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Influence of Plant Growth Regulators on Growth and Yield of Watermelon (*Citrullus lanatus* Thunb)

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HIGHLIGHTS

- Combined foliar application of GA_3 (40 ppm) and NAA (150 ppm) significantly improved vine growth, chlorophyll content, and early flowering in watermelon.
- Maximum fruit yield (15.45 kg/plant) and average fruit weight (4.11 kg) were recorded under GA_3 + NAA treatment, outperforming individual and control treatments.
- Plant growth regulators showed potential to enhance source–sink dynamics and reproductive efficiency in watermelon cultivation under subtropical conditions.

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ABSTRACT

The experiment was carried out in Horticulture Research farm, M.S. Swaminathan School of Agriculture, Centurion University of Technology and Management during Rabi, 2022 and laid out in Randomised Block Design with 3 replicates and 12 treatments. Plant growth regulators were sprayed twice at 2-leaf and 4-leaf stage. GA3 @ 40 ppm + NAA @ 150 ppm has revealed to be best in terms of growth and yield attributes i.e., length of main creeper (3.48 m), number of sub creeper per plant (3.80), chlorophyll content at 30, 60 and 90 DAS (51.10, 45.44, and 16.77), lowest node number at which first male flower appeared (5.33) and female flower appeared (5.73), minimum number of days for the appearance of first male flower (36.80) and female flower (36.13) and the minimum number of days taken to fruit formation (40.80), number of fruits per plant (3.77), average fruit weight (4.11 kg), fruit yield per plant (6.44 kg).

1. INTRODUCTION

Watermelon (*Citrullus lanatus* Thunb.) belongs to the family Cucurbitaceae with chromosome number 2n=22. It holds its primary origin in Southern Africa and secondary origin in India due to larger area of cultivation. In India the current status of area is 123 mha with production 3461 MT (NHB database 2021-22). The fruit of the watermelon is 93% water and has trace levels of other nutrients. One hundred grammes of watermelon flesh have 127 kJ/30 kcal of energy, 7.55 g of carbohydrates,

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6.2 g of sugars, 0.4 g of fibre, 0.2 g of fat, 0.6 g of protein, 569 IU of vitamin A, 8.1 mg of vitamin C, 7 mg of calcium, 0.24 mg of iron, and 4532 g of lycopene (Kumar et al., 2022). Watermelon is essential for maintaining a healthy digestive system and avoids diverticular illness, haemorrhoids, and constipation, cholesterol. In India, watermelon is commonly grown as summer crop under well irrigated condition mostly near river beds of Indo-Gangetic plains for its fresh fruits.

Global demand for watermelon has risen sharply over the last decade, with world production reaching a record 104.9 million t in 2023 and the harvested area expanding to more than 3 million ha, driven largely by Asian markets. Despite this growth, climate variability—in particular erratic rainfall and rising mean temperatures—poses a mounting threat to yield stability. A multi-year study from Zanzibar, for example, found that seasonal rainfall anomalies could depress watermelon output by 17 %–77 %, underscoring the crop's pronounced sensitivity to moisture stress (Hamad et al., 2023). These emerging challenges strengthen the case for agronomic interventions that can buffer plants against abiotic stress while sustaining high productivity.

Plant-growth-regulator (PGR) technology is increasingly viewed as one such eco-friendly tool. Beyond their well-known roles in elongation and sex expression, many PGRs act as biochemical "primers," fine-tuning stomatal conductance, antioxidant activity and osmolyte accumulation so that vines better withstand heat and transient drought. Recent quality-oriented trials illustrate the breadth of responses: a foliar spray of TIBA 30 ppm raised total soluble solids to 11.8 °Brix and improved sugar profiles in open-field watermelon even under fluctuating temperatures (Pasha et al., 2025). Nevertheless, systematic data on combined gibberellin–auxin use under humid subtropical conditions are scarce—particularly for eastern India, where short production windows and frequent rainfall anomalies prevail. Addressing this knowledge gap, the present investigation evaluates single and paired applications of GA_3, NAA, Cycocel and Ethrel with the dual objective of maximising yield components and assessing their potential contribution to climate-resilient watermelon cultivation.

Plant growth regulators (PGRs) are the new generation agro-chemicals which occurs naturally or synthetically. It enhances the plant growth and improve yield by increasing fruit number, fruit set and size. Growth regulator like GA3 and NAA increases the chlorophyll content in the leaf, lengthen internodes, encourage flowering in many plants, and alter the expression of the flower sex in some plants along with that promotes extension of stem, leaf and root. Cycocel application at certain level, thereby reducing the senescence period, improves shelf-life of the crop, increases the greater number of female flower production on lateral branches and hence increases the yield of the crop. Ethrel can alter the sex ratio as it has the ability to develop better gynoecium. It stimulates flower opening, activates enzymes in respiration, inducing branching. Exogenous application of PGRs effect on endogenous hormone of plant which alter the physiological processes of the plant (Nayak 2022). The present study was therefore undertaken to evaluate the potentiality of GA3, NAA, cycocel and ethrel on influencing the growth and yield of watermelon.

2. MATERIALS AND METHODS

The present experiment was carried out in Horticulture Research farm, M.S. Swaminathan School of Agriculture, Centurion University of Technology and Management, Parlakhemundi, Odisha during Rabi, 2022. The area comes under North Eastern Ghat Agro Climatic Zone elevation of 1035 m MSL and receives 1423.6 mm of annual rainfall on average. The experimental site was geo-graphically situated at 18° 48' 11.5524'' N latitude and 84° 8' 16.2384'' E longitude. The area is 66 km away from the Bay of Bengal. The area has a warm, humid, and sub-humid climate. The experiment was laid out in RBD with three replication and twelve treatments i.e., Control (distilled water), GA3 @ 40 ppm, NAA @ 150 ppm, Ethrel @ 250 ppm, Cycocel @ 250 ppm, GA3 @ 40 ppm + NAA @ 150 ppm, GA3 @ 40 ppm + Ethrel @ 150 ppm, GA3 @ 40 ppm + Cycocel @ 250 ppm, NAA @ 150 ppm + Ethrel @ 150 ppm, NAA @ 150 ppm + Cycocel @ 250 ppm, Ethrel @ 150 ppm + Cycocel @ 250 ppm and GA3 @ 40 ppm + NAA @ 150 ppm + Ethrel @ 150 ppm + Cycocel @ 250 ppm. The variety of watermelon chosen for the experimentation was NWMH-354. The soil of experimental area was sandy loamy. The pH of the soil was 7.2. The seeds were sown in ridge and furrow method with the spacing of 0.5 m × 0.5 m and with the recommended dose of N:P:K at 100:60:60 kg/ha respectively (NDUAT, Faizabad) along with 20 t/ha of FYM. The standard cultural practices were followed which includes

weeding, fungicide and insecticide spraying, irrigation. The foliar sprays of plant growth regulators were done at two successive stages of 2-leaf and 4-leaf during morning hours with the help of a hand sprayer till both side of the leaf are properly moistened. The data was obtained from five randomly selected plants. The observations were recorded for length of main creeper (m), number of sub-creepers per plant, chlorophyll content, node number to first male and female flower, days to appearance of first male and female flower, days taken to the formation of fruit, average fruit weight (kg) and fruit yield per plant (kg).

3. RESULTS

The effect of plant growth regulators sprayed at 2-leaf and 4-leaf stage individually and in combination on length of main creeper, number of sub creepers per plant, chlorophyll content as spad units, node number to first male and female flower, days to appearance of first male and female flower, days taken to the formation of fruit, average fruit weight (kg) and number of fruits per plant content are shown in table 1, 2 and 3.

Every parameter taken under growth attributes such as length of main creeper, number of sub creepers per plant, chlorophyll content, node number at which first male and female flower appeared, days taken to appear first male and female flower, days taken to fruit formation were significantly influenced by exogeneous application of the combination of GA3 @ 40 ppm and NAA @ 150 ppm which is found to give best results in increasing the length of main creeper (3.48 m), number of sub creepers per plant (3.80), maximum chlorophyll content at 30, 60 and 90 DAS (51.10, 45.44, and 16.77), lowest node number at which first male flower (5.33) and female flower appeared (5.73), minimum number of days for the appearance of first male flower (36.80) and female flower (36.13) and the minimum number of days taken to fruit formation (40.80). Whereas, [Control (Distilled water)] recorded minimum chlorophyll content (46.23, 38.50, 12.66) at 30, 60 and 90 DAS respectively, maximum number of days for the appearance of first female flower (41.10), minimum average fruit weight (2.61 kg) and minimum fruit yield per plant (6.44 kg). The minimum length of main creeper (2.47 m), number of sub creepers per plant (2.40), highest node number at which first female flower appeared (7.12), maximum number of days for the appearance of first male flower (43.47), maximum days taken from flower to fruit formation (47.73) has been recorded in combination of GA3 @ 40 ppm + NAA @ 150 ppm + Ethrel @ 150 ppm + Cycocel @ 250 ppm. The highest node number (7.00) at which first male flower appeared was recorded in the treatment T6 (GA3 @ 40 ppm + NAA @ 150 ppm).

Table 1. Effect of plant growth regulators on length of main creeper, number of sub creeper per plant, chlorophyll content at 30, 60 and 90 DAS

TREATMENTS	Length of main creeper	Number of sub creeper per plant	Chlorophyll content		
			At 30 DAS	At 60 DAS	At 90 DAS
T_1 (Control)	2.49	2.44	46.23	38.50	12.66
T_2 (GA_3 @ 40 ppm)	3.38	3.48	50.03	44.53	16.27
T_3 (NAA @ 150 ppm)	2.91	2.86	49.67	43.87	14.43
T_4 (Ethrel @ 150 ppm)	2.96	2.90	48.93	43.12	13.95
T_5 (Cycocel @ 250 ppm)	2.47	2.34	46.87	41.48	13.05
T_6 (GA_3 @ 40 ppm + NAA @ 150 ppm)	3.48	3.80	51.10	45.44	16.77
T_7 (GA_3 @ 40 ppm + Ethrel @ 150 ppm)	2.96	3.14	50.93	44.77	16.43
T_8 (GA_3 @ 40 ppm + Cycocel @ 250 ppm)	3.00	3.10	49.79	44.27	14.98
T_9 (NAA @ 150 ppm + Ethrel @ 150 ppm)	2.56	2.49	47.77	42.13	13.88
T_{10} (NAA @ 150 ppm + Cycocel @ 250 ppm)	2.59	2.53	46.69	40.17	13.01
T_{11} (Ethrel @ 150 ppm + Cycocel @ 250 ppm)	2.52	2.47	47.07	41.67	13.55
T_{12} (GA_3 @ 40 ppm + NAA @ 150 ppm + Ethrel @ 150 ppm + Cycocel @ 250 ppm)	2.47	2.40	46.49	39.27	12.82
S.Em. ±	**0.13**	**0.13**	**2.43**	**1.83**	**0.86**
CD (0.05)	**0.39**	**0.38**	**7.11**	**5.37**	**2.53**

Table 2. Effect of plant growth regulators on node no. at which first male and female flower appear, days taken to appear first male and female flower, days taken to fruit formation

TREATMENTS	Node no. at which first male flower appears	Node no. at which first female flower appears	Days taken to appear first male flower	Days taken to appear first female flower	Days taken to fruit formation
T_1 (Control)	5.53	7.10	42.80	41.10	47.60
T_2 (GA_3 @ 40 ppm)	6.67	6.10	38.13	37.93	41.60
T_3 (NAA @ 150 ppm)	5.87	6.10	39.53	39.50	43.60
T_4 (Ethrel @ 150 ppm)	6.40	5.87	42.53	36.93	43.33
T_5 (Cycocel @ 250 ppm)	5.80	7.07	40.80	38.47	46.00
T_6 (GA_3 @ 40 ppm + NAA @ 150 ppm)	7.00	5.73	36.80	36.13	40.80
T_7 (GA_3 @ 40 ppm + Ethrel @ 150 ppm)	6.67	6.33	38.27	37.23	42.73
T_8 (GA_3 @ 40 ppm + Cycocel @ 250 ppm)	6.27	6.27	39.53	37.93	43.47
T_9 (NAA @ 150 ppm + Ethrel @ 150 ppm)	6.07	6.13	40.80	38.67	44.87
T_{10} (NAA @ 150 ppm + Cycocel @ 250 ppm)	5.33	7.07	40.67	38.63	44.07
T_{11} (Ethrel @ 150 ppm + Cycocel @ 250 ppm)	5.73	7.00	42.73	39.94	47.40
T_{12} (GA_3 @ 40 ppm + NAA @ 150 ppm + Ethrel @ 150 ppm + Cycocel @ 250 ppm)	5.67	7.12	43.47	40.30	47.73
S.Em. ±	**0.20**	**0.12**	**0.94**	**0.73**	**1.20**
CD (0.05)	**0.60**	**0.36**	**2.76**	**2.13**	**3.52**

Table 3. Effect of plant growth regulators on number of fruits per plant, average fruit weight and fruit yield per plant

TREATMENTS	Number of fruits per plant	Average fruit weight (kg)	Fruit yield per plant (kg)
T_1 (Control)	2.47	2.61	6.44
T_2 (GA_3 @ 40 ppm)	3.60	3.90	14.03
T_3 (NAA @ 150 ppm)	3.33	3.35	11.14
T_4 (Ethrel @ 150 ppm)	2.73	3.38	9.22
T_5 (Cycocel @ 250 ppm)	3.03	3.11	9.37
T_6 (GA_3 @ 40 ppm + NAA @ 150 ppm)	3.77	4.11	15.45
T_7 (GA_3 @ 40 ppm + Ethrel @ 150 ppm)	3.37	3.81	12.82
T_8 (GA_3 @ 40 ppm + Cycocel @ 250 ppm)	3.40	3.40	11.58
T_9 (NAA @ 150 ppm + Ethrel @ 150 ppm)	3.23	3.22	10.42
T_{10} (NAA @ 150 ppm + Cycocel @ 250 ppm)	2.87	2.95	8.51
T_{11} (Ethrel @ 150 ppm + Cycocel @ 250 ppm)	3.10	3.16	9.80
T_{12} (GA_3 @ 40 ppm + NAA @ 150 ppm + Ethrel @ 150 ppm + Cycocel @ 250 ppm)	2.50	2.71	6.75
S.Em. ±	**0.14**	**0.11**	**0.56**
CD (0.05)	**0.41**	**0.32**	**1.63**

Yield attributes of water melon has significant influenced by exogenous application of growth regulators (table-3) and observed the maximum fruit weight (4.11 kg), highest fruit yield per plant (15.45 kg) was recorded in combined dose of GA3 @ 40 ppm + NAA @ 150 ppm. Lowest fruit weight (2.61 kg) and yield per plant (6.44 kg) observed in control (T1).

4. DISCUSSION

The growth attributes of water melon observed significant variation among treatments due to effect of application of growth regulators. exogeneous application of the combination of GA3 @ 40 ppm and NAA @ 150 ppm which is found to give

best results in increasing the length of main creeper (3.48 m), number of sub creepers per plant (3.80), maximum chlorophyll content at 30, 60 and 90 DAS (51.10, 45.44, and 16.77), lowest node number at which first male flower (5.33) and female flower appeared (5.73), minimum number of days for the appearance of first male flower (36.80) and female flower (36.13) and the minimum number of days taken to fruit formation (40.80). The decrease in chlorophyll content might be due to transportation of photosynthates from sink to source. The growth, development, and yield of the crops are directly influenced by the photosynthetic efficiency. The phenomenon of increase in vine length might be due to increasing plasticity of the cell wall followed by hydrolysis of starch to sugars which lowers the water potential of cell, resulting in the entry of water into the cell causing elongation (Rajashree et al., 2022). GA3 increases the photosynthetic activity, translocation of metabolites which results in cell elongation and rapid cell division hence increasing the number of sub creepers per plant. Similar results of maximum length of main stem were reported by Shantappa et al., (2005) in bitter gourd. The lowest node number at which first female flower appeared because in initial stage during the formation of flowers, all flower bloom carries both the sets of sex organ where high level of auxin and gibberellin in the vicinity of differentiating primordia favours staminate organs changing to pistillate and thereby increasing in female flower bud. The minimum number of days taken for the appearance of first female flower may be because of increased quantities of auxin which have caused the early induction of flowers in treated plants, and this early flowering may be related to the plant's tendency to develop into female (Dalai et al., 2015). The appearance of first staminate flower is delayed and earliness is observed in pistillate flower by relatively low concentrations of GA3 (Wang and Zeng,1996).

Due to various physiological modifications which stimulate the higher photosynthetic rate, translocation of metabolites from source to sink point, cell division and elongation for which the fruit diameter and length increases and thus weight of the fruit increases (Ansari et al.,2018). Similar outcomes were found by Vadigeri et al., (2001), Chaudhary et al., (2016) and Meshram et al., (2022) previously. When there is difficulty with fruit set because of incomplete pollination, GA3 and auxin may be effectively used to increase fruit set and thereby increase fruit yield (Pramanik et al.,2018). The reason for better fruit set might also be due to increment in metabolic activities of the plant.

The pronounced superiority of the GA_3 40 ppm + NAA 150 ppm combination in the present study is consistent with the broader trend that balanced auxin–gibberellin regimes synchronize cell-division and assimilate allocation more efficiently than single-hormone sprays. For instance, Patel and Joshi (2025) reported that foliar GA_3 at 80 ppm nearly doubled fruit yield per vine in 'Sugar Baby' watermelon by accelerating vine elongation and improving the female-to-male flower ratio, yet their yields still lagged behind those achieved when auxin was supplied concurrently in our experiment. Ethrel-centred protocols have also been explored; Thakar et al. (2024) found that Ethrel 150 ppm produced the heaviest fruits in a similar agro-climatic zone, but they observed only 4.02 kg vine^{-1}, compared with 15.45 kg plant^{-1} under GA_3 + NAA here, underscoring the advantage of using growth promoters rather than ethylene-releasing retardants when maximum biomass is the goal. Beyond yield, recent quality-focused work by Pasha et al. (2025) showed that adding TIBA 30 ppm raised total soluble solids to 11.8 °Brix, illustrating that specific regulator choices can be tuned for sweetness or nutraceutical enhancement, a dimension our treatment could complement in follow-up trials. Physiological evidence from other crops reinforces these mechanisms: foliar GA_3 at the eight-leaf stage boosted artichoke head yield and phenolic content by 13–30 % (Othman & Leskovar, 2022), while Ahmed et al. (2021) documented GA_3-mediated increases in fruit set, vitamin C and capsaicin in pepper, attributing improvements to elevated photosynthetic rate and stronger sink demand. Collectively, these studies suggest that the dual-hormone approach adopted here not only expedites flowering and fruit set but also leverages cross-hormonal signalling to sustain photo-assimilate flow until harvest, providing a biologically sound and economically attractive strategy for commercial watermelon production under subtropical conditions.

5. CONCLUSIONS

According to the findings, the treatments with plant growth regulators had a substantial impact on

the watermelon's variety NWMH-354 improved growth and yield. Further, application of GA3 @ 40 ppm + NAA @ 150 ppm took minimum days for first female flower appearance, produced first female flower at early node, maximum number of fruits, average fruit weight, fruit yield per plant. It can be concluded that foliar application of GA3 @ 40 ppm + NAA @ 150 ppm twice at 2-leaf and 4-leaf stage was found superior among all other plant growth regulators and can act beneficial to the agriculture community. The ideal outcome identified in this study can be used by the farmers to improve the quality and quantity of the crop as well as increase the postharvest preservation, which could be a beneficial economical strategy for the agriculture community.

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