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Effect of GA_3 on Growth, Sex Expression and Yield of Watermelon (*Citrullus lanatus* Thunb.)

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ABSTRACT

A field experiment was carried out during the year summer seasons (February to May) of 2019–2021 in at Horticulture Instructional Farm, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar Gujarat (385 506), India to study the effect of GA_3 on growth, sex expression and yield of watermelon (*Citrullus lanatus* Thunb.). Plant growth regulators in cucurbits have shown promise in improving crop growth and productivity by affecting several physiological and developmental processes. The experiment was laid out under randomized block design with three replications and eleven treatments namely T_1 (GA_3 10 ppm), T_2 (GA_3 20 ppm), T_3 (GA_3 30 ppm), T_4 (GA_3 40 ppm), T_5 (GA_3 50 ppm), T_6 (GA_3 60 ppm), T_7 (GA_3 70 ppm), T_8 (GA_3 80 ppm), T_9 (GA_3 90 ppm), T_{10} (GA_3 100 ppm) and T_{11} (Control). The variety sugar baby is tested under the experiment. The results revealed that length of the main vine (219.91 cm), number of days to first male flower (50.98), sex ratio (8.01), number of fruit vine^{-1} (2.99), fruit yield vine^{-1} (5.04 kg) and fruit yield ha^{-1} (33.25 tone) were highest in treatment T_8 (GA_3 @ 80 ppm). Thus, foliar application of GA_3 80 ppm twice at 2–4 leaf stages and at flowering stage found effective in enhancing the growth, sex expression and yield attributes of watermelon. These findings provide valuable insights into optimizing agricultural practices through the integration of PGRs, improving productivity and profitability, and supporting sustainable watermelon cultivation.

KEYWORDS: *Citrullus lanatus*, plant growth regulators, watermelon, yield, gibberellic

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Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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1. INTRODUCTION

Watermelon (*Citrullus lanatus* Thunb.) is one of the important cucurbits vegetable crops grown extensively in India and in tropical and sub-tropical countries of the world. Watermelon belongs to the Cucurbitaceae family having 22 chromosomes. It is commonly known by various names tarbuj or paniphal, mathan, palampanna and kalingaddi in different parts of the country (Raj et al., 2022). It is a major river-bed crop of Uttar Pradesh, Rajasthan, Gujarat, Maharashtra and Andhra Pradesh. Watermelon has high nutritive value. It is rich in vitamins, low in sugar and calories because of high percentage of water (Bose et al., 2002, Chaudhary et al., 2016). These attributes make watermelon not only a refreshing dietary staple but also a functional food with numerous health benefits, including the reduction of chronic disease risks associated with its antioxidant properties (Cooperstone, 2019). Approximately 46 % of melon is edible and contains 9.47 to 10.21% sugar in the red flesh, which is just above the white flesh rind, while central portion in the flesh and the flesh around the seed contains 2.25 to 12.78% sugar (Thakar et al., 2024). In India, watermelon is grown in about 1.16 lakh hectare areas with the production of 3.16 million mt (Anonymous, 2019). Now its cultivation shifted from river bed to ground land. Watermelon is a trailing vine with thin, hairy and angular stem having branched tendrils at each node. The flowers of watermelon are small, yellow, five-petalled with one cm diameter and less showy than other cucurbits (Paris et al., 2013)

The flowering pattern of watermelon contains monoecious, gynoecious, gynomonoecious, andromonoecious, hermaphroditic and trimonoecious (Zhang et al., 2017). Watermelon cultivation faces challenges, particularly regarding sex expression in monoecious crops, where an excess of male flowers can limit fruit set and reduce yield potential. Addressing this imbalance is crucial to maximizing productivity (Pasha et al., 2024, Pangeni, 2024). The plant growth regulators (PGR's) are considered as a new generation agrochemicals after fertilizers, pesticides and herbicides and are known to enhance the source sink relationship and stimulate the translocation of photo-assimilates thereby helping better fruit set. Growth regulators have tremendous effects on sex expression and flowering in various cucurbits lead to suppression of male flowers or an increased number of female flowers (Thappa et al., 2011, Chaudhary et al., 2023), without imposing any deleterious effect on environment and human health. In addition to that that PGR's can alter the sex ratio and sequence if applied at the two-or four-leaf stage, which is the critical stage at which the suppression or promotion of either sex is possible (Sinojiya et al., 2015, Kumar et al., 2023). Gibberellic acid is an important growth regulator which may have many uses to modify the growth, yield and yield contributing characters of plant (Rafeekhar et al., 2001, Kojima et al., 2020, Thakar et al., 2021, Rashid et al., 2023, Yadav et al., 2024). The utilization of GA_3 at a reduced concentration has an impact on plant development and enhances growth metrics, such as the quantity of male flowers and the onset of the first male flower (Rajbhar et al., 2023). Though the GA_3 have great potentialities to influence plant growth morphogenesis (Meshram et al., 2020, Kumar et al., 2022), its application and accrual assessments have to be judiciously planned in terms of optimal concentrations, stage of application etc. Thus, the present investigation was undertaken to evaluate the effect of GA_3 on growth, sex expression and yield of watermelon (*Citrullus lanatus* Thunb.)

2. MATERIALS AND METHODS

The experiment was laid out in Randomized Block Design with three replications the year summer seasons (February to May) of 2019–2021 at Horticulture Instructional Farm, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar (Gujarat). Geographically, Sardarkrushinagar falls in a subtropical climate and is situated at 24.32 °N (latitude) and 72.17 °E (longitude) and about 177 meters above mean sea level. The variety Sugar baby was tested with eleven treatments *viz.*, T_1 (GA_3 10 ppm), T_2 (GA_3 20 ppm), T_3 (GA_3 30 ppm), T_4 (GA_3 40 ppm), T_5 (GA_3 50 ppm), T_6 (GA_3 60 ppm), T_7 (GA_3 70 ppm), T_8 (GA_3 80 ppm), T_9 (GA_3 90 ppm), T_{10} (GA_3 100 ppm) and T_{11} (Control). The seeds were sown at a spacing of 1.5×1 m^2 in the month of February. The application of well decomposed neem cake @ 500 kg ha^{-1} was applied for all the experimental plots uniformly as basal application. Nitrogen @ 100 kg ha^{-1} in the form of urea, phosphorus @ 50 kg ha^{-1} in the form of single super phosphate (SSP) and potassium @ 50 kg ha^{-1} in the form of muriate of potash were applied. Standard cultural practices were followed during the entire crop period in all the experimental plots. The first spray of GA_3 was done at 2–4 leaf stage and second spray was done at flowering stage (Table 1). Conditions were normal during crop period in all three years. Drip irrigation was applied at alternate days. The data were recorded from five randomly selected tagged plants. All the recorded data were analyzed statistically following analysis techniques of Panse and Sukhatme (1985).

The length of the main creeper was measured from the ground level (base) to the growing tip of the main vine at the end of harvesting. Number of days to 1st male flower and number of days to 1st female flower were calculated from the day of sowing to appearance of the first staminate and pistillate flower. The sex ratio of male to female ratio

Table 1: Details of various cultural practices in experimental years

Sl. No.	Description	Year		
		2019	2020	2021
1.	Date of sowing	20.02.2019	14.02.2020	10.02.2021
2.	Date of 1st spray (GA_3)	19.03.2019	11.03.2020	09.03.2021
3.	Date of 2nd spray (GA_3)	18.04.2019	07.04.2020	05.04.2021
4.	Date of last picking	27.05.2019	16.05.2020	13.05.2021
5.	Date of fertilizer application	10.02.2019 25.03.2019	13.02.2020 16.03.2020	08.02.2021 15.03.2021

was observed during the experimentation. Fruits harvested from five tagged vines were weighed separately at every picking. Pooled weight of all the pickings were recorded and calculated the average fruit yield per plant and expressed in kilograms. The yield of fruit per hectare in tons was calculated on the basis of average yield obtained per plot under each treatment.

3. RESULTS AND DISCUSSION

3.1. *Effect of GA_3 on growth character*

Analysis of data revealed that application of GA_3 showed significant effect on length of main vine (Table 2). Application of T_8 (GA_3 80 ppm) gave significantly maximum length of main vine of 236.03 cm, 208.74 cm, 214.93 cm and 219.91 cm in the year 2019, 2020, 2021 and in pooled analysis, respectively, which was statistically at par with T_9 (GA_3 90 ppm), T_{10} (GA_3 100 ppm), T_7 (GA_3 70 ppm), T_6 (GA_3 60 ppm), T_5 (GA_3 50 ppm) and T_4 (GA_3 40 ppm) in all the years. However T_8 (GA_3 80 ppm) was at par with T_9 (GA_3 90 ppm), T_7 (GA_3 70 ppm), T_{10} (GA_3 100 ppm) in pooled analysis. On the other hand significantly the shortest length of main axis of vine was recorded in T_{11} (control) during all the three years as well as pooled (156.23 cm, 150.57 cm, 152.37 cm and 153.06 cm respectively). The beneficial effect of GA_3 at particular concentrations could be attributed to stimulatory action of GA_3 resulting in increased vine length (Hilli et al., 2010). Shantappa (2005) found that the length of main axis of vine increased with the application of GA_3 due to cell elongation and plasticity of cell wall. These results are in accordance with those reported by Dixit et al. (2001), Chovatia et al. (2010) and Kumar (2022) in different cucurbits.

3.2. *Effect of GA_3 on flowering behavior*

Flowering is an important phenomenon that expresses the differentiation process, which initiates the transition phase from vegetative to reproductive phase in plants. The change in the flowering parameters of watermelon affected by various levels of GA_3 are presented in Table 3. The results revealed that the effect of GA_3 on number of days taken to 1st male flower appearance was found not significant during all the years. However T_8 (GA_3 80 ppm) was found significant in the pooled analysis (50.98). Significantly minimum number of days (42.82) from sowing to initiation of first male flower was recorded in the T_{11} (control), while maximum number of days (50.98) for initiation of first male flower was recorded in the treatment T_8 (GA_3 80 ppm). The results revealed that the effect of GA_3 was found to be non-significant on appearance of first female flower during all the years as well as in pooled analysis. The sex ratio of male to female was observed significantly the lowest in the control during all the three years as well as in pooled analysis. The sex ratio was observed maximum in the treatment T_8 (GA_3 80 ppm) in the year 2020 (7.78), 2021 (8.24) and in pooled analysis (8.01), while it was found maximum in the treatment T_{10} (GA_3 100 ppm) during 2019 (8.17). The high ratio ensures that there is enough pollen available for the pollination of the female flowers, which is crucial for fruit set and development. The above results were in agreement with those in bitter gourd (Damodhar et al., 2006 and Hossain et al., 2006), bottle gourd (Birbal et al., 2003) and watermelon (Dixit et al., 2001). They reported that at primordial stage, all the flower carry both the sets of sex organ and application

Table 2: Effect of GA_3 on growth character of watermelon

Sl. No.	Treatments	Length of main vine (cm)			
		2019	2020	2021	Pooled
1.	GA_3 at 10 ppm	185.15	165.89	174.60	175.21
2.	GA_3 at 20 ppm	191.77	169.37	178.96	180.03
3.	GA_3 at 30 ppm	198.67	173.33	184.91	185.63
4.	GA_3 at 40 ppm	204.33	183.38	194.25	193.99
5.	GA_3 at 50 ppm	206.20	187.59	195.80	196.53
6.	GA_3 at 60 ppm	208.47	192.49	198.00	199.65
7.	GA_3 at 70 ppm	212.12	203.28	205.20	206.87
8.	GA_3 at 80 ppm	236.07	208.74	214.93	219.91
9.	GA_3 at 90 ppm	229.33	196.38	213.67	213.13
10.	GA_3 at 100 ppm	219.72	185.85	210.73	205.43
11.	Control	156.23	150.57	152.37	153.06
SEm±		11.28	10.72	7.29	5.16
CD (p=0.05)		33.28	31.63	21.49	14.52
Y×T		–	–	–	NS
CV %		9.56	10.13	6.54	8.88

Table 3: Effect of GA_3 on flowering characters of watermelon

Sl. No.	Treatments	No. of days to 1st male flower				No. of days to 1st female lower				Sex ratio			
		2019	2020	2021	Pooled	2019	2020	2021	Pooled	2019	2020	2021	Pooled
1.	GA_3 at 10 ppm	45.08	43.40	44.20	44.23	48.42	48.67	47.80	48.29	7.03	6.30	6.80	6.71
2.	GA_3 at 20 ppm	46.42	44.60	44.87	45.29	50.73	49.73	50.53	50.33	7.13	6.52	6.94	6.87
3.	GA_3 at 30 ppm	47.70	45.40	46.47	46.52	51.38	49.87	50.60	50.62	7.17	6.47	7.25	6.96
4.	GA_3 at 40 ppm	48.58	46.60	46.87	47.35	51.73	50.47	51.00	51.06	7.30	6.55	7.46	7.10
5.	GA_3 at 50 ppm	49.53	47.13	48.20	48.29	52.85	51.53	52.07	52.15	7.53	6.81	7.69	7.34
6.	GA_3 at 60 ppm	49.67	49.13	48.93	49.24	53.89	52.27	52.87	53.01	7.63	7.02	7.81	7.49
7.	GA_3 at 70 ppm	50.70	49.47	50.07	50.08	54.32	53.07	53.67	53.68	7.87	7.18	7.92	7.66
8.	GA_3 at 80 ppm	51.33	51.47	50.13	50.98	55.93	54.47	54.53	54.98	8.02	7.78	8.24	8.01
9.	GA_3 at 90 ppm	52.67	49.07	51.13	50.96	55.58	53.13	54.40	54.37	8.07	7.00	8.22	7.76
10.	GA_3 at 100 ppm	53.47	45.20	50.07	49.58	54.57	50.20	53.07	52.61	8.17	6.36	8.14	7.55
11.	Control	43.80	41.73	42.93	42.82	45.05	48.13	46.27	46.48	6.81	6.13	6.47	6.47
SEm±		3.10	2.92	2.12	1.41	2.43	3.08	2.77	1.41	0.28	0.27	0.27	0.16
CD (p=0.05)		NS	NS	NS	3.97	NS	NS	NS	NS	0.84	0.80	0.81	0.44
Y×T		–	–	–	NS	–	–	–	NS	–	–	–	NS
CV %		10.95	10.83	7.71	9.96	8.06	10.46	9.32	9.31	6.52	7.01	6.29	6.59

of growth regulators induce transformation of male flower buds into female flowers.

3.3. Effect of GA_3 on yield and yield attributes

Data presented in Table 4 showed significant differences among the treatments on yield and yield attributes. Application of T_8 (GA_3 80 ppm) gave maximum number of fruits vine^{-1} in the year 2019 (3.30), 2021 (2.97) and in pooled analysis (2.99), while T_7 (GA_3 70 ppm) gave significantly higher number of fruits in the year 2020 (2.93). Maximum number of fruits plant^{-1} was recorded with T_8 (GA_3 80 ppm) in the pooled analysis which was statistically at par with T_9 (GA_3 90 ppm), T_{10} (GA_3 100 ppm), T_7 (GA_3 70 ppm), T_6 (GA_3 60 ppm) and T_5 (GA_3 50 ppm) in the year 2019 and T_9 (GA_3 90 ppm), T_{10} (GA_3 100 ppm), T_7 (GA_3 70 ppm), T_6 (GA_3 60 ppm) in the year 2021 and T_9 (GA_3 90 ppm) and T_7 (GA_3 70 ppm) in pooled analysis. The minimum number of fruits vine^{-1} was recorded in treatment T_{11} (control).

Application of GA_3 showed significant effect on fruit yield vine^{-1} during all the three years as well as in pooled analysis. Significantly maximum fruit yield vine^{-1} was recorded in application of T_8 (GA_3 80 ppm) during the year 2019 (5.38 kg vine^{-1}), 2021 (5.18 kg vine^{-1}) and in pooled analysis (5.04 kg vine^{-1}), which was at par with T_7 (GA_3 70 ppm), T_9 (GA_3 90 ppm) and T_{10} (GA_3 100 ppm) in the year 2019, T_9 (GA_3 90 ppm), T_{10} (GA_3 100 ppm), T_7 (GA_3 70 ppm), T_6 (GA_3 60 ppm), T_5 (GA_3 50 ppm) and T_4 (GA_3 40 ppm) in the year 2021 and T_7 (GA_3 70 ppm) and T_9 (GA_3 90 ppm) in pooled analysis. However, T_7 (GA_3 70 ppm) gave significantly higher fruit weight in the year 2020 (4.96 kg vine^{-1}) which was at par with T_8 (GA_3 80 ppm).

Same trend was observed for fruit yield hectare^{-1}. Application of T_8 (GA_3 80 ppm) gave significantly maximum fruit yield ha^{-1} in the year 2019 (35.85 t ha^{-1}), 2021 (34.56 t ha^{-1}) and in pooled analysis (33.25 t ha^{-1}), which was at par with T_9 (GA_3 90 ppm), T_{10} (GA_3 100 ppm), T_7 (GA_3 70 ppm) and T_6 (GA_3 60 ppm) in the year 2019, T_9 (GA_3 90 ppm), T_7 (GA_3 70 ppm), T_{10} (GA_3 100 ppm), and T_6 (GA_3 60 ppm) in the year 2021. Whereas, T_7 (GA_3 70 ppm) gave significantly maximum fruit yield in the year 2020 (32.38 t ha^{-1}). The treatment T_8 (GA_3 80 ppm) was statistically at par with treatment T_7 (GA_3 70 ppm), T_9 (GA_3 90 ppm), T_{10} (GA_3 100 ppm) and T_6 (GA_3 60 ppm) in the pooled analysis. These findings are in accordance with those reported by Susila et al. (2013), Raj et al. (2022) and Kumar et al. (2023). Increment in the fruit weight might be due to the respiration and photosynthesis of treated plants with GA_3 (Ouzounidou et al., 2010). This indicates that, there may be greater accumulation of carbohydrate owing to the process of photosynthesis which resulted into increased in fruit weight and ultimately fruit yield.

Table 4: Effect of GA_3 on yield and yield attributes of watermelon

Sl. No.	Treatments	No. of fruits vine^{-1}				Fruit yield (kg vine^{-1})				Fruit yield (t ha^{-1})			
		2019	2020	2021	Pooled	2019	2020	2021	Pooled	2019	2020	2021	Pooled
1.	GA_3 at 10 ppm	2.52	2.23	2.40	2.38	4.17	3.77	4.05	4.00	27.83	25.16	27.00	26.66
2.	GA_3 at 20 ppm	2.55	2.33	2.47	2.45	4.25	3.79	4.18	4.07	28.35	25.24	27.89	27.16
3.	GA_3 at 30 ppm	2.65	2.40	2.53	2.53	4.34	3.84	4.27	4.15	28.91	25.62	28.45	27.66
4.	GA_3 at 40 ppm	2.73	2.43	2.60	2.59	4.45	4.00	4.32	4.26	30.02	26.69	28.78	28.50
5.	GA_3 at 50 ppm	2.77	2.53	2.67	2.66	4.68	4.14	4.57	4.46	31.17	27.62	30.44	29.74
6.	GA_3 at 60 ppm	2.85	2.57	2.80	2.74	4.91	4.61	4.73	4.75	32.72	30.69	31.56	31.65
7.	GA_3 at 70 ppm	2.97	2.93	2.87	2.92	5.10	4.96	4.97	5.01	34.02	32.38	33.11	33.17
8.	GA_3 at 80 ppm	3.30	2.70	2.97	2.99	5.38	4.55	5.18	5.04	35.85	30.36	34.56	33.25
9.	GA_3 at 90 ppm	3.13	2.57	3.00	2.90	5.29	4.15	5.08	4.84	35.28	27.64	33.89	32.27
10.	GA_3 at 100 ppm	3.03	2.33	2.87	2.74	5.22	3.94	4.93	4.70	34.83	26.27	32.89	31.67
11.	Control	2.33	2.13	2.20	2.22	4.11	3.66	3.78	3.85	27.40	24.38	25.22	25.67
SEm±		0.14	0.09	0.14	0.07	0.20	0.14	0.16	0.10	1.25	0.88	1.09	0.65
CD (p=0.05)		0.41	0.27	0.42	0.20	0.58	0.41	0.48	0.29	3.70	2.60	3.23	1.84
Y×T		–	–	–	NS	–	–	–	NS	–	–	–	NS
CV %		8.56	6.51	9.23	8.28	7.19	5.90	6.24	6.53	6.90	5.57	6.24	6.33

4. CONCLUSION

The foliar application of GA_3 80 ppm twice at 2–4 leaf stages and at flowering stage was found superior for growth, sex expression and yield traits of watermelon like length of main vine, days taken to first male flower appearance, sex ratio, number of fruit vine^{-1}, fruit yield vine^{-1} and fruit yield hectare^{-1}.

5. ACKNOWLEDGMENT

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