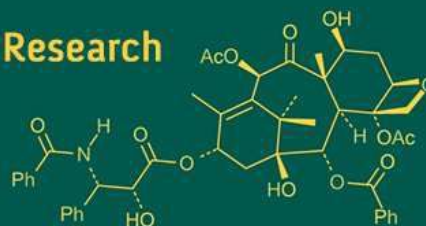


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(2): 402-407
www.biochemjournal.com
Received: 05-12-2025
Accepted: 09-01-2026

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Crosstalk effect of brassinosteroids and gibberellic acid affects plant phenology, yield and fruit quality traits in sugar apple (*Annona squamosa* L.) cv. Balanagar

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i2Se.7642>

Abstract

Present experiment was carried out to investigate the crosstalk effects of brassinosteroids (BRs) and GA₃ on plant parameters, yield characters and composition of sugar apple fruits. Among different treatment combinations comprising brassinosteroids and gibberellic acid, T₅ treatment consisting (BRs @ 0.5ppm + GA₃ @ 25 ppm) Give value of important parameters such as foliar spray of BRs (0.5ppm) + GA₃ (25ppm) significantly maximized the rootstock growth with value (4.81%), scion girth (5.75%), plant height (6.02%) canopy volume, flower number (265.33), flower retention (67.69%), flower size, no of fruits per plant, fruit retention, no of stone fruits, yield per plant (18.51kg/plant).

Keywords: *Annona squamosa*, plant growth regulators, growth yield attributes

Introduction

Custard apple (*Annona squamosa* L.) is an important minor fruit of tropical and subtropical, which belongs to the family *Annonaceae*. The 100 g pulp contains 70.5 g moisture, 23.5 g carbohydrate, 1.6 g protein, 0.9 g minerals, 1.5 mg iron, 17 mg calcium, 47 mg phosphorus and 37 mg vitamin C (Dashora *et al.*, 2004) [5]. Besides, pulp of custard apple is used to prepare different processed products like nectar, RTS, ice-cream and frozen chips. Custard apple is generally used as table fruit, known for its pleasant distinctive texture of pulp, sub-acid and aromatic flavour. Unripe fruits are directly baked on fire and eaten. Custard apple bears flower during April to August depending upon the variety, geographical condition and climate (Kumar *et al.*, 1977; Sahoo *et al.*, 2000) [10]. The greenish yellow flowers arise in extra axillary position usually in clusters and rarely solitary. The flowering is observed mostly on new shoots as well as on old shoot. Flowers consist around six petals are in two whorls and hermaphrodite. However, protogynous dichogamy reported in which the female part matures before the male. In custard apple plant, low fruit set is a major constraint. Several well-known factors such as high and low atmospheric humidity during flowering, moisture stress, dichogamy and competition among developing parts have been reported to have low flower and fruit setting Kumar *et al.*, 1977. [10]. Flowering is highly correlated with defoliation and there after emergence of new growth. Fruit set takes place after the onset of *monsoon* coupled with high relative humidity, however late vegetative growth delays flowering and fruit set. In custard apple, only about two per cent of the flower set and bear fruit. In order to increase fruit set, certain measures like hand pollination, nutrient and water management and use of certain chemicals and plant growth regulators (PGRs) could be used. Plant growth regulators serve as a means for enhancing flowering, fruit set, fruit drop control, yield enhancement and fruit quality in different horticultural crops. They regulate various plant growth and developmental processes by synchronizing flowering, improving fruit set, decreasing pre-harvest fruit drop and thinning of excessive flowers or young fruits (Singh *et al.*, 1976; Bhatia and Yadav, 2003; Singh *et al.*, 2007) [3, 21, 22].

In this concern, recently use of brassinosteroids (BRs) and gibberellic acid (GA₃) in horticultural crops has been standardized and has gained significant importance. Brassinosteroids (BRs) are a group of naturally occurring plant steroids known for its pleiotropic effects. It is a new group of polyhydroxyl steroids which have been recognized as a class of phytohormones has been conferred as novel hormone and hormone of the 21st century, due to its involvement in large number of physiological processes (Khripach *et al.*, 2000) ^[9]. The foliar application of Epi-BI (45 and 60ng/g fruit weight) enhanced the ripening, fruit softening and colour development with increased ethylene and respiration rate in mango crop. The results revealed that foliar application of 3 μ M 24-epibrassinolide favours vegetative growth enhances yield and thereby improves quality of strawberry fruit. Watanabe *et al.* (1997) ^[26], reported increased fruit set in Japanese persimmon when applied BRs exogenously. Mostafa and Kotb (2018) ^[13], reported maximum fruit set, retention, number of fruits/tree and yield and fruit physicochemical quality in BRs treated trees of custard apple with 1mg/l. Similarly, Gibberellins (GA₃) control fruit development in various ways and at different developmental stages. Gibberellins are known to influence both cell division and cell enlargement application of GA₃ is also standardized as it helps in increasing the fruit setting number of fruits per tree, fruit weight and ultimately increase the fruit yield (Shinde *et al.*, 2008) ^[20]. Santos *et al.*, (2016) ^[19], reported that of GA₃ (1500 ppm) improved fruit physicochemical quality of sugar apple and also produced seedless fruits. Likewise, Pereira *et al.* (2014) ^[17], found that GA₃ application on "Gefner" custard apple (*Annona cherimola* x *Annona squamosa*) produced fruit with good pulp proportion, high TSS and imparted seedlessness. Ingle *et al.*, (2001) ^[18], revealed that foliar application of GA₃ @ 25 ppm increased the fruit weight, volume, TSS, ascorbic acid. Eid *et al.* (2016) ^[4], revealed the effect of foliar sprays application of Milagro on yield and fruit quality of Avocado tree cv." Fuerte". The foliar application of milagro (0.2% Brassinolide) increased fruit weight of avocado tree cv. Fuerte. Therefore, the present investigation was undertaken for comparative study with the following objectives: -

- To study the individual effects of Brassinosteroids and gibberellic acid on growth and yield of custard apple.
- To find out the combined effect of Brassinosteroids and gibberellic acid on growth and yield of custard apple.

Materials and Methods

The present experiment was carried out during 2021-22 on 10 year old trees of custard apple cv. balanagar at the Fruit Instructional Farm, Department of Fruit Science, College of Horticulture and Forestry, Jhalrapatan city, Jhalawar (Agriculture University, Kota). The experiment was laid out in a Randomized Block Design with Nine treatment combinations viz., T₀: Control (Water spray), T₁: BRs (0.5ppm) T₂: BRs (1.0ppm) T₃: GA₃ (25ppm) T₄: GA₃ (50ppm) T₅: BRs + GA₃ (0.5ppm + 25 ppm) T₆: BRs + GA₃ (0.5ppm + 50ppm) T₇: BRs+ GA₃ (1.0ppm + 25ppm) T₈: BRs + GA₃ (1.0ppm + 50 ppm) keeping three replications The treatments were applied first spray at the time of initiation of flowering and second at the time of fruiting (fruit set).

3.6 Methodology used for observations

3.6.1 Plant parameters

Plant height (m)

The height of plant was measured from the base of soil to the highest tip of the plant with the help of measuring scale.

Plant Width (m)

The spread of the plants was recorded in East-West and North-South directions separately with the help of a measuring tape and the average for each direction was calculated.

Rootstock girth (mm)

The initial girth of rootstock was measured separately by using digital Vernier Calipers before treatment application in the first week of August. Thereafter, the final observation on rootstock girth was measured at the end of experiment. The per cent increase in girth of rootstock was computed based on the cumulative increase in initial value. (Mostafa and Hatem 2018) ^[13].

Scion girth (mm)

For measuring scion girth, the custard apple plants under different treatments were marked at a fix point with white paint. Initial observations on scion girth were taken during first week of August and final observations were recorded at the end of experiment. The per cent increase in scion girth was calculated on the basis of cumulative increase in initial value. (Mostafa and Hatem 2018) ^[13].

Number of shoots per branch

The number of shoots per branch was counted manually at before foliar application of treatments and thereafter at the end of experiment. The per cent increase in number of shoots per branch was calculated on the basis of cumulative increase on the basis of initial values recorded during August.

Number of leaves per shoot

The number of leaves per shoot under different treatments of Custard apple was counted manually before foliar application of treatments and thereafter at the end of experiment. The per cent increase in number of leaves was estimated on the basis of cumulative increase in initial values of August.

Leaf length (cm)

For measuring leaf length, selected tagged leaves under various treatments of Custard apple were measured initially during August before foliar application of treatments and final values were recorded towards the end of experiment. The per cent increase in leaf length was calculated on the basis of cumulative increase in initial values. (Pujari *et al.* 2021) ^[16].

Leaf width (cm): For measuring leaf width, selected tagged leaves under various treatments of Custard apple were measured initially during August before foliar application of treatments and final values were recorded towards the end of experiment. The per cent increase in leaf width was calculated on the basis of cumulative increase in initial values. (Pujari *et al.* 2021) ^[16].

Number of flowers per plant

It was recorded manually by counting the number of flowers per tree after application of treatments.

- **Number of fruits per tree:** It was recorded by counting the number of fruits per tree at the time of harvesting. (Mostafa and Hatem 2018) ^[13].
- **Flower retention (%):** It was recorded by counting the number of total flowers retained after flowering and which were converted into fruits. (Mostafa and Hatem 2018) ^[13].

$$\text{Flower retention (\%)} = \left(\frac{\text{Total flowers retained}}{\text{Total number of flowers}} \right) \times 100$$

Days taken to fruit set

It was recorded by time interval between flowering to fruiting. (Kavati, 1992).

Fruit set (%)

It was recorded by number of days taken from flowering to fruit set. (Mostafa and Hatem 2018) ^[13].

$$\text{Fruit set (\%)} = \left(\frac{\text{Average number of developed fruitlets}}{\text{Average number of flowers}} \right) \times 100$$

No of fruits per plant

It was recorded by counting manually the number of fruits per tree at the time of harvesting. (Bansidharrao 2016) ^[2].

Fruit retention (%)

It was calculated according to the formula. (Bansidharrao 2016) ^[2].

$$\text{Fruit retention (\%)} = \left(\frac{\text{Average number of retained fruits at harvest}}{\text{Average number of developed fruitlets}} \right) \times 100$$

No of stone fruits

It was calculated by total number of fruits that got converted into hard fruits at the maturity stage.

- **Yield per plant (Kg):** Mature fruits were harvested periodically in each treatment separately and the weight was recorded with the help of electronic balance. Then the total estimated yield (kg / plant) was calculated. (Pujari *et al.* 2021) ^[16].
- **Statistical analysis:** The data collected as a part of experiment will be analysed by following analytical method as followed for Randomized Block Design (RBD) as per method as suggested by Panse and Sukhatme (1995) ^[27].

Results

Table 1: Effect of foliar spray of brassinosteroids and gibberellic acid on Rootstock girth, Scion girth, Plant height, Plant width in custard apple cv. Balanagar.

Sr. No.	Treatment	Rootstock girth (mm)	Scion girth (mm)	Plant height (m)	Plant width	
					EW (m)	NS (m)
1	T ₀ (Control)	145.00(2.11)	109.49(2.25)	2.75(2.70)	3.25(0.92)	2.83(3.37)
2	T ₁ (BR _s 0.5ppm)	159.66(2.78)	108.81(2.64)	2.99(4.41)	3.46(3.92)	3.00(4.02)
3	T ₂ (BR _s 1.0 ppm)	141.33(3.39)	102.86(3.21)	3.03(5.39)	3.71(3.46)	2.89(4.21)
4	T ₃ (GA ₃ 25 ppm)	147.33(3.51)	88.09(4.12)	2.95(5.21)	3.64(2.97)	2.34(4.60)
5	T ₄ (GA ₃ 50 ppm)	171.33(3.81)	116.29(4.50)	2.48(5.36)	3.16(4.73)	3.04(5.50)
6	T ₅ (BR _s 0.5 ppm + GA ₃ 25 ppm)	168.66(4.81)	97.72(5.75)	3.30(6.02)	3.22(6.45)	2.77(6.52)
7	T ₆ (BR _s 0.5 ppm + GA ₃ 50 ppm)	145.66(4.02)	117.14(4.29)	2.92(5.42)	3.29(5.42)	2.97(6.20)
8	T ₇ (BR _s 1.0 ppm + GA ₃ 25 ppm)	144.66(4.08)	112.57(4.26)	2.66(5.52)	3.65(3.49)	2.82(5.41)
9	T ₈ (BR _s 1.0 ppm + GA ₃ 50 ppm)	151.00(3.90)	105.42(4.07)	2.83(5.56)	3.22(3.60)	3.02(4.73)
	SEm (±)	7.85(0.22)	6.75(0.23)	0.80(0.48)	0.29(1.18)	0.22(0.36)
	CD (5%)	23.56(0.68)	20.25(0.70)	0.27(1.03)	0.87(3.56)	0.67(1.08)

The data shows that the maximum Rootstock girth percentage increase in rootstock growth with value (4.81%), scion girth (5.75%), plant height (6.02%), E-W spread (6.45%), N-S plant spread (6.52%) was measured in T₅ (BR_s @ 0.5 ppm + GA₃ @ 25 ppm), Likewise the minimum

per cent increase in rootstock growth of Custard apple cv. Balanagar trees with value (2.11%), scion girth (5.75%), plant height (2.70%), E-W spread (0.92%), N-S spread (3.37%) was recorded in T₀ treatment (control).

Table 2: Effect of foliar spray of brassinosteroids and gibberellic acid on No of shoots/branch, No of leaves/shoot, Leaf length, leaf width, No of flowers/plants in custard apple cv. Balanagar.

Sr. No.	Treatment	No of shoots /branch	No of leaves/shoot	Leaf length	Leaf width	No of flowers/plant
1	T ₀ (Control)	11.66(51.96)	11.66(43.12)	8.92(31.97)	2.73(25.01)	226.66
2	T ₁ (BR _s 0.5ppm)	13.00(63.93)	12.33(44.16)	8.97(33.84)	2.90(35.78)	241.00
3	T ₂ (BR _s 1.0 ppm)	13.33(64.30)	12.66(50.57)	8.96(33.19)	2.95(29.68)	247.66
4	T ₃ (GA ₃ 25 ppm)	14.33(71.23)	13.33(47.41)	8.99(32.83)	3.07(34.56)	256.00
5	T ₄ (GA ₃ 50 ppm)	14.00(69.27)	14.00(55.65)	9.13(34.85)	3.10(36.24)	255.00
6	T ₅ (BR _s 0.5 ppm + GA ₃ 25 ppm)	15.33(63.20)	14.33(75.54)	9.25(36.20)	3.25(40.45)	265.33
7	T ₆ (BR _s 0.5 ppm + GA ₃ 50)	14.66(69.16)	13.00(59.99)	9.16(36.08)	3.24(36.40)	261.66

	ppm)					
8	T ₇ (BRs 1.0 ppm + GA ₃ 25 ppm)	14.33(63.21)	13.66(56.52)	9.10(35.88)	3.00(30.22)	246.33
9	T ₈ (BRs 1.0 ppm + GA ₃ 50 ppm)	14.00(53.09)	13.00(71.24)	9.04(34.78)	2.95(29.48)	252.33
	SEm (±)	0.45(10.11)	0.46(8.64)	0.07(1.62)	0.08(3.33)	1.41
	CD (5%)	1.36(NS)	1.39(25.90)	0.23(NS)	0.26(10.0)	4.24

Table 2 revealed that of different treatments significantly influenced the growth attributes such as, number of shoots per branch, number of leaves per shoot, leaf length, leaf width and no of flowers/plant. The highest per cent increase in number of shoots per branch (71.23%) was recorded in T₃ (GA₃ @ 25ppm), number of leaves per shoots (75.54%), leaf length (36.20%), leaf width (40.45) and no of flowers

(265.33) was estimated in T₅ treatment consisting (BRs @ 0.5ppm + GA₃ @ 25 ppm). However, minimum per cent increase in number of shoots/branches was recorded in T₀ treatment (control) with value (51.96%), number of leaves/shoot (43.12%), leaf length (31.97%), leaf width (25.01%), no of flowers/plant (226.66) was recorded in T₀ treatment (control) in custard apple cv. Balanagar.

Table 3: Effect of foliar spray of brassinosteroids and gibberellic acid on Flower retention, Days taken to fruit set, Fruit set, No of fruits/plant in custard apple cv. Balanagar.

Sr. No.	Treatment	No of shoots /branch	No of leaves/shoot	Leaf length	Leaf width	No of flowers/plant
1	T ₀ (Control)	11.66(51.96)	11.66(43.12)	8.92(31.97)	2.73(25.01)	226.66
2	T ₁ (BRs 0.5ppm)	13.00(63.93)	12.33(44.16)	8.97(33.84)	2.90(35.78)	241.00
3	T ₂ (BRs 1.0 ppm)	13.33(64.30)	12.66(50.57)	8.96(33.19)	2.95(29.68)	247.66
4	T ₃ (GA ₃ 25 ppm)	14.33(71.23)	13.33(47.41)	8.99(32.83)	3.07(34.56)	256.00
5	T ₄ (GA ₃ 50 ppm)	14.00(69.27)	14.00(55.65)	9.13(34.85)	3.10(36.24)	255.00
6	T ₅ (BRs 0.5 ppm + GA ₃ 25 ppm)	15.33(63.20)	14.33(75.54)	9.25(36.20)	3.25(40.45)	265.33
7	T ₆ (BRs 0.5 ppm + GA ₃ 50 ppm)	14.66(69.16)	13.00(59.99)	9.16(36.08)	3.24(36.40)	261.66
8	T ₇ (BRs 1.0 ppm + GA ₃ 25 ppm)	14.33(63.21)	13.66(56.52)	9.10(35.88)	3.00(30.22)	246.33
9	T ₈ (BRs 1.0 ppm + GA ₃ 50 ppm)	14.00(53.09)	13.00(71.24)	9.04(34.78)	2.95(29.48)	252.33
	SEm (±)	0.45(10.11)	0.46(8.64)	0.07(1.62)	0.08(3.33)	1.41
	CD (5%)	1.36(NS)	1.39(25.90)	0.23(NS)	0.26(10.0)	4.24

The data exhibited non-significant effect of brassinosteroids and GA₃ on flower retention percentage in custard apple cv. Balanagar trees are presented in table 4.3. Maximum flower retention (67.69%) was recorded in T₅ treatment, flower retention (67.69%), Minimum number of days taken to fruit

set (53.66), fruit set (76.16%) was estimated in T₅ (BRs @ 0.5 ppm + GA₃ @ 25 ppm) under vertisols of Jhalawar district. However, the maximum number of fruits/ plant (83.90) was obtained in T₈ treatment consisting (BRs @ 1.0 ppm + GA₃ @ 50 ppm).

Table 4: Effect of foliar spray of brassinosteroids and gibberellic acid on in custard apple cv. Balanagar.

Sr. No.	Treatment	Fruit retention (%)	No of stone fruits	Yield/plant (kg)
1	T ₀ (Control)	40.22	5.00	11.42
2	T ₁ (BRs 0.5ppm)	42.52	1.33	12.19
3	T ₂ (BRs 1.0 ppm)	42.34	0.66	12.17
4	T ₃ (GA ₃ 25 ppm)	41.86	3.33	15.10
5	T ₄ (GA ₃ 50 ppm)	41.91	1.66	15.53
6	T ₅ (BRs 0.5 ppm + GA ₃ 25 ppm)	43.81	1.00	18.51
7	T ₆ (BRs 0.5 ppm + GA ₃ 50 ppm)	40.90	2.33	16.81
8	T ₇ (BRs 1.0 ppm + GA ₃ 25 ppm)	41.72	3.00	17.28
9	T ₈ (BRs 1.0 ppm + GA ₃ 50 ppm)	42.04	1.33	17.20
	SEm (±)	0.51	0.72	1.02
	CD (5%)	1.54	2.18	3.07

The results determined that maximum fruit retention (43.81%) comprising (BRs @ 0.5 ppm + GA₃ @ 25 ppm), minimum number of stone fruits (0.66) was estimated in T₂ treatment consisting (BRs @ 1.0 ppm) and maximum yield (18.51kg/plant) was obtained in T₅ treatment consisting (BRs @ 0.5 ppm + GA₃ @ 25 ppm) Similarly the minimum fruit retention (40.22%), maximum number of stone fruits (5.00), minimum yield (11.42 kg/plant) was recorded in T₀ treatment (control).

Discussion

The plant growth parameters of custard apple cv. Balanagar under various treatments involving foliar application of brassinosteroids and gibberellic acid resulted in significant augmentation in plant growth and yield parameters in clayey vertisols of Jhalawar district.

The maximum augmentation in plant height (6.02%), plant width (E-W) value (6.45%), plant width (N-S) value (6.52%), rootstock girth (4.81%), scion girth (5.75%), number of leaves/shoot (75.54%), leaf length (36.20%), leaf

width (40.45%), number of flowers/plant (265.33), flower retention (67.69%), fruit set (76.16%), fruit retention (43.81%), and yield/plant (18.51 kg) were recorded in T₅ treatment consisting (BRs @ 0.5 ppm + GA3 @ 25 ppm) and these parameters were observed significantly higher and relatively better as compared with application of other treatments. However, maximum per cent increase in (North-South plant spread) with value (9.12%) was recorded in T₆ treatment (BRs @ 0.5 ppm + GA3 @ 50 ppm), number of shoots/branch (71.23) was measured in T₃ treatment (GA3 @ 25 ppm) days taken to fruit and number of fruits per plant (83.90) were set (70.34) in T₈ treatment (BRs @ 1.0 ppm + GA3 @ 50 ppm). Similarly, minimum per cent increase in plant height (2.70%), east-west spread (0.92%), north-south spread (3.37%), no of shoots/branch (51.96), no of leaves/shoot (43.12), leaf length (31.97%), leaf width (25.01%), number of flowers/plant (226.66), flower retention (61.70%), fruit retention (40.22%) yield/plant (11.42 kg) were measured in T₀ treatment (control).

The relatively better increase in growth and yield attributes recorded in T₅ treatment may be attributed to the beneficial response of BRs and GA3 in terms of improved carboxylation efficiency, protein synthesis and better integration of various bio-chemical and physiological responses within the plant system of custard apple. The overall better response in T₅ treatment could be ascribed to improved developmental processes including cell elongation, pollen tube growth, flowering, ontogenical fruit development and maturation. The results of present finding are in conformity to those reported by Kalinich (1985)^[8], Mahorker *et al.* (2018), Mostafa and Hatem (2018), Pujari *et al.* (2021), Mahorker *et al.* (2021)^[13, 16].

Conclusions

The effect of study involving foliar spray of brassinosteroids and gibberellic acid in custard apple cv. Balanagar revealed that maximum per cent in growth parameters *viz.* plant height (8.48%), E-W plant width (6.45%), rootstock girth (4.40%), scion girth (6.09%), no. of leaves/shoot (75.54%), leaf length (36.20%), leaf width (40.45%), number of flowers/ branch (265.33), flower retention (67.69%), fruit set (77.49%), fruit retention (43.81%) and yield/plant (18.51 kg) was measured in T₅ treatment consisting (BRs @ 0.5 ppm + GA3 @ 25 ppm).

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