STUDIES ON PERFORMANCE OF GARLIC MUTANTS

THESIS

Submitted to
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
in partial fulfillment of the requirements
for the Degree of

MASTER OF SCIENCE
IN
HORTICULTURE
(VEGETABLE SCIENCE)

By

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I hereby declare that, the experimental work and its interpretation in the thesis entitled **"STUDIES ON PERFORMANCE OF GARLIC MUTANTS"** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis / publication of any University or scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged.

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CERTIFICATE

This is to certify that, the thesis entitled **"STUDIES ON PERFORMANCE OF GARLIC MUTANTS"** submitted in partial fulfillment of the requirement for the degree of **"Master of Science in Horticulture (Vegetable Science)"** of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafide research work carried out by **Karande Priyanka Jalindar** under my guidance and supervision.

The subject of the thesis has been approved by the Student's Advisory Committee.

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ACKNOWLEDGEMENT

I have been accompanied and supported by many people. It is a pleasant aspect that I got a golden opportunity to express my gratitude for all of them.

Words are inadequate to thank God for his grace and blessing which enable me to complete my postgraduate degree program successfully.

At every given moment we are absolutely perfect for what is required for our journey. With a sense of high resolve and reverence my sincere and deep sense of gratitude to adorable, chairman **Dr. V. S. Kale, Professor**, Department of Vegetable Science, Dr. P.D.K.V., Akola, for suggesting need based research work.

My advisory committee members Dr. A. M. Sonkamble, Professor and Head Department of Vegetable Science, Dr. P. D. K. V. Akola, Dr. A. P. Wagh, Professor, Department of Vegetable Science, Dr. P. D. K. V. Akola, Dr. Y. V. Ingle, Professor, Department of Plant Pathology, Dr. P. D. K. V. Akola for their inspiring guidance, limitless support, constructive criticism, timely advisement during the entire course of investigation and constant encouragement has undoubtedly helped me to excel in all endeavors. Without them, this dissertation would not have been completed.

I feel honoured for the opportunity bestowed upon me to work under the guidance of Dr. P. K. Nagre, Dean, Faculty of Horticulture, Dr. P.D.K.V., Akola for affectionate in throughout the studies and providing all necessary guidance during the course of investigation.

I sincerely acknowledge my cordial thanks to Dr. Y. B. Tayade, Associate Dean, Post Graduate Institute, Dr. PDKV, Akola and his academic staff of PGI for their kind cooperation throughout the academic year.

I am also thankful to Dr. S. O. Bawkar Farm in Charge, Instructional Farm, Shri P. S. Umbarkar and R.S. Munghate, Senior

Research Assistant, Department of Vegetable Science for their kind cooperation and help throughout the research work.

I am thankful to Dr. A. B. Bhosale, University Librarian Dr. P. D. K. V. Akola for providing me library facilities during research work.

I am extremely grateful to all of my respected seniors Vipul Mali and Ashitosh Pawar.

I would like to express my sincere appreciation to my colleagues and friends Nagnath, Prathmesh, Likesh, Neha, Karishma, Shraddha, Rutuja, Sumit, Dada, Aditya, Shubhangi, Laxmi, Kirtikumar for providing enthusiastic, cheerful, selfless encouragement and co-operation during my post graduate studies.

I am also deeply obligated to all those authors and scientists, past and present, whose contributions were of immense help to understand these research finding as their literature has been aptly cited to undertake the present investigation.

Above all, I bow my head before the almighty God for providing me beloved parents, loving brothers, bosom friends and many well-wishers.

Words are insufficient to place on record my deepest sense of feeling of love, affection and gratitude to my respected father Shri. Jalindar Mahankal Karande and mother Smt. Pushpa Jalindar Karande, my elder sister Pujanka Pawar and Jiju Bhushan Pawar and elder brother Rohit Karande and younger sister Mayuri for their friendly attitude and continuous motivation had encourage me put on right track, lightened by their knowledge and experience and for providing valuable opportunities and for their sacrifice in molding me to a learned and responsible citizen.

Lastly but not the least, I want to express my grateful gratitude to one and all who helped me in one way or the other for the completion of my research work.

Place: Akola. **(Karande Priyanka Jalindar)**
Date: / /2020 Enrollment No.: QQ-3071

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(D) Abbreviations

%	:	Percent sign
/	:	Per
@	:	At the rate of
^0c	:	Degree celcius
Anon.	:	Anonymus
c.f.	:	Cited from
CD	:	Critical Difference
Cm	:	Centimeter
et al.	:	Et alia (and others)
Fig.	:	Figure
G	:	Gram (s)
Ha	:	Hectare
i.e.	:	id est (that is)
Kg	:	Kilogram
L	:	Litre
M	:	Meter
PDKV	:	Panjabrao Deshmukh Krishi Vidyapeeth
Q	:	Quintal
SE (m)	:	Standard error of mean
Sig.	:	Significant
TSS	:	Total Soluble Solid
Viz.	:	Namely
DAP	:	Days After Planting
GM	:	Garlic Mutant
MT	:	Metric ton

(E) THESIS ABSTRACT

a.	**Title of the thesis**	**:**	**" STUDIES ON PERFORMANCE OF GARLIC MUTANTS"**
b.	**Full name of student**	**:**	**Karande Priyanka Jalindar**
c.	**Name and address of Major Advisor**	**:**	**Dr. V. S. Kale** Professor, Department of Vegetable Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.) – 444104.
d.	**Degree to be awarded**	**:**	M.Sc. (Horticulture)
e.	**Year of award of degree**	**:**	2020
f.	**Major subject**	**:**	Vegetable Science
g.	**Total number of pages in the thesis**	**:**	64
h.	**Number of words in the abstract**	**:**	197
i.	**Signature of the student**		
j.	**Signature, name and address of forwarding authority**		

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ABSTRACT

The present investigation on **"Studies on performance of garlic mutants"** was carried out during *rabi* season of 2019-2020 at Instructional farm, Department of Vegetable Science, College of Horticulture Dr. P.D.K.V., Akola.

The experiment was laid out in randomized block design with three replication. Fourteen mutants such as GM-1, GM-2, GM-3, GM-4, GM-5, GM-6, GM-7, GM-8, GM-9, GM-10, GM-11, GM-12, GM-13 and GM-14 were used for study.

The results indicated that the garlic mutants differed significantly as to the different growth characters and yield characters.

Among the tested mutants, GM-8 performed better for most of the growth characters like sprouting percentage, plant height, leaf area, and chlorophyll content index. GM-5, GM-13 and GM-14 required minimum days to sprouting. GM-7 produced maximum number of leaves per plant. Whereas, the mutant GM-11 recorded minimum neck thickness.

For yield parameters GM-8 performed better for character like diameter of bulb, number of clove per bulb, weight of clove, length of clove, width of clove, weight of fresh bulb per plot in kg and weight of fresh bulb per hectare in quintal. The mutant GM-6 took minimum period for maturity of bulb crop. Weight of fresh bulb were maximum in the mutants GM-11.

CHAPTER I

INTRODUCTION

1.1 Background information

Garlic (*Allium sativum*) is a species in the onion genus, *Allium*. Its close relatives include the onion, Chinese onion, chive, shallot, and leek. Garlic is native to northeastern Iran and Central Asia, and has long been a common seasoning worldwide, with a history of several thousand years of human consumption and use. Garlic has been used both as a food flavoring and as a traditional medicine and it was known to ancient Egyptians. In Ancient Rome, it was "much used for food among the poor". China produces some 80% of the world's supply of garlic.

Garlic (*Allium sativum* L.) belongs to Alliacae family is second most important spice bulb crop next onion. The garlic bulb is a compound bulb consisting of segments or small bulblets called cloves. Garlic is propagated by vegetative methods. Garlic has higher nutritive value than other bulb crops. It is rich source of phosphorus, proteins, carbohydrate and ascorbic acid content. Garlic contains amino acid “Allin”, which is odorless and colorless. However, when cloves are crushed, due to enzymatic reaction of allicin, allinase is converted in to diallyl disulphide, gives true garlic oduor (Shankaracharya, 1974). The garlic can yield 0.06 to 0.1% essential oil. The oil is made up of small amount of allyl propyl disulphide and mainly diallyl disulphide (Chopra *et al.*, 1956). Garlic is known herb used for flavoring of foods.

Garlic cloves are used in preparing chutneys, flavouring foods, curry powder, pickles etc. The leaves are nutritive and flattened, they are used in preparing chutney and flavouring vegetables. It has been recognized world-wide as a valuable spice for foods and a popular remedy for various ailments and physiological disorders particularly cardiovascular disease (Ackermann *et al.*, 2001; Kik and Gebhardt, 2001). Garlic juice is given in sterility, rheumatism, pulmonary tuberculosis, impotency, red eyes and cough (Pruthi, 1976). The cloves of garlic are boiled in edible oil like groundnut oil, coconut oil, mustard oil, sesame oil etc. and its extract is dropped in earache. The garlic extract has insecticidal, bactericidal and fungicidal action (Borukh, 1975; Mantis *et al*., 1979 and Sukul *et al*., 1974). Garlic has been used as a medicine to prevent as well as for treatment of various diseases and ailment.

The fresh clove or supplements made from the clove are used as medicine for treating bites, tumours, wounds, snakebite, ulcers, headaches, cancer and heart diseases etc. It also prevents infections such as the common cold, cough as it has anti-bacterial, anti-fungal and anti-viral property (Mahandjiev *et al*., 2001). It reduces the cholesterol in blood. People eating more than three kilogram of garlic per year, have 85 per cent less incidence of stomach cancer than those eating less. Garlic can inhibit reproduction of toxic germs in the stomach. It stops synthesis of a carcinogen named nitrosamine. Garlic is also reduces blood sugar (Brahmachari and Augusti, 1962).

China, India, Spain, Korea and USA are the most important garlic growing countries. China ranks second in area and first in production, India ranks first in area occupies 3,19,000 hectares under garlic and production of 18,62,000 MT. (NHB 2018) and in productivity 5.08 MT/Ha (Anon., 2017).The important garlic growing states are Madhya Pradesh, Rajasthan, Gujarat, Maharashtra, Uttar Pradesh, Andhra Pradesh, Orissa and Tamil Nadu. Rajsthan is leading state to grow this crop in area nearly 112.89 thousand hectares, whereas production is highest in Rajsthan 582.08 thousand MT and productivity is highest in Punjab 11.42MT/ha (Horticultural Statistics at a Glance. 2018). The export was 26527.72 M T (worth Rs. 11858.11 lakh) in 2017-18 (Anon. 2018). In Maharashtra, it is grown in area of 2.58 thousand hectares with annual production of 13.96 thousand MT and productivity is 5.41MT per hectare (Horticultural Statistics at a Glance. 2018).

The improvement in garlic was attempted for higher yield, better quality and storability in India and world. For successful improvement in any crop the knowledge of its genetic nature is important. Garlic is a sterile diploid (2n=2x=16). Since it is a clonally propagated crop, less variability exist. In consequence garlic breeding has been limited to the selection through the pre-existing genetic variability and increase in garlic variability was attempted via mutation breeding and in-vitro techniques. So, it was important to induce variability through mutation. Various physical and chemical mutagens are used to induce mutations in plants (Ahloowalia and Maluszynski, 2001; Goyal and Khan, 2010; Joshi *et al.*, 2011). In all cases, an effective mass propagation system is needed for multiplication of selected elite material for commercial purposes.

1.2 Importance of study

Mutations give beneficial variation for practical plant breeding purpose. During the past seven decades, more than 2252 mutant varieties of different crops have been officially released in world (Maluszynski *et al.*, 2000). Mutation is a sudden heritable change in organism or character generally the structural change in gene. It is produced by change in the base sequence of genes and it can be induced either artificially or spontaneously both in seed and vegetative propagated crops. Induced mutations have recently become the subject of molecular and biotechnology investigation leading to description of the structure and function of related genes. Induced mutations are highly effective in increasing natural genetic resources and have been used in developing improved cultivars of fruits, cereals and other crops (Lee *et al.*, 2002). A great majority of mutant varieties (64%) were developed by the use of gamma rays (Ahloowalia *et al.*, 2004). Hence, mutation-breeding programme has proved to be a successful tool in bringing better in self-pollinated crops.

Mutation breeding is one of the traditional breeding methods in plant breeding. It is relevant with various fields like, molecular biology, biotechnology, cytogenetic and morphology etc. Mutation breeding has become increasingly popular in recent times as an effective tool for crop improvement and a systematic means supplementing existing germplasm for cultivar development in breeding programs (Acharya *et al.*, 2011).

In mutation breeding, controlling the sensitivity of mutagen is the first step. This is normally determined by finding out LD50 values of the mutagen level. Then the material is treated with the optimum dose (Broejrtes and Harten, 1988).

Chemical mutagenesis is a simple approach to create mutation in plants for their development of potential agronomic traits. Mutation methodology has been used to produce many cultivars with increased economic value and to study the genetics and plant developmental phenomena (Aruna and Adamu, 2010).

Mutagens may cause genetic changes in an organism, produce many new promising traits and break the linkages for the improvement of crop plants. Among the chemical mutagens, ethyl methane sulfonate (EMS) is reported to be the most effective and powerful mutagen (Shah et al,. 2008; Minocha and Arnason, 1962; Hajra, 1979). Irradiation has also been successfully used for mutation breeding in ornamental plants and various crops (Song and Kang, 2003) and has proven an adept means of encouraging the expression of recessive genes and producing new genetic variations (Schum, 2003; Song and Kang, 2003; Yoon *et al.*, 1990).

1.3 Objectives of study

Keeping in view the above facts, the research was planned under the title “**Studies on performance of garlic mutants**” with the following objectives:

1. To study the performance of garlic mutant for yield and yield contributing characters.
2. To find out elite garlic mutant for higher yield and yield contributing characters.

CHAPERT II

REVIEW OF LITERATURE

The present investigation was undertaken to study the **"Studies on performance of garlic mutants"**. The relevant literature on the studies on performance of garlic mutants. Was reviewed and presented in this chapter under the appropriate headings.

2.1 General description

2.2 Growth and development

2.3 Performance of genotypes

2.4 The role of variety on garlic yield and yield components

2.5 Genetic variability

2.1 General description:

Kamenetsky *et al*., (2001) reported that sexual propagation in garlic is expected to facilitate the exchange of genetic traits from one genotype to another and to improve garlic cultivars through classical breeding. Garlic does not produce true seed but it is propagated by cloves. Each bulb usually contains a twelve or more cloves and planted separately. Select only larger outer cloves of the best garlic bulbs for planting because larger cloves yield larger size and mature bulbs at harvest.

Figliuolo *et al*. (2001); Ipek *et al*. (2003) according to garlic belongs to the genus *Allium* family Alliaceae, which includes important vegetable crop such as onion (*Allium cepa*), shallots (*A. asacloncum*) and leek (*A. ameloprisum*). Garlic is a diploid species (2n = 2x = 16) of obligated apomixis and propagated vegetatively.

Zheng *et al*., (2007) reported that review outlines innovative methods for garlic breeding improvement and discusses the techniques used to increase variation like mutagenesis and in vitro techniques, as well as the current developments in florogenesis, sexual hybridization, genetic transformation and mass propagation. Sexual sterility of garlic reduces its potential for improvement of desired traits. All in all, these developments in garlic breeding system innovation show that there are good opportunities for the production of improved garlic cultivars which are better suited for the market. Furthermore this review indicates that also on the fundamental level (e.g. garlic florogenesis, genome organization, genetic transformation and embryogenic cell suspension development) large steps forward have been made, but it is also clear that there are still large gaps present in our knowledge.

Hector *et al.*, (2012) reported that garlic is propagated asexually, but shows a high morphological diversity among cultivars. These cultivars have a wide range of adaptation to different environments. Like onion, garlic plants have thin tape shaped leaves about 30 cm long. Roots reach up to 50 cm depth or little more. Heads or bulbs are white skinned, divided into sections called cloves. Each head could have from 6 to 12 cloves, which are covered with a white or reddish papery layer or “skin”.

McLaurin, (2012) revealed not to divide the bulb until ready to plant; early separation decreases yields. Select “seed bulbs” that are smooth, large, fresh, and free from disease. To plant garlic properly, dig a hole or trench, place the unpeeled clove gently into the hole with the pointed side up (the scar [stem] end down) and cover the clove with soil. Setting the cloves in an upright position ensures a straight neck.

2.2 Growth and development

Figliuolo *et al.*, (2001) reported that garlic shows wide morphological and agronomic variations in characteristics such as color and size of the bulb, plant height, number and size of the cloves, days to harvesting, resistance to storage capacity, dormancy and adaptation to agro-climatic conditions.

Ledesma *et al.* (2001) estimated experiment results show the following development stages in garlic: Sprouting: from sowing to 20-30 days, adventitious roots, leaf emergence and total soluble carbohydrate assimilation in seed cloves are observed. Shoot growth: from the end of sprouting until 140 days after sowing. Translocation of photosynthesis to the bulb begins afterwards. Bulb growth: during the inductive stage, from sprouting, no increases in dry weight in total soluble carbohydrates can be observed up to 90 days.

Messiaen and Rouamba (2004) conducted during the life cycle of plant under go successive stages of growth and development, the dormancy of mature cloves, induced by the temperature of 25-30^{0}C is eliminated most quickly at 6-7^{o}C vegetative growth is optimal at 18-20^{o}C. When 12-14 leaves have been produced, bulb swelling is induced at temperature below 20^{0}C. There is considerable physiological variability amongst garlic cultivars. The total growing period varies from 4 months to about 9 months.

Siktberg and Robin (2006) reported that a period of cold followed by a period of light and heat is needed for proper growth of garlic. Although garlic requires low temperatures in preparation for bulb development, increased day length and heat are necessary for bulbs to begin forming.

Paredes *et al*., (2007) reported that garlic is a species of vegetative propagation, showing high morphological diversity. Besides, its clones have specific adaptations to different agro-climatic regions.

Moore and Gough (2010) reported that Garlic is a cool season plant; it makes all vitality and leaf growth while the temperatures are cool and the day is short. As the temperature becomes warm and the day is lengthen, the plant stops making leaves and begins to form bulbs. Cloves or young plants exposed to temperatures of between 0^{o}C and 10^{o}C for one to two months hastens subsequent bulbing under long days.

McLaurin, (2012) reported that experiment leaves will begin to turn brown and tops will fall, indicating maturity. Stop irrigation at this time to avoid bulb discoloration and bulb rots. To ensure bulbs are fully mature, remove the top layer of soil over the top of a few bulbs and check bulbs to make sure they are fully differentiated (division of bulb into distinct cloves). Harvest the garlic when 1/3 to 1/2 of the leaves have died back in this manner.

McLaurin, (2012) reported that matured garlic cloves planted in the fall go through a dormant period. Garlic cloves require a period of 6-8 weeks of cool weather after planting (below $4.4^{O}C$ to undergo vernalization inducement to bulb) by low winter temperatures. During the fall and winter in Georgia, cloves will develop their root systems and initiate some top growth. The clove will swell considerably, forming a globular bulb with many fine roots. A pair of intertwined leaves will emerge from the terminal end of the bulb and will eventually break through the soil, depending on the weather and location. Leaf development will accelerate with flat, dark green leaves on stems reaching a height of 30 cm or more. Proper bulbing is a function of adequate growth, vernalization, and subsequent growth under longer days. As temperatures rise and day length increases, bulb formation begins.

Mishra *et al*., (2013) evaluated twenty garlic genotype during *rabi* season. The height of plants varied from 85 to 95 cm in different genotypes whereas; there was a significant difference in number of leaves, neck thickness/ plant, bulb diameter (cm), bulb size index (cm), no. of cloves/bulb and bulb diameter (cm). The total soluble sugar (TSS) and dry matter (%) were also varied significantly in each genotype. The entries showed variable degree of pungency. Per hectare yield (q/ha) of garlic genotypes varied from 133.7 - 150.1, being lowest in G- 4 and highest in G-305. Considering the growth, yield, quality, disease resistance and other attributes characters as a positive trait of selection and yield potentiality also with other parameters, the lines G- 189, G- 176, G- 302, G- 304, G-369, G- 366, G-222 and G- 378 were found promising compared to check varieties (G-1, G- 41, G-50, G-323 and G282).

Aslam Tarique *et al*., (2016) evaluated twenty-five genotypes were laid out in Randomized Block Design with three replications. The cloves of each genotype were planted manually on 28th October 2014 in flat beds of 3x2 m size at a spacing of 15x10 cm. The genotypes were categorized on the basis of plant height, number of leaves, leaf length, leaf width, foliage colour, pseudostem length, polar and equatorial diameter of bulb, number of cloves per bulb, skin colour of bulb and cloves and days to harvesting, which differentiate the garlic genotypes. The material assessed in the present investigation possessed wide range of variation for various characters observed. The genotypes were characterized for their morphological characters.

2.3 Performance of genotypes

Burba *et al*., (1982) reported that Large clove size showed taller plants in garlic. Baten *et al*., (1990) examined that the tallest plant was produced when large seed cloves were used as propagules and the small seed cloves produced the shortest ones. Further, Rahim *et al*. (1984) stated that the plant height declined as the size of mother bulb reduced. Hossain (2008) and Talukder (2002) observed that plant height was positively corralled with the size of clove. The tallest plant was obtained from the large seed clove followed by medium and small ones. Similar result was also reported by most of the researchers (Ara *et al*., 1998; Baten *et al*., 1990; Duimovic and Bravo, 1979; El-Habbasha *et al*., 1985).

Chadha *et al*., (1990) reported a study on onion and garlic in India. Area and production of onion and garlic in the world and India, export from other countries and factors limiting production and productivity in India are described. The research infrastructure, varietal improvement and production technology of onions and garlic in India, Kharif onion cultivation in North and East India, seed production and distribution, post-harvest technology, all year round production of onions, disease and pest control and future research requirement are discussed.

Sabur and Mollah (1993) studied on constraints of production and marketing of species in Bangladesh. The study reported that the real price of garlic, onion and turmeric increased significantly by 3.83 percent, 3.58 percent and 3.17 percent respectively during the study period. They examined that the storage facilities for spices, particularly cold storage, were limited and seasonal price variations largely dependent on the perishability of spices.

Mahmood (1995) studied the relative profitability of selected spices, compared with their competing crops. Among all competing crops onion was the most profitable crop with net profit of Tk. 26673, which was followed by potato (Tk. 25875.30), lentil (Tk. 20652.1) and garlic (Tk. 16755.49) in respect of net return per hectare.

Hossain (1996) conducted an experiment in Bangladesh Agricultural University, Mymensingh. Plant highest, leaf number, pseudo stem and bulb diameter, dry matter content of foliage, bulb weight and bulb yield were found significantly higher for mulched plants.

Trevisan *et al*., (1996) revealed that marketable yield and percentage of high quality clove were greatest with cloves planted on 18 may that 27 April and 14 June.

Shrivastava (1998) examined on economics of agro-forestry in Indo-Gangetic alliums of Uttar Pradesh in India. The study was managed under an agro-silvicultural system with Eucalyptus and a mixture of agricultural crops e.g. mustard, gram, coriander, onion, garlic and turmeric. Intercropping was to be carried out over the first 3 years. Detailed cost data were given including initial expenditure, actual and projected working costs of Eucalyptus plantation for the first 6 years and costs of intercropping. Total profit from the first and second cycles was predicted as Rs.28362125 and Rs.75548135 respectively with cost/benefit ratio of 4.0 and 7.2. The system generated 112960 man-days of employment in the first rotation.

Bhuiyan (1999) carried out an experiment on the effect of planting time, mulch and irrigation on the growth and yield of garlic. In this experiment it was found that the highest yield was obtained from 25 October planting (3.92 t/ha) followed by 9 November (3.58t/ha), 25 November (3.55t/ha) and 8 December (3.08t/ha). December 23 planting gave the lowest yield (2.31t/ha). It was observed that earlier planting gave the highest plant height, highest total number of leafs per plant, diameter of bulb, weight of bulb, weight if individual bulb.

Rahman (2002) examined effect of spacing on the growth, yield and storability of some garlic germplasm. The pant spacing showed significant effect on most of the parameters studied. Wider spacing (20x20cm) give the maximum weight of bulb; the closest spacing

(10x10cm) produced maximum yield of bulb ((9.19 t/ha), the lowest yield (3.67 t/ha) was obtained from wider spacing. The performance of garlic bulb during storage varied significantly due to spacing and different germplasm. Wider spacing showed the lowest result in percentage of insect infested bulbs and weight 8 loss (4.92 percent and 24.01 percent respectively). The germplasm G21 showed minimum percentage of insect infestation and weight loss (8.91 percent and 25.24 percent respectively).

Harun-Or-Rashid (2002) reported that production potential and profitability in TPS garlic intercropping system at different spacing and row arrangement. The spacing for TPS was 50x50cm, while that of garlic were 10x10cm, 15x10cm and 15x15cm. The row arrangements were single, double and alternative. The highest gross return (Tk. 169590/ha), Net return (Tk. 74782/ha), LER (1.38) and BCR (1.80) were recorded from potato+garlic at 15x15cm spacing as double row arrangement.

Al-Safadl and Faoury (2004) reported that, this study aimed 01 evaluating the ability of 2S local and introduced cultivars of garlic (*Allium sativum* L.) to tolerate salinity in vitro. Five culture media (M1, M2, M3, M4, and M5) containing different concentrations of NaCl and $Cacl_2$, (0 and O. 17 and 9. 34 and 18, 51 and 27, 68 and 36 mM, respectively) were used in the study. The cvs, Kisswany and Hungary were the most tolerant cultivars to salinity where the average shoot height of plants grown on M5 was more than 50% of the control.

Gupta *et al*., (2007) studied on 14 different collections of garlic and observed significant variability in characters like days to sprout, days to harvest, plant height, leaf length, leaf number, neck diameter, neck height, clove diameter, clove number, bulb weight and yield. High heritability was found for all the characters except for days to sprout. High genetic gain was observed for neck diameter, bulb weight, yield, clove number and neck height.

Pervin *et al*., (2014) reported that field performance and genetic variation of 25 germplasm of garlic. For the study of heritability on broad sense, it was very high in plant height (99.16%), length of leaves

(97.37%), fresh weight of leaves (99.94%), yield of bulb per hectare (96.40%), fresh weight of root (87.21%), dry weight of root (81.25%), number of cloves per bulb (86.94%).

Esho (2015) conducted an experiment with five garlic genotype at Mosul University, Iraq. Results review that Heritability in broad sense was higher for most of traits. While genetic advance was maximum for most of characters except in number of leaves / plant and plant height. High heritability coupled with high genetic advance for characters like head diameter, head weight, and high values of heritability supplemented with moderate genetic advance. It also indicated higher response for selection of high yielding genotype as these traits are governed by additive gene action.

Nandini *et al.*, (2018) nine different garlic genotypes were evaluated at Zonal Agricultural and Horticultural Research Station, Babbur Farm, Hiriyur, during the year of 2016-17 with the main objective to select the promising genotypes for yield and qualitative traits. Among nine genotypes, maximum total soluble solids was recorded in the genotype Agrifound White (40.38 %), whereas the least was recorded in Bhima Purple (32.81 %). Maximum pyruvic acid content was recorded in Yamuna Safed (27.19 µ moles per g fresh weight), while the minimum pyruvic acid content was recorded in Agrifound Parvati (21.15 µ moles per g fresh weight). The highest polar diameter (4.42 cm), equatorial diameter (3.96 cm) and average bulb weight (19.01 g) was noticed in the genotype Bhima Purple. The highest yield was recorded in the genotype Bhima Purple (8.65 t/ha) which was on par with Yamuna Safed-3 (8.59 t/ha), while the minimum yield was observed in the genotype Bhima Omkar (5.20 t/ha).

2.4 The role of variety on garlic yield and yield components

Welsh (1981) studied the yield performances of twenty five garlic germplasms were evaluated and gave quit satisfactory, yielding 6.5-9.4 t/ha in Bangladesh agricultural university (BAU). Garlic germplasm G-49 produced the highest yield (9.4 t/ha) followed by G-53 (7.9 t/ha) and G-27 (7.6 t/ha), the National Seed Board registered the G-49 garlic germplasm as garlic-3 variety for mass production. Allicin content of local germplasm (G-13) is quite high (2.4 mg/ml) (Rahim. M., 2011)

Lokhande and Pawar (1988) estimated that data on 10 quantitative characters for 33 *Allium sativum* cultivars grown during *rabi*. Yield per plot was found to be significant and positively associated with bulb weight, leaf length and plant height.

Kohli and Fageria (1992) estimated that plant height, dry leaf weight and number of cloves per bulb in garlic were positively and significantly correlated with yield. Plant height was found positively correlated with dry leaf weight and number of cloves per bulb.

Rajalingam and Haripriya (2000) conducted 20 aggregatum onion (*Allium cepa* var. *aggregatum*) and showed that the yield components, including plant height leaf length, leaf breadth, number of leaves, weight of plant, number of bulbs, bulb length, bulb diameter and volume of bulb exhibited significant positive association with yield.

Golani *et al*., (2006) conducted correlation study in garlic and showed that there was significant and positive association of bulb yield with number of leaves per plant, bulb length, bulb girth and bulbs weight.

Bishaw *et al*., (2008) evaluated to the variety must be selected from a list of recommended or local varieties. Apart from its adaptation, the variety should have high yield potential, tolerance to biotic and abiotic stresses, good marketability and high consumer preferences. Unless the variety meets the requirements of farmers and consumers, it is less likely to be widely adopted and therefore, the demand for seed cannot be addressed. The character of yield reflects the performance of all plant components and might be considered as the final result of many others i.e. every plant contains an inherent physiological production capacity that operates on energy required for normal plant performance though all accessions do not have the same inherent physiological capacity to yield. Breeders commonly find yield to be a very complex array of plant component interactions and by the manipulation of these genetic systems yield is improved as the result of plant efficiency improvement.

Alam *et al.*, (2010) the results reported that the plant height, number of leaves per plant, fresh and dry weight of bulb, length and diameter of bulb, total number of cloves, yield per plot and yield per hectare were significantly influenced by the treatment of the experiments under study. Results showed that among different germplasm, germplasm G19 was the best for yield and other yield related parameters.

Anwar and Gouda (2012) carried out an experiment during 2010/2011 and 2011/2012 seasons six garlic entries (five cvs namely Sids–40, Egaseed-1, Chinease, Balady, Balady El-Wady and the clone Egaseed-2) were tested for their growth, bulb characteristics and total yield per feddan under Mansoura, Dakahlia Governorate environmental conditions. Major variations were observed among all garlic entries for all the studied parameters. Sids-40 cultivar gave the maximum bulb weight clove weight and total fresh yield in relative to the other garlic cvs. On the contrary, Balady El-Wady and Balady garlic cvs occupied the last position in this respect. The superiority of different garlic cvs grown under Mansoura conditions according to their production can be arranged as follows in descending order, Sids-40 Egaseed-2, Egaseed-1 Chinease, Balady and Balady El-Wady.

Patil *et al.*, (2012) carried out an field experiment on 41 genotypes of garlic and reported that neck thickness, average bulb weight, bulb length, bulb diameter, average weight of cloves and days required for harvesting were positively and significantly correlated with yield. Number of cloves per bulb showed positive and non-significant correlation with yield per hectare and days required for harvest.

Agarwal and Tiwari (2013) conducted experiment on twenty one genotypes of garlic (*Allium sativum* L.) were screened for yield and purple blotch susceptibility under field conditions for two years. Reaction of genotypes to purple blotch disease differed significantly during both years but the pooled analysis reported that most of the variations were due to genotype × environment interaction. Nine genotypes viz., G-1, G-50, G-323, PGS-4, PGS-14, G-313, PGS-99-1, PGS-98 and PGS-99-2 fell into the category of resistant, five showed moderately resistant reaction to disease (PGS-13, PGS-17, KGS-1, HG-17 and PGS-99-3), four were mild susceptible (G-41, DG-2, DARL-52 and DARL-53) whereas three (G-282, DG-1 and RAUC-5) were susceptible. Genotype PGS-313 exhibited maximum yield (199.6 quintal/ha) followed by PGS-99-2 (154.9 quintal/ha). A strong and negative correlation was observed between purple blotch incidence and bulb weight at genotypic level (-0.99).

Khatun *et al*., (2014) the results revealed that there was significant difference among the varieties in respect of plant height (cm), weight of bulb with leaf plant, weight of bulb without leaf plant and number of bulb which might have increased yield significantly. The highest plant height was obtained from BARI Roshun 1 and the highest weight of bulb with leaf plant, weight of bulb without leaf plant, number of bulb were recorded from BARI Roshun 2 which was significantly different from other varieties during two successive years. The highest yield (8.11and 8.04 t ha-1 during two successive years) was obtained from BARI Roshun 2 which was significantly different from other varieties. The lowest yield (6.38 and 5.50 t ha-1 during two successive years) was obtained from local variety.

Ijaz *et al*., (2015) conducted a study to understand the genetic association between yield and its related traits among garlic genotypes. They revealed that garlic bulb yield was associated with plant biomass, bulb diameter, number of bulbs and number of cloves per bulb. The plant traits like leaf area, number of leaves and plant height had minor effects on bulb yield.

Prajapati *et al*., (2016) conducted experiment on 30 genotypes of garlic and reported that number of cloves per bulb followed by pseudostem diameter, number of leaves per plant, leaf width, pseudostem length, equatorial diameter and days to maturity had the high positive direct effect on bulb yield per plant. It was also observed that the high negative direct effect was exerted by leaf length followed by plant height, average weight of ten cloves and polar diameter.

Bhatt *et al.*, (2017) reported 16 diverse indigenous genotypes of garlic and reported that gross bulb yield was found significantly and positively associated with number of cloves per bulb and weight of ten cloves.

Chatoo *et al.*, (2017) conducted that eleven genotypes of garlic (*Allium sativum* L.) were assessed for yield and other yield related attributes. Analysis of variance showed significant difference among all the genotypes for all the characters under study. Little differences were found between magnitude of phenotypic coefficient of variation (PCV) and genetic coefficient of variation for all the traits under study indicated that the trait were least affected by environment and are genetically controlled. High heritability coupled .with high genetic advance as per cent of mean was recorded for total bulb yield (97.66), TSS (96.13), average weight of ten cloves (96.06), average weight of ten bulbs (93.73), no. of cloves (92.14) and marketable yield (89.54) indicating that additive genetic variance was predominant. Among the evaluated germplasm lines, SKAU-G-05 performed better in respect of total bulb yield (308.73 q/ha), marketable yield (290.21 q/ha), average weight of ten bulb (57.93 g), number of cloves (61.33) and no. of pseudo stem length (3.36 cm). Therefore, the results of the present study revealed that good scope for garlic improvement is possible through selection. Furthermore, among the genotypes, SKAU-G-05 being superior for yield and other yield traits might be used by the breeders for further clonal selection.

Umamaheswarappa *et al.*, (2018) conducted an experiment on ten genotypes (NRCWG-5, Agri Found White, NRCWG-6, G-378, G-324, G-282, NRCWG-3, Rajalli Gadde, NRCWG-4, and Agri Found Parvathi were supplied under All India Network Research Project on Onion and Garlic(AINRPOG) and evaluated for growth and yield parameters under Central Dry Zone of Karnataka to identify the high yielding genotypes for this location and were tested in randomized complete block design with three replications at spacing of 15X10 cm during the Rabi season of 2013-14. The characters studied were plant height(cm), Number of leaves, leaf length, leaf width (cm), Pseudo stem length(cm), Polar diameter and equatorial diameter of bulb(cm), Average bulb weight(g), Number of Cloves per bulb, 10 Cloves weight(g), % Marketable yield(q/ha), Marketable yield(q/ha) and Total yield(q/ha). Among the genotypes tested, the results revealed that, significantly the highest total yield (62.72q/ha) and marketable yield (51.33/ha) was observed in the genotype Rajalli Gadde. The traits polar diameter of bulb (3.93 cm), equitorial diameter of bulb (4.50 cm) and Average bulb weight (81.93 g) were recorded significantly the highest in the genotype Rajalli Gadde.

2.5 Genetic variability

Korla and Rastogi (1979) examined eleven genotypes of garlic and reported that genotypes GC-8 and GC-9 had the maximum yield whereas, maximum bulb size and number of cloves per bulb were produced by genotype GC-11.

Korla *et al*., (1981) examined that genetic variability in 11 cloves of garlic. The study reported significant clonal differences for number of cloves per bulb and weight of 20 cloves in both years and for bulb yield per plot and bulb girth in one year. Clone X Year interactions were significant for the first three of these traits. Genotypic coefficient of variation and heritability estimates were highest for number of cloves per bulb and weight of 20 cloves.

Mehta and Patel (1985) estimated genetic variability in 40 genotypes of garlic and revealed that clove weight and bulb yield per plant had highest genotypic coefficient of variation with high heritability (> 90%) and genetic advance, suggesting there by involvement of additive gene action for the traits.

Pandey and Singh (1989) reported that maximum plant height, number of leaves per plant, number of cloves per bulb, weight of bulb and yield in genotype HG-1 .While studying genetic variability on 32 diverse genotypes of garlic by Shaha *et al*., (1990) and reported that high phenotypic coefficient of variation (PVC) and genotypic coefficient of variation (GCV) for weight of 50 cloves, plant height and bulb weight. High heritability along with high genetic advance was observed for plant height and weight of 50 cloves.

Vidyasagar and Monika (1993) reported genetic parameters of variability on 22 cultivars of onion and reported high phenotypic and genotypic coefficient of variation (PCV and GCV) for sprouting losses, bolting rotting and 7 total losses. High heritability along with high genetic advance (GA) for bolting, sprouting, rotting and total losses. Plant height, bulbs maturity, polar diameter, shape index, bulb size and TSS had high heritability.

Singh *et al*., (1995) estimated a field experiment on genetic variability and correlation in nine cultivars of onion. Bulb weight, bulb yield/ha and leaves per plant had high genotypic coefficients of variation (21.95, 20.72 and 20.28 respectively), heritability (97.88, 96.95 and 95.92 per cent, respectively) and genetic advance (44.80, 42.85 and 40.96 per cent, respectively). Bulb yield showed strong positive correlation with bulb weight and neck girth.

Lopez *et al*., (1997) studied genetic variability and correlations in white clonal type garlic characters viz., equatorial diameters, weight and clove number of leaves per bulb. The highest level of phenotypic variance was recorded for bulb weight and number of cloves.

Thakur *et al*., (1997) carried out an experiment at Ludhiana on 53 clones of garlic. The results indicated significant variation in all the characters studied i.e. bulb yield per hectare, weight per bulb, number of cloves per bulb, plant height, leaves per plant and leaf breadth. Yield ranged from 76.9 q/ha (G-15) to 167.1 q/ha (G-57) and the range for bulb weight was 9.6 q/ha (G-15) to 20.8 q/ha (G-57).

Mohanty and Prusti (2001) examined 12 onion cultivars in Orissa and evaluated the heritability and genetic advance of important economic characters and found high values of heritability associated with moderate to high genotypic coefficient of variation and genetic gain were manifested by bulb yield, bulb weight, plant height, number of leaves per plant and neck thickness, which might be attributed to additive gene action regulating their inheritance and phenotypic selection.

Agrawal and Tiwari (2004) examined the genetic variability in 21 genotypes of garlic (*Allium sativum*) and observed sufficient variability among the genotypes for yield and yield attributing traits. High genotypic and phenotypic variance along with high degree of genotypic coefficient of variation and phenotypic coefficient of variation were observed for clove weight, bulb yield and number of cloves per bulb whereas moderate values were obtained for bulb 8 weight and leaf area index. The number of leaves per plant showed the lowest values. High estimates of heritability were recorded for most of the traits including yield except for the number of leaves per plant showing the lowest heritability. High genetic advance was exhibited by clove weight, bulb yield and number of cloves per bulb.

Khar *et al.*, (2005) reported that genetic studies on 47 genotypes of garlic and observed a wide range of variability. Phenotypic and genotypic coefficients of variation were high for neck thickness, number of leaves, weight of bulb, weight of clove and yield. Heritability and genetic advance were also high for yield, weight of clove and weight of bulb.

Futane *et al.*, (2006) estimated eight garlic genotypes during Rabi 2002-03 at Akola condition and recorded the variety G-41 highest values for number of leaves per plant, bulb fresh weight, bulb diameter, total soluble solids and bulb yield. G-282 recorded the highest values for plant height, 100 clove weight and clove thickness, while, G-50 recorded the highest values for number of cloves per bulb and clove length, whereas Godavari took the minimum days to maturity.

Ananthan and Balakrishnamoorthy (2007) reported range, phenotypic and genotypic coefficient of variance, heritability and genetic advance for thirteen characters of sixty two genotypes of onion and recorded higher estimates of genotypic and phenotypic coefficients of variation for bulb weight, reducing sugars, non-reducing sugars, total sugars, total loss and sulphur content.

Yaso (2007) evaluated that high values of heritability, GCV%, and GS% were observed for total and marketable yield and bulb weight. While moderate to high estimates of heritability coupled with low GCV% noticed for days to maturity.

Yadav *et al.*, (2012) carried out an experiment on 56 genotypes of garlic and observed high phenotypic and genotypic coefficient of variation for bulb yield per plant, bulb yield per hectare, bulb yield per plot and average weight of 10 cloves, however, days to maturity, number of leaves per plant, at 30, 60 and 90 days after planting, leaf length (4th leaf), plant height at 30 and 90 days after planting and polar diameter were found to exhibit low estimates of phenotypic and genotypic coefficients of variation. High heritability coupled with high genetic advance was observed for equatorial diameter of bulb, average weight of ten cloves and plant height at 60 days after planting. High heritability with moderate genetic gain was recorded for pseudostem diameter and polar diameter of bulb. High heritability associated with low genetic advance as percentage of mean was exhibited by days to maturity

Dhall and Brar (2013) reported that the maximum value of genotypic coefficient of variation and phenotypic coefficient of variation for clove weight, cloves per bulb and clove diameter. High heritability along with high genetic 9 advance was observed for plant height, bulb weight and cloves per bulb which suggested that these characters were controlled by additive gene effects.

Kumar *et al.*, (2015) reported that 41 genotypes of garlic collected from different agro climate zone of Jammu and assesses for yield, quality and other agronomic characters. The analysis of variance revealed greater variability for all the traits studied except number of leaves per plant, leaf length, dry matter content, total soluble solid and equatorial. High heritability coupled with high genetic advance as percent of mean was observed for plant height, average weight of cloves, yield per hectare, leaf length, equatorial diameter and average weight of bulbs.

Sandhu *et al*., (2015) studied that 40 diverse genotypes of garlic and reported that phenotypic coefficients of variation were higher in magnitude than genotypic coefficients of variability. High heritability coupled with moderate genetic gain was expressed in number of cloves per bulb, leaf width, alcohol insoluble solids and allicin content.

Sharma *et al*., (2016) evaluated 131 garlic genotypes for twelve morpho agronomic traits and reported significant genetic variation for all the traits which showed sufficient variability in germplasm. High estimates of the genotypic coefficient of variance and phenotypic coefficient of variance were observed for plant height, bulb weight per plant, leaf length, number of cloves per bulb and pseudostem height. High heritability was obtained for all traits and coupled with moderate genetic advance was recorded for clove weight, bulb weight per plant, pseudostem height, polar diameter of bulb, equatorial diameter of bulb and number of cloves per bulb.

Bhatt *et al*., (2017) conducted an experiment with 16 diverse indigenous genotypes of garlic and reported a significant genetic diversity among all the studied genotypes. High genotypic coefficient of variance and phenotypic coefficient of variance were observed for volume of bulbs followed by weight of ten uniform cloves in comparison of other characters. Moderate genotypic coefficient of variance and phenotypic coefficient of variance were observed for dry weight of bulb, neck thickness, number of cloves per bulb, plant height and 10 bulb yield. High heritability was observed for bulb yield, weight of ten cloves, number of cloves per bulb, dry weight of bulb and TSS.

Ranjitha *et al*., (2018) conducted an experiment with 150 genotypically diverse genotypes of garlic were studied for assessment of genetic variability, heritability and genetic advance for fifteen yield contributing and economically important character at Vegetable Research Station, Junagadh Agricultural University, Junagadh, during *rabi* 2016-17. Based on the mean performance, the genotypes RGP-498, RGP-501, RGP-487, RGP-619 and RGP-114 were identified as most promising genotypes for bulb yield per plant. In general, estimates of phenotypic coefficient of variation (PCV) were found higher in magnitude than corresponding genotypic coefficient of variation (GCV) for all the traits studied. The higher magnitude of coefficient of variation at genotypic as well as phenotypic levels was recorded for bulb yield followed by bulb weight, while high heritability was recorded for clove weight. The highest genetic advance was observed for bulb yield, while clove weight had high heritability coupled with moderate genetic advance as per cent of mean. It is suggested that selection for these traits will directly increase bulb yield per plant, in garlic crop.

CHAPTER III

MATERIAL AND METHODS

The present investigation **"Studies on performance of garlic mutants"** was carried out at Instructional Farm, Department of Vegetable Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *rabi* season of the year 2019-2020.

3.1 Material

The material under study was constituted of 14 garlic mutants which were collected from Instructional Farm, Department of Vegetable Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola as listed below in table.

Table 1. Name of the garlic mutants under study

Sr. No.	Name of garlic mutant	Source
1	Garlic mutant 1 (GM-1)	Department of Vegetable Science, Dr. P.D.K.V., Akola
2	Garlic mutant 2 (GM-2)	Department of Vegetable Science, Dr. P.D.K.V., Akola
3	Garlic mutant 3 (GM-3)	Department of Vegetable Science, Dr. P.D.K.V., Akola
4	Garlic mutant 4 (GM-4)	Department of Vegetable Science, Dr. P.D.K.V., Akola
5	Garlic mutant 5 (GM-5)	Department of Vegetable Science, Dr. P.D.K.V., Akola
6	Garlic mutant 6 (GM-6)	Department of Vegetable Science, Dr. P.D.K.V., Akola
7	Garlic mutant 7 (GM-7)	Department of Vegetable Science, Dr. P.D.K.V., Akola
8	Garlic mutant 8 (GM-8)	Department of Vegetable Science, Dr. P.D.K.V., Akola
9	Garlic mutant 9 (GM-9)	Department of Vegetable Science, Dr. P.D.K.V., Akola
10	Garlic mutant 10 (GM-10)	Department of Vegetable Science, Dr. P.D.K.V., Akola
11	Garlic mutant 11 (GM-11)	Department of Vegetable Science, Dr. P.D.K.V., Akola
12	Garlic mutant 12 (GM-12)	Department of Vegetable Science, Dr. P.D.K.V., Akola
13	Garlic mutant 13 (GM-13)	Department of Vegetable Science, Dr. P.D.K.V., Akola
14	Check (Buldhana Local)	Department of Vegetable Science, Dr. P.D.K.V., Akola

3.1.1 Experimental site

The investigation **"Studies on performance of garlic mutants"** was carried out at Instructional Farm, Department of Vegetable Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during *rabi* season of 2019-2020.

3.2 Climate and weather conditions

Akola is located in the sub-tropical and semi-arid zone at latitude of 20.7002^{0}N and longitude of 77.0082^{0}E. The altitude of the place is 286 m from mean sea level. The mean annual precipitation on the basis of last fifteen years average is 802 mm, which is received nearly from the South-West monsoon from June to October. The mean annual maximum and minimum and minimum temperature are 34^{0}C and 20^{0}C, respectively. The relative humidity ranges from 54.5 per cent in *rabi* season in Akola. Thus has hot dry summer and moderate cold winter. The hail storms are not common in this area.

The meteorological data in respect of maximum and minimum temperature, rainfall and relative humidity was recorded at University campus during the course of study for the period from October 2019, to March 2020.

3.3 Soil

The experiment at farm was having black cotton soil with uniform texture, colour and good drainage capacity. The experiment at plot was developed into fine tilth by harrowing and ploughing.

3.4 Experimental Details

1	Name of crop	:	Garlic (*Allium Sativum* L.)
2	Family	:	Alliacae
3	Number of replication	:	3
4	Number of treatments	:	14
5	Design	:	Randomized Block Design (RBD)
6	Total No. of plots	:	42
7	Layout	:	Raised bed

8	Place of work	:	Instructional Farm, Department of Vegetable Science, Dr. P.D.K.V. Akola.
9	Plot size	:	2m×1m
1	Spacing	:	10cm×10cm

3.5 Cultural operations

3.5.1 Preparatory tillage

The experimental field was prepared by two ploughing and two criss cross harrowing. Clod crushing was done for obtaining fine texture of soil. Clod crushing was done with the help of rotavator. Prior to last harrowing, well decomposed farm yard manure and was incorporated into the field at the rate of 25 tones ha^{-1} and mixed thoroughly in the soil. Later the plot were laid out as per plan. Stubbles and weeds were cleaned from the experimental area and smoothened with wooden plank to prepare fine raised bed.

3.5.2 Planting

The plots were irrigated two days prior to the date of planting to enable smooth dibbling of cloves in moist soil. These cloves were planted at the spacing of 10 cm × 10 cm and 2.5 cm deep keeping the growing point upwards after seed treatment. The planted cloves were then covered gently with the soil and slightly pressed. After planting, light irrigation was given. The planting was carried out on 19th November 2019.

3.5.3 Fertilizer application

The recommended dose of fertilizer i.e. 100:50:50 Kg nitrogen, phosphorus and potassium ha^{-1} were applied. The full dose of phosphorus and potassium i.e. 50 kg ha^{-1} in the form of Single super phosphate and Murate of potash, respectively and half dose of nitrogen i.e. 50 kg ha^{-1} in the form of urea were applied at the time of planting. Remaining half dose of nitrogen was applied 30 days after the application of basal dose.

Plate 1 General view of experimental plot

Plate 2 Field visit

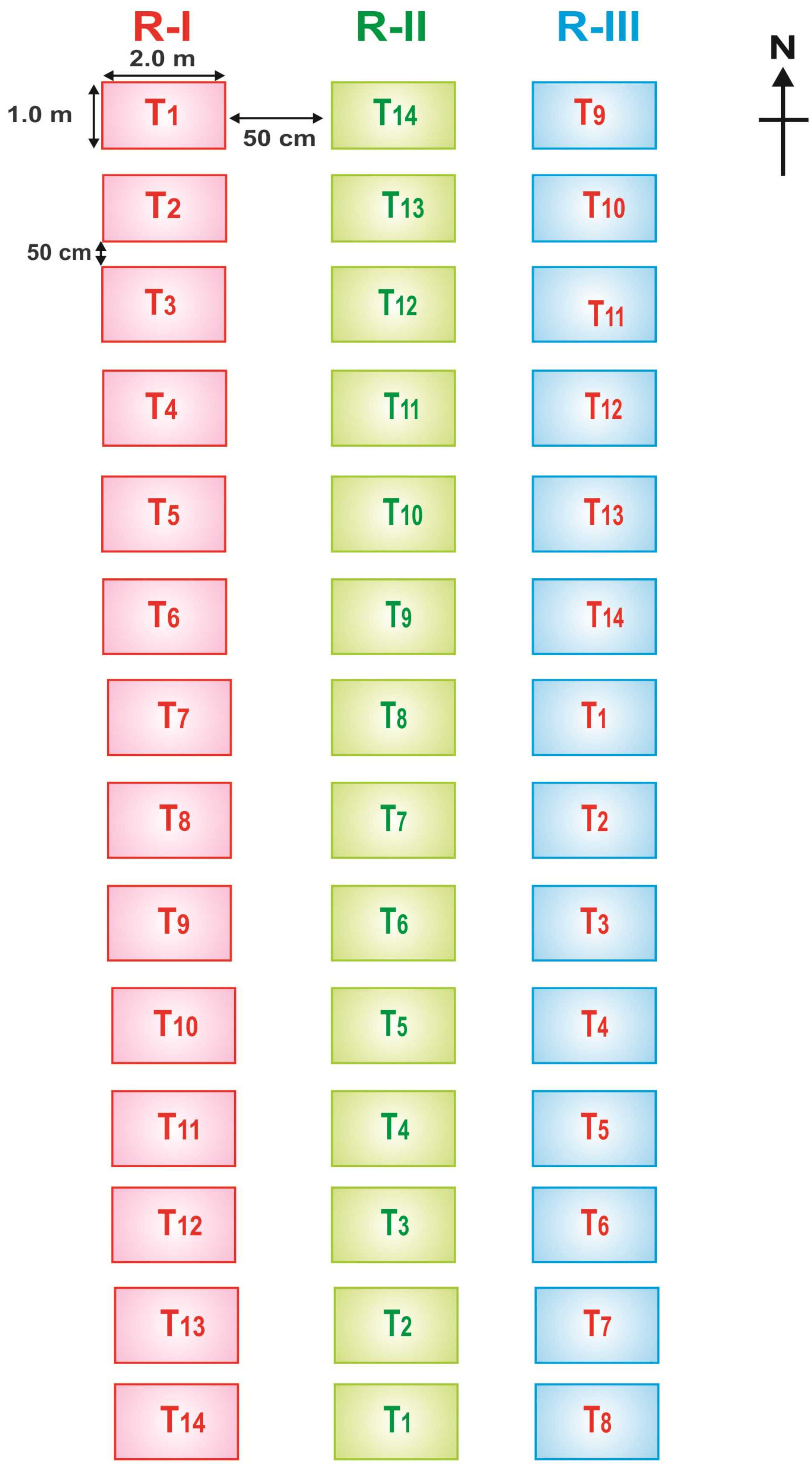

Fig. 1. Plan of layout

3.5.4 Irrigation

The experimental plot, was regularly irrigated with the help of drip irrigation. Crop received 18 irrigations during entire life period. Irrigation was stopped when the plants begin to show yellowing of top leaves, around 50 per cent of the total leaves showing bending towards soil surface of the crop forthcoming maturity.

3.5.5 Interculture

In order to keep the research plots free from weeds and have good aeration to the roots, five hand weeding and earthing up were given.

3.5.6 Plant protection measures

The incidence of thrips was observed during the growing period of crop. Accordingly it was controlled by an application of rogour @ 1.5 ml liter-1. Similarly, drenching with carbandazim @ 2-3 g liter-1 and mancozeb @ 2.5 g liter-1 alternately at an interval of 15 days was undertaken to prevent the infection of fungal diseases.

3.6 Harvesting

Harvesting was undertaken by uprooting the plants by hand. The plants were ready for harvesting when 50 percent of its leaves were fall down or dried, as and when the top portion, turn yellowish (neck fall stage). The bulb were lifted, cleaned and tied in bunches with foliage.

3.7 Curing

The plants were lifted, cleaned and the leaves tied and the bulbs were cured under the shade for 8 days. After the curing was over, the cured bulb along with dried stalks were kept under ambient condition and hanged with the bamboo just below the roof level, with sufficient ventilation.

3.8 Observations

For recording the growth observations, five plants were selected randomly from each plot. Growth observations of these five selected plants from each plot were recorded at 30 days interval. The details of pre-harvest and postharvest observations recorded are given below.

3.9 Pre harvest observations

3.9.1 Sprouting per cent (%)

In an area of 2m x 1m, the total number of germinated plants were counted after 15 days of planting. And accordingly, the sprouting per cent was calculated using formula.

Percent sprouting

$$\text{Percent sprouting} = \frac{\text{Number of cloves sprouted}}{\text{Total number of cloves used for planting}} \times 100$$

3.9.2 Height of plant (cm)

The height of plant was recorded from ground level to the top of all the observation plants from each plot and after computing the mean, it was recorded as height of the plant in centimeter (cm). The height of plant was recorded after 60 days of planting.

3.9.3 Leaf area (cm^2)

The average length and breadth of the leaves were used to calculate leaf area and expressed as square centimeter (cm^2).

3.9.4 Stem girth (cm)

The stem girth below the joint of leaf lamina was measured with the help of vernier caliper and the measurements were expressed in centimeter (cm).

3.9.5 Number of leaves

The number of fully grown, green and photo-synthetically active leaves were recorded and average number of leaves per plant was worked out from five randomly selected plants.

3.10 Post harvest observations

3.10.1 Days required for maturity

The date of maturity i.e. 50 per cent neck fall of growing leaves towards the ground from each plot was noted. Then, the days required for maturity was calculated and recorded accordingly.

3.10.2 Number of cloves per bulb

The cloves from each bulb were separated. The number of cloves in each bulb, were counted of all the observational plants from each plot. Accordingly, the mean was calculated and considered as number of cloves per bulb.

3.10.3 Weight of fresh bulb (g)

Garlic bulb of all observational plants were cured in shade for 8 days and then average weight of single bulb was taken and recorded in grams (g).

3.10.4 Diameter of fresh bulb (cm)

The diameter of bulb of all the observation plants from each plot was recorded with the help of Vernier Caliper. Accordingly, the average diameter of bulb was calculated. It was recorded as diameter of bulb in centimeter (cm).

3.10.5 Length of clove (cm)

The length of the clove of all observational plants from each plot was measured with the help of Vernier caliper. Accordingly, the average length of clove was calculated. It was recorded as length of clove in centimeter (cm).

3.10.6 Width of clove (cm)

Width of clove was measured by Vernier caliper in each treatment. The mean value of five tagged plants was expressed as clove width in centimeters.

3.10.7 Weight of cloves per bulb (g)

The cloves from each bulb were separated. Then the average weight of each single clove was taken and recorded in grams (g).

3.10.8 Yield of fresh bulb per plot (kg)

The bulbs from the net plot area were cured completely. Dried leaves were separated and the bulbs were weighed and expressed as yield per plot in kilograms (kg).

3.10.9 Yield of bulb per hectare (q)

On the basis of bulb yield of net plot, the total bulb yield per hectare was calculated and expressed as yield per hectare in quintals (q).

4.1 Quality parameters

4.1.1 Total soluble solids (^{0} Brix)

The total soluble solids were determined by using ERMA Hand Refractometer and expressed as ^{o} Brix (Ranganna, 1986). Sample of 2 - 3 drops was collected from clove pulp used for analyzing the total soluble solids.

5.1Statistical Analysis

5.1.1 Randomized Block Design (RBD)

The collected data were suitably formulated and the standard method of statistical analysis for randomized block design was carried out as given by Gomez and Gomez (1984). For statistical treatment effect, standard errors of mean and critical differences were calculated at 5 per cent level of significant and correlation equation were worked out for garlic genotypes and treatments with selected variables.

CHAPTER IV

RESULTS AND DISCUSSION

The present investigation was undertaken during the period of 2019-2020 with research entitled **"Studies on performance of garlic mutants"** comprising fourteen mutants of garlic with following objectives:

Objectives

1. To study the performance of garlic mutants for yield and yield contributing characters.
2. To find out elite garlic mutants for higher yield and yield contributing characters.

The characters studied to investigate the above objectives were days to sprouting, sprouting percentage (%), plant height (cm), leaf area (cm^2), number of leaves per plant, stem girth (cm), days to maturity of bulb, weight of fresh bulb (g), diameter of fresh bulb (cm), number of cloves per bulb, weight of clove (g), length of clove (cm), width of clove (cm), yield of fresh bulb per plot (kg), yield of fresh bulb per hectare (q) and chlorophyll content index (cci).

Results obtained during the present investigation are presented here under following heads.

4.1 Growth observations

4.2 Yield observations

4.3 Quality Observation

4.1 Growth observations

The growth contributing characters were recorded for the following variables viz., days to sprouting, sprouting percentage, plant height, number of leaves per plant, stem girth, leaf area and chlorophyll content index and crop duration in during *Rabi* 2019-2020.

4.1.1 Days to Sprouting

The data presented in Table 2 revealed that days to sprouting were significantly differs among various garlic mutants.

Table. 2 Days to sprouting of different garlic mutants

Mutants	Days to sprouting
GM-1	6.00
GM-2	6.00
GM-3	6.33
GM-4	7.33
GM-5	5.00
GM-6	7.00
GM-7	5.33
GM-8	5.66
GM-9	6.66
GM-10	5.66
GM-11	6.66
GM-12	5.33
GM-13	5.00
Check (Buldhana Local)	5.00
F test	Sig.
SE(m)±	0.25
CD @ 5%	0.72

Among garlic mutants the minimum days to sprouting was observed under mutants GM-5 (5 days), GM-13 (5 days) and Check (Buldhana Local) (5 days) and which were found at par with mutants GM-7 (5.33 Days), GM-8 (5.66 days), GM-10 (5.66 days) and GM-12 (5.33 days), while maximum days to sprouting was recorded under mutants GM-4 (7.33 days).

4.1.2 Sprouting percentage

Observations on sprouting percentage were significantly influenced by garlic mutants are presented in table 3 and depicted in Fig 3.

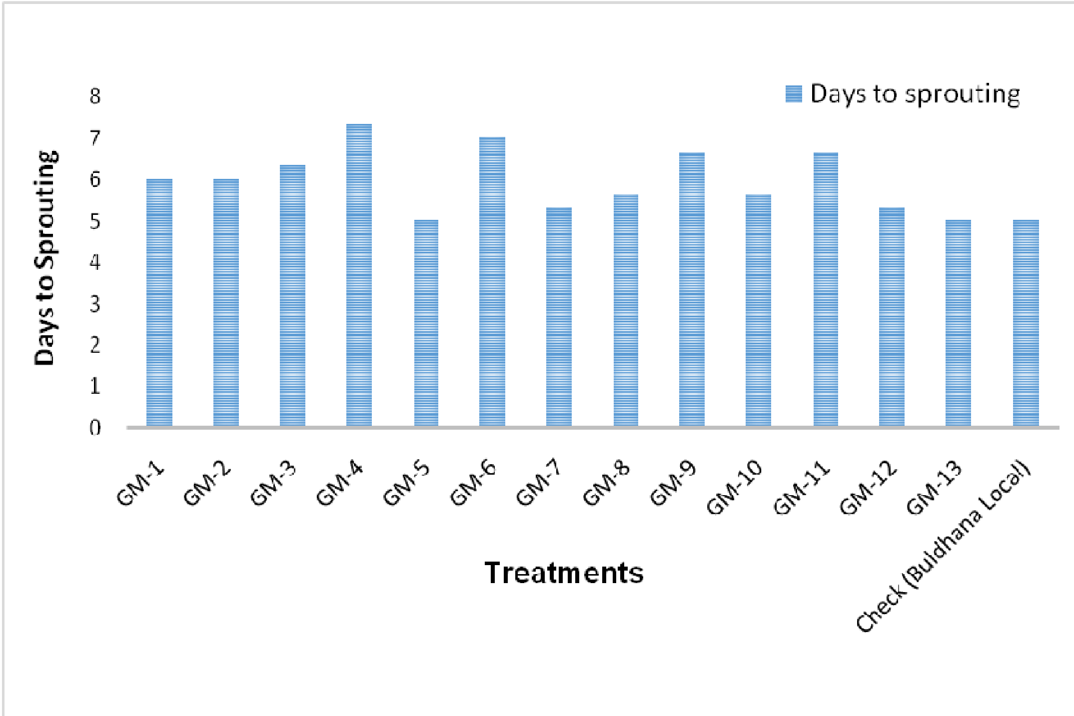

Fig.2: Days to Sprouting of different garlic mutants

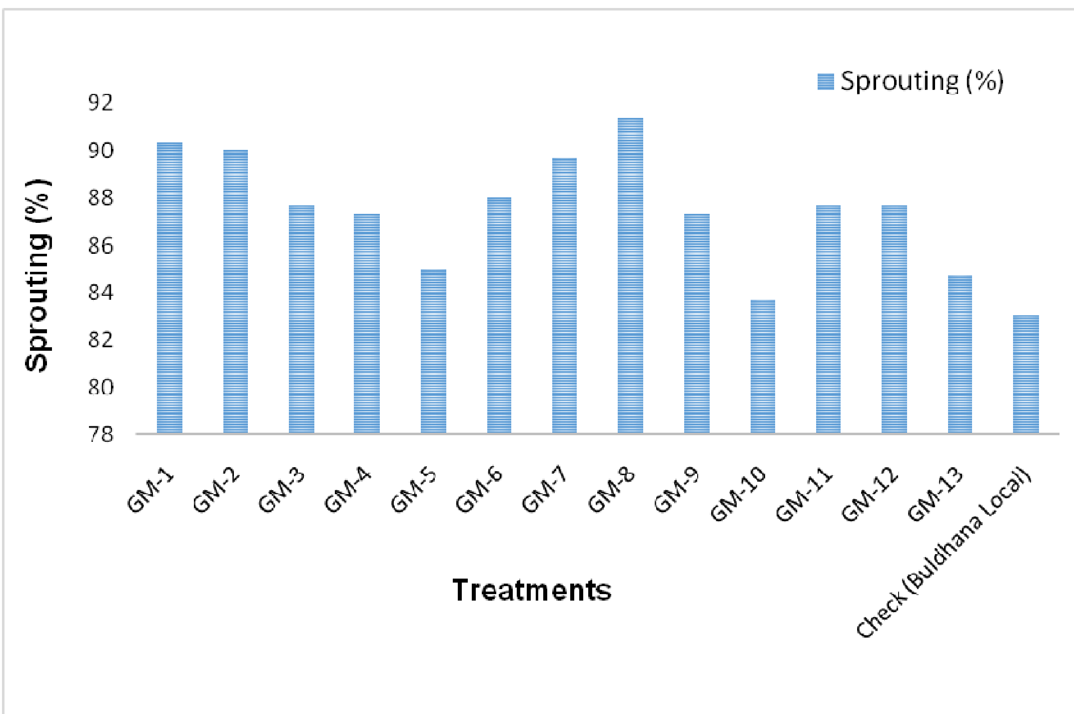

Fig.3: Sprouting Percentage of Different Garlic Mutants

Table. 3 Sprouting percentage (%) of different garlic mutants

Mutants	Sprouting (%)
GM-1	90.33
GM-2	90.00
GM-3	87.66
GM-4	87.33
GM-5	85.00
GM-6	88.00
GM-7	89.66
GM-8	91.33
GM-9	87.33
GM-10	83.66
GM-11	87.66
GM-12	87.66
GM-13	84.66
Check (Buldhana Local)	83.00
F test	Sig.
SE(m)±	1.20
CD @ 5%	3.49

The data from Table 3 revealed that the sprouting percentage of garlic mutants significantly influenced by garlic mutants.

Among garlic mutants the highest sprouting percentage was recorded under mutants GM-8 (91.33%), which was found at par with GM-1 (90.33%), GM-2 (90.00%) and GM-7 (89.66%), while minimum Sprouting percentage was recorded under mutants Check (Buldhana Local) (83.00%).

4.1.3 Plant height (cm)

The height of the plant as influenced by garlic mutants are presented in Table 4 and depicted in Fig 4.

Table. 4 Plant height (cm) of different garlic mutants

Plant height (cm)			
Mutants	**60 DAP**	**90 DAP**	**120 DAP**
GM-1	36.20	60.43	62.76
GM-2	33.86	61.90	64.56
GM-3	38.73	62.53	63.20
GM-4	35.13	58.06	59.06
GM-5	38.66	52.20	53.86
GM-6	38.53	56.60	57.26
GM-7	37.83	59.86	62.20
GM-8	40.80	63.73	70.06
GM-9	35.73	55.46	56.80
GM-10	33.86	53.13	54.80
GM-11	38.73	56.40	57.40
GM-12	38.83	61.70	63.36
GM-13	35.03	59.73	60.73
Check (Buldhana Local)	32.40	50.76	54.53
F test	Sig.	Sig.	Sig.
SE(m)±	1.23	1.65	1.13
CD @ 5%	3.56	4.79	3.30

The data presented in Table 4 indicate that the Plant height as influenced by different garlic mutants was recorded at 60 days, 90 days and 120 days after planting.

Among all garlic mutants, at 60 days after planting, plant height was maximum in GM-8 (40.80cm) and was found at par with the mutants GM-1 (60.43cm), GM-2 (61.90cm), GM-3 (62.53cm), GM-12 (61.70cm), and GM-13(59.73cm). Whereas, minimum plant height was recorded in mutants Check (Buldhana Local) (32.40cm).

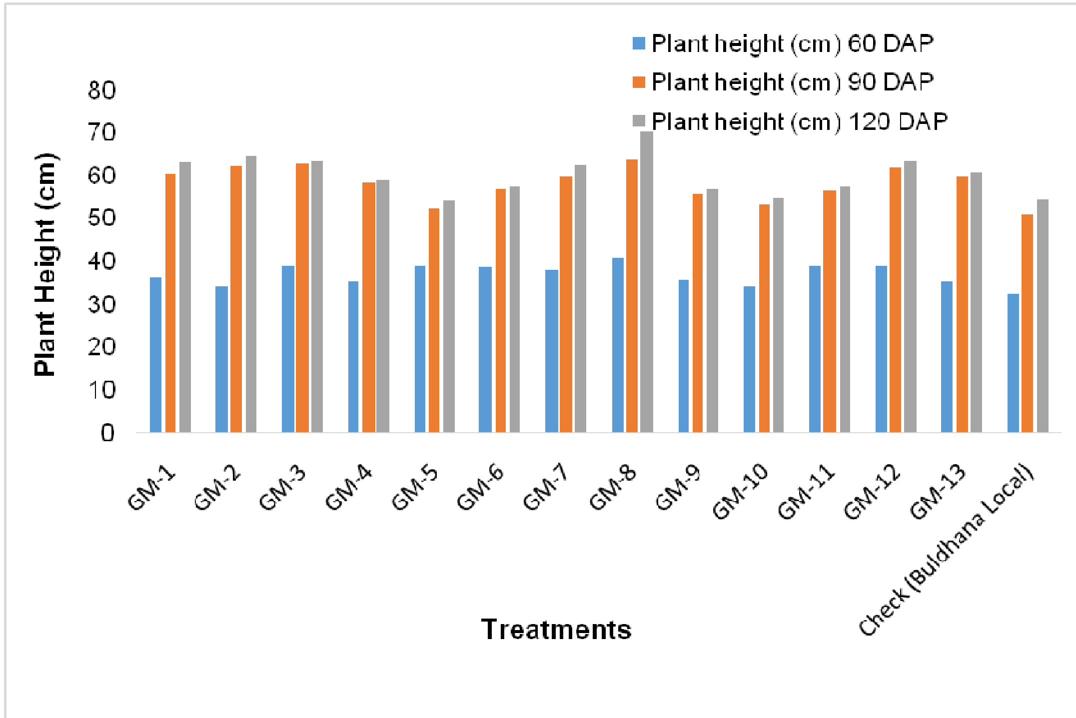

Fig. 4: Plant height (cm) of different garlic mutants

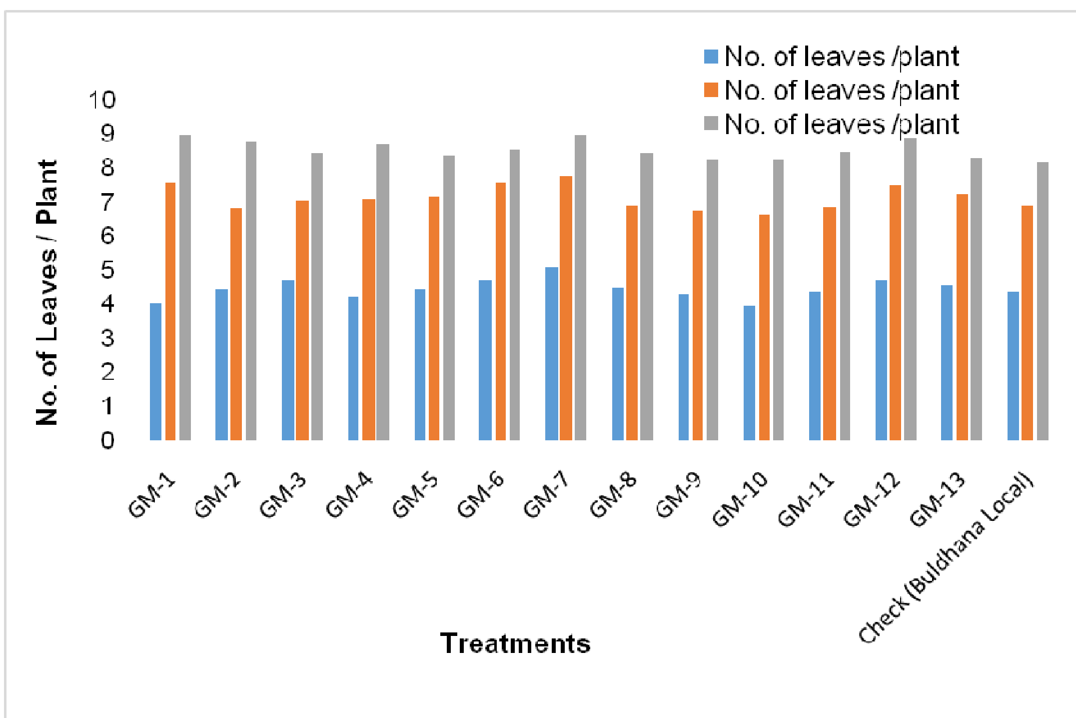

Fig. 5: Number of leaves per plant of different garlic mutants

whereas, at 90 days after planting plant height was maximum in GM-8 (63.73cm) and which was found at par with the mutants GM-3 (38.73cm), GM-5 (38.66cm), GM-6 (38.53cm), GM-7 (37.83cm), GM-11 (38.73cm), and GM-12 (38.83cm). Whereas, minimum plant height was recorded in mutants Check (Buldhana Local) (50.76cm).

Similarly, at 120 days after planting, maximum plant height was recorded in GM-8 (70.06cm). Whereas, minimum plant height was recorded in mutants GM-5 (53.86cm).

4.1.4 Number of leaves per plant

The results obtained in respect of number of leaves per plant were recorded periodically at 60 days, 90 days and 120 days from planting are presented in Table 5 and depicted in Fig 5.

Table. 5 Number of leaves per plant of different garlic mutants

No. of leaves /plant			
Mutants	**60 DAP**	**90 DAP**	**120 DAP**
GM-1	4.00	7.53	8.93
GM-2	4.40	6.80	8.73
GM-3	4.66	7.00	8.40
GM-4	4.20	7.06	8.66
GM-5	4.40	7.13	8.33
GM-6	4.66	7.53	8.53
GM-7	5.06	7.73	8.93
GM-8	4.46	6.86	8.40
GM-9	4.26	6.73	8.20
GM-10	3.93	6.60	8.20
GM-11	4.33	6.82	8.46
GM-12	4.66	7.46	8.86
GM-13	4.53	7.20	8.26
Check (Buldhana Local)	4.33	6.86	8.13
F test	Sig.	Sig.	Sig.
SE(m)±	0.18	0.23	0.16
CD @ 5%	0.54	0.69	0.46

The data presented in Table 5, clearly showed that, the number of leaves per plant were significantly influenced by garlic mutants at all the stages of garlic mutants. The number of leaves per plant at 60 days after planting were maximum in GM-7 (5.06) and which were found at par with the mutants GM-3 (4.66), GM-6 (4.66), GM-12 (4.66), and GM-13 (4.53). Whereas, minimum number of leaves per plant were recorded in mutants GM-10 (3.93).

Whereas, at 90 days after planting number of leaves per plant were maximum in GM-7 (7.73) and was found at par with the mutants GM-1 (7.53), GM-2 (6.80), GM-3 (7.00), GM-4 (7.06), GM-5 (7.13), GM-6 (7.53), GM-8 (6.86), GM-9 (6.73), GM-11 (6.82) and Check (Buldhana Local) (6.86). Whereas, minimum number of leaves per plant was recorded in mutants GM-10 (6.60).

Among all the garlic mutants, at 120 days after planting number of leaves per plant were maximum in GM-1 (8.93) and GM-7 (8.93) and which were found at par with the mutants GM-2 (8.73), GM-4 (8.66), GM-6 (8.53) and GM-12 (8.86). Whereas, minimum number of leaves was recorded in mutants Check (Buldhana Local) (8.13 leaves/plant).

4.1.5 Stem girth (cm)

The data obtained in respect of stem girth of garlic were recorded at 60 days and 120 days after planting and are presented in Table 6 and depicted in Fig 6.

The data presented in Table 6 recorded significant differences in respect of stem girth of garlic as influenced by different garlic mutants.

Among all the garlic mutants, at 60 days after planting stem girth was minimum in GM-11 (0.47cm) and which was found at par with the mutants GM-1 (0.77cm), GM-3 (0.69cm), GM-4 (0.86cm), and GM-5 (0.72cm),GM-8 (0.81cm), GM-9 (0.82cm), GM-10 (0.73cm), GM-12 (0.67cm) and GM-13 (0.55cm). Whereas, maximum stem girth was recorded in mutants Check (Buldhana Local) (1.31cm).

Table. 6 Stem girth (cm) of different garlic mutants

Stem girth (cm)		
Mutants	**60 DAP**	**120 DAP**
GM-1	0.77	1.23
GM-2	1.16	1.49
GM-3	0.69	1.73
GM-4	0.86	1.72
GM-5	0.72	1.13
GM-6	0.98	1.01
GM-7	1.30	1.61
GM-8	0.81	1.32
GM-9	0.82	1.61
GM-10	0.73	1.78
GM-11	0.47	0.96
GM-12	0.67	1.67
GM-13	0.55	1.18
Check (Buldhana Local)	1.31	1.72
F test	Sig.	Sig.
SE(m)±	0.14	0.16
CD @ 5%	0.42	0.48

Similarly, at 120 days after planting stem girth was minimum in GM-11 (0.96cm) and which was found at par with the mutants GM-1(1.23cm), GM-5 (1.13cm), GM-6 (1.01cm), GM-8 (1.32cm) and GM-13 (1.18cm). Whereas, maximum stem girth was recorded in mutants GM-10 (1.78cm).

4.1.6 Leaf area (cm^2)

Observations on leaf area (cm^2) were significantly influenced by garlic mutants.

The data presented in Table 7 recorded significant differences in respect of leaf area of garlic as influenced by different garlic

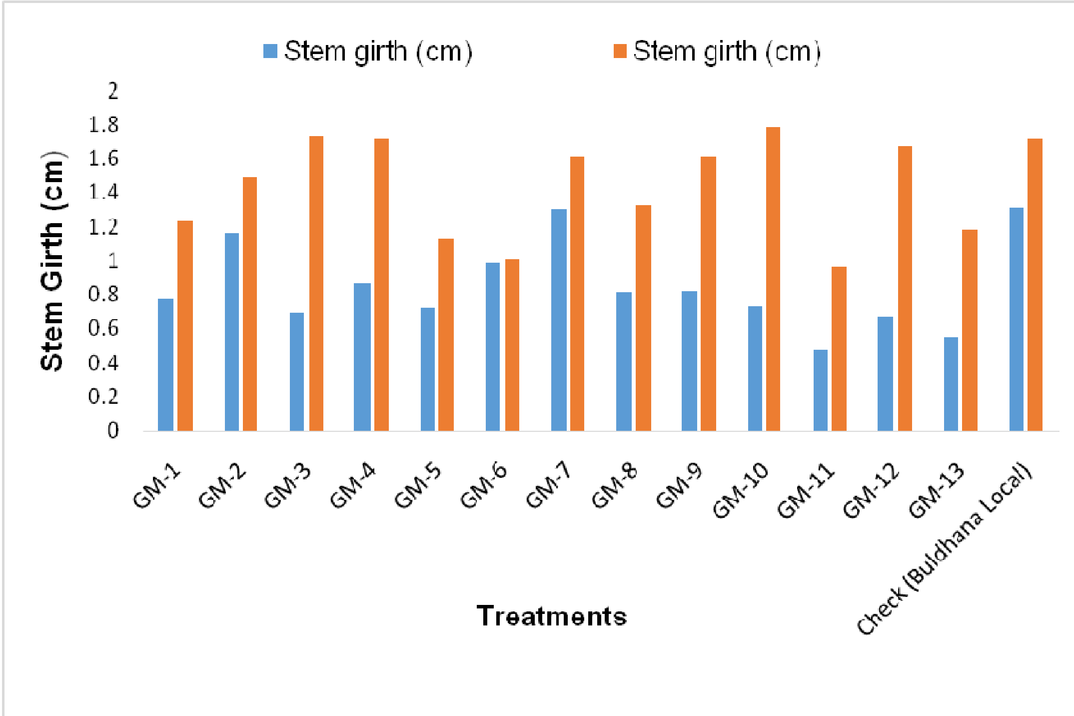

Fig. 6: Stem girth (cm) of different garlic mutants

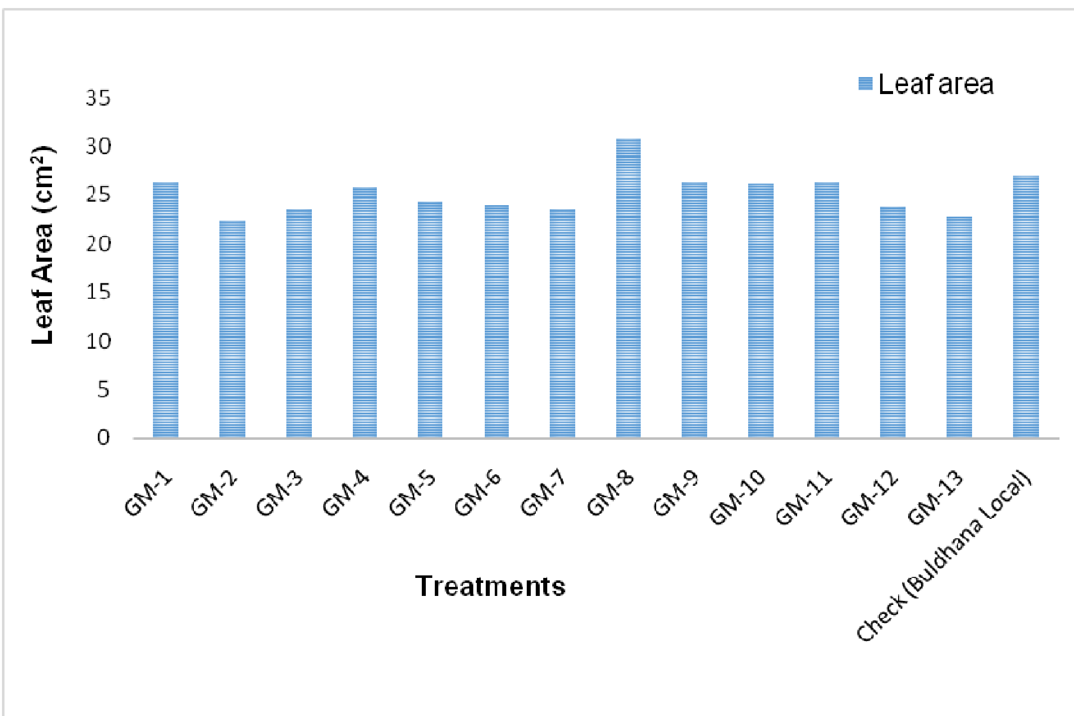

Fig. 7: Leaf area (cm^2) of different garlic mutants

mutants. Leaf area was maximum in GM-8 (30.66cm^2) and which was found at par with the mutants Check (Buldhana Local) (26.94cm^2). Whereas, minimum leaf area was recorded in mutants GM-2 (22.24cm^2).

Table. 7 Leaf area (cm^2) of different garlic mutants

Mutants	**Leaf area (cm^2)**
GM-1	26.27
GM-2	22.24
GM-3	23.51
GM-4	25.66
GM-5	24.28
GM-6	23.84
GM-7	23.44
GM-8	30.66
GM-9	26.17
GM-10	26.06
GM-11	26.20
GM-12	23.70
GM-13	22.68
Check (Buldhana Local)	26.94
F test	Sig.
SE(m)±	1.50
CD @ 5%	4.35

4.1.7 Chlorophyll content index (cci)

Observations on chlorophyll content index (cci) were significantly influenced by garlic mutants are presented in Table 8 and depicted in Fig 8.

Table. 8 Chlorophyll content index (cci) of different garlic mutants

Mutants	Chlorophyll content index (cci)
GM-1	57.33
GM-2	55.09
GM-3	55.81
GM-4	57.59
GM-5	55.90
GM-6	48.28
GM-7	52.96
GM-8	60.40
GM-9	55.06
GM-10	52.24
GM-11	55.23
GM-12	54.80
GM-13	50.73
Check (Buldhana Local)	59.53
F test	Sig.
SE(m)±	1.81
CD @ 5%	5.27

The data from Table 8 revealed that the chlorophyll content index (cci) was maximum in GM-8 (60.40) and which was found at par with the mutants GM-1 (57.33), GM-3 (55.81), GM-4 (57.59), GM-5 (55.90), GM-11 (55.23) and Check (Buldhana Local) (59.53). Whereas, minimum chlorophyll content index was recorded in mutants GM-6 (48.28).

4.2 Yield characters

The yield characters namely Days required to maturity of bulb, Number of cloves per bulb, Weight of fresh bulb (g), Diameter of fresh bulb (cm), Length of clove (cm), Width of clove (cm), Weight of clove (g), Yield of fresh bulb per plot (kg) Yield of fresh bulb per hectare (q) were recorded in individual plants for all the mutants.

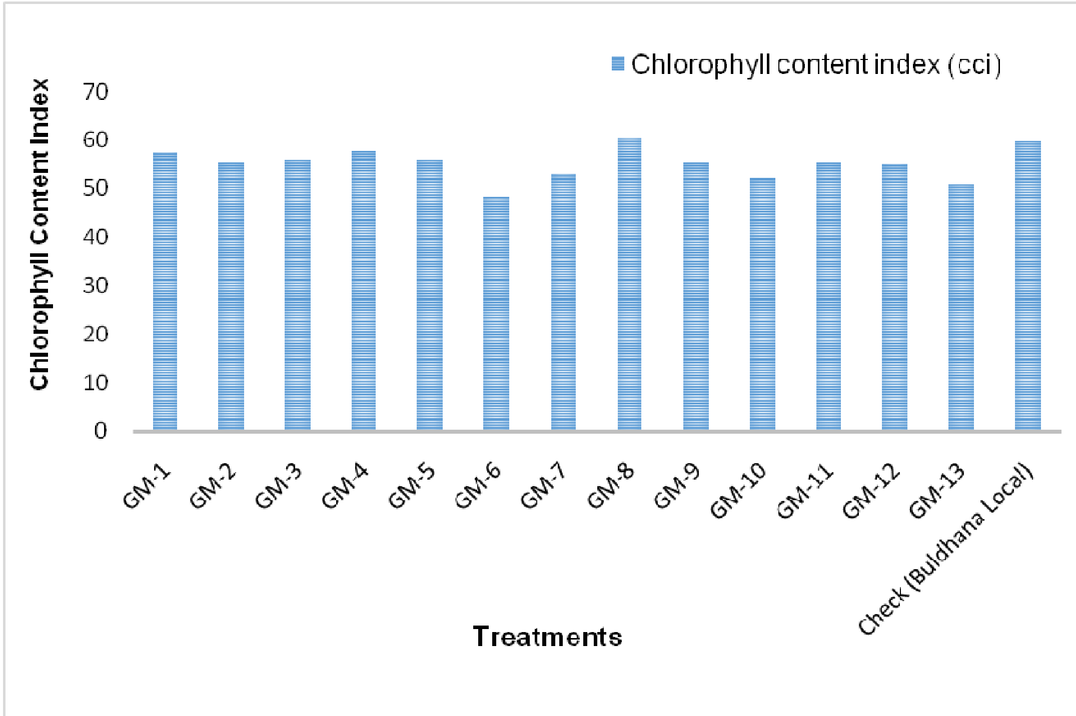

Fig. 8: Chlorophyll content index (cci) of different garlic mutants

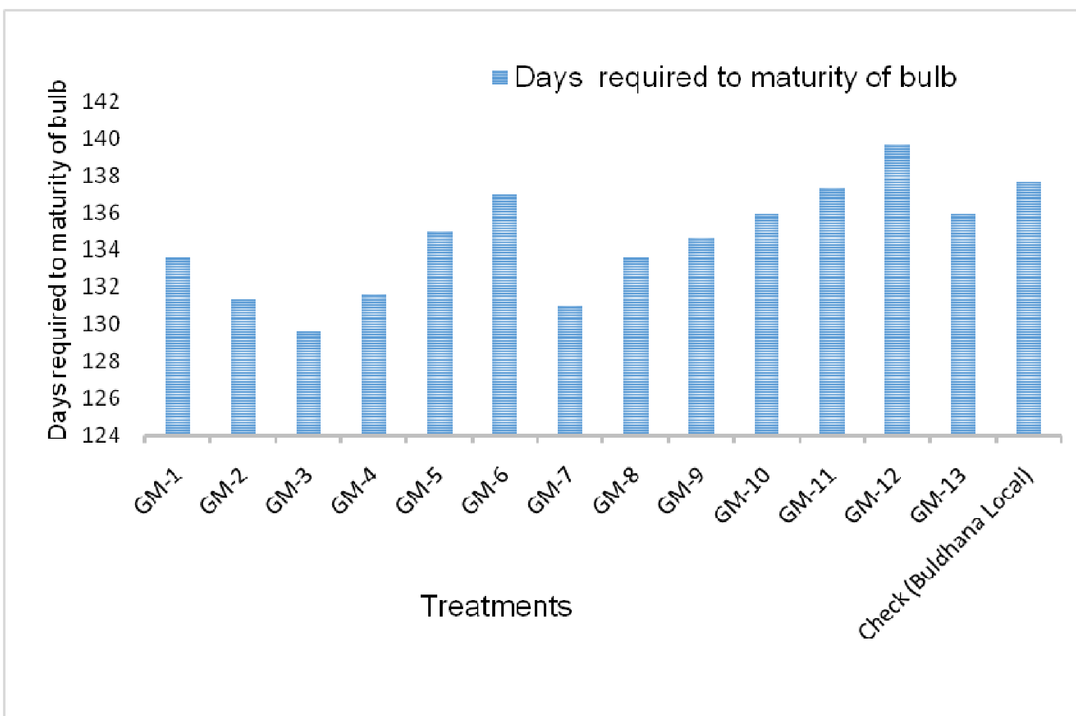

Fig. 9: Days required to maturity of bulb of different garlic mutants

4.2.1 Days required to maturity of bulb

The data in respect of days required for maturity as influenced by different garlic mutants are presented in Table 9 and depicted in Fig 9.

Table. 9 Days required to maturity of bulb of different garlic mutants

Mutants	Days required to maturity of bulb
GM-1	133.66
GM-2	131.33
GM-3	129.66
GM-4	131.66
GM-5	135.00
GM-6	137.00
GM-7	131.00
GM-8	133.66
GM-9	134.66
GM-10	136.00
GM-11	137.33
GM-12	139.66
GM-13	136.00
Check (Buldhana Local)	137.66
F test	Sig.
SE(m)±	1.49
CD @ 5%	4.34

From all the garlic mutants, days required to maturity of bulb was minimum in GM-3 (129.66 days after planting) and which was found at par with the mutants GM-1 (133.66 days after planting), GM-2 (131.33 days after planting), GM-4(131.66 days after planting), GM-7 (131.00 days after planting), and GM-8 (133.66 days after planting). Whereas, maximum days required to maturity of bulb was recorded in mutants GM-12 (139.66 days after planting).

4.2.2 Number of cloves per bulb

The data in respect of number of cloves per bulb as influenced of garlic are presented in Table 10 and depicted in Fig 10.

Table. 10 Number of cloves per bulb of different garlic mutants

Mutants	Number of cloves / bulb
GM-1	20.66
GM-2	19.00
GM-3	18.66
GM-4	19.33
GM-5	18.00
GM-6	16.33
GM-7	21.00
GM-8	24.33
GM-9	20.66
GM-10	18.00
GM-11	23.66
GM-12	21.33
GM-13	18.00
Check (Buldhana Local)	18.00
F test	Sig.
SE(m)±	0.74
CD @ 5%	2.14

The data from Table 10 exhibited significant differences among garlic mutants in respect of number of cloves per bulb was maximum in GM-8 (24.33 cloves/bulb) and which was found at par with the mutants GM-11 (23.66 cloves/bulb. Whereas, minimum number of cloves per bulb was recorded in mutants GM-6 (16.33 clove/bulb).

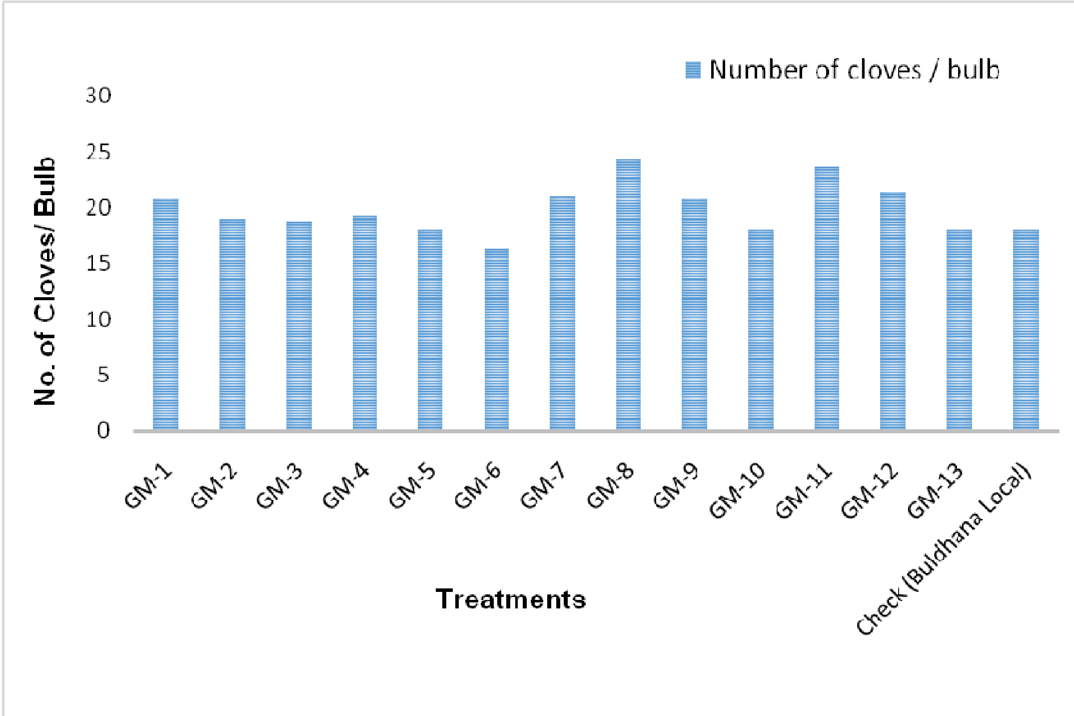

Fig. 10: Number of cloves per bulb of different garlic mutants

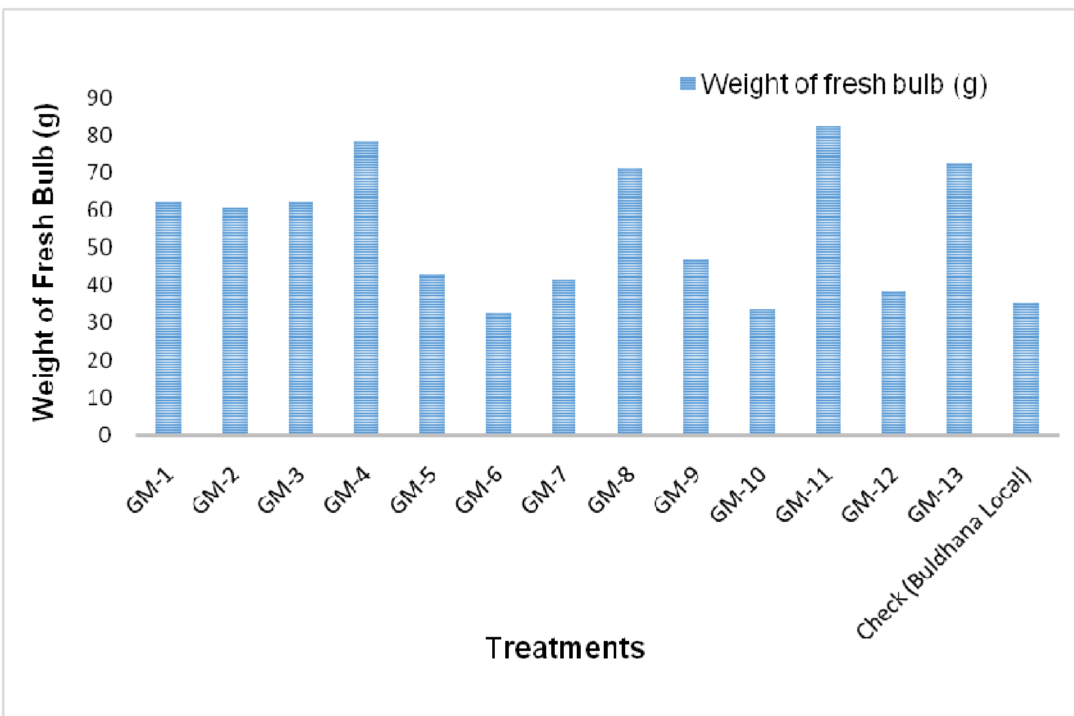

Fig. 11: Weight of fresh bulb (g) of different garlic mutants

4.2.3 Weight of fresh bulb (g)

The data in respect of weight of fresh bulb as influenced by the garlic mutants are presented in Table 11 and depicted in Fig 11.

Table. 11 Weight of fresh bulb (g) of different garlic mutants

Mutants	Weight of fresh bulb (g)
GM-1	62.00
GM-2	60.33
GM-3	62.00
GM-4	78.00
GM-5	42.66
GM-6	32.66
GM-7	41.33
GM-8	71.00
GM-9	46.66
GM-10	33.33
GM-11	82.33
GM-12	38.33
GM-13	72.33
Check (Buldhana Local)	35.00
F test	Sig.
SE(m)±	1.67
CD @ 5%	4.85

Among all the garlic mutants, weight of fresh bulb was maximum in GM-11 (82.33 g) and which was found at par with the mutants GM-4 (78.00 g). Whereas, minimum weight of fresh bulb was recorded in mutants GM-6 (32.66 g).

4.2.4 Diameter of fresh bulb (cm)

The data regarding the diameter of bulb as influenced by the garlic mutants are presented in Table 12 and depicted in Fig 12.

Table. 12 Diameter of fresh bulb (cm) of different garlic mutants

Mutants	Diameter of fresh bulb (cm)
GM-1	3.83
GM-2	4.50
GM-3	4.16
GM-4	4.76
GM-5	3.66
GM-6	4.16
GM-7	3.50
GM-8	5.13
GM-9	4.56
GM-10	4.66
GM-11	5.06
GM-12	4.10
GM-13	4.30
Check (Buldhana Local)	4.56
F test	Sig.
SE(m)±	0.23
CD @ 5%	0.68

The data from Table 12 revealed that the diameter of fresh bulb was maximum in GM-8 (5.13cm) and which was found at par with the mutants GM-4 (4.76 cm), GM-9 (4.56cm), GM-10 (4.66cm), GM-11 (5.06cm) and Check (Buldhana Local) (4.56cm). Whereas, minimum diameter of fresh bulb was recorded in mutants GM-7 (3.50cm).

4.2.5 Length of clove (cm)

The recorded data regarding length of clove seems to be influenced by garlic mutants are presented in Table 13 and depicted in Fig 13.

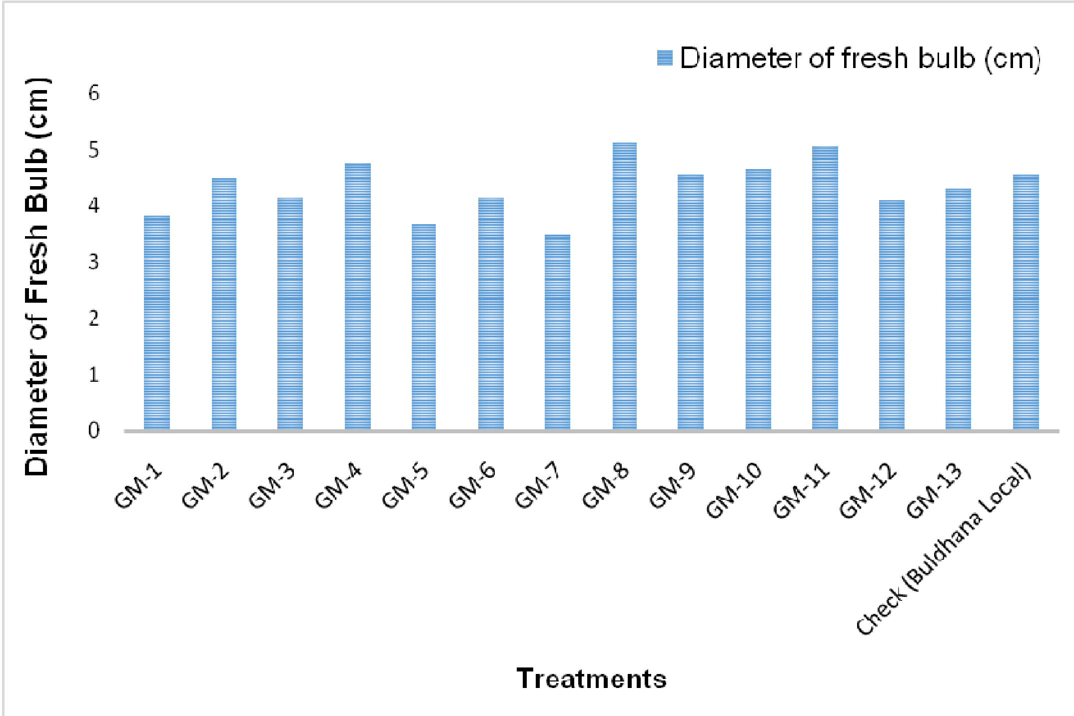

Fig. 12: Diameter of fresh bulb (cm) of different garlic mutants

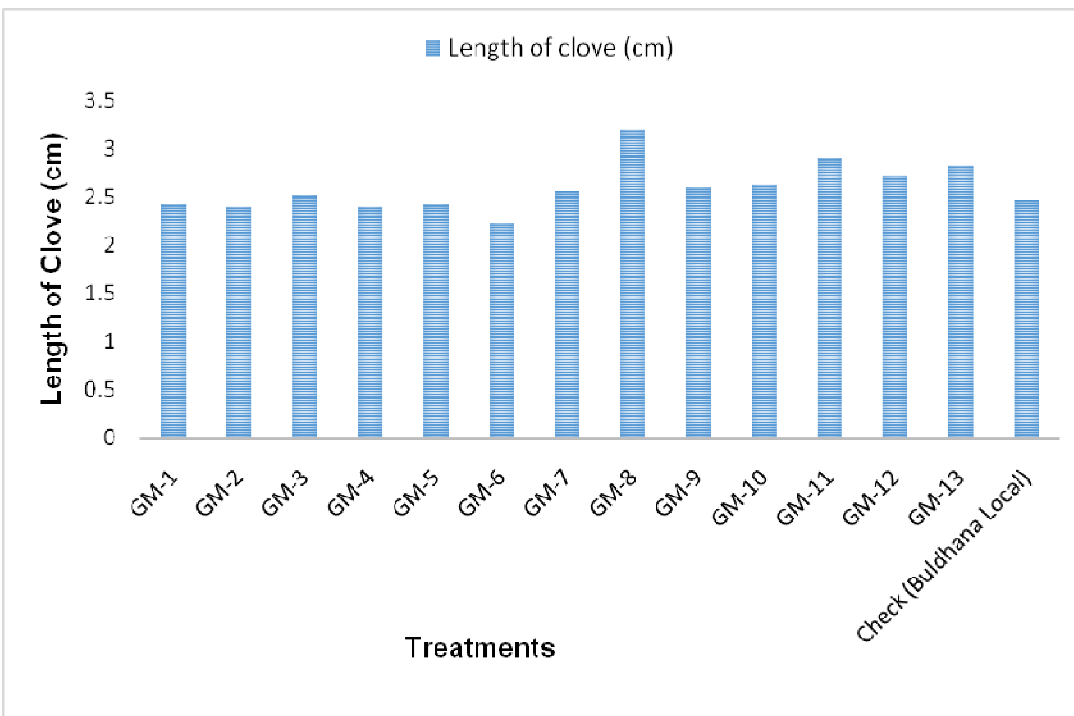

Fig. 13: Length of clove (cm) of different garlic mutants

Table. 13 Length of clove (cm) of different garlic mutants

Mutants	Length of clove (cm)
GM-1	2.43
GM-2	2.40
GM-3	2.53
GM-4	2.40
GM-5	2.43
GM-6	2.23
GM-7	2.56
GM-8	3.20
GM-9	2.60
GM-10	2.63
GM-11	2.90
GM-12	2.73
GM-13	2.83
Check (Buldhana Local)	2.46
F test	Sig.
SE(m)±	0.13
CD @ 5%	0.40

The data presented in Table 13 revealed that the length of clove was maximum in GM-8 (3.20cm) and which was found at par with the mutants GM-11 (2.90cm) and GM-13 (2.83cm). Whereas, minimum length of clove was recorded in mutants GM-6 (2.23cm).

4.2.6 Width of clove (cm)

Observations on width of clove (cm) were significantly influenced by garlic mutants are presented in Table 14 and depicted in Fig. 14.

Table. 14 Width of clove (cm) of different garlic mutants

Mutants	Width of clove (cm)
GM-1	0.72
GM-2	0.75
GM-3	0.88
GM-4	0.82
GM-5	1.01
GM-6	0.81
GM-7	0.90
GM-8	1.51
GM-9	0.78
GM-10	0.96
GM-11	0.87
GM-12	0.92
GM-13	0.92
Check (Buldhana Local)	0.89
F test	Sig.
SE(m)±	0.08
CD @ 5%	0.24

Among all the garlic mutants, width of clove was maximum in GM-8 (1.51cm). Whereas, minimum width of clove was recorded in mutants GM-1 (0.72cm).

4.2.7 Weight of clove (g)

The data in respect of weight of clove as influenced by the garlic mutants are presented in Table 15 and depicted in Fig 15.

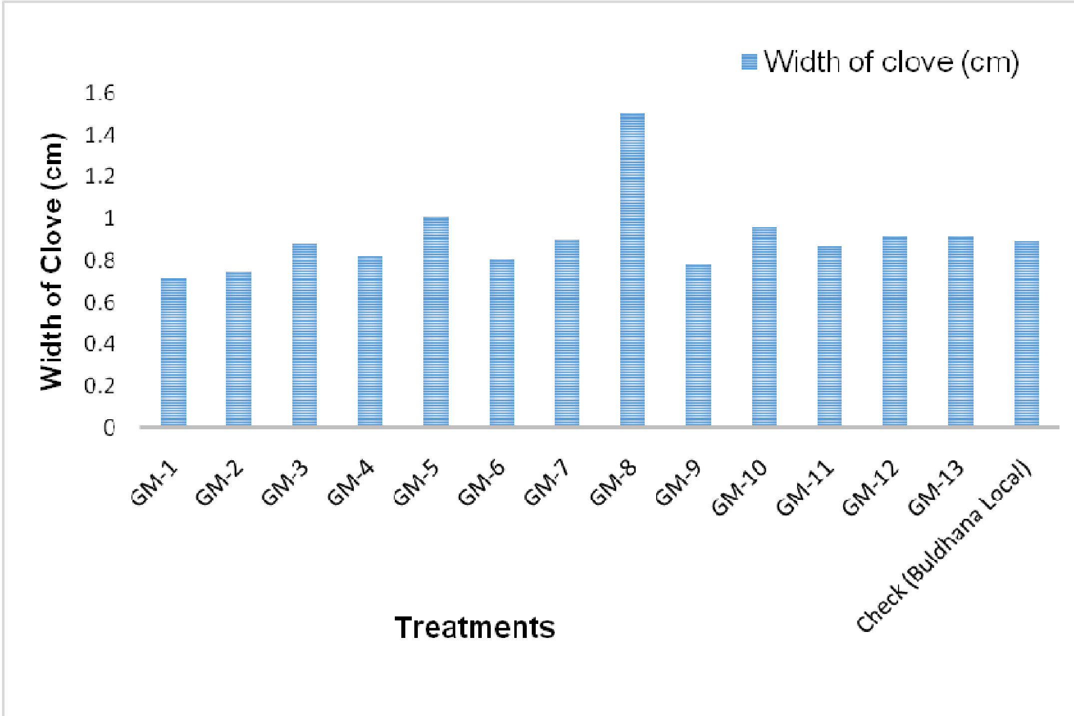

Fig. 14: Width of clove (cm) of different garlic mutants

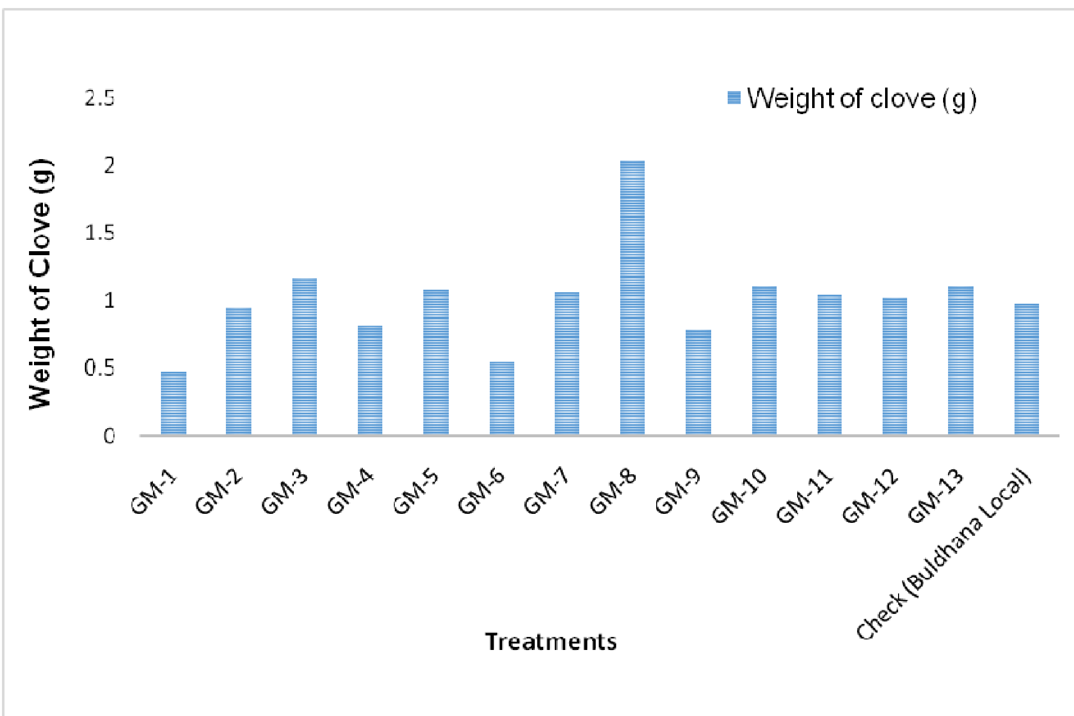

Fig. 15: Weight of clove (g) of different garlic mutants

Table. 15 Weight of clove (g) of different garlic mutants

Mutants	Weight of clove (g)
GM-1	0.47
GM-2	0.94
GM-3	1.16
GM-4	0.81
GM-5	1.08
GM-6	0.54
GM-7	1.06
GM-8	2.03
GM-9	0.78
GM-10	1.10
GM-11	1.04
GM-12	1.02
GM-13	1.10
Check (Buldhana Local)	0.97
F test	Sig.
SE(m)±	0.09
CD @ 5%	0.28

Among all the garlic mutants, weight of clove was maximum in GM-8 (2.03g). Whereas, minimum weight of clove was recorded in mutants GM-1 (0.47g).

4.2.8 Yield of fresh bulb per plot (kg) and Yield of fresh bulb per hectare (q)

Observations on yield of fresh bulb per plot (kg) and yield of fresh bulb per hectare (q) were significantly influenced by garlic mutants are presented in Table 16 and depicted in Fig 16.

Table. 16 Yield of fresh bulb per plot (kg) and yield of fresh bulb per hectare (q) of different garlic mutants

Mutants	Yield of Fresh bulb/ plot (Kg)	Yield of fresh bulb/ ha (q)
GM-1	2.55	83.83
GM-2	6.08	108.50
GM-3	5.28	110.00
GM-4	5.75	103.33
GM-5	6.58	107.16
GM-6	1.42	72.23
GM-7	5.53	96.83
GM-8	8.26	131.66
GM-9	6.53	116.66
GM-10	6.45	97.16
GM-11	7.04	130.16
GM-12	6.69	118.66
GM-13	5.64	93.33
Check (Buldhana Local)	4.83	87.50
F test	Sig.	Sig.
SE(m)±	0.45	8.37
CD @ 5%	1.31	24.26

Among all the garlic mutants, yield of fresh bulb per plot was maximum in GM-8 (8.26kg) and which was found at par with the mutants GM-11 (7.04kg). Whereas, minimum yield of fresh bulb per plot was recorded in mutants GM-6 (1.42kg).

Among all the garlic mutants, yield of fresh bulb per hectare was maximum in GM-8 (131.66 q) and which was found at par with the mutants GM-2 (108.50 q), GM-3 (110 q), GM-5 (107.16 q), GM-9 (116.66 q), GM-11 (130.16 q) and GM-12 (118.66 q). Whereas, minimum yield of fresh bulb per hectare was recorded in mutants GM-6 (72.23 q).

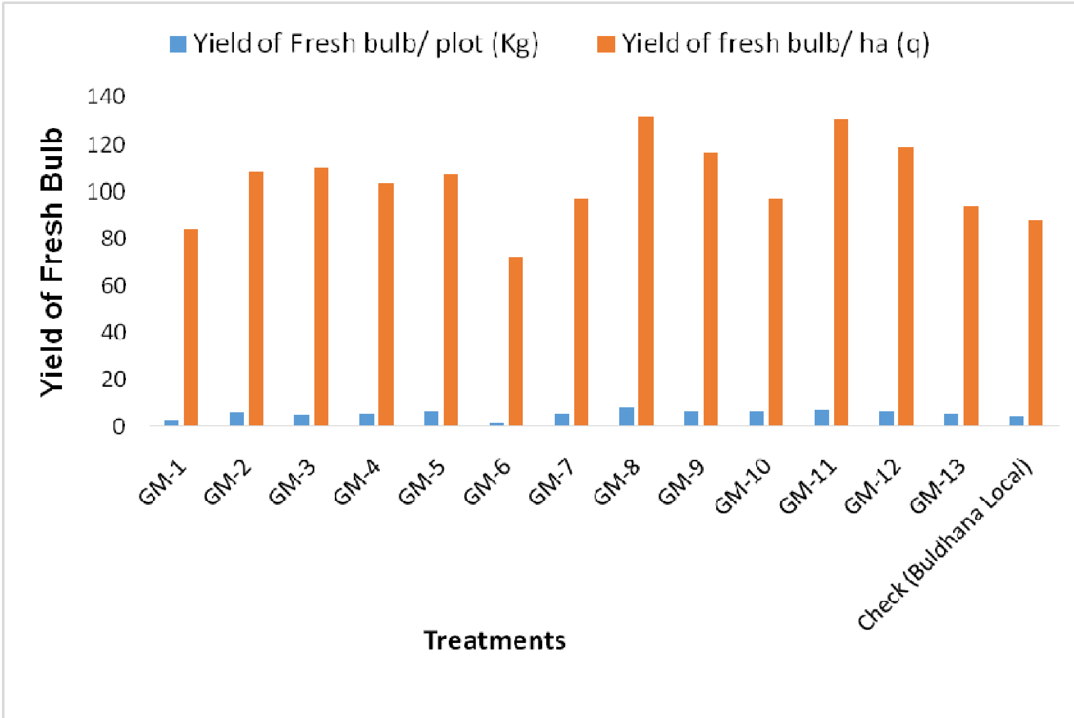

Fig. 16: Yield of fresh bulb per plot (kg) and yield of fresh bulb per hectare (q) of different garlic mutants

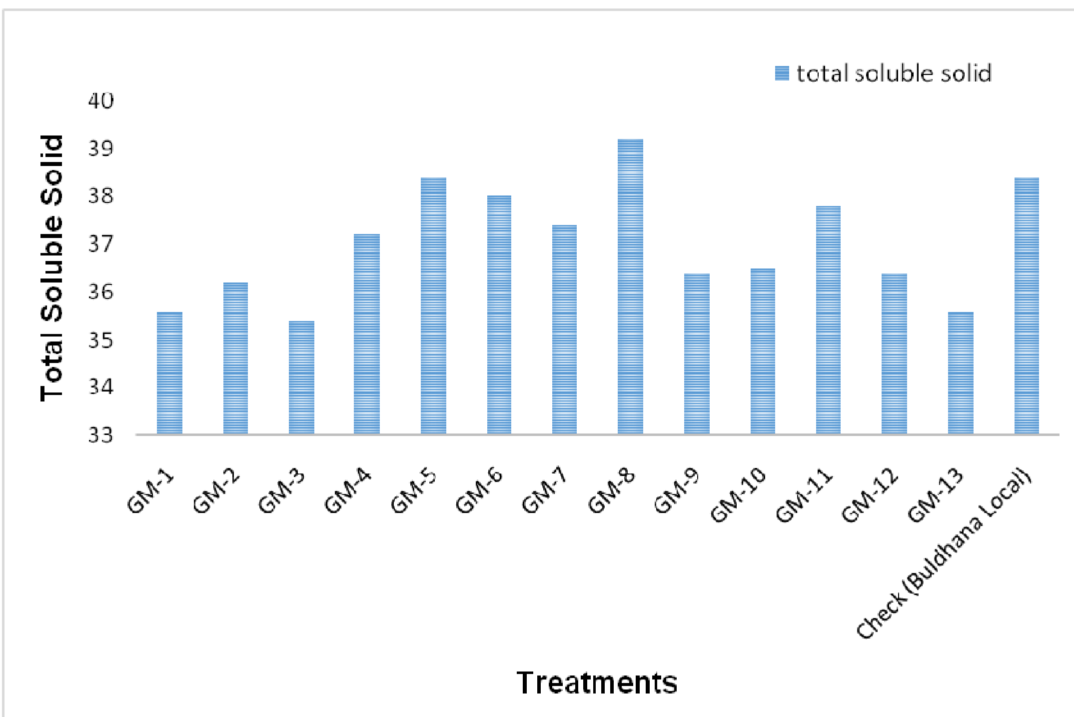

Fig. 17 Total soluble solids (TSS) (^{0} Brix) of different garlic mutants

4.3 Quality Observation

4.3.1 Total soluble solids (^{0}Brix)

The data in respect of total soluble solids (TSS) as influenced by the garlic mutants are presented in Table 17 and depicted in Fig 17.

Table. 17 Total soluble solids (TSS) (^{0} Brix) of different garlic mutants

Mutants	Total soluble solids (^{0}Brix)
GM-1	35.6
GM-2	36.2
GM-3	35.4
GM-4	37.2
GM-5	38.4
GM-6	38.0
GM-7	37.4
GM-8	39.2
GM-9	36.4
GM-10	36.5
GM-11	37.8
GM-12	36.4
GM-13	35.6
Check (Buldhana Local)	38.4
F test	Sig.
SE(m)±	0.13
CD @ 5%	0.38

Among all the garlic mutants, Total soluble solids was maximum in GM-8 (39.2^{0}Brix). Whereas, minimum Total soluble solids was recorded in mutants GM-3 (35.4^{0}Brix).

Discussion

The present investigation entitled with **"Studies on performance of garlic mutants"** was undertaken on fourteen mutants of Garlic

Performance in terms of growth, yield and quality of any crop is influenced by various factors like variety, season, environment etc. Various pre harvest and postharvest observations on growth and yield contributing characters were observed and critically studied. The results obtained are discussed in this chapter.

4.4 Growth Parameters

Vegetative parameters are recorded in terms of days to sprouting, sprouting percentage (%), plant height (cm), number of leaves per plant, stem girth (cm), leaf area (cm^2) and chlorophyll content index (cci).

4.4.1 Days to sprouting

Days to sprouting was significantly varied among the different garlic mutants. Minimum days to sprouting was recorded in the mutants GM-5 (5 days), GM-13 (5 days) and Check (Buldhana Local) (5 days) whereas, maximum days to sprouting was recorded under mutants GM-4 (7.33 days). The variation in days to spouting of the garlic mutants evaluated may be attributed to their inherent genetic makeup and response to environmental conditions.

4.4.2 Sprouting percentage (%)

Sprouting percentage was significantly varied among the different garlic mutants. Maximum sprouting percentage was recorded under mutants GM-8 (91.33%) whereas, minimum Sprouting percentage was recorded under mutants Check (Buldhana Local) (83.00%). The variation in sprouting percentage of the garlic mutants evaluated may be attributed to their inherent genetic makeup and response to environmental conditions. These results are confirmed with the findings of Agrawal and Tiwari (2004).

4.4.3 Plant height (cm)

Plant height was significantly varied among the different garlic mutants at different stages of plant growth. In general as the day's advances, growth of all the mutants increased gradually. Among all the garlic mutants, at 60 days after planting plant height was maximum in GM-8 (40.80cm) and which was found at par with the mutants GM-1 (60.43cm), GM-2 (61.90cm), GM-3 (62.53cm), GM-12 (61.70cm),and GM-13(59.73cm). Whereas, minimum plant height was recorded in mutants Check (Buldhana Local) (32.40cm).

Among all the garlic mutants, at 90 days after planting plant height was maximum in GM-8 (63.73cm) and which was found at par with the mutants GM-3 (38.73cm), GM-5 (38.66cm), GM-6 (38.53cm), GM-7 (37.83cm), GM-11 (38.73cm), and GM-12 (38.83cm). Whereas, minimum plant height was recorded in mutants Check (Buldhana Local) (50.76cm).

Among all the garlic mutants, at 120 days after planting plant height was maximum in GM-8 (70.06cm). Whereas, minimum plant height was recorded in mutants GM-5 (53.86cm). The variation in plant height of the garlic mutants evaluated may be attributed to their inherent genetic makeup and response to environmental conditions. These results are confirmed with the findings of Agrawal and Tiwari (2004), Mishra *et al*., (2013), Pervin *et al*., (2014), Khatun *et al*., (2014) and Umamaheswarappa *et al*., (2018).

4.4.4 Number of leaves per plant

Number of leaves also major vegetative character and significant differences were observed among the garlic mutants. Maximum number of leaves per plant produced by the mutant GM-7 (5.06) and which was found at par with the mutants GM-3 (4.66), GM-6 (4.66), GM-12 (4.66), and GM-13 (4.53). Whereas, minimum number of leaves per plant was recorded in mutants GM-10 (3.93 leaves/plant) at 60 days after planting.

Among all the garlic mutants, at 90 days after planting number of leaves per plant was maximum in GM-7 (7.73) and which was found at par with the mutants GM-1 (7.53), GM-2 (6.80), GM-3 (7.00), GM-4 (7.06), GM-5 (7.13 leaves/plant), GM-6 (7.53), GM-8 (6.86), GM-9 (6.73), GM-11 (6.82) and Check (Buldhana Local) (6.86). Whereas, minimum number of leaves per plant was recorded in mutants GM-10 (6.60).

Among all the garlic mutants, at 120 days after planting number of leaves per plant was maximum in GM-1 (8.93) and GM-7 (8.93) and which was found at par with the mutants GM-2 (8.73), GM-4 (8.66), GM-6 (8.53) and GM-12 (8.86). Whereas, minimum plant height was recorded in mutants Check (Buldhana Local) (8.13). Differences in these observations could be attributed to the genetic makeup of the mutants. The activity of physiological process by stimulating factors in the metabolism and growth of the plant might be the reason for enhanced number of leaves.

Similar results were found in, Yadav *et al*. (2012), Barad *et al*. (2012) Mishra *et al*., (2013) and Umamaheswarappa *et al*., (2018).

4.4.5 Stem girth (cm)

Fourteen mutants of garlic shows greater variation for stem girth. At 60 days after planting stem girth was minimum in GM-11 (0.47cm) and which was found at par with the mutants GM-1 (0.77cm), GM-3 (0.69cm), GM-4 (0.86cm), and GM-5 (0.72cm),GM-8(0.81cm),GM-9 (0.82cm),GM-10(0.73cm), GM-12 (0.67cm), and GM-13(0.55cm). Whereas, maximum stem girth was recorded in mutants Check (Buldhana Local) (1.31cm).

Among all the garlic mutants, at 120 days after planting stem girth was minimum in GM-11 (0.96cm) and which was found at par with the mutants GM-1 (1.23cm), GM-5 (1.13cm), GM-6 (1.01cm), GM-8 (1.32cm), GM-13 (1.18cm). Whereas, maximum stem girth was recorded in mutants GM-10 (1.78cm). The better performance of these mutants may be due to its genetic makeup and its better adaptability to the prevailing environmental conditions. These results are confirmed with the findings of Patil *et al*., (2012) Mishra *et al*., (2013) and Prajapati *et al*., (2016).

4.4.6 Leaf area (cm^2)

Leaf area showed significant differences among the garlic mutants. Leaf area was maximum in GM-8 (30.66cm^2) and which was found at par with the mutants Check (Buldhana Local) (26.94cm^2). Whereas, minimum leaf area was recorded in mutants GM-2 (22.24cm^2).

The significant differences among the mutants is much influenced by genetic and environmental factors. These results are confirmed with the findings of Prajapati *et al.*, (2016).

4.4.7 Chlorophyll content index (cci)

Observations on chlorophyll content index (cci) were significantly influenced by garlic mutants. Among all the garlic mutants, chlorophyll content index (cci) was maximum in GM-8 (60.40) and which was found at par with the mutants GM-1 (57.33), GM-3(55.81), GM-4(57.59), GM-5 (55.90), GM-11 (55.23) and Check (Buldhana Local) (59.53). Whereas, minimum chlorophyll content index was recorded in mutants GM-6 (48.28). The significant differences among the mutants is much influenced by genetic and environmental factors.

4.5 Yield characters

The yield characters namely Days required to maturity of bulb, Number of cloves per bulb, Weight of fresh bulb (g), Diameter of fresh bulb (cm), Length of clove (cm), Width of clove (cm), Weight of clove (g), Yield of fresh bulb per plot (kg) Yield of fresh bulb per hectare (q) were recorded in individual plants for all the mutants.

4.5.1 Days required to maturity of bulb

The data revealed that, the days required to maturity of bulb as influenced by different garlic mutants were found to be significant. Days required to maturity of bulb was minimum in GM-3 (129.66 days after planting) and which was found at par with the mutants GM-1 (133.66 days after planting), GM-2 (131.33 days after planting), GM-4(131.66 days after planting), GM-7 (131.00 days after planting), and GM-8 (133.66 days after planting). Whereas, maximum days required to maturity of bulb was recorded in mutants GM-12 (139.66 days after planting). The significant variation observed among the mutants studied were due to the effect of mutant and its adoptability to the environment. These results are confirmed with the findings of Patil *et al.*, (2012)

4.5.2 Number of cloves per bulb

The varietal differences in respect of number of cloves per bulb were found to be significant. Among all the garlic mutants, number of cloves per bulb was maximum in GM-8 (24.33 cloves/bulb) and which was found at par with the mutants GM-11 (23.66 cloves/bulb. Whereas, minimum number of cloves per bulb was recorded in mutants GM-6 (16.33 clove/bulb). Among the mutants differences in number of cloves per bulb may be due to its genetic makeup and adoptability to the environment. Similar results were found in Mishra *et al*., (2013) and Prajapati *et al*., (2016) and Bhatt *et al*., (2017).

4.5.3 Weight of fresh bulb (g)

Observations on weight of fresh bulb (g) were significantly influenced by garlic mutants. Among all the garlic mutants, weight of fresh bulb was maximum in GM-11 (82.33 g) and which was found at par with the mutants GM-4 (78.00 g). Whereas, minimum weight of fresh bulb was recorded in mutants GM-6 (32.66 g). Among the mutants differences in average weight of fresh bulb may be due to its genetic makeup and adoptability to the environment. These results are confirmed with the findings of Patil *et al*., (2012), Chatoo *et al*., (2017) and Nandini *et al*., (2018).

4.5.4 Diameter of fresh bulb (cm)

Significant differences were noticed for diameter of fresh bulb. Among all the garlic mutants, diameter of fresh bulb was maximum in GM-8 (5.13cm) and which was found at par with the mutants GM-4 (4.76 cm), GM-9 (4.56cm), GM-10 (4.66cm), GM-11 (5.06cm) and Check (Buldhana Local) (4.56cm). Whereas, minimum diameter of fresh bulb was recorded in mutants GM-7 (3.50cm). The differences could be attributed to genetic makeup of the mutants. Similar results were found in Mishra *et al*., (2013), Ijaz *et al*., (2015) and Umamaheswarappa *et al*., (2018).

4.5.5 Length of clove (cm)

The data regarding the influence of garlic mutants on length of clove was found to be significant. Among all the garlic mutants, length of clove was maximum in GM-8 (3.20cm) and which was found at par with the mutants GM-11 (2.90cm) and GM-13 (2.83cm). Whereas, minimum length of clove was recorded in mutants GM-6 (2.23cm). The significant differences among the mutants is much influenced by genetic and environmental factors. This was in accordance as revealed by and Sandhu *et al*. (2015).

4.5.6 Width of clove (cm)

The data regarding the influence of garlic mutants on width of clove was found to be significant. Among all the garlic mutants, width of clove was maximum in GM-8 (1.51cm). Whereas, minimum width of clove was recorded in mutants GM-1 (0.72cm). The significant differences among the mutants is much influenced by genetic and environmental factors.

These results are confirmed with the findings of Agrawal and Tiwari (2004), Singh *et al*., (2012), Dhall and Brar (2013) .

4.5.7 Weight of clove (g)

The weight of clove as influenced by the mutants of garlic were found to be significant. Among all the garlic mutants, weight of clove was maximum in GM-8 (2.03g). Whereas, minimum weight of clove was recorded in mutants GM-1 (0.47g). The significant differences among the mutants is much influenced by genetic and environmental factors.

These results are confirmed with the findings of Agrawal and Tiwari (2004), Singh *et al*., (2012), Dhall and Brar (2013) Bhatt *et al*., (2017) Chatoo *et al*., (2017).

4.5.8 Yield of fresh bulb per plot (kg) and Yield of fresh bulb per hectare (q)

Differences among the mutants for total yield of fresh bulb per plot and total yield of fresh bulb per hectare were to be highly significant. Among all the garlic mutants, yield of fresh bulb per plot was maximum in

GM-8 (8.26kg) and which was found at par with the mutants GM-11 (7.04kg). Whereas, minimum yield of fresh bulb per plot was recorded in mutants GM-6 (1.42kg). This was in accordance as revealed by and Sandhu *et al*. (2015).

Among all the garlic mutants, yield of fresh bulb per hectare was maximum in GM-8 (131.66 q) and which was found at par with the mutants GM-2 (108.50 q), GM-3 (110 q), GM-5 (107.16 q), GM-9 (116.66 q), GM-11 (130.16 q) and GM-12 (118.66 q). Whereas, minimum yield of fresh bulb per hectare was recorded in mutants GM-6 (72.23 q). This may be due to improvement in plant height, number of leaves and stem girth as they have physiological capacity to mobilize and translocate photosynthetic to organ of economic value which in turn might have increased bulb yield as observed in this study. These results are confirmed with the findings of Patil *et al*., (2012), Chatoo *et al*., (2017) and Nandini *et al*., (2018)

4.6 Quality Character

4.6.1 Total Soluble Solid (^{0} Brix)

The data regarding the influence of garlic mutants on total soluble solid was found to be significant. Among all the garlic mutants, total soluble solid was maximum in GM-8 (39.2^{0}Brix). Whereas, minimum total soluble solid was recorded in mutants GM-3 (35.4^{0}Brix). The significant differences among the mutants is much influenced by genetic and environmental factors. Similar results were found in Mishra *et al*., (2013)

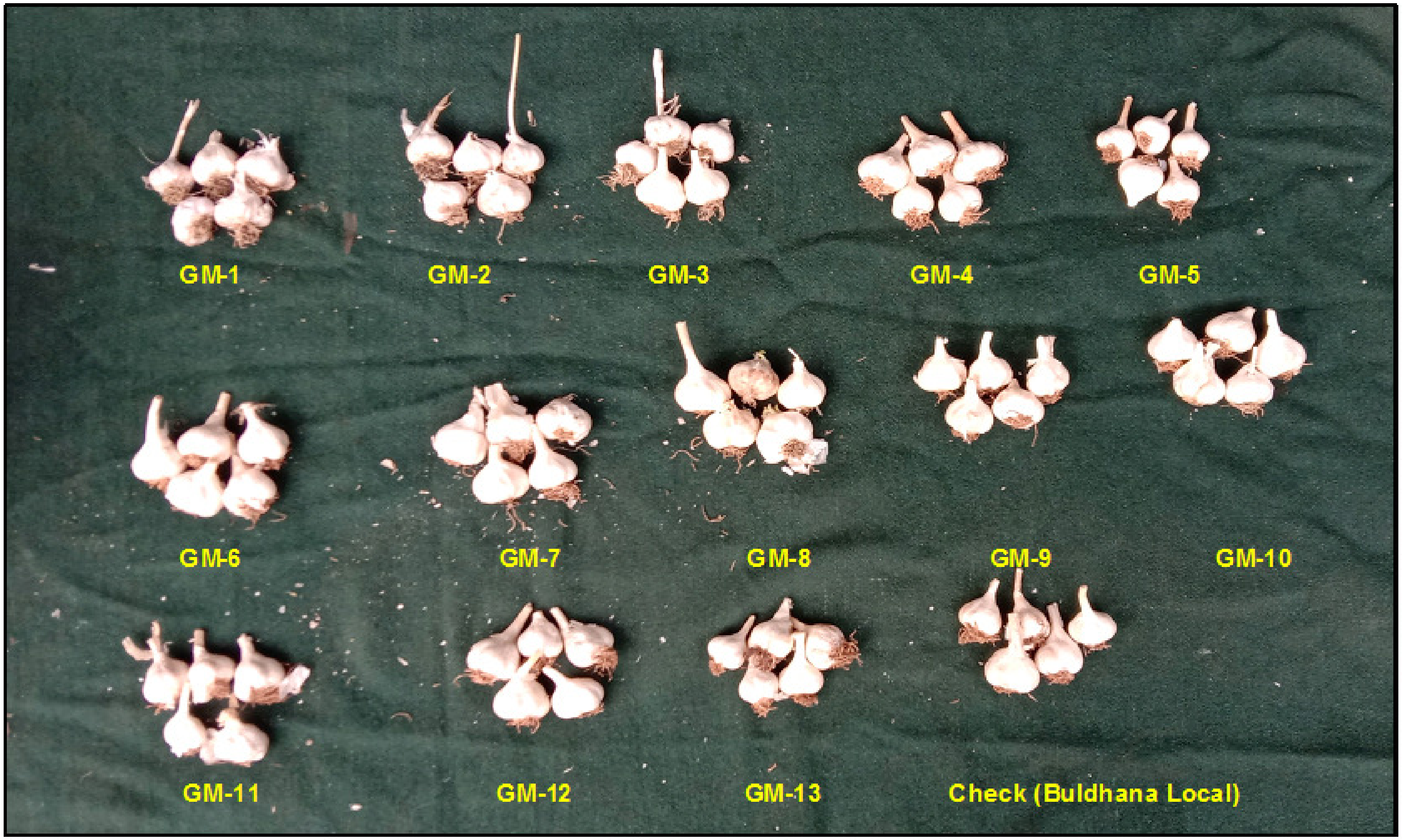

Plate 3 Variation in garlic bulb

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summary

The present investigation entitled **"Studies on performance of garlic mutants"** for their growth and yield was carried out at Instructional farm, Department of Vegetable Science, College of Horticulture Dr. P.D.K.V., Akola during 2019-20 in *rabi* season to study the performance of different garlic mutants. The experiment was laid out in Randomized Block Design with three replications and fourteen treatments. All the fourteen treatments were provided with similar package of practice.

The analysis of variance revealed highly significant differences among the garlic mutants in all the characters. The results obtained in the present investigation in respect of growth and yield contributing characters as influenced by mutants of garlic are summarized below.

Among garlic mutants the minimum days to sprouting was observed under mutants GM-5 (5 days), GM-13 (5 days) and Check (Buldhana Local) (5 days) while maximum days to sprouting was recorded under mutants GM-4 (7.33 days). Among garlic mutants the highest sprouting percentage was recorded under mutants GM-8 (91.33%), while minimum Sprouting percentage was recorded under mutants Check (Buldhana Local) (83.00%).

Among fourteen garlic mutants, the plant height was significantly influenced by the mutant of garlic. The mutant GM-8 produced the maximum plant height (70.06cm). Whereas, minimum plant height was recorded in mutants GM-5 (53.86cm) at 120 days after planting.

The performance of treatment in respect of leaves per plant was significantly the maximum in the mutant GM-1 (8.93 leaves/plant) and GM-7 (8.93leaves/plant). Whereas, minimum plant height was recorded in mutants Check (Buldhana Local) (8.13 leaves/plant) at 120 Days after planting.

Significantly the maximum stem girth at 120 days after planting was minimum in GM-11 (0.96cm). Whereas, maximum stem girth was recorded in mutants GM-10 (1.78cm).

Among fourteen garlic mutants, leaf area was maximum in GM-8 (30.66cm^2). Whereas, minimum leaf area was recorded in mutants GM-2 (22.24cm^2).

Among all the garlic mutants, chlorophyll content index (cci) was maximum in GM-8 (60.40). Whereas, minimum chlorophyll content index was recorded in mutants GM-6 (48.28).

The days required to maturity of bulb were significantly influenced by garlic mutants. The mutant GM-3 took minimum period for maturity in (129.66 days after planting), whereas, maximum days required to maturity of bulb was recorded in mutants GM-12 (139.66 days after planting).

Number of cloves per bulb were significantly influenced by the different mutants of garlic. Number of cloves per bulb was maximum in GM-8 (24.33 cloves/bulb). Whereas, minimum number of cloves per bulb was recorded in mutants GM-6 (16.33 clove/bulb).

Among fourteen garlic mutants, weight of fresh bulb was maximum in GM-11 (82.33 g). Whereas, minimum weight of fresh bulb was recorded in mutants GM-6 (32.66 g).

Among all the garlic mutants, diameter of fresh bulb was maximum in GM-8 (5.13cm). Whereas, minimum diameter of fresh bulb was recorded in mutants GM-7 (3.50cm).

The length of clove and width of clove were significantly influenced by the different mutants of garlic. The maximum length of clove (3.20cm) was recorded in the mutant GM-8. Whereas, minimum length of clove was recorded in mutant GM-6 (2.23cm). The mutant GM-8 produced significantly maximum width of clove (1.51cm). Whereas, minimum width of clove was recorded in mutants GM-1 (0.72cm).

Among all the garlic mutants, weight of clove was maximum in GM-8 (2.03g). Whereas, minimum weight of clove was recorded in mutants GM-1 (0.47g).

The fresh bulb yield per plot and fresh bulb yield per hectare was significantly influenced by the mutant of garlic. Yield of fresh bulb per plot was maximum in GM-8 (8.26kg). Whereas, minimum yield of fresh bulb per plot was recorded in mutants GM-6 (1.42kg).

Among all the garlic mutants, yield of fresh bulb per hectare was maximum in GM-8 (131.66 q). Whereas, minimum yield of fresh bulb per hectare was recorded in mutants GM-6 (72.23 q).

Among all the garlic mutants, total soluble solid was maximum in GM-8 (39.2^0Brix). Whereas, minimum Total soluble solid was recorded in mutants GM-3 (35.4^0Brix).

5.2 Conclusion

From the present investigation, it can be concluded that, the mutant GM-8 was recorded the growth characters like maximum plant height, maximum sprouting percentage and maximum leaf area as well as the yield characters like maximum yield of fresh bulb, maximum number of clove per bulb, maximum length of clove, maximum width of clove, maximum weight of clove, maximum diameter of fresh bulb and chlorophyll content index was maximum. Regarding the number of leaves per plant was maximum in the mutant GM-7. While stem girth was minimum and weight of fresh bulb was maximum in the mutant GM-11.whereas, the mutant GM-3 took minimum period for maturity of bulb. The quality parameter, like TSS was recorded maximum in the mutant GM-8.

CHAPTER VI

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Appendix I

Weeks	Dates	T MAX (^0C)	T MIN (^0C)	BSH (Hrs.)	WS (Km/hr.)	RH I (%)	RH II (%)	Evap (mm)	RF (mm)	Rainy Days
		A	A	A	A	A	A	A	A	A
41	8-14 Oct	33.8	17.9	8.1	0.6	88	48	4.3	0.0	0.0
42	15-21	33.3	16.5	5.0	0.8	91	58	3.9	11.2	1.0
43	22-28	33.0	17.6	5.7	0.8	95	79	2.2	67.5	5.0
44	29-4 Nov	32.6	18.0	4.9	0.5	93	61	3.1	11.8	1.0
45	5-11	32.2	16.4	7.5	0.5	90	50	3.5	0.0	0.0
46	12-18	31.4	11.9	8.0	0.9	90	40	3.9	0.0	0.0
47	19-25	30.8	13.4	7.9	0.5	89	40	3.8	0.0	0.0
48	26-2 Dec	30.7	15.6	7.2	0.7	90	44	3.5	0.0	0.0
49	3-9	30.2	14.8	7.0	10	83	37	4.2	0.0	0.0
50	10-16	29.7	16.6	5.9	0.7	89	49	3.1	0.0	0.0
51	17-23	29.5	15.8	4.1	0.2	90	49	2.9	0.0	0.0
52	24-31	29.0	13.5	3.9	1.1	81	47	3.7	0.0	0.0
1	1-7 Jan	23.1	13.1	3.6	1.9	89	57	3.5	1.2	2.0
2	8-14	26.9	12.2	6.5	0.8	82	41	3.0	0.0	0.0
3	15-21	27.8	14.1	6.7	1.0	80	46	4.1	0.0	0.0
4	22-28	30.7	15.8	7.1	2.0	80	37	4.3	0.0	0.0
5	29-4 Feb	27.6	13.5	6.9	2.9	75	37	4.5	0.0	0.0
6	5-11	27.7	14.6	6.2	1.5	77	43	4.5	0.0	0.0
7	12-18	318	14.2	8.9	2.1	70	23	4.5	0.0	0.0
8	19-25	33.9	17.1	8.6	2.4	59	25	4.9	0.0	0.0
9	26-4 Mar	33.3	16.3	8.8	3.8	61	21	5.9	1.0	0.0
10	5-11	32.5	19.6	8.4	2.6	59	28	7.0	1.5	0.0
11	12-18	33.2	17.9	8.5	2.7	49	26	8.7	0.0	0.0
12	19-25	33.8	18.1	8.6	2.8	43	19	7.7	0.0	0.0
13	26-1 Apr	33.9	18.2	8.7	2.8	40	18	7.8	0.0	0.0