Crossref

IJBSM March 2024, 15(3): 01-07

Article AR5158

Research Article

Natural Resource Management

DOI: HTTPS://DOI.ORG/10.23910/1.2024.5158

Impact of Diverse Plant Growth Regulators on Quality Traits of Garlic (*Allium sativum* L.)

Seelothu Rakesh[1], P. S. Medda[1], Babli Dutta[1], Arunava Ghosh[2] and Surajit Khalko[3]

[1]Dept. of Plantation Crops and Processing, [2]Dept. of Agricultural Statistics, [3]Dept. of Plant Pathology, Uttar Banga Krishi Viswavidyalaya Pundibari, Cooch Behar, West Bengal (736 165), India

Open Access

Corresponding seelothrakesh97@gmail.com

0009-0003-1265-3578

ABSTRACT

The present study was conducted at the instructional cum research farm of the Department of Plantation Crops and Processing of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, India during *rabi* season for consecutive two years (October-2019 to March-2020 and October-2020 to march-2021) to investigate the "Effect of Different Plant Growth Regulators on Quality attributes of Garlic (*Allium sativum* L.)" with various growth regulators (GA_3 @ 50 ppm, GA_3 @ 100 ppm, GA_3 @ 150 ppm, NAA @ 50 ppm, NAA @ 100 ppm, NAA @ 200 ppm, Kinetin @ 10 ppm, Kinetin @ 20 ppm, Kinetin @ 40 ppm and Control (Distilled water). In view of, effect of different plant growth regulators on quality attributes has observed significant variation. Results pertaining to total soluble solids, significantly highest TSS recorded under GA_3 @100 ppm treated plots (32.10 °Brix), however, dry matter content of bulb was highest at GA_3 @ 50 ppm (33.63%). Interestingly, highest oleoresin content of the bulb was also reported from the GA_3 @ 50 ppm treated plots (0.24 g) with lowest physiological loss of bulb weight (7.04%). The control plots treated with distilled water was produced qualitatively inferior bulbs. The aim of the study provided valuable results to determine the potential growth regulator for enhancing post-harvest quality attribute of garlic by employing methodology of Randomized Block Design comprising of three replications with ten treatments. 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: Quality, garlic, GA_3, NAA, kinetin

***Citation* (VANCOUVER):** Rakesh et al., Impact of Diverse Plant Growth Regulators on Quality Traits of Garlic (*Allium sativum* L.). *International Journal of Bio-resource and Stress Management,* 2024; 15(3), 01-07. HTTPS://DOI.ORG/10.23910/1.2024.5158.

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.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 20th January 2024 RECEIVED in revised form on 27th February 2024 ACCEPTED in final form on 17th March 2024 PUBLISHED on 20th March 2024

1. INTRODUCTION

Garlic (*Allium sativum* L.) known as "Lashun", is a well-known spice from the Alliaceae family with chromosome number 2n=16. Its origins can be traced back to Central Asia. It is one of the most widely farmed bulbous crop in the world and the second most widely cultivated Allium species after onion (Anonymous, 2013). Garlic cloves are the economic portion of the plant. Cloves can be used as a seasoning spice or as a condiment. It contains a significant quantity of carbohydrate (29%), protein (6.3%), minerals (0.3%), and essential oils (0.1–0.4%), Garlic oil (0.5%) had growth stimulant (Shafeek et al., 2015), as well as some fat, vitamin C, and sulphur (Memane et al., 2008). It contains many flavonoid antioxidants e.g. β-carotene and vitamins e.g. vitamin-C (Chiavarini et al., 2016). Ascorbic acid is a key component of green garlic. Garlic possesses antibacterial (Arora and Kaur, 1999), antifungal (Hughes and Lawson, 1991), antiviral (Meng et al., 1993) and antiprotozoal properties (Reuter et al., 1996). It is beneficial to cardiovascular and immune system having anti-oxidant and anti-cancer properties (Meng et al., 1993; Harris et al., 2001). Garlic extracts and oil have potential uses as an effective insecticide and fungicide in the present scenario of organic farming (Kumara et al., 2014). Garlic is cultivated all over India on area of 429 thousand hectares with production of 3498 MT with yield of 8366 kg ha^{-1} (Anonymous, 2022)

Plant growth regulators are organic compounds other than nutrients that promote/inhibit or otherwise alter some physiological and biochemical process reaction in plants when used in small quantities. The translocation of food materials or for altering source to sink relationship is changed by application of plant growth regulators. The positive effect of plant growth regulators on horticultural crops have been shown by many workers (Lal et al., 2013, Tameshwar et al., 2017). The principal aims of bulb crops storage are to maintain the 'quality capital' present at harvest and to satisfy consumer demand for extended availability of bulbs of satisfactory quality (Gubb and Tavis, 2002). Gibberellic acid (GA), a plant hormone stimulating plant growth and development, is a tetracyclic di-terpenoid compound. GAs stimulates seed germination, trigger transitions from meristem to shoot growth, juvenile to adult leaf stage, vegetative to flowering. spraying of different concentrations of GA_3 significantly improved the quality of garlic and Welsh onion; (Liu et al., 2019; Vamazaki et al., 2015). GA_3 classically related to a few key developmental processes, thus being essential for the accurate unfolding of plant genetic programs (Castro-Camba et al., 2022). Among several types of plant growth regulators, indole 3-butyric acid (IBA), an auxin precursor that is converted to IAA in a peroxisomal β-oxidation process (Strader and Damodaran, 2019), plays important roles in plant development either under normal or stressful conditions. NAA root dipping treatment was shown to prevent physiological weight loss as well as deterioration (Patel et al., 2010). Kinetin plays important role in garlic such as regeneration of callus in media culture. Different concentrations and formulation of exogenously applied growth regulators are considered as beneficial factor for improving the quality of crop by controlling physiological processes within the plant, but a little information is available for their effect on garlic. Therefore, an attempt was made to evaluate the effectiveness of different concentrations of PGRs on the qualitative attributes of garlic which might be help for substantial contribution to the nation.

2. MATERIALS AND METHODS

2.1. *Environmental conditions*

The present experiment was conducted during Rabi season for consecutive two years (October–2019 to March–2020 and October–2020 to March–2021) the instruction cum 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. The soil at the experimental site (0–15 cm depth) s was acidic in reaction having sandy loam texture with 5.59 pH and 0.06 EC, 0.28% Organic carbon (OC). Available N, P_2O_5, K_2O and S contents were 100.62, 19.15,103.45and 23.83 kg ha^{-1} respectively. Meteorological data pertaining to the cropping seasons revealed that maximum and minimum temperature fluctuated between 33.07 and 5.77 both 2020 and 2021 respectively. Maximum and minimum relative humidity prevailed between 97.67 and 40.43% in both the years.

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: 50 ppm GA_3, T_2: 100 ppm GA_3, T_3: 150 ppm GA_3, T_4: 50 ppm NAA, T_5: 100 ppm NAA, T_6: 200 ppm NAA, T_7: 10 ppm Kinetin, T_8: 20 ppm Kinetin, T_9: 40 ppm Kinetin and T_{10}: Control and replicated thrice.

2.3. Cultural practices

The cloves of garlic treated with carbendazim and sown with spacing of 20×10 cm^2 in the plots of 2.0×1.0 m^2 area. Dropping of cloves was done manually at a depth of 3–5 cm below the soil surface with the help of hand and covered properly with soils. The recommended dose of fertilizer i.e., N:P: K:S @ 100:60:80:40 kg ha^{-1} (Abdhul et al., 2002) were applied respectively. Irrigation was provided after sowing for better germination and subsequent irrigation provided depends on moisture condition. Earthing up carried out 35- and 60-days interval along with weeding. Propiconazole @ 1 ml l^{-1} was used during crop period at 25 days interval to prevent fungal diseases. 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.

2.4. 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.

2.5. Method of data collection

2.5.1. Total soluble solids

Total soluble solid estimated by using Hand Refractometer (Waskar et al., 1999). For the estimation of TSS, at first required quantity of cloves were separated from bulb in each treatment and crushed in mortar and pestle for juice extraction than 2 to 3 drops of juice were placed on prism of hand refractometer and the readings observed in refractometer scale in °brix. The average value computed and recorded as TSS.

2.5.2. Dry matter content

Dry matter content was measured by taking 50 g of homogenate sample and then oven dried it at temperature of 65°C for 48 hrs. and dry weight was measured by using digital balance and calculated by following formulae:

$$DM(\%)=((DW+CW)-CW)/((FW+CW)-CW)\times100$$

Where, DW=dry weight, CW=container weight, FW=fresh weight

2.5.3. Oleoresin content (g)

Oleoresin content of garlic is estimated by using Soxhlet apparatus method given by (Barros et al., 2013). in order to estimate the oleoresin content, required quantity of crushed cloves 10 g were filled into the cellulose thimble and sufficient volume of 100 ml of solvent (hexane) was introduced into the solvent cup. Thereafter, the sample containing beakers placed in Soxhlet apparatus and set the temperature just above the boiling point of the solvent (hexane i.e. 69°C) which is 90°C for 60 minutes in 1st phase than in second phase the temperature rises automatically to 180°C for 15 minutes. at that 180°C the solvent is evaporated and oil remains left. After evaporation of solvent oil containing beakers carefully taken out and weighed and the weight of the oil expressed in terms of grams.

2.5.4. Physiological loss of bulb weight (%)

It was determined by weighing packed garlic on digital balance at periodical interval (60 days) of storage. Physiological loss of bulb weight is due to activity of peroxidase enzyme in bulb. it was calculated using following formula:

$$PLBW (\%)=(Po-Pn)/Po\times100$$

Po: Initial weight at 0^{th} day, Pn: Final weight at n^{th} day

2.6. Statistical analysis

The data recorded from two years of investigation from field and laboratory was arranged in tabular farm and subjected to statistical analysis by adopting randomised block design given by (Panse and Sukhatme, 1967). The significance of treatment varied under various parameters was tested using the Least Significant Difference (LSD) test at a 5% level of significance (p=0.05) by applying the F test (Cochran and Cox, 1975). Fisher and yates table was used to determine the critical difference at a 5% level of significance. 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.

3. RESULTS AND DISCUSSION

Effect of different plant growth regulators on quality contributing characters of garlic

3.1. Dry matter content

The pooled data of both seasons revealed that highest dry matter content of bulb (33.63%) had been reported from T_1 : GA_3 @ 50 ppm (Table 1) and it was statistically at par with T_5: NAA @ 100 ppm (33.27%) followed by T_3: GA_3 @150 ppm (31.98%), and T_6: NAA @ 200 ppm (31.94%). Whereas, lowest dry matter content of bulb (29.02%) was recorded from T_{10} control. The maximum dry matter content (%) per bulb is attributed to excessive loss of moisture from bulbs. Also, it has been reported that increased in dry matter content of bulb due to hydrolysis of fructose, higher corban-di-oxide fixation and RUBP carboxylase activity. Goutam et al. (2018) was also reported that low dry matter content of bulb is due to higher moisture content and lower deposition as well as low accumulation of food materials. Results related to dry matter content of bulb has been agreement with Gautham et al. (2018) in garlic and Akter et al. (2007) in mustard they also reported maximum dry matter content under application of GA_3 @ 50 ppm as well as Kumar et al. (2000) who reported the highest dry matter recovery in onion with the application of Maleic hydrazide (3000 ppm) stored in ambient storage conditions.

3.2. Oleoresin content

Based on pooled analysis noticed that, Significantly, maximum oleoresin Content of garlic obtained with foliar application of T_1: GA_3 @ 50 ppm (0.24 g) (Table 1) which is statistically at par with T_9: kinetin @ 40 ppm (0.22 g). Which is followed by T_8: Kinetin @ 20 ppm (0.19 g) and T_7: Kinetin @ 10 ppm (0.19 g) but, lowest oleoresin content (0.10 g) has been obtained from T_{10}: Control treatment which is at par with T_4: NAA @ 50 ppm (0.11 g). The oleoresin is complex mixture of essential oil and volatile oil, the highest oleoresin content under GA treatment due to GA trigger the formation of maximum number of oil glands (Mohamed et al., 2019).

3.3. Total soluble solids

A thorough look into pooled results clearly indicating that, the treatment T_1: GA_3 @ 50 ppm (31.61˚Brix) failed to produce significant higher value, but it was statistically at par with highest value of TSS (32.10°Brix) as recorded by T_2: GA_3 @ 100 ppm (Table 1) and it was statistically at par with T_9: Kinetin @ 40 ppm (31.83˚Brix) and T_3: GA_3 @150 ppm (31.66˚Brix). Lowest TSS (30.28˚Brix) has been recorded under T_{10} (Control). Foliar spraying of different plant growth regulators recorded significant effect on total soluble solids content of bulb. The maximum TSS recorded in foliar application of gibberellic acid @ 100 ppm, it might be due to the GA_3 accomplished with enhanced enzymatic activity and translocation of food metabolites from source (leaves) to sink and synthesis of starch in garlic bulbs. Dandena et al. (2010) reported that TSS may be raised as a result of assimilates export from the leaves, fruit import, and carbon metabolism, which seem to be responsible for increase in tomato TSS. The increase in TSS is mostly due to the hydrolysis of starch into sugars. The decreased trend of TSS in control is might be due to process of oxidation and increase in rate of respiration, as increased rate of respiration decreases total soluble solids content. These results are in conformity with the findings of (Zinzala and Kumar, 2017), (Govind et al., 2015) in garlic.

3.4. Physiological loss of bulb weight

Data pertaining to physiological loss of bulb weight, it was observed that highest physiological loss of bulb weight (11.33%) was recorded under T_{10}: Control and lowest physiological loss of bulb weight (7.04%) was registered under treatment T_1: GA_3 @ 50 ppm (Table 1). Higher physiological loss (%) of bulb weight has been reported in control treatment.it may be due to the higher level of moisture content in bulb and also due to the lower peroxidase activity in untreated plants. Apart from that, longer storage period also increases the physiological loss of bulb weight (%). As storage period increases, obviously rate of respiration also increases it leads to loss of bulb weight. Lowest physiological loss of bulb weight (%) has been observed with foliar application of GA_3 @ 50 ppm the reason behind that is GA_3 inhibits the process of senescence mainly by inflection of lipid peroxidase enzyme. Evidence from reports of Goutam et al. (2018) who elicited that, the exogeneous application of growth regulators accelerate the peroxidase enzyme activity in bulb which results in removal of detrimental radicles from cytosol and chloroplast which result in minimum physiological loss of bulb weight. Besides that, action of gibberellic acid controls the rate of respiration, which in turn decreases moisture loss from the bulbs. The results agreement with Akhilesh et al. (2010) and Kumara and Patil (2015) in garlic also reported that pre harvest application of growth regulators reduce the moisture content of onion bulb due to cell division activity had been reduced after harvest and maintain the cell structural integrity.

3.5. Yield t ha^{-1}

A thorough look into pooled data (Table 1) pertaining to bulb yield noticed that T_1: GA_3 @ 50 ppm registered the highest bulb yield plot^{-1} (14.25 t ha^{-1}) it was statistically superior over rest of the treatments, followed by T_5: NAA @ 200 ppm (11.95 t ha^{-1}) and T_9: Kinetin @ 40 ppm (11.95 t ha^{-1}) whereas lowest bulb yield plot^{-1} noticed under T_{10}: Control (9.1 t ha^{-1}) yield is an important trait to evaluate a crop variety's commercial viability as well as feasibility. For higher yield, several mechanisms such as vegetative meristem activity, cell elongation, photosynthetic efficiency, and secondary wall bio-synthesis are important. These mechanisms are either genetically regulated or may be manipulated using growth regulators. The maximum bulb production in current investigation 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. Singh et al. (2018) also reported highest bulb yield under lower concentration of gibberellic acid.

3.6. Total biomass t ha⁻¹

Based on the pooled data, it was noticed that T_1: GA_3 @ 50 ppm registered the highest total biomass (20.00 t ha^{-1}) (Table 1) in both the seasons through increase crop growth and production of larger size bulbs having higher bulb weight. The effect of application of GA_3 @ 50 ppm was statistically *at par* with T_5: NAA @ 100 ppm (17.27 t ha^{-1}) whereas, lowest total biomass yielded was recorded under treatment T_{10} (control) with biomass yield of 13.42 t ha^{-1}. and it was statistically *at par* with T_4: NAA @ 50 ppm (16.07 t ha^{-1}), T_6: NAA @ 200 ppm (15.92 t ha^{-1}) and T_8: Kinetin @ 20 ppm (15.87 t ha^{-1}) 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 dry matter content, oleoresin content, total soluble solids and physiological loss of bulb weight, yield and total biomass of garlic

Treatments	Dry matter content (%)	Oleoresin content (g 100 g^{-1})	Total soluble solids (°Brix)	Physiological loss of bulb weight (%)	Yield t ha^{-1}	Total biomass t ha^{-1}
T_1: GA_3 @ 50 ppm	33.63^{a}	0.24^{a}	31.61^{abc}	7.04^{f}	14.25^{a}	20^{a}
T_2: GA_3 @ 100 ppm	31.21^{bc}	0.16^{bcd}	32.10^{a}	8.59^{de}	10.52^{bc}	16.8^{b}
T_3: GA_3 @ 150 ppm	31.98^{b}	0.15^{de}	31.66^{abc}	9.20^{de}	11.67^{b}	17.05^{b}
T_4: NAA @ 50 ppm	30.62^{c}	0.11^{e}	31.05^{abcd}	10.15^{bc}	10.72^{bc}	16.07^{bc}
T_5: NAA @ 100 ppm	33.27^{a}	0.15^{de}	31.65^{abc}	10.51^{ab}	11.95^{ab}	17.27^{ab}
T_6: NAA @ 200 ppm	31.94^{b}	0.20^{c}	30.78^{bcd}	8.37^{e}	10.9^{bc}	15.92^{bc}
T_7: Kinetin @ 10 ppm	30.75^{c}	0.19^{bc}	30.51^{cd}	9.38^{cd}	11.25^{bc}	16.27^{b}
T_8: Kinetin @ 20 ppm	30.78^{c}	0.19^{bc}	30.68^{bcd}	8.90^{de}	11.37^{bc}	15.87^{bc}
T_9: Kinetin @ 40 ppm	30.86^{c}	0.22^{ab}	31.83^{ab}	8.57^{de}	11.95^{ab}	16.95^{b}
T_{10}: Control	29.02^{d}	0.10^{f}	30.28^{d}	11.33^{a}	9.1^{c}	13.42^{c}
SEm±	0.36	0.10	0.40	0.09	0.69	0.88
CD (p=0.05)	1.08	0.03	1.21	0.32	2.21	2.82

3.7. Correlation analysis

Correlation coefficient was estimated between yield and quality contributing characters like oleoresin content and total soluble solids to know the inter relationship among the characters. Yield is complex character controlled by several yield contributing components and is highly influenced by environmental factors. Yield ha^{-1} was positively and significantly associated with oleoresin content (Table 2) (Figure 1) but non-significant correlation associated with TSS.

Table 2: Correlation analysis of yield with oleoresin content and Total soluble solids of garlic

	Yield t ha^{-1}	Oleoresin content	TSS
Yield t ha^{-1}	1		
Oleoresin content	0.750	1	
TSS	0.486	0.269	1

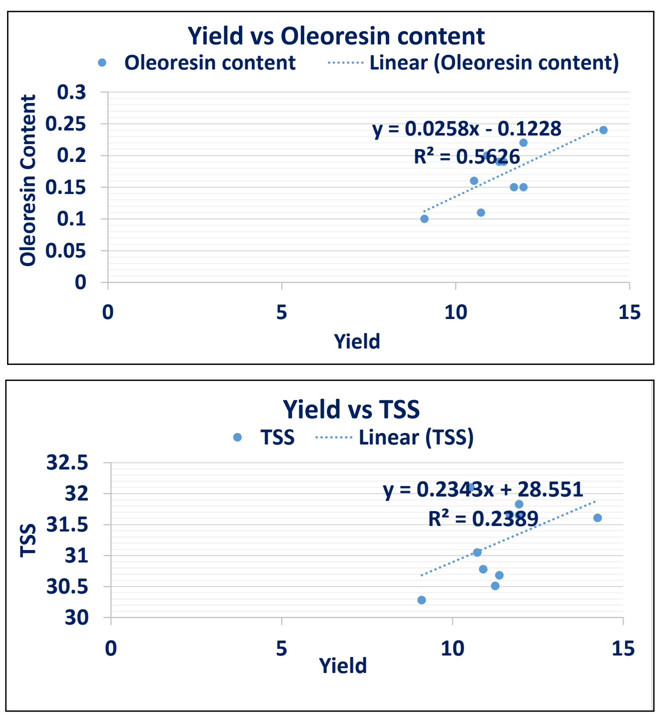

Figure 1: Correlation analysis of yield with oleoresin content and yield with total soluble solids of garlic

4. CONCLUSION

Foliar application of plant growth regulators boosted the Quality characteristics of garlic and based on the current experimental results, GA_3 @ 50 boosted the dry matter content, oleoresin content and restricted the physiological loss of bulb weight but in case of total soluble solids, highest TSS obtain under GA_3 @ 100 ppm. Based on the experiment it may be concluded that foliar application of GA_3 proved the best over other treatments of plant growth regulators

5. ACKNOWLEDGEMENT

We gratefully acknowledge the Uttar Banga Krishi Viswavidyalaya Pundibari, Cooch Behar, West Bengal for giving research field, laboratory and technical support and also to ICAR for financial support to carry out the current research.

6. REFERENCES

Abdhul, H.M., Md Haque, S., Abdul, M., 2002. Influence of growth regulators and their time of application on yield of onion. Pakistan Journal of Biological Sciences 5(10), 1021–1023.

Akhilesh, S., Sharma, K.C., Yudhvir, S., Pathania, N.K., 2010. Effect of pre-harvest treatments and indigenous practices on enhancing storage life of garlic (*Allium sativum* L.). Indian Journal Agricultural Sciences 80, 72–75.

Akter, A., Ali, E., Islam, M.M.Z., Karim, R., Razzaque, A.H.M., 2007. Effect of GA_3 on growth and yield of mustard. International Journal of Sustainable Crop Production 2(2), 16–20.

Anonymous, 2022. E&S Division Department of Agriculture & Farmers Welfare, Agricultural & commercial crops. Available from https://desagri.gov.in/wp-content/uploads/2023/05/Agricultural-Statistics-at-a-Glance-2022.pdf

Anonymous, 2013. Federal Democratic Republic of Ethiopia, Central Statistical Agency, agricultural sample survey of 2012/2013 (2005EC), Volume I, Report on area and production of major crops. Addis Ababa Ethiopia, statistical bulletin 532.

Arora, S.D., Kaur, J., 1999. Antimicrobial activity of spices. Journal of Antimicrob Agents 12, 257–262.

Barros, N.A., Rocha, R.R., Assis, A.R., Mendes, M.F., 2013. Extraction of basil oil (*Ocimum basilicum* L.) using supercritical fluid. 3rd Ibero American Conference on Supercritical Fluids Cartagena de Indias, Colombia.

Castro-Camba, R., Sánchez, C., Vidal, N., Vielba, J.M., 2022. Plant development and crop yield: the role of gibberellins. Plants 11, 2650. https://doi.org/10.3390/plants11192650.

Chiavarini, M., Minelli, L., Fabiani, R., 2016. Garlic consumption and colorectal cancer risk in man: a systematic review and meta-analysis. Public Health Nutrition 9(2), 308–317.

Cochran, W.G., Cox, G.M., 1975. Experimental designs. Wiley, New York.

Dandena, G., Bekele, A., Lemma, D., 2010. Effects of gibberellic acid and 2, 4 dichloro-phenoxy-acetic acid spray on fruit yield and quality of tomato (*Lycopersicon esculentum* Mill.). Journal of Plant Breeding and Crop Science 2(10), 316–324.

Goutam, N., Kumar, D., Kumar, R., Kumar, S., Sharma, S., Dogra, B., 2018. Growth and yield of garlic (*Allium sativum* L.) as influenced by clove weight and plant growth regulators. International Journal of Farm Science 4(3), 49–57.

Govind, S., Maji, R., Kumawat, A., Kumar, S., Saha, S., 2015. Improvement of growth, yield and quality of garlic (*Allium sativum* L.) cv. G-282. through a Novel approach. The Bioscan 10(1), 23–27.

Gubb, I.R., Tavis, M.S.H., 2002. Onion preharvest and postharvest considerations. In: Rabinowitch, H.D., Currah, L. (Eds.), Allium crop science. CABI publishing, UK. pp. 237–250.

Harris, J.C., Cottrell, S.L., Plummer, S., Lloyd, D., 2001. Antimicrobial properties of *Allium sativum* L. (garlic). Applied Microbiology and Biotechnology 57, 282–286.

Hughes, B.G., Lawson, L.D., 1991. Antimicrobial effect of *Allium sativum* L. (garlic), *Allium ampeloprasum* (elephant garlic) and *Allium cepa* L. (onion), garlic compound and commercial garlic supplement products. Phytotherapy Research 5, 154–158.

Kumar, M., Prasad, B., Mandal, G., Kumar, M., 2000. Effect of maleic hydrazide and curing on storage quality *kharif* onion. Environment and Ecology 18(4), 859–862.

Lal, N., Das, R.P., Verma, L.R., 2013. Effect of plant growth regulators on flowering and fruit growth of guava (*Psidium guajava* L.) cv. Allahabad safeda. Asian Journal of Horticulture 8(1), 54–56.

Liu, H., Deng, R., Huang, C., Cheng, Z., Meng, H., 2019. Exogenous gibberellins alter morphology and nutritional traits of garlic (*Allium sativum* L.) bulb. Scientia Horticulture 246, 298–306.

Memane, P.G., Tomar, R.S., Kakade, D.K., Kulkarni, G.U., Chovatia, R.S., 2008. Effect of clove weight and plant growth regulators on growth and yield of garlic (*Allium sativum* L.) cv GG 3. The Asian Journal of Horticulture 3(1), 82–86.

Meng, Y., Lu, D., Guo, N., Zhang, L., Zhou, G., 1993. Anti-HCMV effect of garlic components. Virologica Sinica 8, 147–150.

Mohamed, S.A., Elwahed, A., Mahdy, H.A., El-Saeid, H.M., Hussein, F.A., 2019. Effect of some bio-regulators on yield quantity and quality of garlic plants (*Allium sativum* L.). Middle East Journal of Applied Sciences 09(01), 17–24.

Patel, M.J., Patel, H.C., Chavda, J.C., 2010. Influence of plant growth regulators and their application methods on yield and quality of onion (*Allium cepa* L.). The Asian Journal of Horticulture 5(2), 263–265.

Reuter, H.D., Koch, H.P., Lawson, L.D., 1996. Therapeutic effects and applications of garlic and its preparations. In: Garlic: the science and therapeutic applications of *Allium sativum* L. and related species (HP Koch and LD Lawson eds). Baltimore: Williams and Wilkins, pp 135–213.

Shafeek, M.R., Helmy, Y.I., Omar, N.M., 2015. Stimulants for improving the growth, yield and bulb quality of onion plants (*Allium cepa* L.) under sandy soil conditions. Middle East Journal of Applied Sciences 5(1), 68–75.

Singh, H.D., Maji, S., Kumar, V., Yadav, R.K., 2018. Influence of plant bio-regulators on growth, yield and quality of garlic (*Allium sativum* L.). Bulletin of Environment, Pharmacology and Life Sciences 7(6), 68–71.

Strader, L., Damodaran, S., 2019. Indole 3-butyric acid metabolism and transport in Arabidopsis thaliana. Frontiers in Plant Science 10, 851.

Tameshwar, Prasad, V.M., Lal, N., 2017. Effect of plant growth regulators on gladiolus cv. Jester. Trends in Biosciences 10(20), 3982–3985.

Waskar, D.P., Khedlar, R.M., Garande, V.K., 1999. Effect of post-harvest treatments on shelf life and quality of pomegranate in evaporative cool chamber and ambient conditions. Journal of Food Science and Technology 36(2), 114–117.