The Pharma Innovation Journal 2022; 11(2): 1123-1126

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(2): 1123-1126

www.thepharmajournal.com
Received: 21-11-2021
Accepted: 30-01-2022

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Effect of plant growth regulators (Gibberellic acid, naphthalene acetic acid) and Brassinosteroids on flowering, fruit set and yield in Guava (*Psidium guajava* cv. Allahabad Safeda)

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Abstract
The experiment entitled "Effect of Plant Growth Regulators (Gibberellic acid, Naphthalene acetic acid) and Brassinosteroids on Flowering, Fruit set and Yield in Guava (*Psidium guajava* cv. Allahabad Safeda) was carried out at Guava Orchard, Horticulture Research Farm, Department of Horticulture, SHUATS, Prayagraj during the year 2020-2021. The experiment was laid out in Randomized Block Design with 10 treatments. Three growth regulators (Gibberellic Acid, Naphthalene Acetic Acid and Brassinosteroids) were applied through foliar spray during research work on Guava (*Psidium guava* cv. Allahabad Safeda). The study revealed that all the characters were significantly affected by the application of the treatments. On the basis of present investigation, it is concluded that the application of T_3 (Brassinosteroids @600ppm) treatment was found best in terms of flowering, fruit set and yield *viz.*, plant height (6.40), number of primary branches (8.31), plant spread (6.93 & 6.46), days required for flowering (31.59), days required from flower to fruit set (31.08), days required from fruit set to maturity (124.2), number of flowers per plant (183.75), number of fruits per plant (165.94), fruit weight (114.92), fruit yield (18.58), fruit polar and radial diameter (8.63 & 8.71), number of seeds (318.85), pulp weight (106.58), seed weight(8.77), fruit setting % (92.04),TSS(10.24),Ascorbic acid(204.96), acidity(0.41), in guava. It is concluded that application of treatment T_3 Brassinosteroids@600ppm has given the best result as compared to other treatments in guava. Therefore, application of Brassinosteroids@600ppm will provide better flowering, fruit set and yield.

Keywords: Guava, gibberellic acid, naphthalene acetic acid, brassinosteroids, flowering, fruit set, yield

Introduction
Guava (*Psidium guajava* L.) is a very important tropical fruit crop grown throughout the tropical and sub-tropical areas. Guava is native of tropical America and it belongs to the natural order myrtles and the botanical family Myrtaceae bearing chromosome number 2n-22. India is the leading producer of guava in the world. The fruit (Berry) is an excellent source of vitamin C (210-305 mg/100 g fruit pulp) and pectin (0.5-1.8%) but has low energy (66 cal /100g). The ripe fruits contain 12.3-26.3% dry matter, 77.9-86.9% moisture, 0.51-1.02% ash, 0.10-0.70% crude fat, 0.82-1.45% crude protein and 2.0-7.2% crude fiber. The fruit is also rich in minerals like Phosphorus (22.5-40.0 mg/100g pulp), Calcium (10.0-30.0 mg/100g pulp) and Iron (0.60-1.39 mg/100g pulp) as well as vitamins like Niacin (0.20-2.32 mg/100g pulp), Panthotenic acid, Thiamine (0.03-0.07 mg/100 g pulp), Riboflavin (0.02-0.04 mg/100 g pulp) and vitamin–"A". Plant Growth Regulators are hormones or substances naturally produced by plants that control normal plant functions, such as root growth, fruit set and drop, growth and other development processes. Gibberellic acid (GA_3) is one of the important growth stimulating substances which promote cell elongation and cell division thus help in the growth and development of many plants The application of GA_3 improves the size, shape and weight of the fruits. GA_3 increases fruit set and fruit retention of the tree. Naphthalene acetic acid (NAA) is a synthetic auxin, that can bring changes in the phenotype of plants and affects growth either by enhancing or by stimulating the natural growth regulatory system from seed germination to senescence. It stimulates cell elongation, cell division in the cambium, differentiation of phloem and xylem and induces flowering and fruiting. It increases T.S.S. and Ascorbic acid content of fruits and reduces acidity and number of seeds in the fruits. Brassinosteroids are a new group of polyhydroxyl steroids which have been recognized as a class of phytohormones.

Brassinosteroids play prominent roles in many developmental processes including the increase of cell elongation, pollen tube growth, flowering, senescence, abscission and maturation.

Materials and Methods

The present investigation entitled "Effect of Plant growth regulators (Gibberellic Acid, Naphthalene Acetic Acid) and Brassinosteroids on flowering, fruit set and yield in Guava (*Psidium guajava* cv Allahabad Safeda)" was carried out at the experimental orchard in Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj during the year 2020-2021. The experiment was laid out in randomized block design with three replications and ten treatment combinations including control (water spray). Ten treatments *viz.*, T_0: Control, T_1: Brassinosteroids@200ppm, T_2: Brassinosteroids@400ppm,T_3:Brassinosteroids@600ppm, T_4: GA_3@100ppm, T_5: GA_3 @150ppm, T_6: GA_3@200ppm, T_7: NAA@50ppm, T_8: NAA@100ppm, T_9: NAA@150ppm were applied through foliar spray during research work on Guava (*Psidium guajava* cv. Allahabad Safeda). Five or six year old uniform healthy bearing guava trees grown under similar cultural practices were selected for the present study. Total 30 guava trees were selected for the experiment. Total three sprays were done in three stages in 30 days interval between. First spray was done before flowering. Second spray was done in fruiting stage and the third spray was done during the fruit set stage. Following observations like Days required for flowering, Days required from flower to fruit set, Days required from fruit set to maturity, Number of flowers per plant, Number of fruits per plant were recorded at 30 days interval.

Observation

Growth parameters	Yield and Quality parameters
Plant height (m)	Fruit weight (g)
Number of primary branches plant^{-1}	Fruit yield per tree (kg)
Plant spread (m^2)(E-W) and (N-S)	Fruit polar and radial diameter (cm)
Days required for flowering	Number of seeds per fruit
Days required from flower to fruit set	Pulp weight
	Fruit setting (%)
Days required from fruit set to maturity	Total soluble solid (^{0}Brix)
	Ascorbic acid (mg / 100 g)
Number of flower per plant	Total sugar
Number of fruit per plant	Acidity

Results and Discussions

The research results statistically provided us with the evidence of improving flowering, fruit set and yield traits of guava in response to the plant growth regulators. The results regarding to plant height of guava were significantly influenced by the application of plant growth regulators and brassinosteroids. The maximum and significant plant height (6.40m) was observed with treatment T_3 Brassinosteroids@ 600ppm while the minimum plant height (3.85m) was recorded with treatment T_0 Control. This might be due to the role of Brassinosteroids which regulates plant growth and development effecting cell division, cell elongation, root and shoot growth, xylem differentiation. Brassinosteroids promotes plant cell elongation through a complex signalling cascade that modulates the activities of growth-related genes in which the plant height has been effected. Variations in plant stature influence plant performance in terms of stability and yield. The maximum number of primary branches plant^{-1} (8.31) was observed in treatment T_3 Brassinosteroids@600ppm while the minimum number of branches (4.18) was observed in treatment T_0 Control. This might be due to the significant increase in the growth and promotion of cell elongation which could be associated with Brassinosteroids-induced elevation of carbohydrate supply by means of the up-regulation in the activity of an extracellular invertase enzyme which also effects the growth of primary branches. The maximum Plant spread (m^2)(E-W) and (N-S) (6.93 & 6.46) was observed in treatment T_3 Brassinosteroids@600ppm which was statistically at par with treatment T_6 GA_3@200ppm while the minimum Plant spread (m^2)(E-W) and (N-S) (4.10 & 3.94) was found in treatments T_0 Control. This may be due to immediate absorption of auxins, which increased the endogenous auxin level that resulted in cell elongation and enhanced vegetative growth. Treatment T_3 Brassinosteroids@600ppm gave the minimum Days required for flowering (31.59) which was statistically at par with treatment T_8 NAA@100ppm Where as the maximum Days required for flowering (50.97) was found in treatments T_0 Control. The minimum days to flowering maybe due to application of brassinosteroids which stimulates higher ethylene production which in turn causes the plant to induce flowering faster. Treatment T_3 Brassinosteroids@600ppm gave the minimum Days required from flower to fruit set (31.08) which was statistically at par with treatment T_5 GA_3@150ppm where as the maximum Days required from flower to fruit set (41.07) was found in treatments T_0 Control. In general, Brassinosteroids increase the fruit dimension comparably better than GA_3. The increased in yield under Brassinosteroids treatments was associated with increase the Days required from flower to fruit set. Treatment T_3 Brassinosteroids@600ppm gave the minimum Days required from fruit set to maturity (124.62) where as the maximum Days required from fruit set to maturity (146.59) was found in treatments T_0 Control. The yield increase in guava may be related to improvement in the assimilation efficiency of photosynthetic carbon of the sprayed plants and the movement of metabolites and nutrients into developing fruits into maturity**.** The Brassinosteroids treatments plays an important role in increase in yield which was also associated with days required from fruit set to maturity**.** The maximum Number of flower per plant (183.75) was observed in treatment T_3 Brassinosteroids@600ppm which was statistically at par with T_8 NAA@100ppm Where as the minimum Number of flower per plant (140.61) was found in treatments T_0 Control. It has been established that Brassinosteroids also influence flowering in some plants including fruit crops For example, Pipattanawong *et al.*, (1996) reported that exogenous application of BRs significantly increased the number of flowers in strawberry and grapes. The maximum Number of fruit per plant (165.94) was observed in Treatment T_3 Brassinosteroids@600ppm where as the minimum Number of fruit per plant (102.74) was found in treatments T_0 Control. Plant physiological functions and biomass production are influenced greatly by the Brassinosteroids application hence modulation of several horticultural traits like flowering, fruit set, fruit growth and yield etc. of various fruit crops is possible. The maximum Fruit weight(g) (114.92) was observed in Treatment T_3

Brassinosteroids@600ppm where as the minimum Fruit weight (g) (72.55) was found in treatments T_0 Control. Increase in fruit weight maybe attributed to the strengthening of middle lamella and consequently cell wall, which later may have increase the free passage of solutes to the fruits. The maximum Fruit yield per tree (kg) (18.58) was observed in Treatment T_3 Brassinosteroids@600ppm which was statistically at par with treatment T_6 GA_3@200ppm Where as the minimum Fruit yield per tree (kg) (7.46) was found in treatments T_0 Control. The increase in fruit yield and the positive impact on several length and breadth significantly increased with foliar application of plant growth reguIncrease in fruit weight maybe attributed to the strengthening of middle lamella and consequently cell wall, which later may have increase the free passage of solutes to the fruits. The increase in fruit size maybe due to accelerated rate of cell division and cell enlargement and more intercellular space with the application of higher concentration of growth substances. Parameters may be attributed to Brassinosteroids uptake from the leaf from the applied Brassinosteroids sprays. The physiological mechanism by which Brassinosteroids-induced yield and components of yield may be due to stimulation of elongation, pollen tube growth and reproductive development. The maximum Fruit polar and radial diameter (cm) (8.63 & 8.71) was observed in Treatment T_3 Brassinosteroids@600ppm which was statistically at par with treatment T_2 Brassinosteroids@400ppm Where as the minimum Fruit polar and radial diameter (cm) (6.33 & 7.08) was found in treatments T_0 Control. Maximum increase in Fruit polar and radial diameter might be due to the application of Brassinosteroids which can act synergistically and induces the fruit length and diameter. The maximum Number of seeds per fruit (318.85) was observed in Treatment T_3 Brassinosteroids@600ppm which was statistically at par with treatment T_7 NAA@50ppm Where as the minimum Number of seeds per fruit) (179.78) was found in treatments T_0 Control. This might be due to the application of Brassinosteroids which also promote seed germination and counteract the germination-inhibition. It is proposed that Brassinosteroids promote seed germination by directly enhancing the growth potential of the emerging embryo. The maximum Pulp weight (g) (106.58) was observed in Treatment T_3 Brassinosteroids@600ppm which was statistically at par with treatment T_9 NAA@150ppm Where as the minimum Pulp weight (g) (66.12) was found in treatments T_0 Control. The increase in fruit pulp weight may be due to stimulate cell division and increased volume in the newly divided cells (or may be enhance uptake of water and accumulation of sugar and other food reserves in a greater amount as well as increased volume of intracellular spaces in pulp of fruit. The maximum seed weight (g) (106.58) was observed in treatment T_3 Brassinosteroids@600ppm which was statistically at par with treatment T_4 GA_3@100ppm Where as the minimum seed weight (g) (66.12) was found in treatments T_0 Control. The maximum Fruit setting (%) (92.04) was observed in treatment T_3 Brassinosteroids@600ppm Where as the minimum Fruit setting (%) (73.07) was found in treatments T_0 Control. The maximum Total soluble solid (^{0}Brix) (10.24) was observed in Treatment T_3 Brassinosteroids@600ppm Where as the minimum Total soluble solid (^{0}Brix) (7.78) was found in treatments T_0Control. The upper values of soluble solids induced by brassinosteroid may be due to mobilization of metabolites from source to sink and also conversion of starch and acids into sugars which the major part of soluble solids. The maximum Ascorbic acid(mg / 100 g) (204.96) was observed in Treatment T_3 Brassinosteroids@600ppm where as the minimum Ascorbic acid (mg / 100 g) (157.85) was found in treatments T_0 Control. The use of BRs regulate leaf Abscorbic acid content and synthesis. Brassinosteroids treatment increase the content of Abscorbic acid in suspension cultured cells or in seedlings under stress conditions. Treatment T_3 Brassinosteroids@600ppm gave the minimum acidity (0.41) Where as the maximum acidity (0.70) was found in treatments T_0 Control. The reason for decrease in titratable acidity maybe due to the metabolic changes with fast conversation of organic acids into sugars and their derivatives by reactions involving reversal of glycolytic pathway or be used in respiration.

Table 1: Effect of Plant growth regulators (Gibberellic acid, Naphthalene acetic acid) and Brassinosteroids on growth parameters of Guava (*Psidium guava cv. Allahabad Safeda*)

Treatments	Growth Parameters								
	Plant height (m)	Number of primary branches plant^{-1}	Plant spread(m^2)		Days required for flowering	Days required from flower to fruit set	Days required from fruit set to maturity	Number of flowers per plant	Number of fruits per plant
			(E-W)	(N-S)					
T_0	3.85	4.18	4.10	3.94	50.97	41.07	146.59	140.61	102.74
T_1	4.79	5.46	4.67	5.50	41.68	35.89	134.91	148.88	134.13
T_2	5.23	6.19	4.66	5.57	39.97	34.14	133.32	159.18	146.44
T_3	6.40	8.31	6.93	6.46	31.59	31.08	124.62	183.75	165.94
T_4	5.89	5.82	5.49	5.25	36.92	32.91	134.87	178.77	154.37
T_5	5.63	6.93	5.84	5.27	36.07	35.22	132.82	170.59	149.18
T_6	5.75	6.36	6.41	6.23	48.24	35.73	134.51	176.53	145.29
T_7	4.71	6.60	6.58	5.11	36.41	35.27	142.55	170.81	148.22
T_8	5.52	5.56	5.21	6.26	34.55	35.64	128.22	175.77	157.60
T_9	5.64	6.34	5.53	5.86	35.12	33.51	138.80	159.15	128.26
S.Ed. (±)	0.078	0.368	0.287	0.338	1.110	1.897	2.297	3.387	6.439
C.D at 0.5%	0.164	0.773	0.603	0.711	2.331	3.985	4.827	7.115	13.528
C.V	1.789	7.299	6.346	7.471	3.471	6.629	2.082	2.493	5.507

Table 2: Effect of Plant growth regulators (Gibberellic acid, Naphthalene acetic acid) and Brassinosteroids on yield and quality parameters of Guava (*Psidium guajava* cv. Allahabad Safeda)

Treatments	Yield and Quality parameters										
	Fruit weight (g)	Fruit yield per tree (kg)	Fruit polar and radial diameter (cm)		Number of seeds per fruit	Pulp weight	Seed weight(g)	Fruit setting(%)	Total soluble solid (^{0}Brix)	Ascorbic acid (mg / 100 g)	Acidity
T_0	72.55	7.46	6.33	7.08	179.78	66.12	6.43	73.07	7.78	157.85	0.70
T_1	92.64	12.43	7.42	7.58	225.25	84.43	8.21	90.09	8.94	172.77	0.52
T_2	94.41	13.85	7.96	8.09	308.22	85.66	8.75	86.85	9.45	181.46	0.50
T_3	114.92	18.58	8.63	8.71	318.85	106.58	8.77	92.04	10.24	204.96	0.41
T_4	112.81	17.41	8.43	8.55	306.48	104.48	8.33	86.39	9.55	185.53	0.45
T_5	106.22	15.82	8.33	8.53	264.84	98.01	8.21	87.53	10.20	203.76	0.54
T_6	111.48	16.21	7.89	8.02	246.59	102.71	8.54	82.28	9.33	204.05	0.61
T_7	111.86	16.07	7.97	7.49	262.64	103.45	8.40	90.33	9.42	196.74	0.46
T_8	108.56	17.11	8.08	8.22	276.14	100.28	8.28	89.72	9.39	182.88	0.51
T_9	108.40	14.73	7.75	7.94	275.12	99.86	8.34	80.58	10.16	177.92	0.42
S.Ed (±)	3.511	0.925	0.299	0.170	27.681	3.472	0.188	3.683	0.237	2.961	0.080
C.D at 0.5%	7.377	1.943	0.628	0.357	58.156	7.294	0.395	7.737	0.498	6.221	0.168
C.V	4.160	7.566	4.651	2.594	12.727	4.468	2.802	5.251	3.075	1.941	19.134

Conclusion

From the present investigation, it is concluded that treatment T_3 Brassinosteroids@600ppm is best suited and beneficial for the plant growth, fruit yield and quality of guava fruit in respect to Plant height (m),Number of primary branches plant^{-1}, Plant spread (m^2)(E-W) and (N-S), Days required for flowering, Days required from flower to fruit set, Days required from fruit set to maturity, Number of flower per plant, Number of fruit per plant, Fruit weight (g), Fruit yield per tree (kg), Fruit polar and radial diameter (cm), Number of seeds per fruit, Pulp weight, Fruit setting (%), Total soluble solid (^{0}Brix), Ascorbic acid (mg / 100 g), Acidity.

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