13}	NAA+GA_3+BA(20ppm+50ppm+5ppm)	Mid May	78.50	2.57	30.71(33.59)
T_{14}	NAA+GA_3+BA(20ppm+50ppm+5ppm)	Mid June	74.16	2.91	30.66(33.48)
T_{15}	Control	Mid May/ June	97.00	2.70	31.48(34.09)
$CD_{0.05}$			12.24	0.17	4.04

*Figures in the parentheses are arcsine transformed value

In the present investigations minimum rind weight and thickness were observed by the GA_3 applications. The reduction in rind thickness may be attributed to increase in cell wall plasticity (Tiaz and Zeiger, 2006) [20], which caused cell enlargement, thus stretched the rind and made it thinner (Arie *et al.* 1997) [4]. Our findings are in line with the results of Venkatesan and Mohideen (1994) [21], who also observed reduction in rind thickness with NAA in pomegranate cv. Ganesh.

Aril Weight

The data regarding the effect of plant growth regulators on mean aril weight in pomegranate cv. Kandhari are presented in Table 4. It is clear from the data that application of NAA, GA_3, 6-BA and their combination at different concentrations caused significant effect on aril weight. The aril weight under various treatments ranged from 166.33g to 334.33g. Significantly higher aril weight (334.33g) was recorded with treatment NAA 30ppm (T_2), when applied in the month of May, in comparison to all other treatments including Control (T_{15}). However, minimum aril weight (166.33g) was registered in the treatment NAA+GA_3+6-BA @ 20ppm + 50ppm + 5ppm (T_{14}), when applied in the month of June.

Table 4: Effect of plant growth regulators on aril weight and aril percentage of pomegranate cv. Kandhari

Treatments		Time of application	Aril weight (g)	Aril percentage
T_1	NAA(20ppm)	Mid May	207.00	76.53(61.20)
T_2	NAA(30ppm)	Mid May	334.33	74.84(59.91)
T_3	NAA(20ppm)	Mid June	210.46	73.78(59.37)
T_4	NAA(30ppm)	Mid June	188.00	75.10(60.12)
T_5	GA_3(50ppm)	Mid May	207.67	70.59(57.36)
T_6	GA_3(75ppm)	Mid May	184.67	72.17(58.45)
T_7	GA_3(50ppm)	Mid June	180.33	66.82(55.23)
T_8	GA_3(75ppm)	Mid June	239.00	71.09(57.82)
T_9	6-BA(5ppm)	Mid May	225.00	67.59(55.28)
T_{10}	6-BA(10ppm)	Mid May	178.67	66.01(54.32)
T_{11}	6-BA(5ppm)	Mid June	196.67	66.44(54.60)
T_{12}	6-BA(10ppm)	Mid June	213.00	71.48(57.89)
T_{13}	NAA+GA_3+BA(20ppm+50ppm+5ppm)	Mid May	249.85	64.48(53.40)
T_{14}	NAA+GA_3+BA(20ppm+50ppm+5ppm)	Mid June	166.33	65.00(54.25)
T_{15}	Control	Mid May/ June	199.66	62.00(51.97)
$CD_{0.05}$			67.29	5.10

*Figures in the parentheses are arcsine transformed value

Aril Percentage

The data in Table 4 reveals that the application of NAA, GA_3, 6-BA and their combination at different concentrations exerted significant effect on aril percentage. The aril percentage under various treatments ranged from 62.00 to 76.53 per cent. Maximum aril percentage (76.53%) was recorded with treatment NAA 20ppm (T_1), when applied in the month of May, which was statistically at par with the

treatments T_2, T_3, T_4, T_6, T_8, and T_{12}. However, minimum aril percentage (62.00%) was registered in the treatment Control (T_{15}).

In our findings NAA 30ppm and 20ppm increased the aril weight and its percentage. The increase in aril weight and aril percentage might be attributed to increased cell size and intercellular spaces coupled with accumulation of water, sugars and other soluble solids in greater amount as a result of translocation of metabolites. The beneficial effects of NAA 40ppm on aril weight and its percentage was also recorded by Adi and Prasad (2012) [1] in pomegranate cv. Ganesh and Anawal *et al*. (2015) [2] in cv. Bhagwa, whereas increase in aril weight by NAA was also reported by Rahemi and Atahosseini (2004) [15] in cv. Shishep Cup.

Total Soluble Solids (TSS)

The data pertaining to the effect of plant growth regulators on TSS in pomegranate cv. Kandhari are presented in Table 5. It is evident from data that application of NAA, GA_3, 6-BA and their combination at different concentrations induced significant effect on Total Soluble Solids (TSS) content of fruits. The TSS under various treatments ranged from 14.60 to 15.67 ^{0}B. Maximum TSS (15.67 ^{0}B) was recorded with treatment NAA 30ppm (T_4), when applied in the month of June and further was statistically at par with the treatments T_1, T_3, T_5, T_8, T_9, T_{10} and T_{13}. However, minimum TSS (14.60 ^{0}B) was registered in the treatment GA_3 50ppm (T_7), when applied in the month of June.

The increase in total soluble solids percentage by NAA 30ppm may be caused due to starch hydrolysis and early maturation of fruits. The present findings are in conformity with those reported by Goswami *et al.* (2013) [10] in pomegranate cv. Sindhuri. The increased total soluble solids might be due to the quick metabolic transformation of starch and pectin into soluble compounds and rapid translocation of sugars from leaves to developing fruits. The similar results were obtained by Ghosh *et al*. (2009) [9] in cv. Ruby and Anawal *et al*. (2015) [2] in cv. Bhagwa in pomegranate, Sharma and Dhillon (1986) [16] in litchi and Chavan *et al*. (2009) [6] in sapota.

Titratable Acidity

From the perusal of data on the effect of plant growth regulators on titratable acidity inpomegranate cv. Kandhari presented in Table 5 reveals that application of NAA, GA_3, 6-BA and their combination at different concentrations exerted significant effect on titratable acidity. The titratable acidity under various treatments ranged from 0.39 to 0.64%. Maximum titratable acidity (0.64%) was recorded with treatment GA_3 75ppm (T_6), when applied in the month of May as compared to all the treatments, except T_7, T2, T_9, T_{14} and T_{12}, which were found statistically at par with the treatment GA_3 75ppm (T_6). However, minimum titratable acidity (0.39%) was registered in the treatment NAA 20ppm (T_3), when applied in the month of June.

Table 5: Effect of plant growth regulators on TSS, Titratable acidity and TSS/Acid ratio of pomegranate cv. Kandhari

Treatments		Time of application	TSS (^{0}Brix)	Titratable acidity (in%)	TSS/Acid ratio
T_1	NAA(20ppm)	Mid May	15.06	0.47	32.22
T_2	NAA(30ppm)	Mid May	14.70	0.58	25.34
T_3	NAA(20ppm)	Mid June	15.06	0.39	38.61
T_4	NAA(30ppm)	Mid June	15.67	0.48	32.64
T_5	GA_3(50ppm)	Mid May	15.30	0.41	37.30
T_6	GA_3(75ppm)	Mid May	14.66	0.64	22.90
T_7	GA_3(50ppm)	Mid June	14.60	0.63	23.17
T_8	GA_3(75ppm)	Mid June	15.20	0.41	37.07
T_9	6-BA(5ppm)	Mid May	15.40	0.58	28.00
T_{10}	6-BA(10ppm)	Mid May	15.60	0.42	37.14
T_{11}	6-BA(5ppm)	Mid June	15.00	0.41	38.58
T_{12}	6-BA(10ppm)	Mid June	14.80	0.56	26.42
T_{13}	NAA+GA_3+BA(20ppm+50ppm+5ppm)	Mid May	15.20	0.47	32.34
T_{14}	NAA+GA_3+BA(20ppm+50ppm+5ppm)	Mid June	14.90	0.57	26.14
T_{15}	Control	Mid May/ June	14.80	0.53	27.92
$CD_{0.05}$			0.63	0.09	6.13

TSS/Acid ratio

The data pertaining to the effect of plant growth regulators on TSS/acid ratio in pomegranate cv. Kandhari are presented in Table 5. The data indicates that application of NAA, GA_3, 6-BA and their combination at different concentrations exerted significant effect on TSS/acid ratio. The TSS/acid ratio under various treatments ranged from 22.90 to 38.61. Maximum TSS/acid ratio (38.61) was recorded with treatment NAA 20ppm (T_3), when applied in the month of June, which remained statistically at par with the treatments T_4, T_5, T_8, T_{10}, T_{11} and T_{13}. However, minimum TSS/acid ratio (22.90) was registered in the treatment GA_3 75ppm (T_6), when applied in the month of May.

The treatments which produced highest amount of total sugars and low acid content in fruits gave higher sugars/acid ratio. NAA 20ppm the highest TSS/acid ratio. These results of the present studies on sugars/acid ratio discussed above are in consonance with the findings of Desai *et al.* (1993) [8] in cv. Ganesh with NAA 500ppm treatment.

Total-Sugars

The data depicting the effect of plant growth regulators on total-sugars in pomegranate cv. Kandhari are presented in Table 6. It is evident from data that application of NAA, GA_3, 6-BA and their combination at different concentrations exerted significant effect on total-sugars. The total- sugars under various treatments ranged from 9.86 per cent to 12.86 per cent. Maximum total-sugars (12.86%) was recorded with treatment NAA 20ppm (T_1), when applied in the month of May, which was significantly higher over all the treatments, except 6-BA 10ppm (T_{10}) which was found at par with the treatment T_1. However, minimum total-sugars (9.88%) was registered in the treatment GA_3 50ppm (T_7), when applied in the month of June.

Reducing-sugars

The data regarding the effect of plant growth regulators on reducing-sugars in pomegranate cv. Kandhari are presented in Table 6. It is evident from data that application of NAA, GA_3, 6-BA and their combination at different concentrations exerted significant effect on reducing-sugars. The reducing-sugars under various treatments ranged from 8.74 per cent to 11.66 per cent. Significantly higher reducing-sugars (11.66%) was recorded with treatment NAA 20ppm (T_1), when applied in the month of May in comparison to all other treatments. However, minimum reducing-sugars (8.74%) was registered in the treatment Control (T_{15}).

Table 6: Effect of plant growth regulators on total sugars, reducing sugars and non-reducing sugars of pomegranate cv. Kandhari

Treatments		Time of application	Total-sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)
T_1	NAA(20ppm)	Mid May	12.86	11.66	1.14
T_2	NAA(30ppm)	Mid May	11.91	10.27	1.56
T_3	NAA(20ppm)	Mid June	11.88	10.28	1.52
T_4	NAA(30ppm)	Mid June	11.37	10.06	1.24
T_5	GA_3(50ppm)	Mid May	9.98	9.08	0.86
T_6	GA_3(75ppm)	Mid May	10.44	9.16	1.22
T_7	GA_3(50ppm)	Mid June	9.86	9.04	0.78
T_8	GA_3(75ppm)	Mid June	11.09	9.79	1.24
T_9	6-BA(5ppm)	Mid May	11.85	10.18	1.59
T_{10}	6-BA(10ppm)	Mid May	12.31	10.05	2.15
T_{11}	6-BA(5ppm)	Mid June	10.68	9.36	1.25
T_{12}	6-BA(10ppm)	Mid June	11.68	10.35	1.26
T_{13}	NAA+GA_3+BA (20ppm+50ppm+5ppm)	Mid May	10.74	9.22	1.44
T_{14}	NAA+GA_3+BA (20ppm+50ppm+5ppm)	Mid June	10.92	9.52	1.34
T_{15}	Control	Mid May/ June	10.23	8.74	1.41
$CD_{0.05}$			0.84	1.26	NS

Non-reducing sugars

The data pertaining to the effect of plant growth regulators on non-reducing sugars in pomegranate cv. Kandhari are presented in Table 6. The data clearly reveals that application of NAA, GA_3, 6-BA and their combination at different concentrations could not significantly affect the non-reducing sugars. In our studies the total sugars and reducing sugars were found to be increased by NAA 20ppm. The significant improvement in sugars might be due to better formation and translocation of carbohydrates which improved the fruit quality. These results are in line with Hussein *et al.* (1994) [12] and Venkatesan and Mohideen (1994) [21] in pomegranate with 10ppm and 25ppm of NAA was used. Application of NAA 40 ppm resulted in increase in reducing, non-reducing and total sugars reported by Anawal *et al.* (2015) [2] in pomegranate cv. Bhagwa. Sheikh (2015) [17] also found similar results with NAA in cv. Ganesh. Also, the increase in sugar percentage may be due to starch hydrolysis and early maturation of fruits. These results are in conformity with those reported by Goswami *et al.* (2013) [10] in pomegranate cv. Sindhuri.

Juice Content

The data pertaining to the effect of plant growth regulators on juice content of pomegranate cv. Kandhari are presented in Table 7. It is evident from data that application of NAA, GA_3, 6-BA and their combination at different concentrations exhibited non-significant effect on juice content. However, the maximum juice content was recorded with treatment NAA 30ppm (T_2), when applied in the month of May, whereas the minimum juice content was registered in the treatment Control (T_{15}).

Ascorbic Acid

The data regarding the effect of plant growth regulators on ascorbic acid of pomegranate cv. Kandhari are presented in Table 7. It is clear from the data that application of NAA, GA_3, 6-BA and their combination at different concentrations exerted significant effect on ascorbic acid. The ascorbic acid under various treatments ranged from 9.40 to 13.20 mg $100g^{-1}$. Maximum ascorbic acid (13.20mg $100g^{-1}$) was recorded with treatment NAA+GA_3+6-BA @ 20+50+5ppm (T_{14}), when applied in the month of June in comparison to all other treatments, except the treatments T_2, T_3, T_5, T_6, T_7, T_8 and T_{13}, which were statistically at par with the T_{14}. However, minimum ascorbic acid (9.40 mg $100g^{-1}$) was found in the treatment 6-BA 10ppm (T_{10}), when applied in the month of May.

Table 7: Effect of plant growth regulators on juice content and ascorbic acid of pomegranate cv. Kandhari

Treatments		Time of application	Juice content (ml 100g of arils^{-1})	Ascorbic acid (mg $100g^{-1}$)
T_1	NAA(20ppm)	Mid May	68.33	10.20
T_2	NAA(30ppm)	Mid May	71.67	12.13
T_3	NAA(20ppm)	Mid June	67.67	11.33
T_4	NAA(30ppm)	Mid June	69.33	10.60
T_5	GA_3(50ppm)	Mid May	60.00	11.93
T_6	GA_3(75ppm)	Mid May	61.67	12.00
T_7	GA_3(50ppm)	Mid June	63.33	11.80
T_8	GA_3(75ppm)	Mid June	62.33	12.13
T_9	6-BA(5ppm)	Mid May	66.67	10.66
T_{10}	6-BA(10ppm)	Mid May	65.67	9.40
T_{11}	6-BA(5ppm)	Mid June	67.00	9.46
T_{12}	6-BA(10ppm)	Mid June	64.00	10.73
T_{13}	NAA+GA_3+BA(20ppm+50ppm+5ppm)	Mid May	69.33	12.13

T_{14}	NAA+GA_3+BA(20ppm+50ppm+5ppm)	Mid June	67.67	13.20
T_{15}	Control	Mid May/ June	59.33	10.53
$CD_{0.05}$			NS	2.18

The perspective increase in ascorbic acid content might be due to catalytic activity of plant bio-regulators on its bio-synthesis from its precursor glucose-6-phosphate or inhibition of its conversion into dehydro ascorbic acid by ascorbic acid oxidase enzymes or both (Brahmachari and Rani, 1996) [5].

Conclusions

On the basis of the results obtained during the present investigation, it is concluded that among various plant growth regulators, NAA 30ppm (May and June) was proved to be the most effective growth regulator for improving the fruit quality of pomegranate and GA_3 and BA shows minimum improvement in the quality of pomegranate.

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