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Influence of Various Plant Growth Regulators on Growth and Yield of Garlic (*Allium sativum* L.) under *Terai* Region of West Bengal

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ABSTRACT: The investigation was carried out on influence of various plant growth regulators on growth and yield of garlic (*Allium sativum* L.) in *Rabi* season during 2019-2020 and 2020-2021 in *Terai* zone of West Bengal. The PGRs namely- GA_3 (50, 100 and 150ppm), NAA (50, 100 and 200ppm) and Kinetin (10, 20 and 40ppm) were used. The experiment laid out in Randomized Block Design comprising of ten treatments and replicated thrice. By using the chemical nutrients high cost of production therefore, the role of different growth regulators on growth and yield of crop investigated. The results obtained that Maximum plant height (80.50cm), leaf length (50.05cm), number of leaves (9.30), neck thickness (13.46mm) and number of roots per plant (74.26), maximum polar and equatorial diameter (3.37 and 4.25cm) with heavier cloves (13.70 g), highest number of cloves per bulb (27.50), fresh and dry weight of cloves (13.70g and 8.31g), higher total biomass yield (4.0kg) and plot yield of bulb (2.85kg) with a projected yield of (9.96 tons) of bulb per ha was registered under GA_3 @ 50 ppm.

Keywords: Garlic, GA_3, NAA, Kinetin, growth and yield.

INTRODUCTION

Garlic (*Allium sativum* L.) popularly known as "Lashun", is a well-known spice belongs to the Alliaceae family with chromosome number 2n=16. Its origin can be traced back to Central Asia. It is one of the most widely cultivated bulbous crop in the world and the second most widely cultivated Allium species after onion. Garlic cloves are the economic portion of the plant. Cloves can be used as a seasoning spice or as a condiment. The composition of clove constitutes about 0.1 percent volatile oil in it. Diallyl disulphide (60%), Diallyl trisulphide (20%) and Allyl propyl trisulphide (6%), as well as potassium, phosphorus and magnesium are the primary constituents of oil. Most important component of garlic is Allicin. It is found in aqueous extract of garlic. It lowers the level of cholesterol in human blood. Garlic is more nutrient-dense crop than other bulbous crops. It contains a significant quantity of carbohydrate (29%), protein (6.3%), minerals (0.3%), and essential oils (0.1-0.4%), as well as some fat, vitamin C, and sulphur (Memane *et al.*, 2008). Ascorbic acid is a key component of green garlic. Garlic possesses anti-bacterial, anti-viral, anti-fungal and anti-protozoan functions (Arora and Kaur 1999) having anti-oxidant and anti-cancer properties (Meng *et al.*, 1993; Harris *et al.*, 2001). It is employed in a variety of situations in stomach aches, headaches, toothaches, neurological diseases and rheumatism etc. Garlic contains therapeutic characteristics that guard against gastro-intestinal neoplasia and function as a gastric stimulant to aid in food digestion and absorption. In diabetic treatment, it is also utilised as a co-adjuvant therapy. Garlic extract mixed with ginger and chilli efficiently fight against nematodes.

Garlic mostly consumed by Indians throughout the year in different ways. Since it is such a perishable commodity, storage is a major problem to made available to consumption. In India generally harvesting of garlic carried out during period of March – April and preserved for the rest of the year to

sowing of next crop in mid-November and December due to climatic constraints. Plants are exposed to higher temperatures before bulb formation and during bulb development which exists between February – April and ultimately results in low yield with poor quality bulb plant growth regulators have been used to increase crop yield and efficiency by modifying plant characteristics such as plant height, number of leaves per plant, biomass yield, net bulb yield, and so on by controlling physiological processes within the plant. Considering importance of the crop attempt has made to increase production of crop.

MATERIALS AND METHODS

The present investigation was carried out to study the influence of various plant growth regulators on growth and yield of garlic (*Allium sativum* L.) for two consecutive years during *Rabi* seasons of the year 2019-2020 and 2020-2021 at the instructional cum research farm of the Department of Plantation Crops and Processing of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar West Bengal. The experiment compromising three different growth regulators namely-gibberellic acid (GA_3), Naphthalene Acetic Acid (NAA) and Kinetin each sprayed with different concentrations *i.e*., 50, 100 and 150 ppm of GA_3; 50, 100 and 200 ppm of NAA and 10, 20 and 40 ppm of Kinetin and one control plot sprayed with distilled water. The growth regulators sprayed at different intervals of 30, 60 and 90 days after planting. The experiment laid out in Randomized Block Design comprising of ten treatments (T_1: 50ppm GA_3, T_2: 100ppm GA_3, T_3: 150ppm GA_3, T_4: 50ppm NAA, T_5: 100ppm NAA, T_6: 200ppm NAA, T_7: 10ppm Kinetin, T_8: 20ppm Kinetin, T_9: 40ppm Kinetin and T_{10}: Control and replicated thrice. During experimental investigation standard cultural practices was adopted. The experimental area was ploughed twice and levelled followed by application of well decomposed FYM @ 25 tones/ ha. was incorporated thereafter, the field was prepared with paths and channels between flat beds of plot size 2.0 m × 1 m. Garlic (Pundibari local) used as experimental material. Desirable healthy cloves were selected and sown with spacing of 20 × 10cm. Before sowing, cloves were treated with carbendazim to destroy any fungal inoculums. The application of fertilizers was carried out at final land preparation before five days of planting. The recommended dose of fertilizer *i.e*., N: P: K: S @ 100: 60: 80: 40 kg/ha (Abdhul *et al*., 2002) were applied respectively. Irrigation was provided after 25 days of planting of cloves during initial stages of crop growth and later it was provided based on moisture content of soil when moisture required. Manual weeding was carried to keep the plots free from weed population. Four hand weeding's were performed during entire crop period. Propiconazole @ 1ml/litre was used during crop period at 25 days interval to prevent fungal diseases. The operation of harvesting was carried out manually through uprooting individual plants from plots. The plants were ready to harvest when 70% of their leaves were dried and the top portion of the plant had turned yellowish at neck fall stage. At that stage the bulb was lifted, and bundled with foliage in bunches and sundried for 5 days for curing. After curing, the dried leaves were cut using sickle at neck portion and stored in perforated nylon bags.

Preparation of Stock solution. Gibberellic acid (GA_3), NAA and Kinetin were in the form of solid state *i.e*., powder form for the making of stock solution sufficient quantity was weighed by using micro balance after that the weighed powder was transferred into volumetric flask and just to dissolve the powder of GA_3, NAA and Kinetin very low quantity of alcohol (Ethanol), 1.0 % Na $(OH)_2$ and 1.0 % Na $(OH)_2$ were used respectively. After that, it was diluted to required concentration of solution by adding distilled water.

Procedure of data collection. Sampling process was performed by selecting ten healthy plants randomly from each treatment of each replication. The morphological data was recorded at an interval of 60, 90 and 120 days after planting. The observations like plant height measured from ground to tip of leaf with help of 90cm long scale and recorded in terms of centimetre (cm), length of leaves and width of leaves measured at broadest point by using 90 long scale and recorded in terms of centimetre (cm). The neck thickness was noted by using vernier calliper and expressed in millimetre (mm) and number of leaves and roots per plant was counted manually. After harvesting the yield parameters like bulb polar and equatorial diameter at broadest point was recorded with vernier calliper in terms of centimetre (cm). The width and breadth of cloves were measured at widest point by using 60cm scale and listed in terms of centimetre (cm). The fresh and dry weight of cloves and yield of bulbs per plot was recorded by using electrical balance.

Statistical Analysis. A two-year pooled analysis was also performed using the Gomez and Gomez technique (1983). Pro Glm of the Statistical Analysis System (SAS) programme was used to perform analysis of variance for each parameter.

RESULTS AND DISCUSSION

Effect of plant growth regulators on morphological parameters

Plant height (cm). The data obtained with respect to plant height of garlic at 60, 90 and 120 days after planting found statistically significant variation among the treatments. The maximum height of the plant (49.75 cm, 70.88cm and 80.50cm) was recorded under foliar application of GA_3 @ 50 ppm at 60,90 and 120 days after planting respectively (Table 1). Whereas, Lowest plant height (40.94 cm, 62.13 and 71.05) was recorded under Control *i.e*., foliar application with distilled water. The maximum height of plant recorded under application of gibberellic acid (GA_3) might be due to GA_3 accelerate the vegetative growth of the plants by the active mechanism of cell division, cell enlargement and cell elongation (Singh

et al., 2018). Ferdows *et al.* (2017) also reported maximum plant height in French bean recorded under foliar application of GA_3 @ 50 ppm. The foliar application of GA_3 @ 50 ppm as well as enhanced meristematic elongation which accounts increasing of inter nodal length it leads to gradual increase in plant height. The fact that gibberellic acid produces vigorous, healthy plants promotes in the mobilisation of higher amounts of reserve food material.

Length of leaves (cm). Data respect to leaf length found statistically significant. On the basis of pooled data, T_1 -GA_3 @ 50 ppm was recorded the highest leaf length (44.13 cm) at 60 DAP, (49.49cm) at 90 DAP and (50.50cm) at 120 DAP and it was significantly superior over rest of the treatments (Table 2), on other hand, treatment T_{10} (control) recorded the lowest leaf length (35.69cm 41.64cm and 41.11cm) at 60 90 and 120 days after planting. There is a significant increase in leaf length from 60 to 90 days after planting. Thereafter, virtual decrease in leaf length had been observed at 120 days after planting. The similar trend was reported by Rashid (2010) and the fact behind that, leaves may undergo senescence and drying of leaf tips indicating maturity. However, the increase in leaf length was due to foliar application of growth regulators particularly, gibberellic acid (GA_3) may regulate the endogenous hormonal activities. Eventually, it leads to leaf elongation creating lower water potential levels in cell wall results entry of water in cell wall to cause elongation and finally, increases the leaf length (Parmar *et al.*, 2018).

Number of leaves per plant. Significantly Maximum number of leaves per plant (6.40) was counted under treatment T_2-GA_3 @ 100 ppm at 60 days after planting, However, at 90 and 120 days of showed significantly higher number of leaves (8.86) and (9.30) was registered under the treatment applied with GA_3@ 50 ppm and proved the superiority of GA_3 at lower concentration. Contradictory, treatment T_{10}-(control) numerically listed the lowest number of leaves per plant during different crop stages *i.e.*, 60, 90 and 120 days after planting (Table 4). Highest number of leaves under GA_3 might be due to gibberellic acid accelerate the individual plants to utilisation of nutrients as well as enhance metabolic activity particularly photosynthesis which provide higher amount of food material and increase permeability of cell membrane as well, as available fresh favourable weather conditions helped to mobilise larger quantities of reserve food materials in the plant. The results obtained from the experiment symmetrically similar to the results of Bideshki *et al.* (2013).

Width of leaves (cm). Significantly higher leaf width (1.69cm) under treatment T_9 -kinetin @ 40 ppm at 60 days after planting (Table 3). At 90 and 120 days after planting, also highest width of leaves was also recorded by the application of kinetin @ 40 ppm. At 120 DAP kinetin @ 40 ppm registered highest leaf width (1.78 cm) followed by GA_3 @ 50 ppm (1.68cm). However, lowest leaf width was reported under control plots.

Neck thickness (mm). Significantly, T_1-GA_3 @ 50 ppm registered highest average increase of neck thickness (8.73 mm, 12.67mm and 13.46 mm) at 60 90 and 120 days after planting respectively (Table 5). On other hand, 90 and 120 days after planting minimum value of neck thickness (6.61mm, 10.43 and 10.34) was recorded from T_{10}-Control. Exogenous application of GA_3 administration aids in increasing neck thickness through fast cell division. Gibberellins may aid cell elongation by triggering enzymes that weaken cell membranes. Gibberellin treatment causes the production of a proteolytic enzyme that should liberate tryptophan, an indole acetic acid precursor (Muralidhara *et al.*, 2014).

Number of roots per plant. Significant higher number of roots per plant (74.26) was counted in plots treated with T_1-GA_3 @ 50 ppm (Table 6). On other hand, lowest number of roots per plant (54.06) was under treatment T_{10}-Control. As per Elo *et al.* (2009), gibberellins may stimulate cambial activity, which benefits plant secondary growth of the plant and resulting in enlargement of stems as well as increases in number of roots.

Effect of plant growth regulators on Yield and yield attributing characters of garlic.

Number of Cloves per bulb. Significantly higher number of cloves (27.50) per bulb were counted under treatment T_1-GA_3@50 ppm. However, minimum number of cloves per bulb (20.16) was counted under T_{10}-Control (Table 6). The maximum number of cloves observed with spraying of GA_3-50 ppm, which might be due to accelerated photosynthetic rate and increased food material transportation from source to the sink, resulting in a higher number of cloves per bulb. These results are conformity with Govind *et al.* (2015) that maximum number of cloves per bulbs registered under treatment of GA_3 @50 ppm + liquid manure.

Polar and equatorial diameter of bulb (cm). Significant increase in polar and equatorial diameter of the bulb (3.37cm and 4.25cm) (Table 7) under treatment T_1 -GA_3 @ 50 ppm and it was superior to remaining all other treatments (Table 6). The lowest polar and equatorial diameter of bulb (2.92 cm and 3.82cm) was recorded under treatment T_{10} –control. The growth regulators induce expansion of xylem and phloem played important role in transporting of food material, water and nutrients from various parts of the plant resulting in deposition of larger quantity of food material into bulb, which in turn increased polar and equatorial diameter of bulb. Govind *et al.* (2015) obtained highest diameter of bulb under treatment of gibberellic acid.

Clove Length and Breadth (cm). Based on pooled data, T_1-GA_3 @ 50 ppm registered maximum length (2.93 cm) of clove and breadth of clove (1.09 cm) and it was significantly superior over all treatment (Table 8). Among all the treatments, GA_3 @ 50 ppm registered maximum length of cloves that may be due to increase in photosynthetic activity, rapid cell

division, cell elongation, deposition large amount of food materials and accumulation of more dry matter in bulbs has resulted increased length of cloves. The data recorded from the experiment has been accordance with Chattopadhyay *et al.* (2015). Zinzala *et al.* (2017) also recorded maximum length of clove under foliar application of gibberellic acid.

Fresh and dry weight of cloves (g). Significantly, maximum fresh and dry weight of cloves (13.70g and 8.31g) has been recorded under T_1-GA_3@50 ppm and it was significantly superior over other treatments. In comparison, T_{10}-control registered the minimum fresh and dry weight of cloves 10.90g and 6.31g respectively (Table 9).

Bulb yield (Kg/plot) and projected bulb yield (t/ha). The results shows that significantly highest bulb yield/plot and projected bulb yield (t/ha) (2.85 kg/plot and 9.96 t/ ha) was registered under T_1-GA_3 @ 50 ppm it was statistically superior over rest of the treatments (Table 10), whereas lowest bulb yield /plot (1.82kg/plot) and minimum projected yield/ ha (6.38 t/ ha) was noticed under T_{10}-control. For higher yield, several mechanisms such as vegetative meristem activity, cell elongation, photosynthetic efficiency, and secondary wall bio-synthesis are important apart from that according to Gautam *et al*. (2014) the transportation of food materials from source to sink increases the bulb weight. The maximum bulb production might be owing to the maximum plant height and average bulb weight, which resulted in a higher overall yield with application of lower dose of gibberellic acid than other growth regulators (Chattopadyay *et al.*, 2015).

Total Biomass (Kg/plot). Based on the pooled data, it was noticed that T_1-GA_3@ 50 ppm registered the highest total biomass (4.00 kg/plot) in both the seasons through increase crop growth and production of larger size bulbs having higher bulb weight. Whereas, lowest total biomass yielded was recorded under treatment T_{10} (control) with biomass yield of 2.69 kg/plot (Table 10). The production of higher biomass is due to effect of different plant growth regulators which initiate the physiological process to modify the morphological, biochemical and physiological behaviour of plants. Therefore, application of plant growth regulators influences the physiology of plant to produces higher vegetative and reproductive growth.

Table 1: Effect of different plant growth regulators on plant height at 60, 90 and 120 days after planting.

Treatments	60 Days after planting			90 Days after planting			120 Days after planting		
	2019-2020	2020-2021	Pooled	2019-2020	2020-2021	pooled	2019-2020	2020-2021	pooled
T_1: GA_3 @ 50 ppm	49.73^{a}	49.76^{ab}	**49.75^{a}**	70.27^{a}	71.48^{a}	**70.88^{a}**	83.67^{a}	77.33^{a}	**80.50^{a}**
T_2: GA_3 @ 100 ppm	47.04^{bc}	47.16^{cd}	**47.10^{bc}**	61.27^{f}	70.03^{ab}	**65.65^{de}**	75.62^{b}	74.69^{bc}	**75.15^{def}**
T_3: GA_3 @ 150 ppm	45.41^{c}	45.85^{de}	**45.63^{cd}**	68.72^{ab}	70.06^{ab}	**69.39^{ab}**	75.44^{b}	75.06^{bc}	**75.25^{def}**
T_4: NAA @ 50 ppm	46.44^{bc}	46.49^{cde}	**46.47^{cd}**	64.96^{cd}	67.47^{bcd}	**66.21^{cd}**	78.48^{b}	68.64^{e}	**73.56^{f}**
T_5: NAA @ 100 ppm	49.76^{a}	44.23^{e}	**46.99^{bc}**	62.10^{ef}	64.91^{de}	**63.50^{ef}**	76.52^{b}	71.20^{d}	**73.86^{fe}**
T_6: NAA @ 200 ppm	46.54^{bc}	47.39^{bcd}	**46.97^{bc}**	65.38^{cd}	70.12^{ab}	**67.75^{bcd}**	78.447b	76.01^{ab}	**77.23^{bc}**
T_7: Kinetin @ 10 ppm	45.86^{c}	44.40^{e}	**45.13^{d}**	65.80^{c}	65.20^{cd}	**65.50^{de}**	78.02^{b}	73.35^{c}	**75.69^{cde}**
T_8: Kinetin @ 20 ppm	48.32^{ab}	48.49^{abc}	**48.40^{ab}**	66.29^{cb}	69.86^{ab}	**68.08^{bc}**	81.76^{a}	76.02^{ab}	**78.89^{ab}**
T_9: Kinetin @ 40 ppm	47.38^{bc}	49.92^{a}	**48.65^{a}**	64.67^{cde}	68.66^{abc}	**66.66^{cd}**	76.35^{b}	76.06^{ab}	**76.20^{cd}**
T_{10}: Control	42.58^{d}	39.30^{f}	**40.94^{e}**	62.62^{def}	61.64^{e}	**62.13^{f}**	71.23^{c}	70.88^{d}	**71.05^{g}**
CD (0.05)	**2.11**	**2.41**	**1.54**	**2.80**	**3.46**	**2.36**	**3.21**	**1.78**	**1.82**
S.Em (±)	**0.711**	**0.81**	**0.52**	**0.94**	**0.16**	**0.79**	**1.08**	**0.60**	**0.61**
C.V (%)	**2.62**	**3.04**	**1.93**	**2.50**	**2.96**	**2.06**	**2.41**	**1.40**	**1.40**

Table 2: Effect of different plant growth regulators on Leaf length at 60, 90 and 120 days after planting.

Treatments	60 Days after planting			90 Days after planting			120 Days after planting		
	2019-2020	2020-2021	Pooled	2019-2020	2020-2021	pooled	2019-2020	2020-2021	pooled
T_1: GA_3 @ 50 ppm	43.96^{a}	44.30^{a}	**44.13^{a}**	50.92^{a}	48.06^{a}	**49.49^{a}**	51.86^{a}	48.24^{a}	**50.05^{a}**
T_2: GA_3 @ 100 ppm	40.10^{bcd}	41.41^{cd}	**40.76^{bc}**	49.20^{abc}	43.94^{cd}	**46.57^{cd}**	51.51^{a}	44.79^{cd}	**48.15^{b}**
T_3: GA_3 @ 150 ppm	41.15^{b}	40.77^{cde}	**40.96^{bc}**	46.34^{e}	44.75^{bcd}	**45.54^{d}**	48.20^{c}	46.30^{b}	**47.25^{bc}**
T_4: NAA @ 50 ppm	39.97^{bcd}	40.77^{cde}	**40.41^{cde}**	48.66^{bcd}	43.75^{d}	**46.20^{cd}**	51.11^{a}	44.30^{d}	**47.71^{bc}**
T_5: NAA @ 100 ppm	40.55^{bc}	38.70^{f}	**39.62^{de}**	50.20^{ab}	45.52^{bc}	**47.86^{b}**	51.50^{a}	42.28^{e}	**46.89^{bc}**
T_6: NAA @ 200 ppm	38.90^{d}	40.01^{de}	**39.45^{e}**	46.22^{e}	45.67^{b}	**45.95^{d}**	49.32^{bc}	46.11^{b}	**47.72^{bc}**
T_7: Kinetin @ 10 ppm	39.51^{cd}	39.28^{ef}	**39.40^{e}**	47.56^{cde}	44.46^{bcd}	**46.01^{d}**	48.68^{c}	45.52^{bc}	**47.10^{bc}**
T_8: Kinetin @ 20 ppm	39.02^{d}	42.06^{bc}	**39.40^{bcd}**	48.92^{abcd}	45.96^{b}	**47.42^{bc}**	49.48^{bc}	45.78^{bc}	**47.63^{bc}**
T_9: Kinetin @ 40 ppm	39.47^{cd}	43.49^{ab}	**41.48^{b}**	46.82^{de}	45.68^{b}	**46.25^{cd}**	47.82^{c}	45.87^{bc}	**46.85^{c}**
T_{10}: Control	35.57^{e}	35.81^{g}	**35.69^{f}**	40.08^{f}	43.20^{d}	**41.64^{e}**	41.68^{d}	40.53^{f}	**41.11^{d}**
CD (0.05)	**1.27**	**1.68**	**1.03**	**2.17**	**1.64**	**1.24**	**1.83**	**1.12**	**1.05**
S.Em (±)	**0.43**	**0.56**	**0.34**	**0.73**	**0.55**	**0.41**	**0.61**	**0.37**	**0.35**
C.V (%)	**1.87**	**2.41**	**1.50**	**2.66**	**2.12**	**1.56**	**2.18**	**1.45**	**1.30**

Table 3: Effect of different plant growth regulators on leaf width at 60, 90 and 120 days after planting.

Treatments	60 Days after planting			90 Days after planting			120 Days after planting		
	2019-2020	2020-2021	Pooled	2019-2020	2020-2021	pooled	2019-2020	2020-2021	pooled
T_1: GA_3 @ 50 ppm	1.27^{a}	1.42^{b}	**1.34^{b}**	1.58^{ab}	1.74^{a}	**1.66^{a}**	1.60^{b}	1.77^{b}	**1.68^{b}**
T_2: GA_3 @ 100 ppm	1.30^{a}	1.42^{b}	**1.36^{b}**	1.48^{cd}	1.66^{bc}	**1.57^{b}**	1.57^{b}	1.76^{b}	**1.67^{b}**
T_3: GA_3 @ 150 ppm	1.39^{a}	1.36^{bcd}	**1.37^{b}**	1.57^{ab}	1.74^{a}	**1.66^{a}**	1.56^{b}	1.76^{b}	**1.66^{b}**
T_4: NAA @ 50 ppm	1.41^{a}	1.31^{d}	**1.36^{b}**	1.42^{d}	1.63^{cd}	**1.52^{c}**	1.59^{b}	1.72^{b}	**1.65^{b}**
T_5: NAA @ 100 ppm	1.43^{a}	1.34^{cd}	**1.38^{ab}**	1.52^{bc}	1.65^{c}	**1.58^{b}**	1.55^{b}	1.65^{c}	**1.60^{c}**
T_6: NAA @ 200 ppm	1.57^{a}	1.34^{cd}	**1.45^{ab}**	1.47^{cd}	1.58^{de}	**1.52^{c}**	1.57^{b}	1.76^{b}	**1.67^{b}**
T_7: Kinetin @ 10 ppm	1.60^{a}	1.33^{cd}	**1.47^{ab}**	1.48^{dc}	1.56^{e}	**1.52^{c}**	1.55^{b}	1.74^{b}	**1.65^{bc}**
T_8: Kinetin @ 20 ppm	1.71^{a}	1.40^{bc}	**1.55^{ab}**	1.41^{d}	1.69^{abc}	**1.55^{bc}**	1.55^{b}	1.74^{b}	**1.64^{bc}**
T_9: Kinetin @ 40 ppm	1.74^{a}	1.53^{a}	**1.63^{a}**	1.61^{a}	1.72^{ab}	**1.66^{a}**	1.72^{a}	1.84^{a}	**1.78^{a}**
T_{10}: Control	1.72^{a}	1.18^{e}	**1.45^{ab}**	1.27^{e}	1.55^{e}	**1.41^{d}**	1.43^{a}	1.62^{c}	**1.53^{d}**
CD (0.05)	**0.61**	**0.07**	**0.30**	**0.07**	**0.06**	**0.04**	**0.05**	**0.06**	**0.04**
S.Em (±)	**0.20**	**0.02**	**0.10**	**0.02**	**0.02**	**0.01**	**0.01**	**0.02**	**0.01**
C.V (%)	**23.38**	**3.00**	**12.38**	**2.98**	**2.33**	**1.55**	**2.14**	**2.17**	**1.74**

Table 4: Effect of different plant growth regulators on Number of leaves at 60, 90 and 120 days after planting.

Treatments	60 Days after planting			90 Days after planting			120 Days after planting		
	2019-2020	2020-2021	Pooled	2019-2020	2020-2021	pooled	2019-2020	2020-2021	pooled
T_1: GA_3 @ 50 ppm	6.40^{bc}	6.00^{a}	**6.20^{abc}**	9.13^{a}	8.60^{a}	**8.86^{a}**	9.46^{a}	9.13^{a}	**9.30^{a}**
T_2: GA_3 @ 100 ppm	6.80^{a}	6.00^{a}	**6.40^{a}**	9.06^{a}	8.26^{abc}	**8.66^{ab}**	9.20^{abc}	8.40^{d}	**8.80^{bc}**
T_3: GA_3 @ 150 ppm	6.60^{ab}	5.73^{ab}	**6.16^{abc}**	8.53^{b}	8.40^{ab}	**8.46^{b}**	9.26^{abc}	9.00^{ab}	**9.13^{a}**
T_4: NAA @ 50 ppm	6.10^{cd}	5.40^{bc}	**5.75^{d}**	7.66^{c}	7.73^{c}	**7.70^{c}**	8.26^{ef}	8.20^{d}	**8.23$^{.}$**
T_5: NAA @ 100 ppm	6.13^{cd}	5.60^{abc}	**5.86^{cd}**	7.73^{c}	7.86^{bc}	**7.80^{c}**	9.00^{cbd}	8.33^{d}	**8.66^{cd}**
T_6: NAA @ 200 ppm	6.26^{cb}	5.60^{abc}	**5.93^{bcd}**	7.93^{c}	8.0^{bc}	**7.96^{c}**	9.40^{ab}	8.40^{d}	**8.90^{b}**
T_7: Kinetin @ 10 ppm	6.06^{cd}	5.26^{c}	**5.66^{d}**	7.66^{c}	7.86^{bc}	**7.76^{c}**	8.66^{de}	8.26^{d}	**8.46^{d}**
T_8: Kinetin @ 20 ppm	6.80^{a}	5.73^{ab}	**6.26^{ab}**	7.73^{c}	8.06^{abc}	**7.90^{c}**	8.73^{d}	8.73^{c}	**8.73^{bc}**
T_9: Kinetin @ 40 ppm	6.26^{bc}	5.73^{ab}	**6.00^{bcd}**	8.00^{c}	8.00^{bc}	**8.00^{c}**	8.93^{cd}	8.8^{bc}	**8.90^{b}**
T_{10}: Control	5.80^{d}	4.73^{d}	**5.26^{e}**	7.26^{d}	6.86^{d}	**7.06^{d}**	8.13^{f}	8.20^{d}	**8.16^{e}**
CD (0.05)	**0.38**	**0.41**	**0.35**	**0.38**	**0.56**	**0.35**	**0.44**	**0.26**	**0.20**
S.Em (±)	**0.128**	**0.14**	**0.11**	**0.12**	**0.19**	**0.11**	**0.14**	**0.08**	**0.06**
C.V (%)	**3.53**	**4.35**	**3.43**	**2.78**	**4.14**	**2.58**	**2.87**	**1.81**	**1.37**

Table 5: Effect of different plant growth regulators on Neck thickness at 60, 90 and 120 days after planting.

Treatments	60 Days after planting			90 Days after planting			120 Days after planting		
	2019-2020	2020-2021	Pooled	2019-2020	2020-2021	pooled	2019-2020	2020-2021	pooled
T_1: GA_3 @ 50 ppm	8.90^{a}	8.56^{a}	**8.73^{a}**	12.98^{a}	12.36^{a}	**12.67^{a}**	13.58^{a}	13.34^{a}	**13.46^{a}**
T_2: GA_3 @ 100 ppm	8.50^{b}	8.18^{b}	**8.34^{b}**	11.84^{ef}	11.08^{bc}	**11.46^{bcde}**	12.38^{c}	11.68^{bc}	**12.03^{de}**
T_3: GA_3 @ 150 ppm	8.21^{cd}	8.02^{b}	**8.11^{c}**	12.66^{b}	10.99^{bc}	**11.82^{b}**	12.72^{b}	11.92^{b}	**12.32^{bc}**
T_4: NAA @ 50 ppm	7.78^{e}	7.28^{cd}	**7.53^{e}**	11.73^{f}	10.50^{bc}	**11.11e**	12.45^{c}	11.76^{bc}	**12.10^{cd}**
T_5: NAA @ 100 ppm	8.35^{bc}	7.47^{c}	**7.91^{d}**	12.27^{cd}	10.36^{bc}	**11.32^{de}**	12.42^{c}	11.13^{d}	**11.78e**
T_6: NAA @ 200 ppm	8.44^{b}	7.38^{c}	**7.91^{d}**	12.05^{de}	11.28^{bc}	**11.67^{bcd}**	12.81^{b}	12.07^{b}	**12.45^{b}**
T_7: Kinetin @ 10 ppm	8.13^{d}	7.06^{d}	**7.60^{e}**	12.08^{de}	10.66^{bc}	**11.37^{cde}**	12.36^{c}	11.33^{cd}	**11.84d^{e}**
T_8: Kinetin @ 20 ppm	8.43^{b}	8.09^{b}	**8.26^{bc}**	12.10^{d}	10.90^{bc}	**11.50^{bcde}**	12.40^{c}	11.69^{bc}	**12.04^{d}**
T_9: Kinetin @ 40 ppm	8.53^{b}	8.61^{a}	**8.57^{a}**	12.48^{bc}	11.05^{bc}	**11.76^{bc}**	12.79^{b}	11.89^{b}	**12.34^{bc}**
T_{10}: Control	7.00^{f}	6.22^{e}	**6.61^{f}**	11.37^{g}	9.48^{d}	**10.43^{f}**	10.40^{d}	10.27^{e}	**10.34^{f}**
CD (0.05)	**0.19**	**0.27**	**0.16**	**0.24**	**0.88**	**0.43**	**0.17**	**0.45**	**0.26**
S.Em (±)	**0.067**	**0.09**	**0.05**	**0.08**	**0.29**	**0.14**	**0.05**	**0.15**	**0.08**
C.V (%)	**1.41**	**2.07**	**1.23**	**1.18**	**4.75**	**2.18**	**0.80**	**2.28**	**1.27**

Table 6: Effect of different plant growth regulators on number of roots and number of cloves per bulb.

Treatments	Number of Roots per plant			Number of cloves per bulb		
	2019-2020	2020-2021	Pooled	2019-2020	2020-2021	pooled
T_1: GA_3 @ 50 ppm	73.13a	75.40^{a}	**74.26^{a}**	27.13^{ab}	27.86^{a}	**27.50^{a}**
T_2: GA_3 @ 100 ppm	71.13^{abc}	68.60^{bcd}	**69.86^{bc}**	23.46^{c}	23.20^{bcd}	**23.33^{d}**
T_3: GA_3 @ 150 ppm	67.26^{bc}	64.00^{e}	**65.63^{d}**	24.13^{c}	22.73^{cd}	**23.43^{d}**
T_4: NAA @ 50 ppm	68.80^{abc}	65.46 ^{de}	**67.13^{dc}**	23.00^{c}	22.33^{cd}	**22.66^{d}**
T_5: NAA @ 100 ppm	66.73^{c}	67.73b^{cd}	**67.23^{dc}**	28.13^{ab}	24.93^{bc}	**26.53^{ab}**
T_6: NAA @ 200 ppm	70.06^{abc}	69.80^{bc}	**69.93^{bc}**	28.66^{a}	22.26^{cd}	**25.46^{bc}**
T_7: Kinetin @ 10 ppm	66.73^{c}	66.667^{cde}	**66.70^{cd}**	27.60^{ab}	24.06^{bc}	**25.83^{abc}**
T_8: Kinetin @ 20 ppm	66.33^{c}	67.93^{bcd}	**67.13^{dc}**	23.20c	24.93^{bc}	**24.06^{cd}**
T_9: Kinetin @ 40 ppm	72.26^{ab}	70.60^{b}	**71.43^{ab}**	25.53^{bc}	25.80^{ab}	**25.66^{abc}**
T_{10}: Control	55.40^{d}	52.73^{f}	**54.06^{e}**	19.26^{d}	21.06^{d}	**20.16^{e}**
CD (0.05)	**5.41**	**3.24**	**3.71**	**2.82**	**2.86**	**1.99**
S.Em (±)	**1.82**	**1.09**	**1.24**	**0.95**	**0.96**	**0.67**
C.V (%)	**4.65**	**2.82**	**3.21**	**6.58**	**6.99**	**4.75**

Table 7: Effect of different plant growth regulators on polar and equatorial diameter of bulb.

Treatments	Polar diameter (cm)			Equatorial diameter (cm)		
	2019-2020	2020-2021	Pooled	2019-2020	2020-2021	pooled
T_1: GA_3 @ 50 ppm	3.50^{a}	3.25^{a}	**3.37^{a}**	4.21^{ab}	4.29^{a}	**4.25^{a}**
T_2: GA_3 @ 100 ppm	3.30bc	2.95cde	**3.13^{bd}**	4.33^{a}	4.10^{b}	**4.21^{ab}**
T_3: GA_3 @ 150 ppm	3.08^{fe}	3.06^{b}	**3.07^{cde}**	4.19^{abc}	3.91^{cd}	**4.05^{cd}**
T_4: NAA @ 50 ppm	3.01^{f}	2.98^{cde}	**3.00^{ef}**	4.02d^{e}	3.87^{d}	**3.94^{e}**
T_5: NAA @ 100 ppm	3.21^{cd}	2.98^{bcd}	**3.09^{bcde}**	4.09^{bcde}	3.94^{cd}	**4.02^{cde}**
T_6: NAA @ 200 ppm	3.28^{bc}	2.93^{de}	**3.10^{bcd}**	4.23^{ab}	3.99^{bcd}	**4.11^{bc}**
T_7: Kinetin @ 10 ppm	3.09^{def}	2.94^{cde}	**3.01^{def}**	4.05^{cde}	3.89^{d}	**3.97^{de}**
T_8: Kinetin @ 20 ppm	3.19^{cde}	2.86^{ef}	**3.03^{de}**	4.13^{bcd}	3.99^{cbd}	**4.06^{dc}**
T_9: Kinetin @ 40 ppm	3.34^{b}	3.03^{bc}	**3.19^{b}**	3.94^{e}	4.03^{cb}	**3.99^{de}**
T_{10}: Control	3.02^{f}	2.82^{f}	**2.92^{f}**	3.95^{e}	3.68^{e}	**3.82^{f}**
CD (0.05)	**0.12**	**0.10**	**0.1**	**0.15**	**0.12**	**0.10**
S.Em (±)	**0.04**	**0.03**	**0.03**	**0.05**	**0.04**	**0.03**
C.V (%)	**2.26**	**2.03**	**1.88**	**2.21**	**1.88**	**1.54**

Table 8: Effect of different plant growth regulators on clove and breadth length of garlic.

Treatments	Clove Length (cm)			Clove Breadth (cm)		
	2019-2020	2020-2021	Pooled	2019-2020	2020-2021	pooled
T_1: GA_3 @ 50 ppm	2.88^{a}	2.97^{a}	**2.93^{a}**	1.07^{a}	1.11^{a}	**1.09^{a}**
T_2: GA_3 @ 100 ppm	2.70bc	2.62cd	**2.66^{bc}**	0.98^{ab}	0.93^{c}	**0.95^{b}**
T_3: GA_3 @ 150 ppm	2.50^{d}	2.69^{bc}	**2.60^{bcd}**	0.99^{ab}	0.91^{bc}	**0.95^{b}**
T_4: NAA @ 50 ppm	2.59^{cd}	2.75^{b}	**2.67^{bc}**	0.98^{ab}	0.91^{bc}	**0.95^{b}**
T_5: NAA @ 100 ppm	2.54^{d}	2.54^{d}	**2.54^{de}**	0.94^{b}	0.97^{bc}	**0.95^{b}**
T_6: NAA @ 200 ppm	2.52^{d}	2.62^{cd}	**2.57^{cde}**	1.00b^{a}	1.00^{ab}	**1.00^{b}**
T_7: Kinetin @ 10 ppm	2.59^{cd}	2.51^{d}	**2.55^{de}**	1.01^{ba}	0.91^{bc}	**0.96^{b}**
T_8: Kinetin @ 20 ppm	2.54^{d}	2.39^{e}	**2.47^{ef}**	0.95b^{a}	0.98^{b}	**0.97^{b}**
T_9: Kinetin @ 40 ppm	2.84^{ab}	2.53^{d}	**2.69^{b}**	1.02b^{a}	0.96^{b}	**0.99^{b}**
T_{10}: Control	2.25^{e}	2.60^{c}	**2.42^{f}**	0.82^{c}	0.85^{c}	**0.83^{c}**
CD (0.05)	**0.14**	**0.11**	**0.10**	**0.11**	**0.12**	**0.08**
S.Em (±)	**0.04**	**0.03**	**0.03**	**0.04**	**0.04**	**0.02**
C.V (%)	**2.23**	**2.59**	**2.42**	**7.09**	**7.56**	**4.92**

Table 9: Effect of different plant growth regulators on Fresh and Dry weight of cloves.

Treatments	Fresh weight of cloves (g)			Dry weight of cloves (g)		
	2019-2020	2020-2021	Pooled	2019-2020	2020-2021	pooled
T_1: GA_3 @ 50 ppm	12.20^{a}	15.20^{a}	**13.70^{a}**	8.02^{a}	8.60^{a}	**8.31^{a}**
T_2: GA_3 @ 100 ppm	10.80^{cd}	12.83^{bcd}	**11.82^{bc}**	7.15ab	6.72^{d}	**6.94^{de}**
T_3: GA_3 @ 150 ppm	10.60^{de}	12.68^{bcd}	**11.64^{c}**	6.90^{ab}	7.00^{cd}	**6.95^{cde}**
T_4: NAA @ 50 ppm	10.73^{de}	12.71^{bd}	**11.72^{c}**	7.42^{ab}	7.13^{cd}	**7.28^{bcd}**
T_5: NAA @ 100 ppm	11.93^{a}	11.97^{cd}	**11.95^{bc}**	7.22^{ab}	6.56^{de}	**6.89^{de}**
T_6: NAA @ 200 ppm	10.90^{cd}	13.36^{b}	**12.13^{bc}**	7.23^{ab}	8.14^{ab}	**7.69^{ab}**
T_7: Kinetin @ 10 ppm	11.23^{cb}	13.27^{cb}	**12.25^{bc}**	6.88^{ab}	7.37^{c}	**7.13^{bcd}**
T_8: Kinetin @ 20 ppm	12.03a	13.01cb	**12.52^{b}**	6.75ab	7.03cd	**6.89^{de}**
T_9: Kinetin @ 40 ppm	11.36^{b}	13.22^{cb}	**12.29^{bc}**	7.71^{ab}	7.54^{bc}	**7.63^{bc}**
T_{10}: Control	10.30^{e}	11.51^{d}	**10.90^{d}**	6.56^{b}	6.07^{e}	**6.31^{e}**
CD (0.05)	**0.43**	**1.32**	**0.70**	**1.31**	**0.61**	**0.67**
S.Em (±)	**0.14**	**0.44**	**0.23**	**0.44**	**0.20**	**0.22**
C.V (%)	**2.28**	**5.93**	**3.40**	**10.70**	**4.92**	**5.48**

Table 10: Effect of different plant growth regulators on bulb yield Kg/plot projected yield tons/ha and total biomass (Kg/plot).

Treatments	Bulb Yield Kg/plot			Projected Yield tons/ha.			Total Biomass Kg/plot.		
	2019-2020	2020-2021	Pooled	2019-2020	2020-2021	pooled	2019-2020	2020-2021	pooled
T_1: GA_3 @ 50 ppm	3.25^{a}	2.45^{a}	**2.85^{a}**	11.36^{a}	8.56^{a}	**9.96^{a}**	4.18^{a}	3.82^{a}	**4.00^{a}**
T_2: GA_3 @ 100 ppm	2.36^{cde}	1.85^{defg}	**2.11^{bcde}**	8.26^{cde}	6.46^{cdefgh}	**7.36^{bcdef}**	3.74^{ab}	2.98^{de}	**3.36^{b}**
T_3: GA_3 @ 150 ppm	2.56^{cd}	2.11^{bc}	**2.34^{bc}**	8.97^{cd}	7.37^{bc}	**8.17^{bcd}**	3.62b^{a}	3.20^{bc}	**3.41^{b}**
T_4: NAA @ 50 ppm	2.38^{cde}	1.91^{cdef}	**2.15^{bcde}**	8.34^{cde}	6.68^{cdef}	**7.51^{bcdef}**	3.39b^{a}	3.04^{cd}	**3.21^{bc}**
T_5: NAA @ 100 ppm	3.05^{ab}	1.73^{defgh}	**2.39^{b}**	10.68^{ab}	6.04^{efghi}	**8.36^{bc}**	4.09^{a}	2.82^{ef}	**3.46^{ab}**
T_6: NAA @ 200 ppm	2.51^{cde}	1.85^{cdefg}	**2.18^{bcde}**	8.77^{cde}	6.47^{cdefg}	**7.62^{bcdef}**	3.46^{ab}	2.91^{de}	**3.19^{bc}**
T_7: Kinetin @ 10 ppm	2.57^{c}	1.93^{bcde}	**2.25^{bcde}**	8.99^{c}	6.76^{bcde}	**7.88^{bcdef}**	3.49^{ab}	3.02^{cde}	**3.26^{b}**
T_8: Kinetin @ 20 ppm	2.53^{cde}	2.02^{bcd}	**2.28^{bcd}**	8.85^{cde}	7.08^{bcd}	**7.97^{bcde}**	3.47^{ab}	2.88^{fde}	**3.17^{bc}**
T_9: Kinetin @ 40 ppm	2.56^{cde}	2.22^{ab}	**2.39^{b}**	8.97^{cd}	7.76^{ab}	**8.37^{b}**	3.44^{ab}	3.34^{b}	**3.39^{b}**
T_{10}: Control	2.09^{e}	1.55^{h}	**1.82^{e}**	7.33^{e}	5.43^{i}	**6.38^{f}**	2.69^{b}	2.68^{f}	**2.69^{c}**
CD (0.05)	**0.44**	**0.29**	**0.44**	**1.55**	**1.02**	**1.56**	**1.07**	**0.21**	**0.54**
S.Em (±)	**0.14**	**0.09**	**0.13**	**0.51**	**0.34**	**0.48**	**0.36**	**0.07**	**0.18**
C.V (%)	**9.93**	**8.66**	**1.43**	**9.92**	**8.65**	**2.69**	**17.61**	**4.01**	**9.58**

CONCLUSION

In the present investigation, foliar application of plant growth regulators boosted the growth and yield of garlic and based on the current experimental results, it may be concluded that foliar application of GA_3 @ 50 ppm proved the best over other treatments of plant growth regulators followed by treatment with Kinetin @ 40 ppm.

FUTURE SCOPE

Screening of suitable varieties of garlic for the region with integrated nutrient scheduling. Studies aiming to increase self-life as well as influence of bio-stimulants on storage behaviour of garlic.

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