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Effect of Plant Growth Regulators on Economics and Harvest Index of Garlic (*Allium sativum* L.) under Terai region of West Bengal

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Garlic (*Allium sativum* L.) most widely farmed bulbous crop in the world and the second most widely cultivated Allium species after onion. The aim of the study to provide input and output per hectare. of garlic to determine the potential growth regulator. Through the application of chemical fertilizers environmental pollution through nitrate poisoning and exterminating soil micro-flora thereby, the

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alternatives to those problem the growth regulators play important role in economic production and cost management of garlic by employing methodology of Randomized Block Design comprising of three replications with ten treatments. The present experiment conducted on various kinds of growth regulators (Gibberellic acid (GA_3) @ 50 ppm, GA_3@ 100ppm, GA_3@ 150 ppm, Naphthalene acetic acid (NAA) @ 50 ppm, NAA@ 100 ppm, NAA@ 200ppm, Kinetin@ 10 ppm, Kinetin@ 20 ppm, Kinetin@ 40 ppm and Control (Distilled water) at the instructional and research farm of the Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, India, during the autumn and winter seasons for two consecutive years. In view of effect of different plant growth regulators on the economics of garlic under *terai* region of west Bengal has observed significant variation. The result obtained that the foliar application of GA_3@50 ppm generated maximum net returns (812753 Rs/ ha.) and benefit cost ratio (4.44) over other treatments. The control plots treated with distilled water was produced qualitatively inferior bulbs and generated lowest net returns (461946Rs/ha.) and benefit cost ratio (2.62). Interestingly the highest harvest index obtained under the Knetin@20 ppm (71.53) and lowest HI obtained under treatment of GA_3 @100 ppm. (62.59). Based on the current experimental results, it may be concluded that foliar application of GA_3 @ 50 ppm proved the best over other plant growth regulators.

Keywords: Economics; garlic; GA_3, NAA; kinetin; returns.

1. INTRODUCTION

The climate variables exert an impact on the transpiration rate, which determines plant growth and productivity through the drought stress effect [1]. As the use of chemical fertilizers are very burden to the farmer community. Apart from that environmental pollution through nitrate poisoning and exterminating soil micro-flora by application of chemical fertilizers and pesticides which adversely affect the physico-chemical properties of soil and create health hazards thereby, the alternatives to those problem the growth regulators play important role in economic production and management of garlic. Economical returns directly correlated with Yield therefore, Crop plant yields are mostly determined by abiotic environmental elements, su ch as temperature and precipitation. It is crucial to conduct assessments for the economic production of plant species that exhibit both the best performance attributes and the best adaptation to climatic changes, given the patterns in climate change that have been recorded.

Garlic is the second most commonly grown *Allium* species After onions cultivation [2] with chromosome number 2n = 2X = 16 and a member of the Amaryllidaceae family. Garlic is native to Southern Europe and Central Asia, particularly the Mediterranean region. The closest related and garlic's progenitor is thought to have been the wild species of *Allium longicuspis.* It is an annual herbaceous crop with a thin, papery sheath around it. The edible underground stem is a composite bulb made up of several smaller bulbs called cloves which was Economic part of the garlic. It has distinctive smell and pungent principle are caused by diallyl disulphide (DDS), which is present in allylradicle and *alliinin* forms. It has long been acknowledged as a beneficial culinary condiment. Most Indians eat this crop, which is produced all throughout the country's plains. Garlic has significant therapeutic properties against digestive diseases, eye sores, and earaches, according to the Unani and Ayurvedic systems that are practiced in India. Cloves can be used as a condiment or as a spice for flavouring. It has a high concentration of essential oils (0.1-0.4%), minerals (0.3%), carbohydrates (29%), protein (6.3%), and fat (Memane et al., 2008). Garlic oil (0.5%) has growth stimulating properties [3]. It has a lot of vitamins, such vitamin C, and flavonoid antioxidants, like α-carotene (Chiavarini et al. 2016). A vital component of green garlic is ascorbic acid. According to Meng et al. [4] garlic has antibacterial, antifungal, antiviral, and antiprotozoal qualities [5]. Because of its antioxidant and anti-cancer qualities, it is advantageous to the immune system and cardiovascular system [4,6]. In the current organic agricultural environment, garlic extracts and oils have potential use as efficient fungicides and insecticides [7]. Madhya Pradesh, Gujarat, Maharashtra, Orissa, Rajasthan, Uttar Pradesh, and Karnataka are the principal garlic-growing states in India. In India, 429 thousand hectares are used for the cultivation of garlic, which yields 8366 kg ha-1 and 3498 MT of output year [8]. Garlic is farmed on a limited scale in west Bengal, mostly on 3.70 thousand hectares of land in the Gagnatic plains of Malda, Nadia, 24 Parganas North district, and Cooch Behar and

Jalpaiguri districts in the Terai region. The region produces 36.10 MT of garlic annually, with a productivity of 9.76 MT/ha. [9].

The plant's ability to change its growth behaviour is largely dependent on plant growth regulators, which in turn improve plant growth, quality, and production. These are organic substances other than nutrients that, when applied in tiny amounts, encourage, hinder, or otherwise change some physiological and biochemical process reactions in plants. Synthetic auxins like naphthalene acetic acid (NAA) can alter a plant's phenotypic and growth, speeding up the pace at which shoots and roots grow and ultimately increasing production [10]. The positive effect of plant growth regulators on horticultural crops have been shown by many workers [11,12]. Tetracyclic di-terpenoid chemical gibberellic acid (GA) is a plant hormone that promotes plant growth and development. Growth-stimulating agents like GA3 encourage cell division and elongation, which aids in the growth and development of several plants. Garlic can break dormancy and sprout more quickly when GA_3 is added. Gibberellic acid is essential for many different growth processes, including as the formation of seeds, the lengthening of organs, senescence, and the regulation of blooming time [13-14]. NAA root dipping treatment was shown to prevent physiological weight loss as well as deterioration [10]. In media culture, kinetin is vital for processes like callus renewal. Though little is known about how exogenously applied growth regulators affect garlic, various doses and formulations are thought to be advantageous for increasing crop production and net returns via regulating physiological processes within the plant. Consequently, an effort was undertaken to assess the impact of various PGR concentrations on the qualitative, quantitative, and economic characteristics of garlic, which might potentially aid in making a significant contribution to the country.

2. MATERIALS AND METHODS

2.1 Environmental Conditions

The instruction/research farm of the Department of Plantation Crops and Processing, Faculty of Horticulture, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India, located at 26.52430 North latitude and 89.10750 East longitude, was the site of the current experiment, which was carried out during the autumn and winter season for two consecutive years (October-2019 to March 2020 and October-2020 to march-2021). At the experimental location (0–15 cm depth), the sandy loam soil had an acidic response with a pH of 5.59, 0.06 EC, and 0.28 % organic carbon (OC). The contents of available N, P2O5, K2O, and S were 100.62, 19.15, 103.45, and 23.83 kg ha-1, respectively. According to meteorological data maximum and lowest temperatures in 2020 and 2021, respectively, varied between 5.77 and 33,07 degrees. In both years, the range of maximum and minimum relative humidity was between 40.43 and 97,67%.

2.2 Experiment and Treatments

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 each of them 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.

2.3 Cultural Practices

Garlic cloves treated with carbendazim which was in the form of powder for whole night were seeded in 2.0 x 1.0 m^2 area plots with a spacing of 20 x 10 cm. Cloves were manually dropped with the use of a hand tool, 3-5 cm below the soil and then carefully covered with dirt. The recommended doses of fertilizer applied as N, P, K and S @ 100,60,80 and 40 kg/ha (Abdul et al. 2002) as Half dose of N and full doses of P, K applied at the time of land preparation and remaining doses of N applied in the form of split at 45 and 60 days after planting. For improved germination, irrigation was given after seeding, and further irrigation was given based on the moisture content. Along with weeding, earthing up is done at intervals between 35 and 60 days. During the crop cycle, propiconazole (1 milligram per litre) was applied every 25 days to avoid fungal infections. When 70% of the leaves on the plants had dried and the tops of the plants had turn yellow at the neck fall stage, the plants were ready to be harvested. At that point, the bulb was removed, packed in bunches with greenery, and sun-dried for five days to let it to cure. The dried leaves were placed in perforated nylon bags and

chopped with a sickle at the neck region after drying.

2.4 Preparation of Stock Solution

In order to create a stock solution, a sufficient amount of gibberellic acid (GA3), (NAA), and kinetin were all in the solid state, that is, in the form of powder. The weighed powder as required as per treatment was collected and transferred into a volumetric flask, and very little alcohol (ethanol @1%) and 1.0 percent Na $(OH)_2$ was needed to dissolve the powder in the form. After that, distilled water was added to dilute it to the necessary concentration of solution.

Table 1. Common cost of cultivation for one hectare of the experiment

S. No.	Particulars of operation	Rate	Quantity, Men Days, Area/Ha.	Cost/Ha.
A.	**Fixed cost of cultivation**			
1	Land lease	Rs 2000 /Bigha	7.5 Bigha.	15000 Rs
2	Ploughing	Rs 1000 /Bigha	7.5 Bigha.	7500 Rs
3	Fertilizers			
	i. FYM t/ha	Rs 1000 /t	25 t/ha.	25000 Rs
	ii. Urea kg/ha	Rs 7 /Kg	217 Kg/ha.	1519 Rs
	iii. SSP kg/ha	Rs 9 /Kg	475 Kg/ha.	4275 Rs
	iv. MOP kg/ha	Rs 20 /Kg	133 Kg/ha.	2660 Rs
	v. Sulphur kg/ha	Rs 98 /Kg	50 Kg/ha.	4900 Rs
4	Planting material (Seed) cost	Rs 150 /Kg	500 Kg/ha.	75000 Rs
5	Layout and bed preparation	Rs 300 /Day	30 MD	9000 Rs
6	Sowing	Rs 300 /Day	15 MD	4500 Rs
7	Intercultural operations i. Hoeing ii. Irrigation iii. Weeding v. Drainage vi. Earthing up vii. Spraying	Rs 300 /Day	65 MD	19500 Rs
8	Harvesting	Rs 300 /Day	15 MD	4500 Rs
9	Plant protection measures	Rs 1800 /L	1.5L	2700 Rs
	Total fixed cost			**176054** Rs
B.	**Treatment Cost**			
I	**Growth regulators**			
a.	GA_3 @ 50 ppm GA_3 @ 100 ppm GA_3 @ 150 ppm	Rs 95.9 /g	75g 150g 225g	7192.5 Rs 14385 Rs 21577.5 Rs
b.	NAA @ 50 ppm NAA @ 100 ppm NAA @ 200 ppm	Rs 5.8/g	75g 150g 300g	435 Rs 870 Rs 1740 Rs
c.	Kinetin @ 10 ppm Kinetin @ 20 ppm Kinetin @ 40 ppm Control	Rs 159.32 /g 0	15g 30g 60g 0	2389.8 Rs 4779.6 Rs 9559.2 Rs 0
	Total treatment cost (Rs.)			**62928.6**

2.5 Economics

1. Gross Income (Rs) = Total crop production (TCP) x Value of the product (VOP)

2. Total cost (TC) = Common cost (CC) + Treatment cost (TC)

3. Net return (Rs per ha): Net return (Rs per ha) of individual treatment was calculated by deduction of cost of cultivation from the gross return (GR) of particular treatment

Net return (NR) = Gross Return (GR) – Total Cost of Cultivation (TCC).

Benefit: Cost ratio to find out the B:C Ratio = Net return/ Total Cost of Cultivation.

2.6 Harvest Index

HI= (Economic yield/ Biological yield) x100

2.7 Statistical Analysis

After two years of field and laboratory data collection, the data was organized into tabular form and statistical analysis was performed using the randomized block design recommended by Panse and Sukhatme (1967). Using the F test and the Least Significant Difference (LSD) test at a 5% threshold of significance, the significance of treatment changed under different parameters [15]. At a significance level of 5%, the crucial difference was ascertained using the Fisher and Yates table. Additionally, a two-year pooled analysis was conducted utilizing the Gomez and Gomez methodology (1983). Analysis of variance was carried out for each parameter using Pro Glm, a tool included in the Statistical Analysis System (SAS) software.

3.RESULTS AND DISCUSSION

3.1 Economics and Benefit Cost Ratio

Benefit cost ratio for garlic crop was influenced significantly by interactive effect of growth regulators. Among the foliar application of growth regulators T_1 -GA_3 @ 50 ppm gave the highest net returns (812753 Rs/ ha.) and benefit cost ratio (4.44) (table-2) which was subsequently followed by T_5-NAA @ 100 ppm (3.73) treated plants. The lowest benefit (2.62) was obtained from T_{10} (control) plants without any application of plant growth regulators concentration. foliar spray of GA_3@50 ppm independently gave higher growth, yield and better quality.

Yield has direct effect on economics, Numerous processes, including photosynthetic efficiency, cell elongation, vegetative meristem activity, and secondary wall biosynthesis, are crucial for increased output. These processes can be altered by growth regulators or are controlled by genetics. The maximum plant height and average bulb weight in the current study may have contributed to the maximum bulb output since they increased the total yield while requiring a lower dosage of gibberellic acid than other growth regulators.

Table 2. Harvest Index of garlic at different concentration of growth regulators under *terai* region of West Bengal

	Harvest Index		
Treatments	**2019-2020**	**2020-2021**	**Pooled**
T_1: GA_3 @ 50 ppm	77.76^{a}	64.14^{bcd}	70.95^{ab}
T_2: GA_3 @ 100 ppm	63.09^{f}	62.09^{d}	62.59^{c}
T_3: GA_3 @ 150 ppm	70.85^{de}	65.94^{bc}	68.39^{ab}
T_4: NAA @ 50 ppm	70.21^{e}	62.83^{d}	66.52^{bc}
T_5: NAA @ 100 ppm	74.68^{ac}	61.42^{d}	68.05^{ab}
T_6: NAA @ 200 ppm	72.52^{cde}	63.56^{cd}	68.04^{ab}
T_7: Kinetin @ 10 ppm	73.68^{cd}	63.93^{bcd}	68.80^{ab}
T_8: Kinetin @ 20 ppm	72.93^{cde}	70.14^{a}	71.53^{a}
T_9: Kinetin @ 40 ppm	74.44^{c}	66.46^{b}	70.45^{ab}
T_{10}: Control	77.70^{ab}	57.84^{e}	67.77^{ab}
CD (0.05)	4.66	3.34	2.79
S.Em (±)	1.57	1.13	8.34

Table 3. Economics and benefit cost ratio of garlic at different concentration of growth regulators under *terai* region of West Bengal

Treatments	Doses (g)	Fixed cost (Rs.)	Treatment cost (Rs.)	Total cost (Rs.)	Bulb yield (t/ha)	Price of Bulb (Rs/Kg)	Gross return (Rs)	Net return (Rs)	B:C Ratio
T_1: GA_3 @ 50 ppm	75	176054	7192.5	183246.5	9.96	100	996000	812753.5	4.44
T_2: GA_3 @ 100 ppm	150	176054	14385	190439	7.36	100	736000	545561	2.86
T_3: GA_3 @ 150 ppm	225	176054	21577.5	197631.5	8.17	100	817000	619368.5	3.13
T_4: NAA @ 50 ppm	75	176054	435	176489	7.51	100	751000	574511	3.26
T_5: NAA @ 100 ppm	150	176054	870	176924	8.36	100	836000	659076	3.73
T_6: NAA @ 200 ppm	300	176054	1740	177794	7.62	100	762000	584206	3.29
T_7: Kinetin @ 10 ppm	15	176054	2389.8	178443.8	7.88	100	788000	609556.2	3.42
T_8: Kinetin @ 20 ppm	30	176054	4779.6	180833.6	7.97	100	797000	616166.4	3.41
T_9: Kinetin @ 40 ppm	60	176054	9559.2	185613.2	8.37	100	837000	651386.8	3.51
T_{10}: Control	0	176054	0	176054	6.38	100	638000	461946	2.62

It could be because growth regulators are physiologically more active to change source and sink connections for growing bulbs, which raises overall yields, and accumulate enough food reserves. The anticipated yield rises in tandem with the bulb yield, proportionately. On the source of the research as well as economic point of views, an application of plant growth regulators produced its significant impact on net returns and B:C ratio [16]. Maximum returns under GA_3 at 50 ppm result from improving the yield under GA_3 foliar spray. The current experimental results ware correlated with Zinzala and Kumar (2016) and [17] in onion.

3.2 Harvest Index

The two-season data pertaining to harvest index the highest harvest index obtained under the foliar application of Knetin@20 ppm (71.53) (table-1) and lowest HI obtained under treatment of GA_3 @100 ppm. (62.59). the highest harvest index in lower concentration of growth regulators due to manipulation of morphological characters which direct effect on the yield component [18-19].

4. CONCLUSION

In the present investigation, foliar application of plant growth regulators boosted the yield and Quality characteristics of garlic which are direct effect on net returns and benefit cost ratio of garlic and based on the current experimental results, GA_3 @ 50 boosted the yield and economics and highest harvest index obtained under Kinetin @ 20ppm. Based on the experiment it may be concluded that foliar application of GA_3 proved the best over other treatments of plant growth regulators.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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