RESPONSE OF VARIOUS MYCORRHIZAL STRAINS ON GROWTH AND YIELD CHARACTERISTICS OF BOTTLE GOURD [*Lagenaria siceraria* (MOL.) STANDL.]

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BANARAS HINDU UNIVERSITY

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF

MasterofScience(Agriculture)

in

Horticulture

Supervisor

Prof. Anand Kumar Singh

Submitted by

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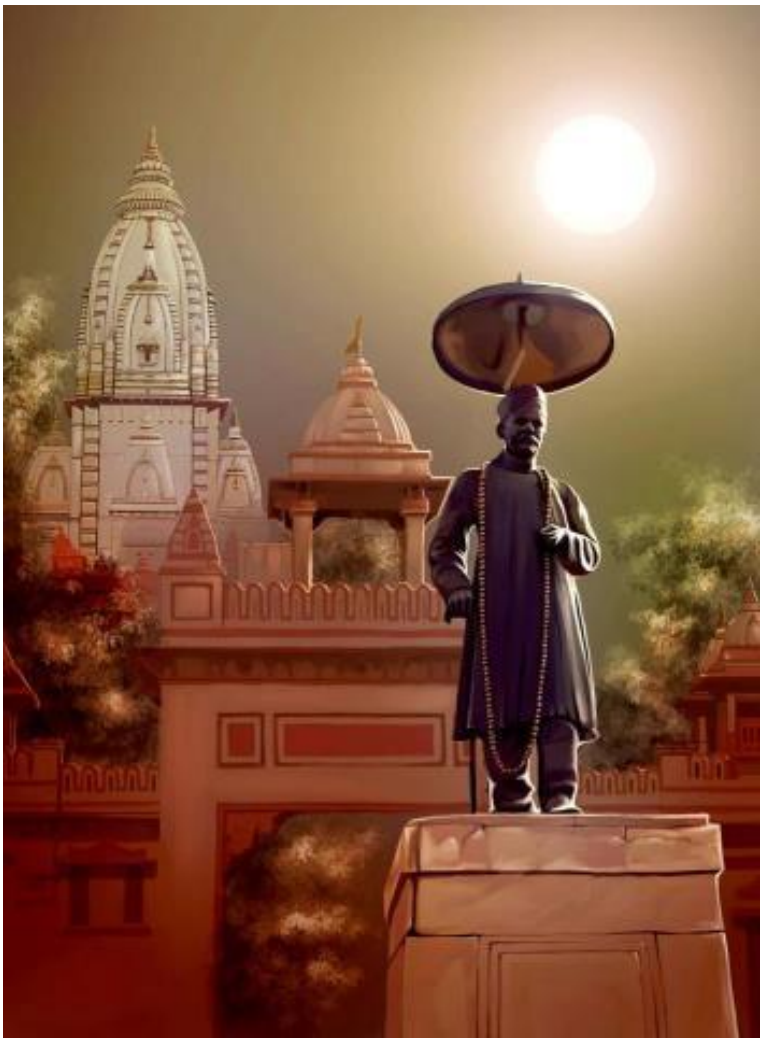

My Beloved Parents

…who sacrificed their today

for my tomorrow.

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Dear Sir,

I have great pleasure in forwarding the thesis entitled **"Response of various mycorrhizal strains on growth and yield characteristics of bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]"** of **Mr. Mukul Kumar Gupta, I.D. No. : H-15134, Enrollment No.: 332687** submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **HORTICULTURE** from Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi.

I certify that the work has been carried out solely by **Mr. Mukul Kumar Gupta** under my supervision and guidance and his findings and data presented herein are to the best of my knowledge and belief genuine and original and no part of the work has been submitted for any other degree or distinction.

Thanking you,

Yours faithfully

Forwarded:

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Supervisor

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Date:
Place: **(MUKUL KUMAR GUPTA)**

LIST OF ABBREVIATIONS

%	:	per cent
/	:	per
@	:	at the rate of
°C	:	degree centigrade
CD (p = 0.05)	:	critical difference at 5 per cent probability
cm	:	centimeter
cv.	:	Cultivar
DAS	:	days after sowing
d.f.	:	Degree of freedom
et al.	:	et alia (and other)
etc.	:	Etcetera
Fig.	:	Figure
g	:	gram
ha	:	hectare
i.e.	:	that is
K	:	Potassium
Kg	:	kilogram
L	:	liter
M	:	meter
m^2	:	square meter
ml	:	milliliter
MT	:	metric tone
no.	:	number
N	:	nitrogen
P	:	phosphorus
q	:	quintal
RBD	:	randomized block Design
RH	:	relative humidity
SE.m	:	standard error mean
Spp.	:	Species
viz.	:	Videlicet namely

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CHAPTER-I

INTRODUCTION

Vegetables are so common in human diet that a meal without a vegetable is supposed to be incomplete in any part of the world. Vegetables supply many of most essential health building and protective substances, such as vitamins and minerals, which are wanting in other food minerals. The crops used for vegetable purpose in the world belong to 1200 species under 78 families and out of them, more than 860 species under 59 families belong to dicot and about 340 species under 19 families belong to monocot. About 90 species of vegetable crops are cultivated in the tropical and subtropical parts of world, only about 40 of them are commercially important.

In India growing of vegetable is 4.8 times more remunerative than cereals and other field crops. Vegetable cultivation generates more employment. After China, India is the second largest producer of vegetables in the world. The total area under vegetable crops is about 9.42 million ha, while total vegetable production is 166.57 mt in 2015 (Anonymous, 2015) and 166.61 mt vegetable from an area of 9.57 million ha in 2016. West Bengal having first position in both area and production 1.39 million ha and 22.83 mt in 2016 respectively followed by Uttar Pradesh and Bihar in area and Uttar Pradesh and Madhya Pradesh in production (Anonymous, 2016). In India, the consumption of vegetables is about 230 grams, which is a low figure as against the total requirement of 300 grams per day per head. The usual recommendation for an average adult is 112 grams of leafy vegetables, 74 grams of roots and tubers and 74 grams of other vegetables. India accelerates the vegetable production by developing high yielding varieties, varieties resistant to pests and diseases, hybrids and production technologies. Still there is a need to achieve target for supply optimum 300 g vegetable/capita/day.

Vegetables are rich and comparatively cheaper source of vitamins. Consumption of these items provides taste, palatability, increases appetite and provides fiber for digestion and to prevent constipation. Their consumption in plenty provides fair amount of protein. They also play key role in neutralizing the acids produced during digestion of proteinicious and fatty foods and also provide valuable

roughages which help in movement of food in intestine. Some of the vegetables are good sources of carbohydrates (leguminous vegetables, sweet potato, potato, onion, garlic and methi), proteins (peas, beans, leafy vegetables and garlic), vitamin A (carrot, tomato, drumstick, leafy vegetables), Vitamin B (peas, garlic and tomato), Vitamin C (green chilies, drumstick leaves, Cole crops, leafy vegetables), minerals (leafy vegetables, drumstick pods). As per dietician, daily requirement of vegetables is 112g of green leafy vegetables, 74g of other vegetables and 74g of roots and tubers with other food. Many of the vegetable crops posses high medicinal value for curing certain diseases. For instance, onion and garlic are found to possess antibacterial property. Many solanaceous and cucurbitaceous vegetables are found to possess Vitamin D.

In India, about 40 kinds of vegetables belonging to different groups are being cultivated. These include solanaceous, cucurbitaceous, leguminous, cruciferous (Cole crops), root crops and leafy vegetables. Among vegetables, cucurbitaceous has great significance, Cucurbitaceae family is commonly mentioned as the gourd, melon or pumpkin family, is medium sized generally a climbing plants family, composing 118 genera and 825 species, the most important of which are: *Cucurbita* (squash, pumpkin, zucchini, some gourds), *Lagenaria* (mostly inedible gourds), *Citrullus* (watermelon and others), *Cucumis* (cucumber and various melons) and *Luffa*. All species are sensitive to frost. The plants of which provide the major contribution for economically important domesticated species and many of these are earliest cultivated plants and are used for medicinal and nutritional values (Habibur, 2003).

Among all plants of the cucurbitaceae family, *Lagenaria* species have important contribution for the overall popularity. Bottle gourd belongs to the genus *Lagenaria* which is derived from *lagena*, meaning “bottle”. Bottle gourd (syn. white flowered gourd) is an important warm-season fruit vegetable. It is grown throughout India and its fruits are available in the market throughout the year. Bottle gourd found wild in India, the Moluccas and Ethiopia. The centre of origin has been located as the coastal areas of Malabar (north Kerala) and the humid forests of Dehradun (north India).

Genus *Lagenaria* to which bottle gourd belongs is characterized by key characters-fruits fleshy, and many seeded pepo, flowers solitary and chalky white. Both the male and female flowers open at the same time. Male flowers open only for a few hours, after word the petals withered, thus the flowers are short lived. Being a monoecious crop, bottle gourd is strictly cross pollinated. Bees are the major pollinators (Decker-Walter *et al*., 2004 and Sivaraj and pandravada, 2005). Two varieties of this fruit sweet and bitter are mentioned. Botanically, both belong to same genus, the former known by the Sanskrit synonym alaba and tumbi and latter by the names as Iksuaku, Katutumbi and mahaphala. The sweet variety is generally used as a vegetable, while the wild variety bitter, latter is preferred for the medicinal use. The former variety is cultivated widely for its fruit and vegetable. The latter is found wild previously in most areas but now in some hot areas of country, obviously as wild and has bitter fruits and preferred for medicinal use.

Lagenaria siceraria fruits are traditionally used for its cardio protective, cardio tonic, general tonic, diuretic, aphrodisiac, antidote to certain poisons and scorpion strings, alternative purgative, cooling effects. It cures pain, ulcers and fever and used for pectoral cough, asthma and other bronchial disorders-especially syrup prepared from the tender fruits. The pulp of the fruit is considered cool, diuretic, antibilious, and useful in coughs and as antidote to certain poisons. The tribal communities (Koyas, Gutti Koyas, and Lambadas) located in the northern Telangana zone use the dry hard shells of bottle gourd fruits for various purposes. Bottle gourd is variously referred as sorakaya, anapakaya, anamgapkaya, burrakaya, and tumri in the vernacular language by the tribal communities. Domestic utensils like bottles, bowls, milk pots, spoons, and containers of several types are made out of the dried shells. It is a common sight everywhere in the tribal dominated pockets of Khammam district that the ethnic groups are mainly using the dry shells for carrying country liquor (mahua drink, toddy), honey, and water. In some of the pockets it is being used for making stringed and wind musical instruments and pipes. At few places, the natives use the dried shells as floats on water bodies as well. Though it is nutritionally less calorific, tribal prefer bottle gourd as a vegetable for preparation of curries and pickles. Probably, the bitter principle found in the wild bottle gourds is responsible for the purgative property. The Gutti Koya tribals use the bottle gourd as a cure for

headache (external application) by mixing the seed oil with castor oil. The pulp of the fruit is considered cool and diuretic. Leaves of *Lagenaria siceraria* are taken as emetic in the form of leaf juice or decoction. This by adding sugar also used in Jaundice. Crushed leaves are used for baldness and applied on the head for the headache. Leaves are also used as alternative purgative.

The edible portion of fruits is fair source of ascorbic acid, beta carotene and good source of vitamin B complex, pectin dietary soluble fibers and contains highest source of choline level-a lipotropic factor, a healer of mental disorders, along with required metabolic and metabolite precursors for brain function, amongst any other vegetable known to man till date. It is also good source of minerals and amino acids. The fruit is reported to contain the triterepeniode cucurbitacins B, D, G, H and 22-deoxy cucurbitacin "the bitter principle of cucurbitaceae". It forms an excellent diet being rich in vitamins, iron and minerals. Extract of lauki seeds show antibiotic activity. The fruit juice is helpful in constipation, premature graying hair, urinary disorders and insomnia. Fruit juice contains beta glycosidedase-elasterase enzyme. Lauki has the highest content of choline among all the vegetables known to man till date, *Lagenaria siceraria* is a vegetable useful in the management of many disease like cardiac disorder, hepatic disease and ulcer. Bottle gourd juice helps to regulate blood pressure of hypertensive patients, because of its high potassium content. It helps in losing weight quickly, because of its high dietary fiber and low fat and cholesterol content (Nadkarni *et al*., 1992).

Soil microorganisms have a very prominent role in biogeochemical cycling of nutrients and their availability to plants and this is also significant from the point of maintaining soil health and sustainable development of agriculture. In light of this role of vesicular arbuscular mycorrhiza (VAM) is very important.

Mycorrhizal fungi are species of fungi that intimately associate with plant roots forming a symbiotic relationship, with the plant providing sugars for the fungi and the fungi providing nutrients such as phosphorus, to the plants. Mycorrhizal fungi can absorb, accumulate and transport large quantities of phosphate within their hyphae and release to plant cells in root tissue (Barman *et al.*, 2016).

A mycorrhiza ("fungus – root") is a type of endophitic, biotrophic, mutualistic symbiosis prevalent in many cultivated and natural ecosystems. There are three major groups of mycorrhiza: Ectomycorrhiza, Ectendomycorrhiza and Endomycorrhiza. Ectomycorrhiza and endomycorrhiza are important in agriculture and forestry. In Thailand, endomycorrhiza biofertilizer has been investigated for ten years. Initially the mycorrhizal biofertilizer production is for economic crops such as fruit trees (durian, longan, sweet tamarind, mangosteen, papaya). Now the biofertilizer can be used for vegetables and rubber.

Endomycorrhiza (vesicular arbuscular mycorrhiza; VA mycorrhiza; now known as arbuscular mycorrhiza, AM) play a very important role on enhancing the plant growth and yield due to an increase supply of phosphorus to the host plant. Mycorrhizal plants can absorb and accumulate several times more phosphate from the soil or solution than non–mycorrhizal plants. Plants inoculated with endomycorrhiza have been shown to be more resistant to some root diseases (Alizadeh *et al.*, 2011).

Arbuscular Mycorrhizal (AM) fungi (or Vesicular-Arbuscular Mycorrhizal, VAM fungi), belonging to the Phylum Glomeromycota are symbionts with terrestrial plant roots. It is now generally recognized that they improve not only the phosphorus nutrition of the host plant but also its growth, which may result in an increase in resistance to drought stress and some diseases. Therefore, AM fungi offer a great potential for sustainable agriculture, and the application of AM fungi to agriculture has been developed. In fact, in some countries the AM fungal inocula have been commercialized. Since it is laborious and cost-consuming for production of AM fungal inocula because of their obligate biotrophic nature, the ways to increase the function of the indigenous AM fungi in soil have also been developed.

Mycorrhiza increase root surface area for water and nutrients uptake. The use of mycorrhizal biofertilizer helps to improve higher branching of plant roots and the mycorrhizal hyphae grow from the root to soil enabling the plant roots to contact with wider area of soil surface, hence, increasing the absorbing area for water and nutrients absorption of the plant root system. Therefore, plants with mycorrhizal association will have higher efficiency for nutrients absorption, such as nitrogen, phosphorus, potassium, calcium, magnesium, zinc, and copper; and also increase plant resistance

to drought. There are number of benefits of mycorrhizal biofertilizer. In general they allow plants to take up nutrients in unavailable forms or nutrients that are fixed to the soil. Some plant nutrients, especially phosphorus, are elements that dissolve were in water in neutral soil. In the extreme acidic or basic soil, phosphorus is usually bound to iron, aluminum, calcium or magnesium, leading to water insolubility, which is not useful for plants. Mycorrhiza plays an important role in phosphorus absorption for plant via cell wall of mycorrhiza to the cell wall of plant root. In addition, mycorrhiza help to absorb other organic substances that are not fully soluble for plants to use, and also help to absorb and dissolve other nutrients for plants by storage in the root it is associated with.

By virtue of that mycorrhiza enhance plant growth, improve crop yield, and increase income for the farmers. Arising from improved water and essential nutrients absorption for plant growth by mycorrhiza, it leads to improvement in plant photosynthesis, nutrients translocation and plant metabolism processes. Therefore, the plant has better growth and yield, reduce the use of chemical fertilizer, sometimes up to half of the suggested amount, which in turn increases income for the farmers. As in the trial involving mycorrhizal biofertilizer on asparagus it was observed that, when the farmers used suggested amount of chemical fertilizer together with mycorrhizal biofertilizer, it was found that the crop yield improved by more than 50% and the farmers' income increased 61% higher than when chemical fertilizer alone was used. Mycorrhizal association in plant roots will help plant to resist root rot and collar rot diseases caused by other fungi. It can be used together with other agricultural chemicals. Mycorrhiza are endurable to several chemical substances; for example; pesticide such as endrin, chlordane, methyl parathion, methomyl carbofuran; herbicide such as glyphosate, fuazifopbutyl; chemical agents for plant disease elimination such as captan, benomyl, maneb triforine, mancozed and zineb.

Keeping in view the above facts, the present experiment was planned to study the "Response of various mycorrhizal strains on growth and yield characteristics of bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]". The present study carried out during Kharif season of 2016 at Vegetable Research Farm of Department of

Horticulture, Institute of Agricultural sciences, B.H.U., Varanasi (U.P.) with following objectives:

1. To study the growth parameters of bottle gourd as affected by different mycorrhizal strains.
2. To study the yield and yield parameters of bottle gourd as affected by different mycorrhizal strains.

CHAPTER-II

REVIEW OF LITERATURE

The symbiotic association between plant and fungi (mycorrhizal association) is an amazing phenomenon observed in nature. The mycorrhizal association is one of nature's boons for sustainable agriculture. It exerts no adverse effects on soil health and environment. Other than this mycorrhiza helps plant to withstand with various types of biotic and abiotic stresses.

The information available on the research work done regarding the mycorrhizal strains on growth and yield of bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] and other vegetables are reviewed in the following paragraphs.

Nurbaity *et al*. (2016) conducted a greenhouse experiment using mixtures of spores of *Glomus* sp. and inoculant of mycorrhizal helper bacteria *Pseudomonas diminuta* reduce the use of chemical fertilizers in production of potato grown on different soil types. Results of experiment showed that application of *Glomus sp.* and *P. diminuta* reduced the use of NPK up to 50%, where the growth (plant height and tuber number), N,P,K uptake and tuber yields of potato had similar effect to the highest recommendation rate of NPK fertilizer. Inceptisols in general had better response to the biofertilizer compared to Andisols. Findings from this experiment confirmed the evidences that biofertilizer could reduce the use of chemical fertilizer and the widely distributed soil in Indonesia such as Inceptisols, is potential to be used as a medium for potato production.

Miceli *et al.* (2016) studied on yield and quality of mini-watermelon [*Citrullus lanatus* (thumb.) Matsum and Nakai] as affected by grafting and mycorrhizal inoculums. Ungrafted plants or grafted onto rootstock RS 841 (*Cucurbita maxima* × *C. moschata*) were transplanted to the field. Grafting and AMF inoculation caused significant increases in yield and fruit weight. Qualitative characteristics of watermelon fruits were significantly affected mainly by grafting. The combined use of grafting with mycorrhizal inoculation may increase the yield of mini-watermelon fruit, maintaining good quality characteristics.

Chandrasekeran and Mahalingam (2015) focused on the effect of Arbuscular Mycorrhizae Fungi (AMF) on the changes of physico chemical composition in tomato fruits. There were significant changes in the mean values between the analyzed parameters. Glucose and fructose, lycopene and potassium concentrations were strongly and positively correlated. This study reveals that the tomato cultivated with AMF isolates increase the taste, color, texture and chemical composition. Among all the AMF isolates Glomus mosseae treated tomato yields the best results followed by Acaulospora sp, Glomus sp, Glomus aggregatum and Glomus fasiculatum.

Habibzadeh (2015) evaluated the effect of arbuscular mycorrhizal (*Glomus mosseae* and *Glomus intraradices*) fungi and phosphorus levels on root traits of cucumber (*Cucumis sativus* L.) plants. Results show that above-ground dry matter of inoculated cucumber at both species with 155.00 and160.83 mg/plant had the highest values. Both species (*Glomus mosseae* and *Glomus intraradices*) had more root fresh and dry weight, root length and root volume than control. Colonization of *G. mosseae* and *G. intraradices*, with 53.20% and 44.59% had the highest values at the 2 mg P/kg soil. *G. mosseae* and *G. intraradices* had the highest leaf phosphorus with 486.06 and 477.60 mg/100 g of leaf dry weight at the 15 mg P/kg soil, respectively.

Michalojc *et al*. (2015) studied the effect of AMF and two nutrient solution concentrations: standard(S) with average EC 2.6 mS/cm and reduced (R) with average EC 1.9 mS/cm, on the yield and chemical composition of fruit and leaves of tomato. Tomato plants cultivar 'Admiro F1' was cultivated in greenhouse with fertigation system in rock wool and straw medium in 2012–2013 years. In the research, no effect of AMF on the total and marketable yield as well as on number of fruit/plant was detected. Fruits of tomato inoculated with AMF contained significantly more sugars as compared to plants growing without mycorrhization. Significant higher dry matter content was detected in fruit of tomato fertigated with standard nutrient solution (S), compared to reduced solution (R). More total nitrogen was recorded in leaves of plants mycorrhized with AMF; although this increase was not statistically confirmed in every treatment. More calcium was determined in fruits of tomato inoculated with AMF as compared to those harvested from non-mycorrhized plants.

Adavi and Tadayoun (2014) studied on growth and yield of potato (*Solanum tuberosum* L.) in Esfahan, Iran during 2013 growing season. Four phosphorus fertilizer levels of 25%, 50%, 75% and 100% P recommended with two levels of mycorrhiza: with and without Mycorrhiza. Results showed that tuber size, number of tuber/plant, tuber yield, and starch yield were significantly higher in inoculated plants than in non-inoculated plants. According to the results, application of mycorrhiza in the presence of 50% P recommended had a favorable result and could increase tuber yield and starch production to an acceptable level.

Babaj *et al.* (2014) studied the effects of endogenous mycorrhiza (*glomus spp*.) on plant growth and yield of grafted cucumber (*Cucumis sativum* L.) under common commercial greenhouse conditions. Graded seeds of cucumber (cv. Ekron F1), and graded seeds of a rootstock (cv. Nimbus F1*; C. maxima* Duchesne x *C. moschata* Duchesne), were sown in polysterol trays. Three types of grafted seedlings; self-grafted (SEG), splice grafted (SG) and root pruned splice grafted (RPSG) were simultaneously produced in equal number as inoculated and non-inoculated with endogenous mycorrhiza. Despite of commonly higher relative growth rate of RPSG seedlings till the transplanting time, SG seedlings have a significantly higher total plant dry weight (W). No difference was found regarding leaf dry weight (LW), while a significantly larger leaf area was found for RPSG seedlings. No effect of AM fungi presence was found regarding the growth parameters of grafted cucumber seedlings during the nursery stage, but the presence of AM fungi has significantly improved the growth rate of each grafting method after transplanting, as also increased the total harvested yield. The highest yield was recorded by AM inoculated RPSG seedlings.

Bhuvaneswari *et al.* (2014) studied the effect of AM fungi and Trichoderma species as stimulations of growth and morphological character of chilli (*Capsicum annuum* L). In double inoculated chilli plant showed significant increase in plant growth parameters like number of shoot length, root length dry weight of shoot and root, number of leaves, number of branching and number of spores as compared to control. Compatible combinations of various species of *AM* and *Trichoderma*, which result in cropping systems that fully utilize *AM* and *Trichoderma* symbiosis, are the most efficient, sustainable, and environmentally sound large scale methods for food production. The results reveal that mixed *Mycorrhizal* and *Trichoderma* species

inoculation contribute best growth and development of chilli (*Capsicum annuum L*) plant under pot experiment.

Maaitah *et al.* (2014) investigated the response of potted-grown tomato (*Lycopersicon esculentum* Mill var. lorely F1) to inoculation with arbuscular mycorrhizal fungi (AMF) as well as the application of organic and inorganic fertilizers under glasshouse conditions. Results indicated that the main effects of fertilizer and fungus on growth parameters at both growing stages tested (50 and 80 days after planting) were significantly increased with increasing fertilizer level and mycorrhizal inoculation. Root colonization by mycorrhizal fungi in inoculated treatment was high, especially at low level of organic and chemical fertilizers. The highest level of inorganic fertilizer significantly reduced the root colonization; mean while, organic fertilizer exhibit non-significant effect. Inoculation tomato plants with mycorrhiza had pronounced significant effect on root colonization.

Olawuyi *et al.* (2014) studied the influence of arbuscular mycorrhiza and NPK fertilizer on the productivity of cucumber (*Cucumis sativus*). The results showed that plants treated with 500 kg/ha fungi produced higher cumulative weight of harvested fruits per plant. This yield was significantly higher than other treatments. It thus appeared that 500 kg/ha is the optimum level of AM fungi that is required for cucumber cultivation above which to a waste. The values of phosphorus in post-harvest soil analysis revealed that lower values of P were recorded in all the AM treated pots while all the plants treated with NPK fertilizer produced higher P than the pre-planting soil state. The fruit yield of Cucumber was optimized with 500 kg/ha AM fungi and it reduced P toxicity in the soil.

Shuab *et al.* (2014) observed benefits of inoculation of Arbuscular Mycorrhizal Fungi on growth and development of onion (*Allium cepa*) plant and found that there is a net increase in the above and below ground growth of the plant with each 20 days interval after germination. The study seems interesting since it pertains the work on modified stem *vis a vis* mycorrhizal relationship of a modified stem than normal root. The Chlorophyll content besides morphological growth parameters and fresh and dry weight content of onion plant are shown to present in higher levels in the mycorrhiza infected as compared to the non-inoculated ones.

Agarwal *et al.* (2013) conducted an experiment on *in vitro* establishment of Arbuscular Mycorrhizal Fungi (AMF) in cucumber (*Cucumis sativus*) roots, study aimed was as certain whether root colonization of AMF could be effected in vitro without undertaking complex and complicated culture conditions. Ultimate being to use the system either for sporal dissemination or hyphal inoculums as biofertilizer. Also this could form an economically viable technique for root organ cultivation of AM fungi.

Saha *et al*. (2013) reported that mycorrhizal treatments showed almost two times higher ex vitro survival than the control plantlets. Mycorrhization plantlet showed increase in vine length in Pusa Vishesh (194.02 cm) in mixed strain, leaf area in Pusa Vishesh (107.91 cm2) in *Acaulospora scorbiculata*, chlorophyll in Pusa Do Mausami (3.29 mg/g FW) in *A. scorbiculata* and total phenols content in Pusa Do Mausami (7.84 µg/g FW) in *E. columbiana*. Photosynthetic rates were enhanced in arbuscular mycorrhizal fungi (AMF) treated plant in Pusa Do Mausami (10.75 µmol $CO_2/m^2/s1$) in mixed strain in comparison to an uninoculated control. Among the AMF species, mixed strain (Nutrilink®) showed good as high as 38% root colonization for all the cultivars. In this experiment the mixed AMF strain has contributed significantly in survival of the plantlets and plant establishment in the field.

Maboko *et al.* (2013) found effect of arbuscular mycorrhiza and temperature control on plant growth, yield and mineral content of tomato plants grown hydroponically. Tomato seedlings were treated with a mycorrhizal inoculant (Mycoroot™) at transplanting to potentially enhance nutrient uptake by the plant. Plants grown in the non-temperature controlled (ntc) tunnel had significantly poorer plant growth, lower fruit mineral concentration, and lower yield compared with fruit from plants in the temperature-controlled (tc) tunnel. Leaves from plants in the ntc tunnel had higher micro element concentrations than those in the tc tunnel. Highest yields were obtained from plants fertigated with 75% of the recommended nutrient concentration and not from the 100% nutrient concentration. Application of arbuscular mycorrhizal fungi (AMF) neither enhanced plant growth, nor yield, nor fruit mineral nutrient concentrations. However, temperature control positively

affected the fruit Mn and Zn concentration in the tc tunnel following AMF application.

Suhail (2013) conducted a factorial experiment in green house in clay loam soil, to study the effect of seaweed extract applied as a foliar spray concentration (0,1.0, 2.5, 4.0 and 5.5) ml/l with or without mixture of fungus mycorrhiza (*Glomus fasciculatum* + *Acoulospora laevis*) on growth and yield of cucumber. The plant length, fresh weight, dry weight, percentage of total chlorophyll, leave area, number of fruits, yield per plant and total yield was found maximum at 2.5 ml/l seaweed extract with fungus mycorrhiza compared to other concentration and increase significant (14.65, 112.32, 59.21, 15.97, 27.26, 52.28, 82.42 and 82.46%) respecvely.

Sensoy *et al*. (2013) examined the effects of AMF on seedling growth in hybrid melon cultivars. Hybrid melon cultivars (Super Magnum F_1, Extra Early Galia F_1, Rambo F_1 and Sempati F_1) were inoculated with 3 different AMF (Arbuscular Mycorrhizal Fungi) [*Gigaspora margarita (Gm), Glomus intraradices (Gi*), and *G. etunicatum (Ge)*]. The seedling traits, nutrient uptake, colonization, and relative mycorrhizal dependency (RMD) were assessed in the experiment. Mycorrhizal colonization of melon cultivars ranged from 38.9 to 54.9%. The nitrogen, phosphorous, potassium, magnesium, and manganese contents were affected by melon cultivars, AMF, or their combinations. Relative mycorrhizal dependency also varied widely; only half of the melon cultivar mycorrhizae combinations showed positive mycorrhizal dependencies. The *Gi* inoculations had higher positive RMDs, while the *Gm* inoculations had lower negative RMDs.

Ortas *et al*. (2013) conducted an experiment for selection of arbuscular mycorrhizal fungi species for tomato seedling growth, mycorrhizal dependency and nutrient uptake. This study was designed to assess the effects of several mycorrhizal fungi species and their cocktail on tomato (*Solanum lycopersicon* L.) seedling growth, quality and nutrient uptake. Tomatoes were grown in growth medium and inoculated with *Glomus spp*. *G. mosseae, G. clarum, G. etunicatum, G. intraradices, G. caledonium* and cocktail of them. In experiments, non-inoculated, seed inoculation and seedling inoculation were compared. Pre-inoculation and re-inoculation increased growth parameters of tomato seedlings in three years. The inoculated plants produced

significantly higher biomass than those of non-inoculated plants. In general, plants re-inoculated at seedling stage had higher growth performance than seed inoculated plants. However pre-inoculation (seed stage inoculation) have higher mycorrhizal dependency than re-inoculation (seedling stage). All the inoculated plants were extensively colonized by all of the AM fungi species. Inoculated plants flowered earlier than non-inoculated plants.

Castillo *et al.* (2013) determine the effect of arbuscular mycorrhizal (AM) fungal inoculation, using a locally isolated *Claroideoglomus claroideum* (Gc) ecotype, on the seedling development of Chilean pepper plants, and to select an appropriate growth substrate, along with different phosohorus solubilizing strain. After 28 weeks of planting, plants were harvested and fruit number, weight, and length were recorded. A synergistic interaction between *C. claroideum* and *P. albidum* to improve fruit weight and phosphorous (P) concentration was evidenced, suggesting a sustainable alternative for chilean pepper production.

Tanwar *et al.* (2013) studied the effect of two arbuscular mycorrhizal fungi [*G. mosseae* (G) and *A. laevis* (A)] with *P. fluorescence* (Pf) in the presence of super phosphate (P) fertilization on growth and yield of bell pepper (*Capsicum annuum* var. California Wonder and reported that with the prevalence of AM colonization was highest in G+A+Pf with F1 and bio inoculants (G+A+Pf) along with right dose of P fertilizer (half of the recommended P) during seedling transplantation to increase overall growth and yield performance of bell pepper and could be considered as a sustainable substitute to higher phosphorus fertilizer for bell pepper cultivation.

Isfahani and Besharati (2012) evaluated the use of plant growth promoting rhizobacteria produced by Pseudomonas sp. and phosphate biofertilizer produced by Pseudomonas putida strain P13 and Pantoea agglomerans strain P5 and chemical fertilizers in the separate treatments on yield and yield components of cucumber. The symbol of P represents chemical fertilizer by amount of respectively (0, 25%, 50%, 75%, 100%), B1 shows plant growth promoting rhizobacteria (PGPR) and B2 indicates bio fertilizer. The results showed that P1B0 has the most yields, and control treatments have the least yield. P100B1 has the most length of plant and P100B0 has the least length of plant, P25B1 has the most amount of chlorophyll and P75B2 has

the least chlorophyll. P75B2 has the most shoots dry weight and P100B0 has the least shoots dry weight. B1P50 has the most shoots fresh weight and P25B2 has the least shoots fresh weight. B1P50 has the most roots dry weight and P100B0 has the least roots dry weight. B1P50 has the most roots fresh weight and P25B2 has the least roots fresh weight. So the results indicate that use of biological fertilizers have caused increase yield and components yield of cucumber.

Han *et al.* (2012) studied the effects of arbuscular mycorrhiza fungi (AMF) on the plant growth, fruit yield, and fruit quality of cucumber variety 'Jinchun No. 2' under salt stress. Under salt stress, the plant growth was inhibited, and the plant N, P, K, Cu, and Zn contents and K+/Na+ ratio, fruit yield and fruit soluble protein, total sugar, vitamin C, and nitrate contents decreased, while inoculation with AMF could mitigate the inhibitory effect of salt stress on the plant growth, made the plant N, P, K, Cu and Zn contents increased by 7.3%, 11.7%, 28.2%, 13.5% and 9.9% respectively and made the plant K+/Na+ ratio, fruit yield, and fruit soluble protein, total sugar and vitamin C contents have an obvious increase and the fruit nitrate content have a significant decrease. It was suggested that AMF could promote the plant growth and nutrient uptake of cucumber under salt stress, increase the plant salt tolerance, and improve the fruit yield and its nutrient quality.

Yan *et al*. (2012) performed a pot experiment to determine the effects of arbuscular mycorrhizal fungi (AMF) communities on soil properties and the growth of cucumber seedlings in a degraded soil that had been used for continuous cucumber monoculture in a greenhouse for 15 years. Inoculation with AMF communities did not affect soil pH but increased soil aggregate stability and decreased the concentrations of salt ions and electrical conductivity (EC) in the soil. Inoculation with AMF communities increased the numbers of culturable bacteria and actinomycetes but reduced the number of fungi. AMF communities increased plant growth, soluble sugar content, chlorophyll content, and root activity compared to non-mycorrhizal or a single AMF species treatments. Improvements of soil quality and plant growth were greatest with the following two communities: *Glomus etunicatum* + *G. mosseae* + *Gigaspora margarita* + *Acaulospora lacunose* and *G. aggregatum* + *G. etunicatum* + *G. mosseae* + *G. versiforme* + *G. margarita* + *A. lacunosa*. The results suggested that certain AMF communities could substantially improve the quality of degraded soil.

Nwangburuka *et al.* (2012) reported the effect of Arbuscular mycorrhizae (AM), poultry manure (PM), NPK fertilizer and the combination of AM-PM on the growth and yield of okra (*Abelmoschus esculentus*). AM-PM treatments can conveniently replace NPK in the growth and yield of okra. There was a significant positive correlation between plant height, leaf area, fruit width at maturity, pod weight and seed weight in okra. Bab okr3 and NH.Cb/07/008 performed well in pod weight per plant and fruit length at maturity and would make good putative parent for selection in an okra hybridization program.

Srivastava *et al*. (2012) studied on ten vegetable and fruit yielding plants for VAM fungal association. The vegetables were ash gourd, water melon, ivy gourd, musk melon, cucumber, pumpkin, bottle gourd, ridged gourd, bitter gourd and snake gourd. Presences of 23 VAM fungi associated with these plants were identified up to species level. Data on qualitative composition and specific association with host plants has been generated. *Glomus* was represented by 10 species, *Acaulospora* by six species, *Scutellospora* by three species and *Entrophospora* by three species and was represented by one species.

Olawuyi *et al*. (2012) examined the influence of *Glomus clarum* and organomineral fertilizer on productivity of okra was studied in a field experiment conducted in National Horticulture Research Institute (NIHORT) Ibadan. The arbuscular mycorrhiza fungi (AMF) and organomineral fertilizer (OMF) were applied into 6 kg soil at the rate of 5, 10 and 15 g each per plant, while the control had 0 g. The result showed that the yield of plants treated with 5 g AM fungi produced highest cumulative number of harvested fruit (2.17) and harvested weight per fruit (7.71 g/plant) while, plants treated with 10 g OMF and 5 g AM fungi produced higher cumulative harvested fruit number which were not significantly different from each other. The fruit yield of Okra was optimized with 5g AM fungi.

Ramakrishnan and Selvakumar (2012) studied the effect of arbuscular mycorrhiza on plant growth, mycorrhizal dependency and tissue nutrient content in *Lycopersicum esculentum*. Seeds and plants were treated with single and combined inoculation of *Glomus fasciculatum*, *Glomus intraradices* fungi. The growth parameters of tomato plants were observed at seedling stage such as leaf area (cm^2),

shoot length (cm), root length (cm), biomass (g) and mycorrhizal dependency (%) in treated tomato plants. The per cent increase of mycorrhizal dependency was recorded highest (106.35%) in the combined treatment when compared to single inoculations and control. However, the results further envisaged that the amount of available nitrogen, phosphorus, potassium, zinc and copper contents in plant tissues have been found to increase significantly in inoculated plants than that of the control.

Hadad *et al*. (2012) investigated the effect of alien and indigenous strains of mycorrhizal fungi on two tomato cultivars recommended for economical production in Oman under greenhouse conditions under salinity condition. Three levels of phosphorus applied by them during experiment. Indigenous mycorrhiza performed well. Number of branches, shoot and root weights, number and weight of fruits, tissue phosphorus was increased and effect of salinity also decreased.

Basak *et al.* (2011) conducted an experiment to determine the effects of various doses of mycorrhiza treatment on morphological characteristics and color quality of tomato seedlings (*Lycopersicum esculentum* L.) which are grown under 100 nM salinity stresses. Two different types of tomatoes "Aspendos F_1" and "Donna F_1" were used in this study. Mycorrhiza treatment was performed by using ROOTS-novozymes endo-mycorrhiza fungus (VAM) to obtain 10, 50 and 100 mycorrhiza/ plants. VAM treatment prevented the decrease in the length of the plants caused particularly by high level soil salinity, both in Aspendos and Donna species. Both species became bigger than the control plants and the plants grown under salt conditions. High mycorrhiza treatment also increased the weight of fresh stem and root but had no particular effect on dry stem and root. While chlorophyll a, b and total chlorophyll quantities of the mycorrhiza treatment with M50 and M100 doses grown under salt conditions were found to be high in comparison to control and salt treatment, carotenoid level was found to be low. Conclusively, mycorrhiza treatment to tomato seedlings which are grown under salt conditions was caused to have seedlings grown by preventing negative effects of salt, and provided a high quality growth and which kept the green color of the seedlings.

Ortas (2010) studied the effect of mycorrhiza application on plant growth and nutrient uptake in cucumber production under field conditions. The field experiment

results showed that mycorrhiza inoculation significantly increased cucumber seedling survival, fruit yield, P and Zn shoot concentrations. Indigenous mycorrhiza inoculums was successful in colonizing plant roots and resulted in better plant growth and yield. The relative effectiveness of each of the inocula tested was not consistent in the different experiments, although inoculated plants always grew better than control no inoculated. The most relevant result for growers was the increased survival of seedlings.

Oseni *et al.* (2010) conducted a greenhouse experiment to evaluate the responsiveness of tomato (*Lycopersicon esculentum* L.) seedlings to arbuscular mycorrhizal inoculation in a soilless medium on the transplant production performance in vermiculite. AM fungi inoculated seedlings exhibited better transplant performance due to its higher shoot fresh weight (avg.11.28 g/plant), high shoot/root ratio (avg. 0.236), higher root biomass (avg. 2.17 g plant-1) higher relative growth rate (RGR) (7.34 mg/g/day) and unit leaf rate (ULR) (1.28 mg/cm/day). AM inoculation resulted in 23.3% root colonization by the fungi in the vermiculite medium. The use of AM fungi appeared to provide benefits to the development of tomato seedling transplants in a soilless nursery condition and might be of particular interest under organic farming conditions.

Cardarelli *et al.* (2010) carried out an experiment to mitigate alkaline stress by arbuscular mycorrhiza in zucchini plants grown under mineral and organic fertilization. By increasing the concentration of NaHCO3 from 0 to 10 mM in the nutrient solution significantly decreased yield, plant growth, SPAD index, net assimilation of CO_2 (A_{CO2}), N, P, Ca, Mg, Fe, Mn and Zn concentration in leaf tissue. The +AM plants under alkaline conditions had higher total, marketable yield and total biomass compared to –AM plants. The higher yield and biomass production in +AM plants seems to be related to the capacity of maintaining higher SPAD index, net A_{CO2}, and to a better nutritional status (high P, K, Fe, Mn and Zn and low Na accumulation) in response to bicarbonate stress with respect to –AM plants. The percentage root colonization was significantly higher in organic-fertilized (35.7%) than in mineral-fertilized plants (11.7%). Even though the AM root colonization was higher in organic-fertilized plants, the highest yield and biomass production were

observed in mineral-fertilized plants due to the better nutritional status (higher N, P, Ca, and Mg), higher leaf area, SPAD index, and A_{CO2}.

Rouphael *et al.* (2010) studied the effects of AMF inoculation on 2 cucumber genotypes (the hybrid Ekron and the open-pollinated Marketmore) and reported significant effects of genotype on most of the investigated traits and also reported that mycorrhizal cucumber plants had a higher macronutrient concentration in the leaf tissue compared to non-inoculated ones. They also observed that *Glomus intraradices* enhanced the uptake and translocation of Fe toward the shoot.

Tufenkci *et al.* (2010) evaluated the colonization, nutrient uptake, dependency, and other seedling traits of 4 cucumber hybrids (Ceren F1, Beta F1, SilyonF1 and Maraton F1) inoculated by 3 different AMF [*Glomus intraradices* (*Gi*), *Glomus etunicatum* (*Ge*) and *Gigaspora margarita* (*Gm*)]. AMF-inoculated cucumber seedlings had shorter hypocotyledons and wider and longer cotyledons than non-inoculated seedlings. *Gm*-inoculated seedlings had the narrowest stem diameter and lowest leaf number. AMF-inoculated seedlings had shorter shoots and longer roots than non-inoculated ones. There was significant mycorrhizal effect on the iron (Fe) content of shoots and the mycorrhizal colonization rate in roots. Relative mycorrhizal dependency (RMD) varied widely among the hybrid cucumber cultivars tested.

Zhao *et al*. (2010) studied the effects of arbuscular mycorrhizae on microbial population and enzyme activity in replant soil used for watermelon production. Results showed that the total soil microbe, bacteria, and actinomycete population, and the activities of soil proteinase, polyphenoloxidase, urease and saccharase in replant soils gradually declined, while the fungal population, and the fungi/total microbe ratio increased, as replanting years rose. In each replant soil, the inoculation with AM fungus *Glomus versiforme* enhanced soil bacteria and actinomycete population, and decreased the fungal numbers and the fungi/total microbe ratio in replanting soils and improved soil proteinase, polyphenol oxidase, urease, and saccharase activities, compared with controls. It is concluded that the AM fungal inoculation can reduce watermelon replant problems through effectively modifying the soil microbe population and community structure, and increasing the soil enzyme activities.

Zhi-yu *et al.* (2008) carried out an experiment on tomato (*Lycopersicon esculentum* Mill.) cultivar Hansheng, to study the effects of inoculating Arbuscular mycorrhizal fungi (AMF) *Glomus mosseae* and *Nicolson Gerdemann* on growth, photosynthetic parameters and mineral element contents of tomato seedlings leaves. The results indicated that growth vigor, chlorophyll content, photosynthetic parameters and N, P, K, Ca, Mg Zn contents of leaves were markedly increased by inoculating AMF. Effects of inoculating AMF on plant height, leaf area, shoot growth, chlorophyll content, photosynthetic rate and Zn content were more significant. This trial initially showed that inoculating tomato with AMF was feasible in cultivating seedlings.

Wang *et al.* (2008) studied the effects of arbuscular mycorrhizal fungi on growth and yield of cucumber plants. The results indicated that growth of seedlings was significantly enhanced by *G. mosseae*, inhibited by *G. versiforme*, and not significantly influenced by *G. intraradices*. The dry weight of seedlings inoculated with *G. mosseae* was 1.2 times its counterparts. The concentrations of nitrogen (N) and phosphorus (P) in roots and magnesium (Mg), copper (Cu) and zinc (Zn) concentration in shoots were increased by inoculating the three AMF, and potassium (K) and iron (Fe) concentrations in shoots decreased significantly. The weights of single fruit of plants pre inoculated with *G. mosseae* and *G. versiforme* were about 1.4 and 1.3 times higher than those from the uninoculated treatment, respectively.

Westphal *et al*. (2008) reported that mycorrhizal fungi have been enhanced plant growth in watermelon and muskmelon under soil borne diseases and nematodes prone land, enhanced root growth and function and colonization of watermelon roots. Mycorrhizal fungi inoculations improved early plant establishment and increased the most valuable early fruit yield under some environmental stress conditions.

Zhang *et al.* (2008) conducted a pot experiment to evaluate the influence of pre-inoculation of cucumber plants with each of the three arbuscular mycorrhizal (AM) fungi *Glomus intraradices*, *Glomus mosseae*, and *Glomus versiforme* on reproduction of the root knot nematode *Meloidogyne incognita*. Numbers of galls per root system were significantly reduced only in the *G. intraradices + M. incognita* treatment. The number of eggs per root system was significantly decreased by AM

fungus inoculation, no significant difference among the three AM fungal isolates. AM inoculation substantially decreased the number of females, the number of eggs/g root and of the number of eggs per egg mass. The number of egg masses/g root was greatly reduced by inoculation with *G. mosseae* or *G. versiforme*. By considering plant growth, nutrient uptake and the suppression of *M. incognita* together, *G. mosseae* and *G. versiforme* were more effective than *G. intraradices*.

CHAPTER-III

MATERIAL AND METHODS

The present experiment entitled "Response of various mycorrhizal strains on growth and yield characteristics of bottle gourd (*Lagenaria siceraria* (Mol.) Standl.)" was carried out at Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during the Kharif season of 2016. The detail of materials used and methodology adopted in the experiment is given below.

3.1 LOCATION OF EXPERIMENTAL SITE

The Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University is situated at a distance about 10 km away from Varanasi railway station in South – Eastern direction of Varanasi city and is geographically situated at 25^0 15' North latitude and 83^0 03' East longitudes. The altitude of the location is about 123.23 m above mean sea level.

3.2 CLIMATIC CONDITION

Varanasi is situated in the eastern part of Uttar Pradesh and lies in the centre of north alluvial plain on the left side of river the Ganges and enjoys a humid subtropical climate with large variation in summer and winter temperature *i.e.* extreme of hot weather in summer and cold in winter. On the basis of climatic condition the entire year could be divided into three distinct seasons *i.e.* summer season start from last week of March to third week of June, rainy season from last week of June to middle of October and winter season from end of October to February. The maximum temperature ranges in summer from 32^0C to 46^0C. Winters in Varanasi have very large diurnal variations, with warm day and cold night. Fog is common in winter season while hot dry winds, called loo blow in summer. The average rainfall is about 1110 mm. The major part of the rain occurs from July to September. The mean relative humidity is about 68% which rises up 81% during July to September and falls down to 39 % during the end of April to early June. The mean monthly value of weather data recorded at Metrological Observatory, Agronomy Farm Institute of Agricultural Sciences, Banaras Hindu University (Table 3.1).

Table: 3.1 Weekly meteorological data, Varanasi, Year - 2016. Source: Metrological Observatory, Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi.

Week No.	Month & Date	Rainfall (mm)	Temperature ^{0}C		R.H. %		Wind Speed (km/hr)	Sunshine hours	Evaporation (mm)
			MAX	MIN	Morn.	Even			
26.	24-30	0.0	37.1	26.9	78	53	4.4	6.1	5.0
27.	July 01-07	176.2	32.3	26.4	87	72	4.2	2.7	4.9
28.	08-14	46.6	33.4	26.7	91	69	5.4	5.3	4.5
29.	15-21	158.4	31.1	26.1	95	82	4.2	0.5	2.7
30.	22-28	49.2	32.4	26.0	90	72	1.9	1.9	3.5
31.	29-04	60.4	31.2	24.9	93	76	2.8	4.4	4.2
32.	Aug 05-11	110	31.0	25.8	92	79	4.7	4.5	4.0
33.	12-18	175.6	30.4	24.7	93	86	2.3	2.4	2.8
34.	19-25	98.6	31.5	24.8	85	77	4.3	4.7	3.7
35.	26-01	1.4	34.0	26.0	83	69	1.8	5.1	4.0
36.	Sep 02-08	31.1	31.6	26.2	90	80	4.7	3.1	3.4
37.	09-15	2.6	31.4	26.4	91	80	1.5	2.9	2.6
38.	16-22	64.8	31.2	25.6	92	82	1.2	2.7	2.6
39.	23-29	115.8	28.6	24.0	95	88	2.0	2.3	2.6
40.	30-06	2.6	32.4	26.3	88	74	1.3	5.8	2.9
41.	Oct 07-13	1.5	32.0	23.4	87	61	1.7	6.5	2.4
42.	14-20	0.0	32.4	18.4	74	43	0.8	8.7	3.2
43.	21-27	0.0	32.4	17.9	74	43	1.2	7.7	2.8
44.	28-03	0.0	31.4	16.6	77	43	0.2	8.0	2.2
45.	Nov 04-10	0.0	29.2	15.3	80	45	1.1	3.9	2.1

3.3 EXPERIMENTAL SITE

A homogenous piece of land was selected from the composite block of the experimental farm, keeping in view the irrigation facilities. All management practices were applied equally for all the plots.

3.4 WEATHER CONDITIONS

Varanasi possesses sub-tropical climate with an average rainfall of 1110 mm mostly received during rainy season.

3.5 CHARACTERISTICS OF EXPERIMENTAL SOIL

The soil was of sandy loam with good drainage and moderate water holding capacity. Soil samples were collected before sowing the crop seed from five randomly selected spots at a depth of 30 cm from the experimental plot. The soil was air-dried and ground to pass through 20 mm sieve before analysis.

Table 3.1: Presented physico-chemical properties of soil

Parameter	Value (%)	Method Employed
1.**Mechanical analysis**		
a. Coarse sand	5.38	Boyoucos Hydrometer method (Boyoucos, 1962)
b. Fine sand	44.82	
c. Silt	29.59	
d. Clay	18.41	
2. Chemical analysis		
a. Available Nitrogen	0.095	Modified Kjeldahl's method (Jackson, 1967)
b. Available Phosphorus	0.081	Bicarbonate extractable 'P' and development of blue color (Jackson, 1967)
c. Available Potash	0.542	Neutral normal ammonium acetate method (Jackson, 1967)

3.6 EXPERIMENTAL MATERIAL USED

EXPERIMENTAL DETAILS

Cultivar

Bottle gourd cultivar (Pusa Summer Prolific Long) was used for the present study. This is a leading variety of the bottle gourd with yield potential of 270-280 q/ha in rainy and 230-340 q/ha in summer season with duration of 90 days.

Treatments

The present experiment was conducted with using different Mycorrhizal strain.

Table 3.2: Name of Mycorrhiza and there doses in different experimental plots.

Treatments	
T_1	Untreated Control
T_2	Soil application with Myc100 @ 250 g/ha × 1 application @ 15 DAS
T_3	Soil application with RhizoMyco100 @ 250 g/ha × 1 application @ 15 DAS
T_4	Soil application with RhizoMyxo100 @ 250 g/ha × 1 application @ 15 DAS
T_5	Soil application with Bolt Gr. @ 10 kg/ha × 1 application @ 15 DAS
T_6	Soil application with Ratchet @ 300 ml/ha × 1 application @ 20 DAS
T_7	Soil application with Ratchet @ 300 ml/ha × 2 applications @ 20 and 50 DAS
T_8	Soil application with Ratchet @ 450 ml/ha × 1 application @ 20 DAS
T_9	Soil application with Ratchet @ 450 ml/ha × 2 application @ 20 and 50 DAS

3.7 EXPERIMENTAL DESIGN AND LAYOUT

A. Experimental design

The experiment was laid out in randomized block design with three replications. The experiment was conducted at Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, BHU, Varanasi.

B. Details of the layout plan

Experimental design	:	RBD
Number of genotypes	:	1
No. of Treatments	:	9
Number of replications	:	3
Total number of plots	:	3×9 = 27
Size of plot	:	4.2 × 3 m
Field border	:	1 m
Block border	:	0.5 m
Main channel	:	1 m
Sub-channel	:	0.3 m
Date of sowing	:	26th June 2016
Spacing	:	2× 0.6 m
Fertilizers	:	Recommended dose N: P: K (100:75:60 kg/ha)
Duration of harvesting	:	22nd August to 6th November 2016

3.8 CULTIVATIONAL OPERATION

3.8.1 Soil and field preparation

After deciding the experimental field, the field was irrigated to have optimum level of moisture condition. First, deep ploughing was done with disc plough and subsequent light ploughings were done with cultivator followed by planking. Then the required area was marked and 27 plots were prepared according to the layout plan.

3.8.2 Fertilizer application

Recommended dose of fertilizers (100 kg N, 75 kg P_2O_5 and 60 kg K_2O per hectare) was applied to the soil. The entire quantity of phosphorus and potassium and half quantity of nitrogen were mixed thoroughly and broadcasted in each plot uniformly as basal dose before sowing. Two topdressings with nitrogen at 30 to 35 DAS and 50 to 55 DAS was done.

3.8.3 Selection of seed and sowing

Pure and healthy seeds were collected before sowing. The seeds were soaked in water for 12 hours to get good germination. The distance of 0.6m between plant to plant and 2 m between rows to row was maintained. The sowing was done on 26th June 2016.

3.8.4. Mycorrhizae spraying

Total three sprayings of mycorrhiza were performed. The first spray of mycorrhizal products namely Myc100 @ 250 g/ha, RhizoMyco100 @ 250 g/ha, RhizoMyxo100 @ 250 g/ha and Bolt Gr. @ 10 kg/ha in T_2, T_3, T_4 and T_5 respectively was done 15 DAS at 10th July, while the second spray of the products namely Ratchet @ 300 ml/ha in T_6 and T_7 and Ratchet @ 450 ml/ha in T_8 and T_9 was done 20 DAS at 20th July and the third spraying with the products namely Ratchet @ 300 ml/ha in T_7 and Ratchet @ 450 ml/ha in T_9 was done 50 DAS at 15th August.

3.8.5 Intercultural operation

The experimental plot was irrigated during the cropping period with light irrigations. Weeding was done three times according to the requirement of maintaining uninterrupted growth of the crop.

3.8.6 Selection of plant for observation

In a field experiment, detailed study of the entire population is rather difficult. Since all the plants get identical environment, *i.e*. some plants from the population were randomly selected for detailed investigation, then five plants were selected at random in each plot and tagged for identification and recording their observations on the traits mentioned earlier.

3.9. OBSERVATIONS RECORDED

Observations on all the characters were made on five random plants of individual plots and in each treatment and replication. The observations recorded on the five plants were averaged to get mean value. For other traits, as specified above, the procedure is described under the respective sub-headings.

3.9.1 Days to first staminate flower anthesis

Number of days from date of sowing to the anthesis of first staminate flower in a plot was recorded as the number of days required for anthesis of first staminate flower.

3.9.2 Days to first pistillate flower anthesis

Number of days from date of sowing to the anthesis of first pistillate flower in a plot was recorded as the number of days required for anthesis of first pistillate flower.

3.9.3 Days to 50% staminate flower anthesis

The period from the day of sowing to the anthesis of first staminate flowering in 50% of plants in each plot were recorded.

3.9.4 Days to 50% pistillate flower anthesis

The period from the day of sowing to the anthesis of first pistillate flowering in 50% of plants in each plot were recorded.

3.9.5 Node at which first staminate flower appears

The node number from the base of the plant at which first staminate flower appeared was recorded as the node at which first staminate flower appears.

3.9.6 Node at which first pistillate flower appears

The node number from the base of the plant at which first pistillate flower appeared was recorded as the node at which first pistillate flower appears.

3.9.7 No. of staminate flowers per plant

Staminate flowers were counted from the first flower initiation to cessation of flowering.

3.9.8 No. of pistillate flowers per plant

Pistillate flowers were counted from the first flower initiation to cessation of flowering.

3.9.9 Sex ratio

It was obtained by dividing number of staminate flowers per plant on a plant by number of pistillate flowers per plant on the same plant.

3.9.10 Days to first fruit harvesting

Number of days from date of sowing to days to first fruit harvesting in a plot was recorded as the number of days required for days to first fruit harvesting.

3.9.11 Fruit length (cm)

Fruit length of edible fruits was recorded on five randomly selected fruits of a plot in each replication. The length of each fruit was measured as perpendicular

distance between the points of attachment of the stalk and centre of the blossom end with the help of measuring tape in centimeters and mean value was worked out

3.9.12 Fruit diameter (cm)

Fruit diameter of edible fruits was recorded on same five randomly selected fruits of a plot in each replication on which fruit length was measured. The measurement of fruit diameter at the thickest portion of the fruit was taken with the help of vernier caliper in centimeter and mean value was worked out.

3.9.13 Vine length (m)

The vine length was measured in meter from the ground level to the tip of the vine at the time of last picking from five randomly selected plants.

3.9.14 Number of primary branches on main axis of plant

Total number of primary branches of five randomly selected plants of a plot was counted at the time of last picking on main axis and average value was worked out.

3.9.15 Number of nodes on main axis of plant

The no. of nodes is counted from ground to top of the main axis of plant from five randomly selected plants.

3.9.16 Average fruit weight (g)

Through electronic weighing machine, individual fruit weight of five fruit was taken in grams from all the treatments and average value was worked out.

3.9.17 Number of fruits per plant

Number of edible fruits was counted at each picking and summed up for all the pickings of a plot. Number of fruits per plant was calculated after dividing total number of fruits in a plot by total number of plants in a plot.

3.9.18 Fruit yield per plant (kg)

The total fruit yield over all the pickings was recorded in kilogram for each plot and divided by total number of plant to obtain fruit yield per plant.

3.9.19 Fruit yield per plot (kg)

The total fruit yield over all the pickings was recorded in kilogram for each plot and sum up for obtain fruit yield per plot (kg).

3.9.20 Fruit yield (q/ha)

Total fruit yield (q/ha) of bottle gourd was based on the fruit yield per plot. The size of plot was 12.6 square meters and according to this total bottle gourd fruit yield was recorded on hectare basis.

3.10 STATISTICAL ANALYSIS

The results obtained from field observations were analyzed statistically as per Panse and Sukhatme (1985) for Randomized Block Design. The significance was tested by referring to 'F' tables of Fisher and Yates (1963).

The results from RBD can be arranged in two way table according to the replications (blocks) and treatments; there will be `rk' observations in total. The data can be arranged in the following table

Treatments	Blocks $b_1 \ldots b_2 \ldots \ldots b_j \ldots \ldots \ldots b_r$	Treatment Totals	Means
t_1	y_{11} $y_{12}, \ldots$ $y_{1j} \ldots \ldots \ldots y_{1r}$	T_1	$\overline{T}_1$
t_2	y_{21} $y_{22}, \ldots$ $y_{2j} \ldots \ldots \ldots y_{2r}$	T_2	$\overline{T}_2$
.	. . . .	.	.
.	. . . .	.	.
.	. . . .	.	.
t_i	y_{i1} $y_{i2}, \ldots$ $y_{ij} \ldots \ldots \ldots y_{ir}$	Ti	$\overline{T}$ i
.	. . . .	.	.
.	. . . .	.	.
t_k	y_{k1} $y_{k2}, \ldots$ $y_{kj} \ldots \ldots \ldots y_{kr}$	T_k	$\overline{T}_k$
Block totals	B_1 $B_2 \ldots \ldots B_j \ldots \ldots B_r$	G.T.	
Means	$\overline{B}_1$ $\overline{B}_2 \ldots \ldots \overline{B}_j \ldots \ldots \overline{B}_r$		

Mathematical model:

$$Y_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij} \qquad (i = 1,2,\ldots k;\ j = 1,2,\ldots \ldots r)$$

Where y_{ij} is the response of the j^{th} block and i^{th} treatment

μ = general mean effect

α_i = the effect due to i^{th} treatment

β_j = the effect due to j^{th} block

ε_{ij} is the error effect ($\varepsilon_{ij} \sim N(0,\sigma^2)$)

Null hypothesis: i) H_{01} : There is no significant difference between the treatment effects.

i.e. $\alpha_1 = \alpha_2 = \ldots\ldots\ldots\ldots\ldots = \alpha_k$

ii) H_{02}: There is no significant difference between the block effects

i.e. $\beta_1 = \beta_2 = \ldots\ldots\ldots\ldots\ldots = \beta_r$

The null hypothesis can be verified by applying the ANOVA procedure. The different steps are in the analysis of data are:

1) Correction factor $= \dfrac{(G.T)^2}{rk}$

2) *Treatment Sum of Squares (Tr.S.S.)* $= \dfrac{(T_1)^2 + (T_2{}^2) + \ldots\ldots\ldots\ldots + (T_K{}^2)}{r} - CF$

$$= \frac{\sum_{i=1}^{k} T_k{}^2}{r} - CF$$

3) *Block Sum of Squares (BSS)* $= \dfrac{(B_1{}^2) + (B_2{}^2) + \ldots\ldots\ldots\ldots + (B_r{}^2)}{k} - CF$

$$= \frac{\sum_{j=1}^{r} B_j{}^2}{k} - CF$$

4) *Total Sum of Squares (TSS)* $= \{y_{11}{}^2 + y_{12}{}^2 + y_{13}{}^2 + \ldots\ldots\ldots + y_{kr}{}^2\} - CF$

$$= \sum_{i=1}^{k}\sum_{j=1}^{r} y_{ij}{}^2 - CF$$

5) *Error Sum of Square (ESS)* $= TSS - Tr.S.S. - SSB$

ANOVA TABLE

Sources of variation	D.F	S.S	M.S.	F-Cal.Value	F-table value At 5% LOS
Treatments	*k-1*	*Tr.S.S.*	$TMS = \dfrac{Tr.S.S.}{k-1}$	$F_t = \dfrac{TMS}{EMS}$	*F[k-1,{(r-1)(k-1)}]*
Blocks (Replications)	*r-1*	*BSS*	$BMS = \dfrac{BSS}{r-1}$	$F_b = \dfrac{BMS}{EMS}$	*F[r-1, {(r-1)(k-1)}]*
Error	*(r-1)(k-1)*	*ESS*	$EMS = \dfrac{ESS}{(r-1)(k-1)}$		
Total	rk-1	TSS			

i. If the calculated value of F (Treatments) < table value of F, we accept H_0 and hence we may conclude that there is no significant difference between the treatment means.

ii. If calculated value of F (Treatments) > table value of F, we reject H_0 and hence we may conclude that there is significant difference between the treatment means.

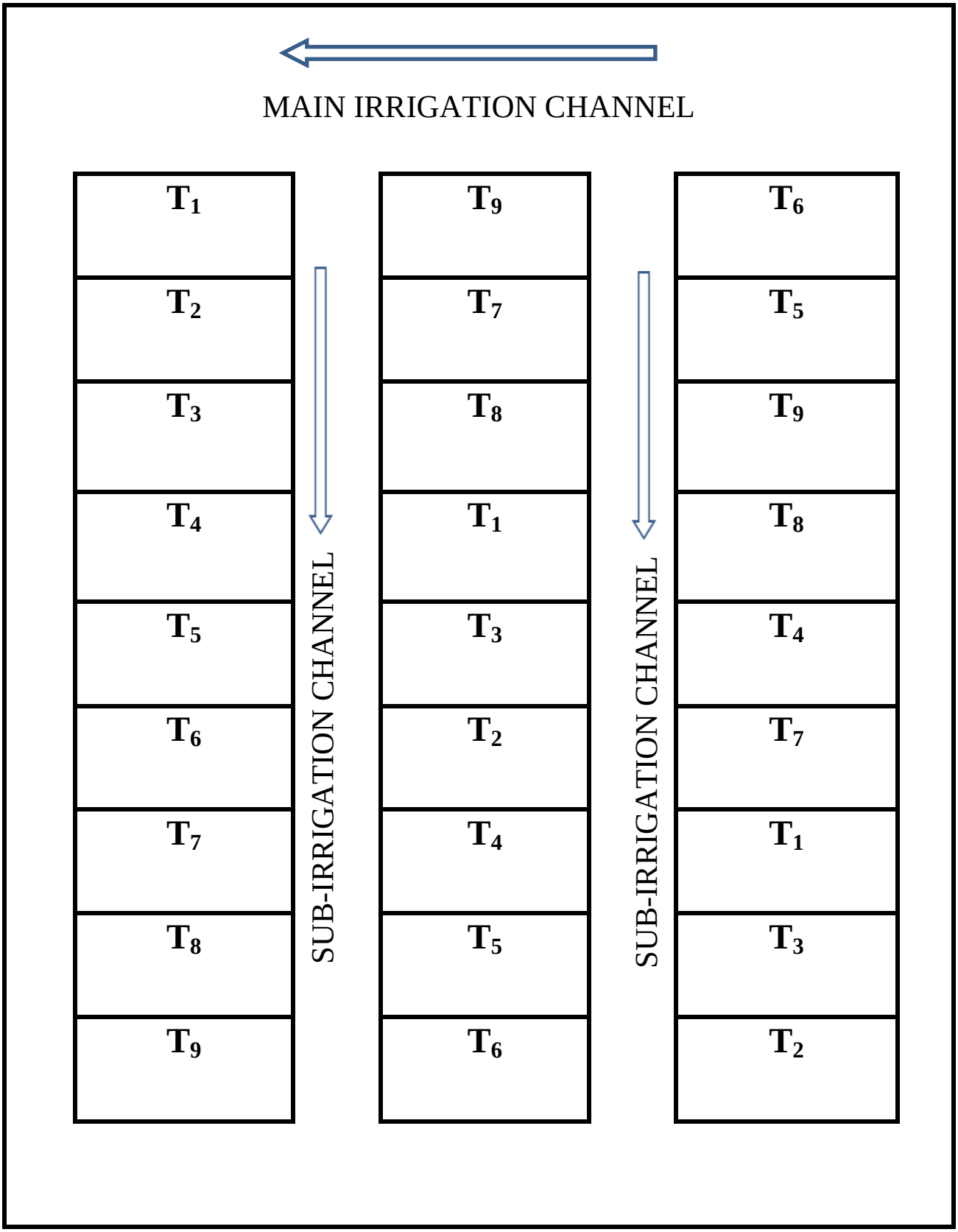
iii. If the treatments are significantly different, the comparison of the treatments is carried out on the basis of Critical Difference (C.D.).

C.D. = SED (Tr) x $t_{(r-1)(k-1)}$ at α level of significance

Where SED = $\sqrt{\frac{2xEMS}{r}}$

F (Blocks) should be not significant, if the planning of experiment is well manner.

Fig. 3.2: LAYOUT PLAN OF THE EXPERIMENTAL FIELD



CHAPTER-IV

EXPERIMENTAL FINDINGS

The present experiment entitled "Response of various Mycorrhizal strains on growth and yield characteristics of bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]" was designed to study the efficacy of different Mycorrhiza strain on growth and yield of bottle gourd. The results obtained are presented under following heads.

Days to first staminate flower anthesis

Data presented in the Table 4.1 and Fig. 4.1 had revealed that days to first staminate flowering had significant differences among the treatments. The number of days taken to first staminate flowering ranged between 44.00 days to 49.67 days. Among the treatments, T_9 recorded minimum number of days (44.00 days) followed by T_8 (45.67 days) and T_7 (46.00 days) and they were statistical at par with each other. The treatment T_2 took maximum number of days *i.e.* 49.67 for appearance of first staminate flower. Across the treatments, mean value of days to first staminate flowering was 47.11 days.

Days to first pistillate flower anthesis

The results of observations on days to first pistillate flower anthesis are presented in Table 4.1 and Fig. 4.2. The results revealed significant differences among the treatments for the trait. The number of days taken to first pistillate flower anthesis ranged between 51.00 days to 55.33 days. Among the treatments, T_3 recorded minimum number of days (51 days) followed by T_9 (52.33 days) and T_4 (52.67 days) where the treatments T_9 and T_4 were statistical at par with T_3. Maximum number of days (55.33 days) to first pistillate flowering was observed in treatment T_2 followed by T_1 (55.00 days) and T_6 (54.67 days), respectively. The population mean of these parameters was 53.40 days.

Table 4.1: Effect of various mycorrhizal strains on days to first staminate and pistillate flower anthesis

Treatments	Doses	DFSFA	DFPFA
T_1	Untreated Control	49.33	55.00
T_2	Soil application with Myc100 @ 250 g/ha × 1 application @ 15 DAS	49.67	55.33
T_3	Soil application with RhizoMyco100 @ 250 g/ha × 1 application @ 15 DAS	47.33	51.00
T_4	Soil application with RhizoMyxo100 @ 250 g/ha × 1 application @ 15 DAS	47.67	52.67
T_5	Soil application with Bolt Gr. @ 10 kg/ha × 1 application @ 15 DAS	48.00	54.00
T_6	Soil application with Ratchet @ 300 ml/ha × 1 application @ 20 DAS	46.33	54.67
T_7	Soil application with Ratchet @ 300 ml/ha × 2 applications @ 20 and 50 DAS	46.00	52.67
T_8	Soil application with Ratchet @ 450 ml/ha × 1 application @ 20 DAS	45.67	53.00
T_9	Soil application with Ratchet @ 450 ml/ha × 2 application @ 20 and 50 DAS	44.00	52.33
GRAND MEAN		47.11	53.40
SE.M.±		0.934039	0.719129
CD 5%		2.775171	2.136642

DFSFA- Days to first staminate flower anthesis

DFPFA- Days to first pistillate flower anthesis

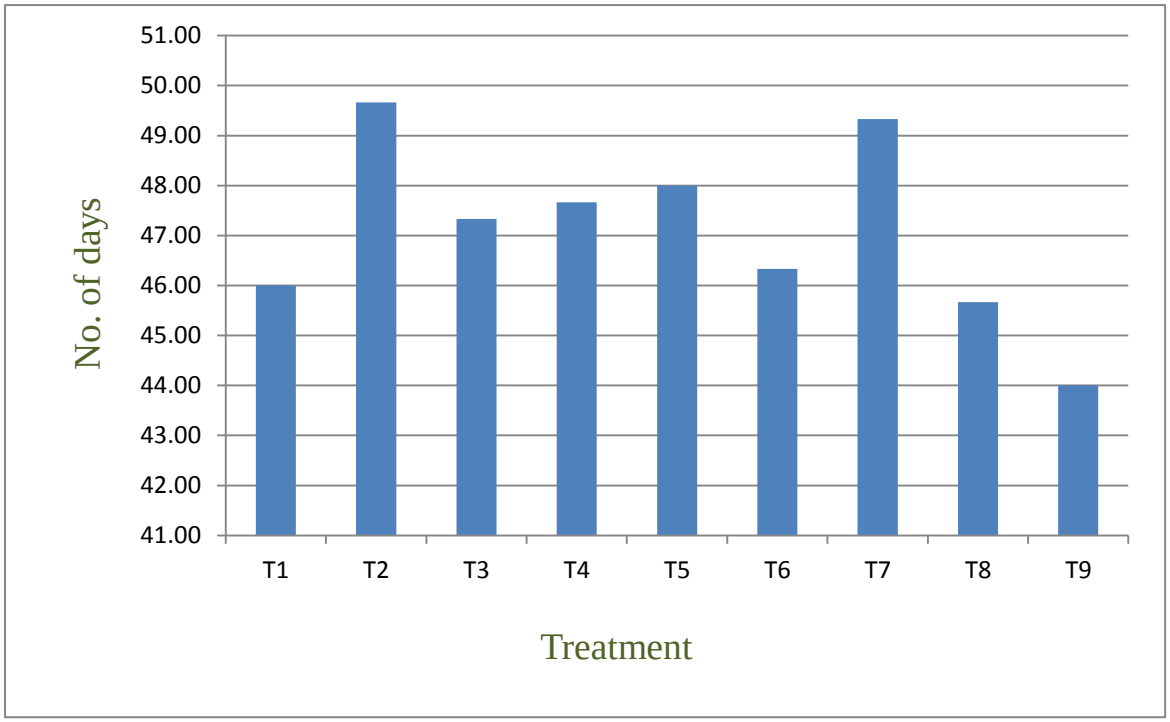


Fig. 4.1: Days to first staminate flower anthesis

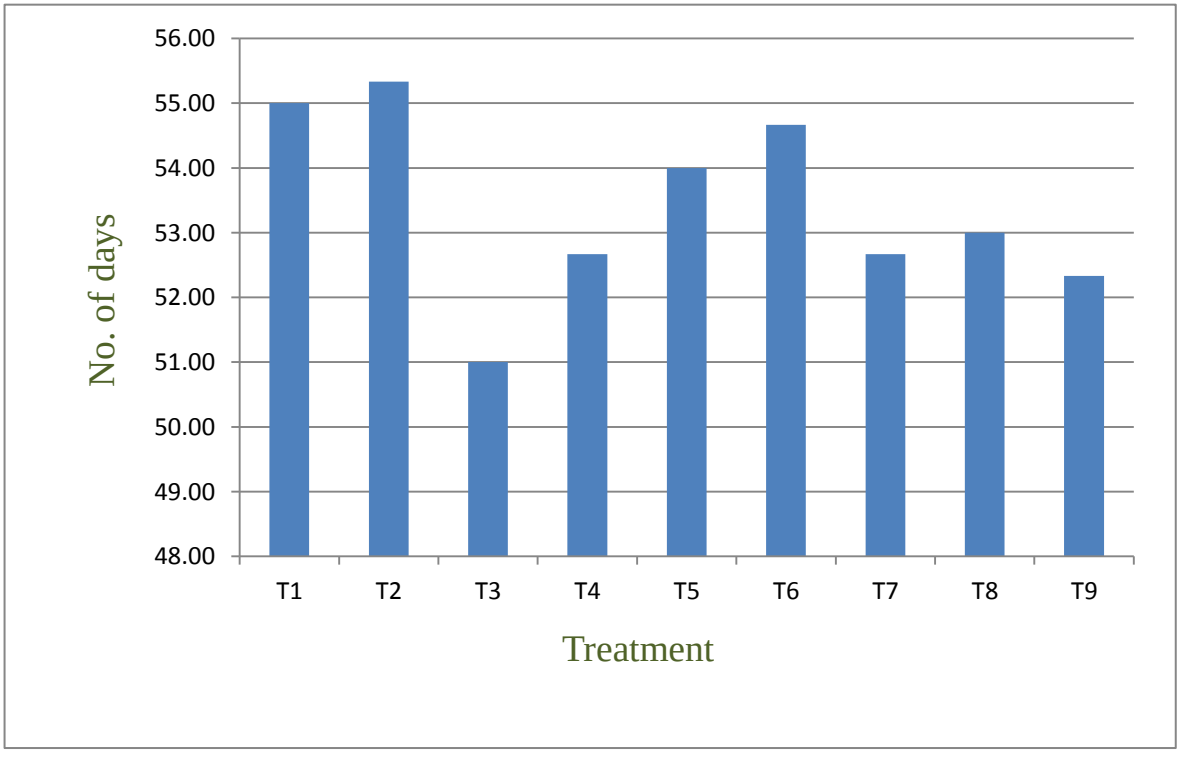


Fig. 4.2: Days to first pistillate flower anthesis

Days to 50% staminate flower anthesis

The results on days to 50% staminate flower anthesis are presented in the Table 4.2 and Fig. 4.3. The number of days taken to 50% staminate flowering ranged between 50 days to 54.33 days. Minimum number of days recorded in the treatments T_7 and T_8 (50 days) that is followed by T_6 (50.67 days) and T_3 (51days) and they were statistically at par. Maximum number of days to 50% flowering (54.33 days) was noted in treatment T_2 followed by T_1 (53.67 days). The population mean of this parameter was 51.81days.

Days to 50% pistillate flower anthesis

The data recorded for days to 50% pistillate flower anthesis are presented in the Table 4.2 and Fig. 4.4. The results revealed that days to 50% pistillate flowering was significantly affected by the treatments. The number of days taken to 50% pistillate flowering ranged between 56 to 60.33 days. Among the treatments, T_3 recorded minimum number of days (56 days) and it was at par with T_9 (57.00 days) T_7 (57.33 days), T_4 and T_5 (58 days). The treatment T_1 recorded maximum number of days to 50% flowering (60.33 days) followed by T_2 (60 days) and T_6 (59 days). Population mean of this parameter was 58.25 days.

Node at which first staminate flower appears

Data for the trait are presented in the Table 4.3 and Fig. 4.5. The results obtained showed that number of node at which first staminate flower appears showed significant differences among the treatments. The number of node at which first staminate flower appears ranges between 14.20 to 16.93 nodes and treatment T_9 produced staminate flower on the earliest node *i.e.* (14.20 node) followed by T_5 (14.30 node) and T_7 (14.67 node) where they were statistically at par with each other. The maximum node for this trait (16.93 node) was observed by treatment T_4. The population mean across the treatment was 15.46 node.

Table 4.2: Effect of various mycorrhizal strains on days to 50% staminate and pistillate flower anthesis

Treatments	Doses	D50% SFA	D50% PFA
T_1	Untreated Control	53.67	60.33
T_2	Soil application with Myc100 @ 250 g/ha × 1 application @ 15 DAS	54.33	60.00
T_3	Soil application with RhizoMyco100 @ 250 g/ha × 1 application @ 15 DAS	51.00	56.00
T_4	Soil application with RhizoMyxo100 @ 250 g/ha × 1 application @ 15 DAS	52.00	58.00
T_5	Soil application with Bolt Gr. @ 10 kg/ha × 1 application @ 15 DAS	51.67	58.00
T_6	Soil application with Ratchet @ 300 ml/ha × 1 application @ 20 DAS	50.67	59.00
T_7	Soil application with Ratchet @ 300 ml/ha × 2 applications @ 20 and 50 DAS	50.00	57.33
T_8	Soil application with Ratchet @ 450 ml/ha × 1 application @ 20 DAS	50.00	58.67
T_9	Soil application with Ratchet @ 450 ml/ha × 2 application @ 20 and 50 DAS	53.00	57.00
GRAND MEAN		51.81	58.25
SE.M.±		0.787418	1.009557
CD 5%		2.33954	2.999546

D50% SFA: Days to 50 % staminate flower anthesis

D50% PFA: Days to 50 % pistillate flower anthesis

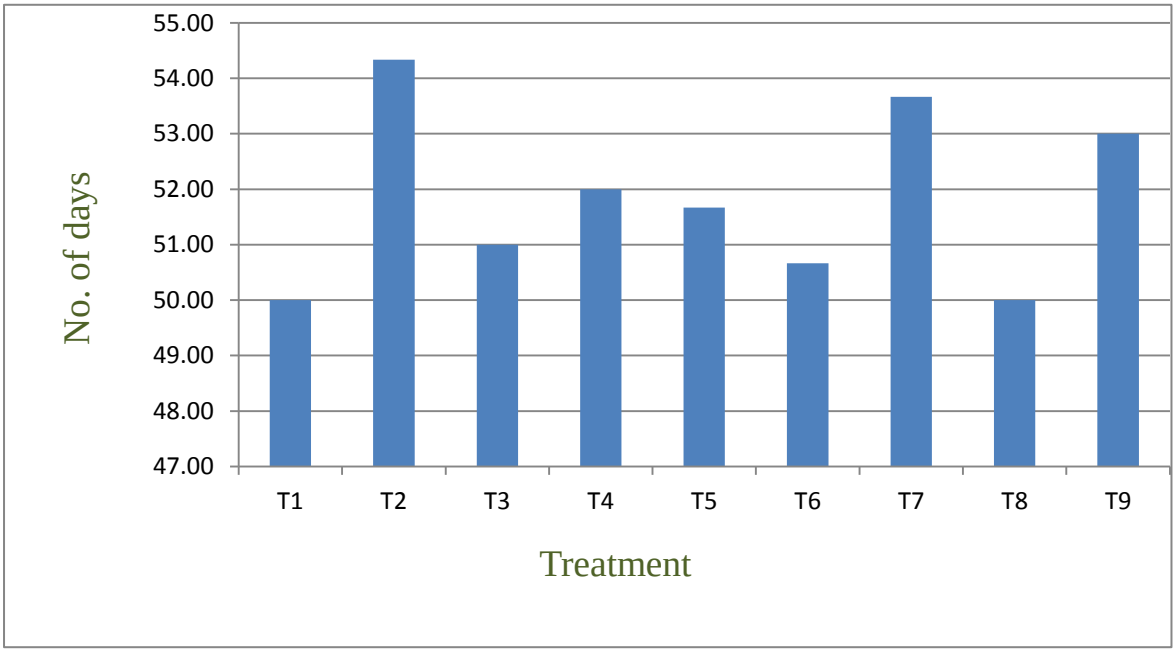


Fig. 4.3: Days to 50% staminate flower anthesis

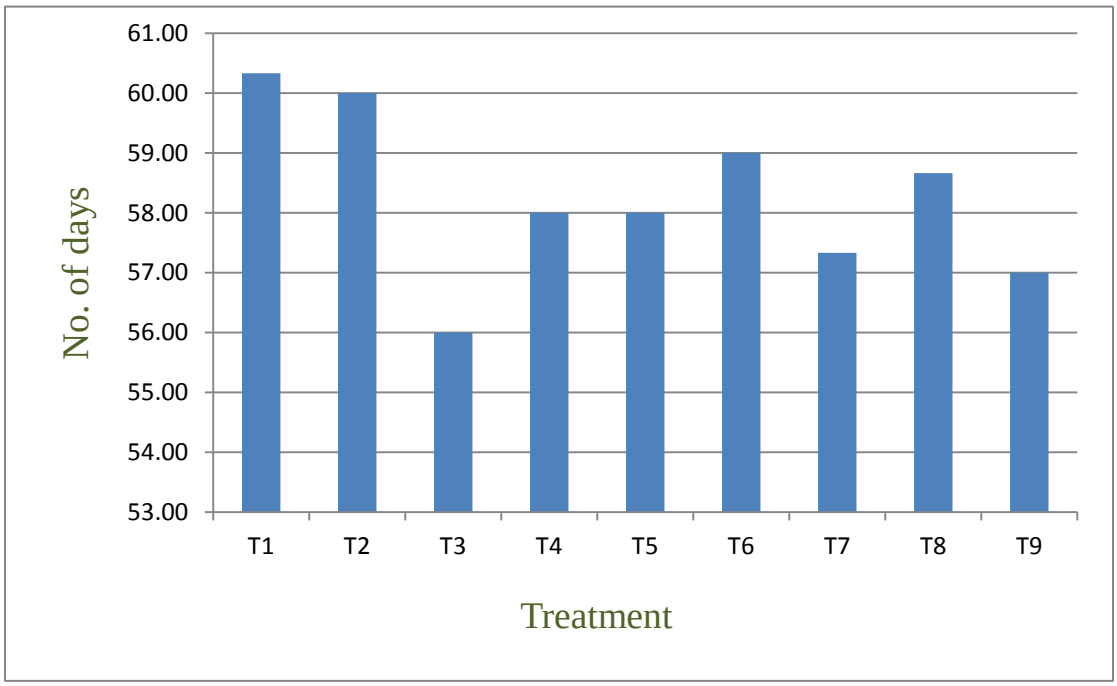


Fig. 4.4: Days of 50% pistillate flower anthesis

Node at which first pistillate flower appears

The results on node number at which first pistillate flower appeared are presented in Table. 4.3 and Fig. 4.6. The number of node at which first pistillate flower appeared which was ranged between 20.53 to 22.13 node and the analysis of variance revealed that the treatment T_5 produced pistillate flower on the earliest node *i.e.* (20.53 node) followed by T_9 (20.60 node) and T_7 (20.67 node), while the treatment T_4 produced pistillate flower on a higher node number (22.13 node) but all the treatments including control were statistical at par with each other. The population mean for this character was found 21.15 node.

No. of staminate flowers per plant

Data for number of staminate flowers per plant presented in the Table 4.4 and Fig. 4.7 which was ranged between 103.47 to 91.07 and shown that the less number of staminate flowers per plant were recorded by treatment T_8 (91.07) followed by T_1 (91.60), T_7 (93.67) and T_9 (94.67) and they were statistical at par. Highest number of staminate flowers per plant was observed in the treatment T_3 (103.47) followed by T_6 (99.13) and T_4 (98.40). Population mean for this trait was (96.09) flowers.

No. of pistillate flowers per plant

Data on number of pistillate flowers per plant ranged between 8.50 to 11.93 and are presented in the Table 4.4 and Fig. 4.8 which indicated that highest number of pistillate flowers per plant was recorded in treatment T_2 (11.93) followed by T_4 (11.83) and T_3 (11.40) where T2 was statistical at par with T_4 and T_3, while treatment T_1 produced least number (8.50) of pistillate flowers per plant followed by T_8 (9.07). Population mean for this character was 10.65 flowers.

Sex ratio

The data for sex ratio ranged between 8.12 to 10.81 and are presented in Table 4.5 and Fig.4.9. The results revealed that treatment T_2 (8.12) had lower sex ratio which was followed by T_7 (8.21), T_4 (8.35) and T_9 (8.74) and all were statistical at par with each other. Higher sex ratio was found in control T_1 (10.81) which at par with T_5 (10.19), T_8 (10.10), T_3 (9.11) and T_6 (8.78) and its population mean is 9.15 we know that lower sex ratio is desirable in bottle gourd.

Table 4.3: Effect of various mycorrhizal strains on node at which first staminate and pistillate flower appears

Treatments	Doses	NWFSFA	NWFPFA
T_1	Untreated Control	16.13	20.87
T_2	Soil application with Myc100 @ 250 g/ha × 1 application @ 15 DAS	16.13	21.33
T_3	Soil application with RhizoMyco100 @ 250 g/ha × 1 application @ 15 DAS	15.00	21.73
T_4	Soil application with RhizoMyxo100 @ 250 g/ha × 1 application @ 15 DAS	16.93	22.13
T_5	Soil application with Bolt Gr. @ 10 kg/ha × 1 application @ 15 DAS	14.30	20.53
T_6	Soil application with Ratchet @ 300 ml/ha × 1 application @ 20 DAS	16.33	21.60
T_7	Soil application with Ratchet @ 300 ml/ha × 2 applications @ 20 and 50 DAS	14.67	20.67
T_8	Soil application with Ratchet @ 450 ml/ha × 1 application @ 20 DAS	15.47	20.93
T_9	Soil application with Ratchet @ 450 ml/ha × 2 application @ 20 and 50 DAS	14.20	20.60
GRAND MEAN		15.46	21.15
SE.M.±		0.691592	1.18405
CD 5%		2.054824	3.517994

NWFSFA: Node at which first staminate flower appears

NWFPFA: Node at which first pistillate flower appears

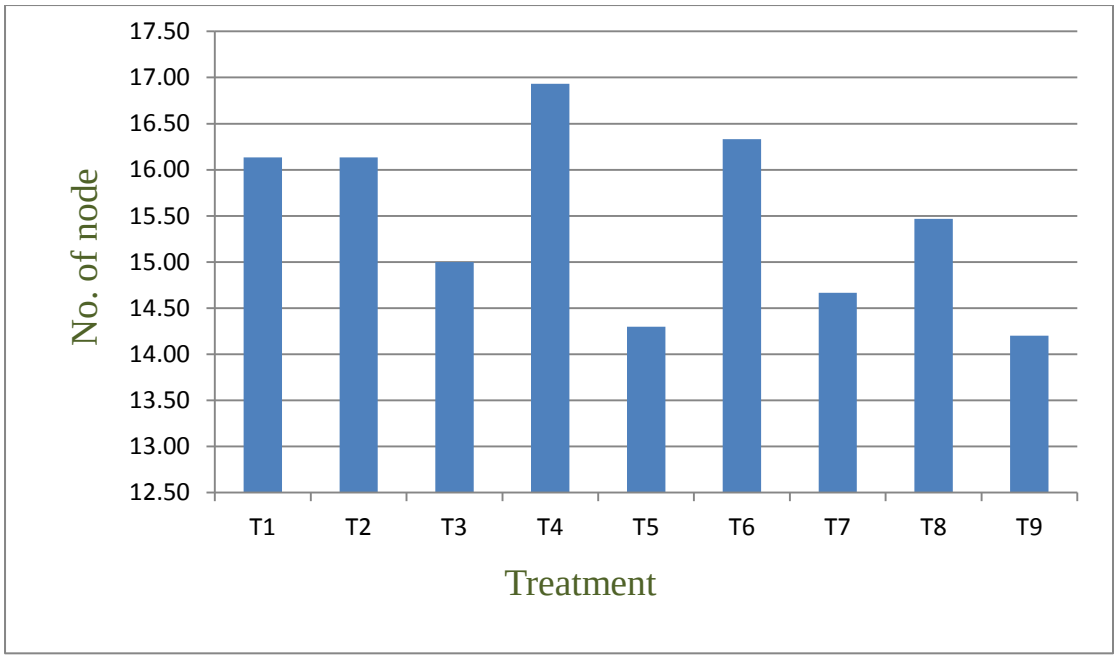


Fig. 4.5: Node at which first staminate flower appears

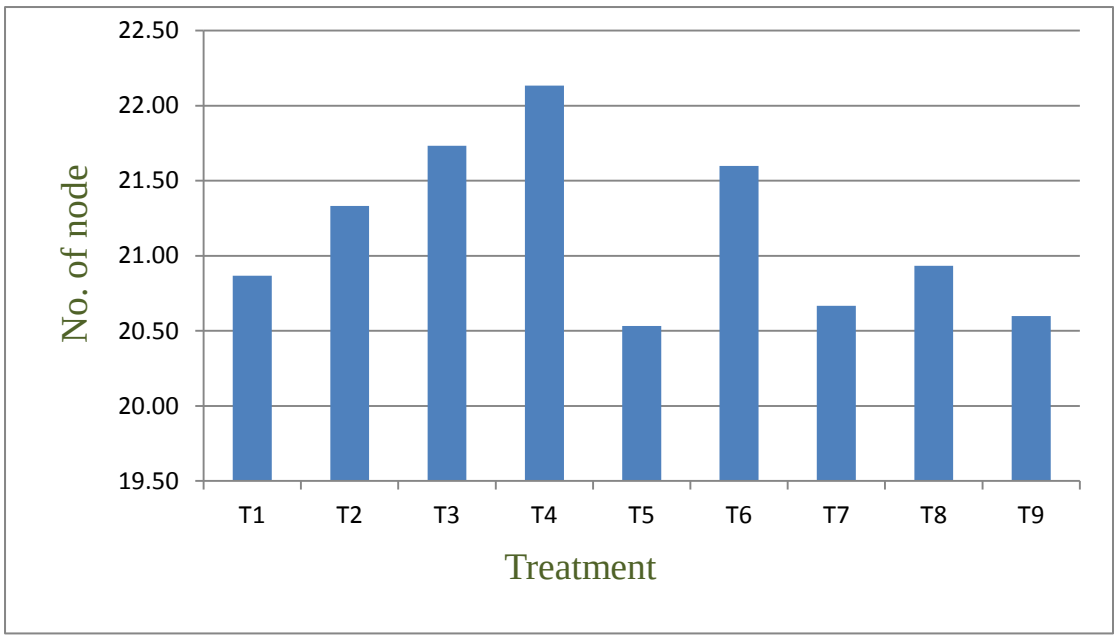


Fig. 4.6: Node at which first pistillate flower appears

Days to first fruit harvesting

Data on days to first fruit harvesting are presented in the Table 4.5 and Fig. 4.10. The number of days taken to first fruit harvesting ranged between 59.67 to 63.67 days. Among the treatments, T_3, T_5 and T_9 took minimum number of days for first fruit harvesting (59.67 days) followed by T_6 and T_7 (60.00 days), whereas maximum number of days to first fruit harvesting (63.67 days) was noted in treatment T_1 however all the treatments along with control were statistical at par. The population mean of this parameter was 60.81 days.

Fruit length (cm)

The data related to fruit length ranged between 39.37 to 45.90 cm and are presented in the Table 4.6 and Fig. 4.11 revealed that there was significant difference in fruit lengths depending on different treatments. The treatment T_6 produced longest fruit (45.90 cm) followed by T_7 (45.50 cm) and T_9 (45.00 cm) and they were statistically at par with each other. Shortest fruit were found in the treatment T_8 (39.37 cm). In the present study population mean observed for this character was 43.10 cm.

Fruit diameter (cm)

Statistical analysis revealed that there were significant differences in fruit diameter depending on different treatments. Data for fruit diameter are presented in the Table 4.6 and Fig.4.12. Among different treatments, fruit diameter ranged between 5.53 to 6.31 cm whereas treatment T_6 recorded maximum diameter of fruits (6.31 cm) followed by T_5 (6.30 cm) and T_2 (6.25 cm) where treatment T_5 and T_2 were statistically at par with each T_6. While treatment T_3 produced minimum diameter of fruit (6.31 cm).The population mean for this character was found to be 6.04 cm.

Vine length (m)

Data presented in the Table 4.7 and Fig.4.13 had shown that vine length was significantly affected by the treatments and which ranged between 4.76 to 6.29 m. longest vines was exhibited by treatment T_2 (6.29 m) and was significantly different with all other treatments. The next longest vine was recorded by treatment T_6 (6.08 m) followed by T_7 and T_3 (5.91 m) and they were statistical at par with treatment T_2. Treatment T_1 and T_5 recorded shortest vine length of 4.76 m and 5.06 m, respectively. Vine length showed a population mean of 5.63 m.

Table 4.4: Effect of various mycorrhizal strains on no. of staminate and pistillate flowers per plant

Treatments	Doses	NSFP	NPFP
T_1	Untreated Control	91.60	8.50
T_2	Soil application with Myc100 @ 250 g/ha × 1 application @ 15 DAS	96.27	11.93
T_3	Soil application with RhizoMyco100 @ 250 g/ha × 1 application @ 15 DAS	103.47	11.40
T_4	Soil application with RhizoMyxo100 @ 250 g/ha × 1 application @ 15 DAS	98.40	11.83
T_5	Soil application with Bolt Gr. @ 10 kg/ha × 1 application @ 15 DAS	96.60	9.50
T_6	Soil application with Ratchet @ 300 ml/ha × 1 application @ 20 DAS	99.13	11.33
T_7	Soil application with Ratchet @ 300 ml/ha × 2 applications @ 20 and 50 DAS	93.67	11.43
T_8	Soil application with Ratchet @ 450 ml/ha × 1 application @ 20 DAS	91.07	9.07
T_9	Soil application with Ratchet @ 450 ml/ha × 2 application @ 20 and 50 DAS	94.67	10.87
GRAND MEAN		96.09	10.65
SE.M.±		1.402858	0.457434
CD 5%		4.168105	1.359105

NSFP: No. of staminate flowers per plant

NPFP: No. of pistillate flowers per plant

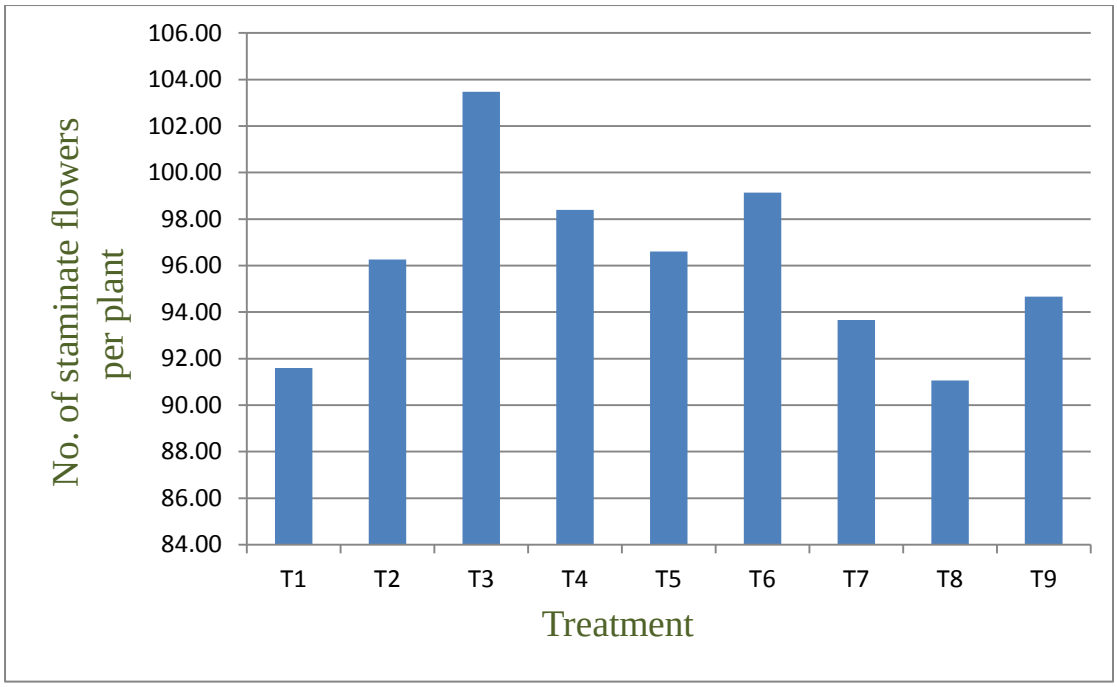


Fig. 4.7: Number of staminate flowers per plant

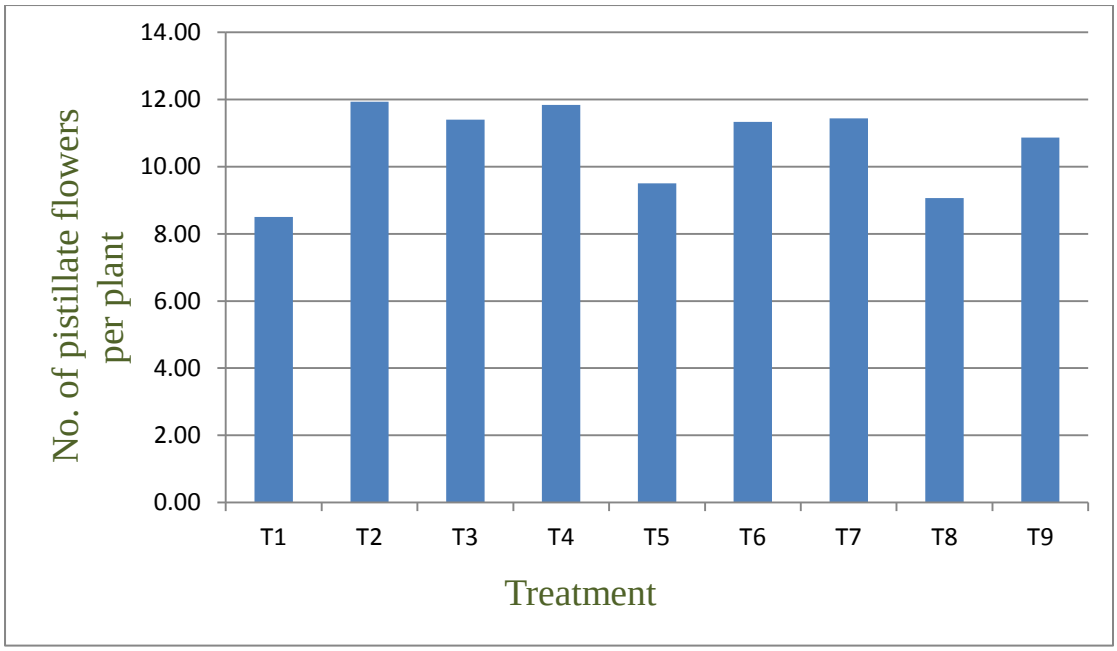


Fig. 4.8: Number of pistillate flowers per plant

Number of primary branches on main axis of plant

Number of primary branches on main axis of plant was ranges between 3.60 to 5.43 and are presented in the Table 4.7 and Fig. 4.14 indicated that the maximum number of branches per plant was recorded in treatment T_2 (5.43) followed by T_3 (5.20), T_6 and T_8 (4.77) and they were statistically at par with each other. The treatment T_1 recorded minimum number of branches (3.60). The population mean of this parameter was 4.70.

Number of nodes on main axis of plant

Data presented in the Table 4.8 and Fig. 4.15 revealed that the no. of node on main axis of plant ranged between 20.20 to 23.13 and the maximum number of node on mane axis per plant was recorded in treatment T_2 and T_3 (23.13) and was significantly superior to all other treatments. This was followed by treatment T_6 (23.00) and T_7 (22.53) and they were statistically at par with treatment T_2 and T_3. The minimum nodes were observed in treatment T_9 (20.20). The population means value of this parameter was found to be 21.97.

Average fruits weight (g)

The data on average fruits weight is presented in the Table 4.8 and Fig.4.16 indicated that among the different treatments fruit weight varied between 707.32 to 916.33 g. Maximum fruit weight were produced by treatment T_2 (916.33 g). This trait was followed by treatment T_7 (881.55 g) and T_5 (844.67 g). While minimum fruit weight were observed with treatment T_4 (707.32 g). The population mean for this character was 806.71 g.

Number of fruits per plant

The data on number of fruits per plant pertaining to different treatments are represented in Table 4.9 and Fig.4.17. Significant difference in number of fruits per plants noticed due to different treatments. This was ranged between “6.53 to 7.97". On the basis of mean performance, it was revealed that highest number of fruits was produced by treatment T_3 (7.97). This was superior to all other treatments. The next best treatment was T_4 with 7.77 fruits per plant followed by T_2 and T_8 (7.47). Minimum no. of fruits was observed in treatment T_1 (6.53). All the treatment they were statistically at par except control. The population mean for this trait was 7.32.

Table 4.5: Effect of various mycorrhizal strains on sex ratio and days to first fruit harvesting

Treatments	Doses	Sex ratio	DFFH
T_1	Untreated Control	10.81	63.67
T_2	Soil application with Myc100 @ 250 g/ha × 1 application @ 15 DAS	8.12	62.00
T_3	Soil application with RhizoMyco100 @ 250 g/ha × 1 application @ 15 DAS	9.11	59.67
T_4	Soil application with RhizoMyxo100 @ 250 g/ha × 1 application @ 15 DAS	8.35	62.33
T_5	Soil application with Bolt Gr. @ 10 kg/ha × 1 application @ 15 DAS	10.19	59.67
T_6	Soil application with Ratchet @ 300 ml/ha × 1 application @ 20 DAS	8.78	60.00
T_7	Soil application with Ratchet @ 300 ml/ha × 2 applications @ 20 and 50 DAS	8.21	60.00
T_8	Soil application with Ratchet @ 450 ml/ha × 1 application @ 20 DAS	10.10	60.33
T_9	Soil application with Ratchet @ 450 ml/ha × 2 application @ 20 and 50 DAS	8.73	59.67
GRAND MEAN		9.15	60.81
SE.M.±		0.296347	1.463783
CD 5%		0.880493	4.349123

DFFH: Days to first fruit harvesting

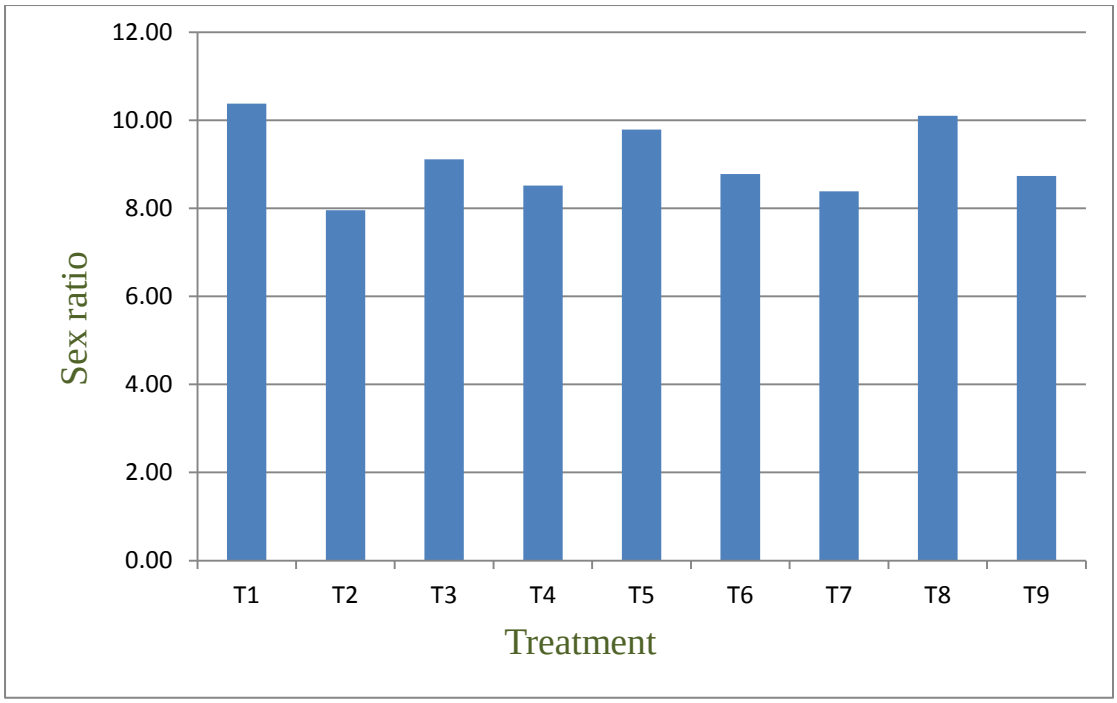


Fig. 4.9: Sex ratio

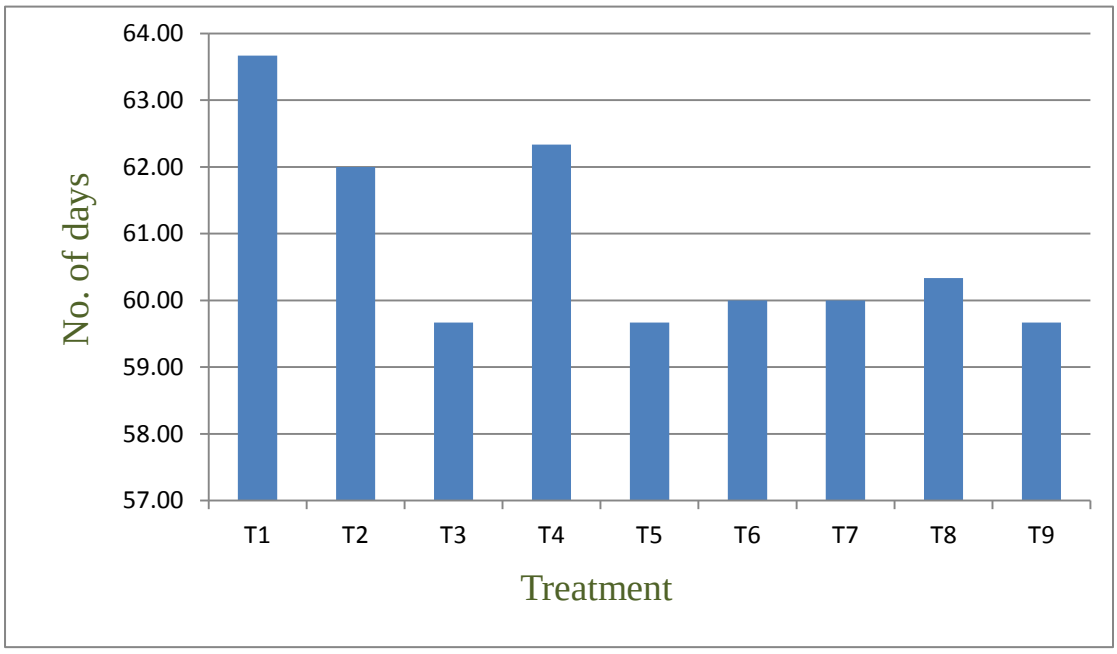


Fig. 4.10: Days to first fruits harvesting

Fruit yield per plant (kg)

The data on fruit yield per plant is presented in the Table 4.9 and Fig.4.18. The population mean for this character was (5.92 kg) and which range between 4.65 to 6.83 kg. The treatment T_2 produced highest fruit yield per plant (6.83 kg) and was significantly superior. The next best treatments was T_7 (6.40 kg), T_3 (6.39 kg) and T_8 (6.18 kg) and they were statistically at par with treatment T_2. Treatment T_1 was found to be the lowest yielder with a fruit yield per plants of 4.65.

Fruit yield per plot (kg)

Fruit yield per plot ranged between 46.56 to 68.36 kg and are presented in the Table 4.10 and Fig. 4.19. The treatment T_2 produced highest fruit yield per plot *i.e.* 68.36 kg followed by T_7 (64.03 kg), T_3 (63.92 kg) and T_5 (62.42 kg) and treatment T_7, T_3 and T_5 were statistically at par with treatment T_2. The treatment T_1 was found to be the lowest yielder with a fruit yield per plot of 46.56 kg. The population mean for this character was 59.31 kg.

Fruit yield (q/ha)

The data recorded for fruit yield (q/ha) are presented in the Table 4.10 and Fig. 4.20. The results revealed that fruit yield (q/ha) was significantly affected by the treatments. The fruit yield (q/ha) ranged between 369.53 to 542.58 (q/ha). Among the treatments, T_2 recorded maximum fruit yield (542.58 q/ha) followed by T_7 (508.17 q/ha), T_3 (507.37 q/ha) and T_5 (495.44 q/ha) and they were statistically at par with each other. The treatment T_1 recorded minimum fruit yield (369.53 q/ha). Population mean of this parameter was 470.82 (q/ha).

Table 4.6: Effect of various mycorrhizal strains on fruit length (cm) and fruit width (cm)

Treatments	Doses	Fruit length (cm)	Fruit diameter (cm)
T_1	Untreated Control	40.70	5.85
T_2	Soil application with Myc100 @ 250 g/ha × 1 application @ 15 DAS	43.70	6.25
T_3	Soil application with RhizoMyco100 @ 250 g/ha × 1 application @ 15 DAS	40.97	5.53
T_4	Soil application with RhizoMyxo100 @ 250 g/ha × 1 application @ 15 DAS	41.93	6.07
T_5	Soil application with Bolt Gr. @ 10 kg/ha × 1 application @ 15 DAS	44.90	6.30
T_6	Soil application with Ratchet @ 300 ml/ha × 1 application @ 20 DAS	45.90	6.31
T_7	Soil application with Ratchet @ 300 ml/ha × 2 applications @ 20 and 50 DAS	45.50	5.88
T_8	Soil application with Ratchet @ 450 ml/ha × 1 application @ 20 DAS	39.37	6.07
T_9	Soil application with Ratchet @ 450 ml/ha × 2 application @ 20 and 50 DAS	45.00	6.17
GRAND MEAN		43.10	6.04
SE.M.±		1.169602	0.215025
CD 5%		3.475067	0.638871

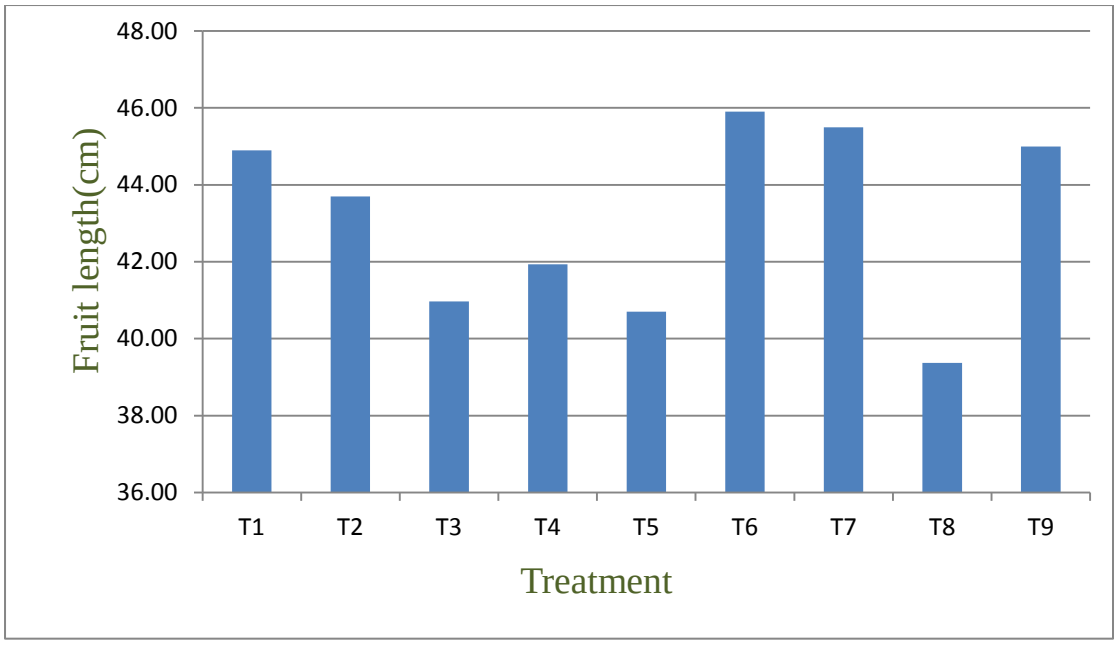


Fig. 4.11: Fruit Length (cm)

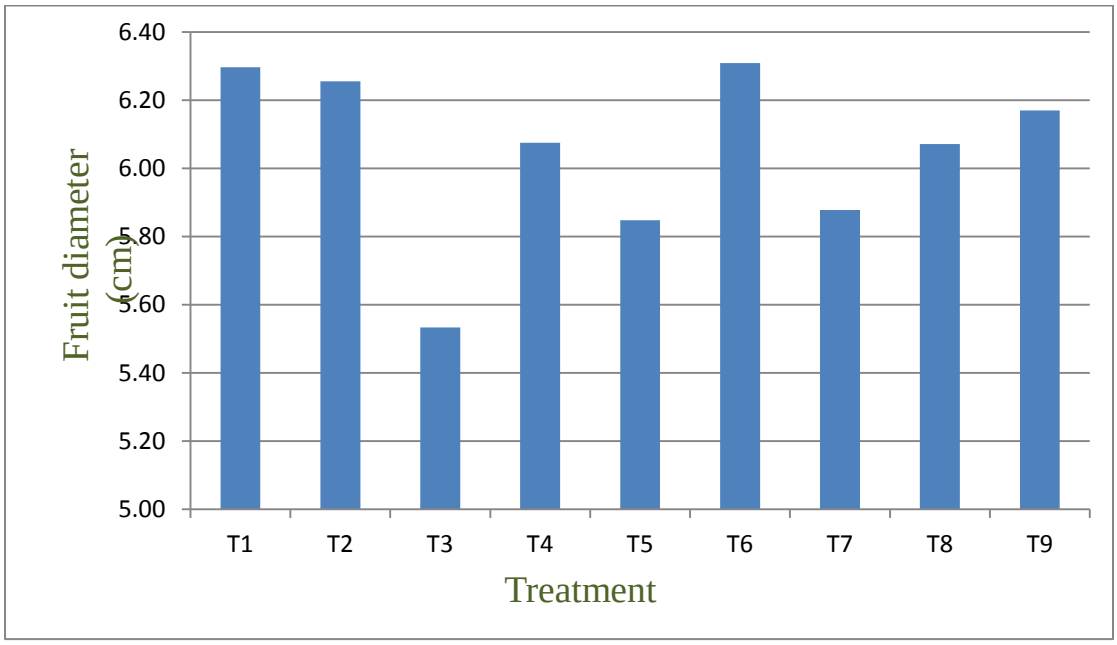


Fig. 4.12: Fruit diameter (cm)

Table 4.7: Effect of various mycorrhizal strains on vine length and number of primary branches on main axis of plant

Treatments	Doses	Vine length (m)	NPBMA
T_1	Untreated Control	4.76	3.60
T_2	Soil application with Myc100 @ 250 g/ha × 1 application @ 15 DAS	6.29	5.43
T_3	Soil application with RhizoMyco100 @ 250 g/ha × 1 application @ 15 DAS	5.91	5.20
T_4	Soil application with RhizoMyxo100 @ 250 g/ha × 1 application @ 15 DAS	5.59	4.63
T_5	Soil application with Bolt Gr. @ 10 kg/ha × 1 application @ 15 DAS	5.06	4.70
T_6	Soil application with Ratchet @ 300 ml/ha × 1 application @ 20 DAS	6.08	4.77
T_7	Soil application with Ratchet @ 300 ml/ha × 2 applications @ 20 and 50 DAS	5.91	4.57
T_8	Soil application with Ratchet @ 450 ml/ha × 1 application @ 20 DAS	5.89	4.77
T_9	Soil application with Ratchet @ 450 ml/ha × 2 application @ 20 and 50 DAS	5.21	4.67
GRAND MEAN		5.63	4.70
SE.M.±		0.291813	0.272292
CD 5%		0.86702	0.80902

NPBMA: Number of primary branches on main axis of plant

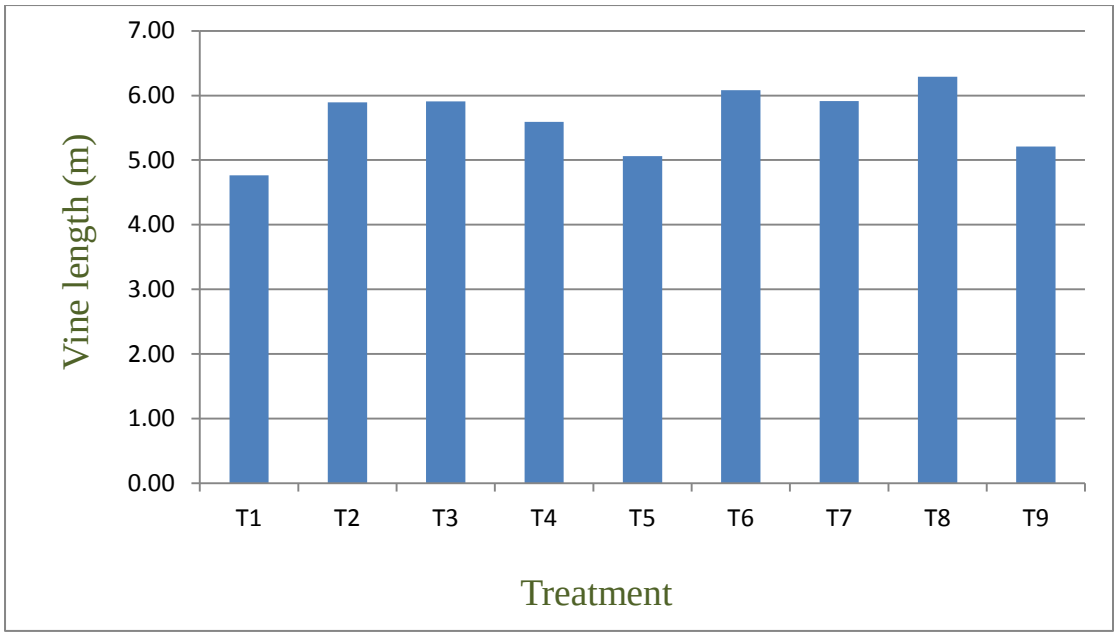


Fig. 4.13: Vine length (m)

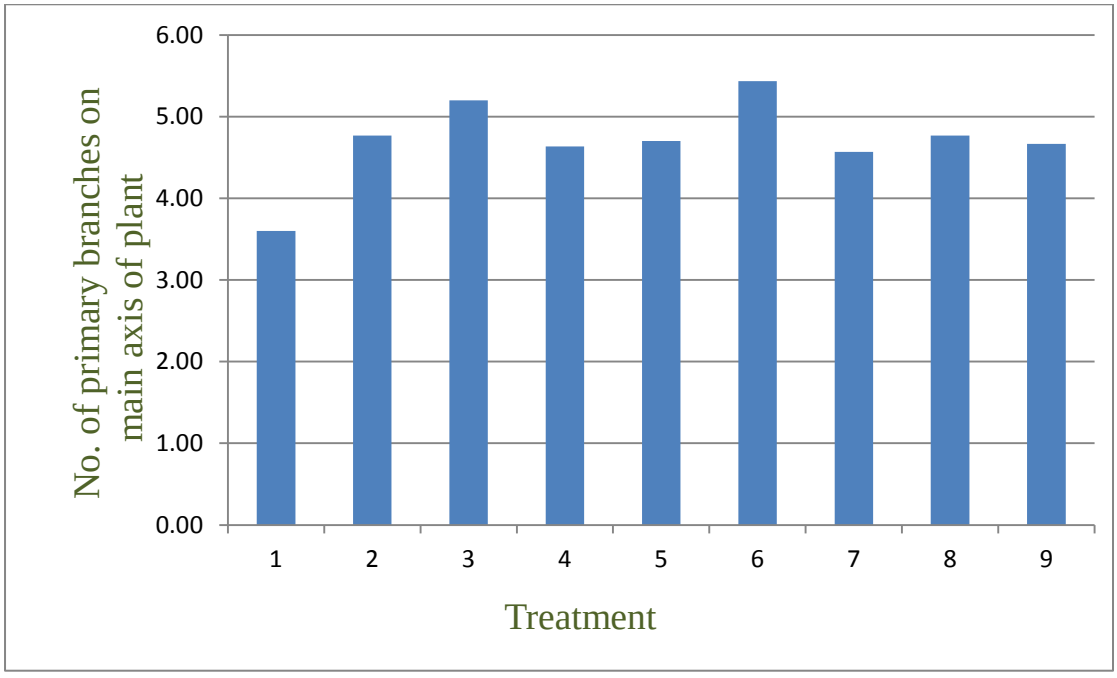


Fig. 4.14: No of primary branches on main axis of plant

Table 4.8: Effect of various mycorrhizal strains on number of nodes on main axis of plant and average fruit weight (g)

Treatments	Doses	NNMA	Average fruit weight (g)
T_1	Untreated Control	20.80	712.81
T_2	Soil application with Myc100 @ 250 g/ha × 1 application @ 15 DAS	23.13	916.33
T_3	Soil application with RhizoMyco100 @ 250 g/ha × 1 application @ 15 DAS	23.13	802.59
T_4	Soil application with RhizoMyxo100 @ 250 g/ha × 1 application @ 15 DAS	22.47	707.32
T_5	Soil application with Bolt Gr. @ 10 kg/ha × 1 application @ 15 DAS	21.07	844.67
T_6	Soil application with Ratchet @ 300 ml/ha × 1 application @ 20 DAS	23.00	819.93
T_7	Soil application with Ratchet @ 300 ml/ha × 2 applications @ 20 and 50 DAS	22.53	881.55
T_8	Soil application with Ratchet @ 450 ml/ha × 1 application @ 20 DAS	21.40	806.88
T_9	Soil application with Ratchet @ 450 ml/ha × 2 application @ 20 and 50 DAS	20.20	768.41
GRAND MEAN		21.97	806.71
***SE.M.*±**		0.602145	6.178845
CD 5%		1.789065	18.35829

NNMA*:* Number of nodes on main axis of plant

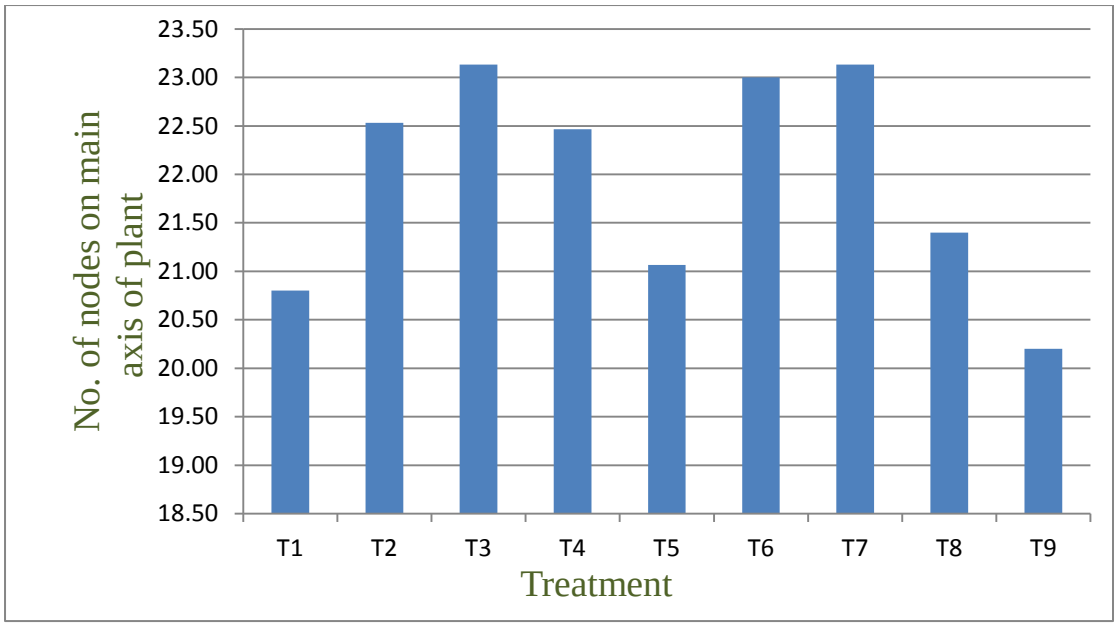


Fig. 4.15: No. of nodes on main axis of plant

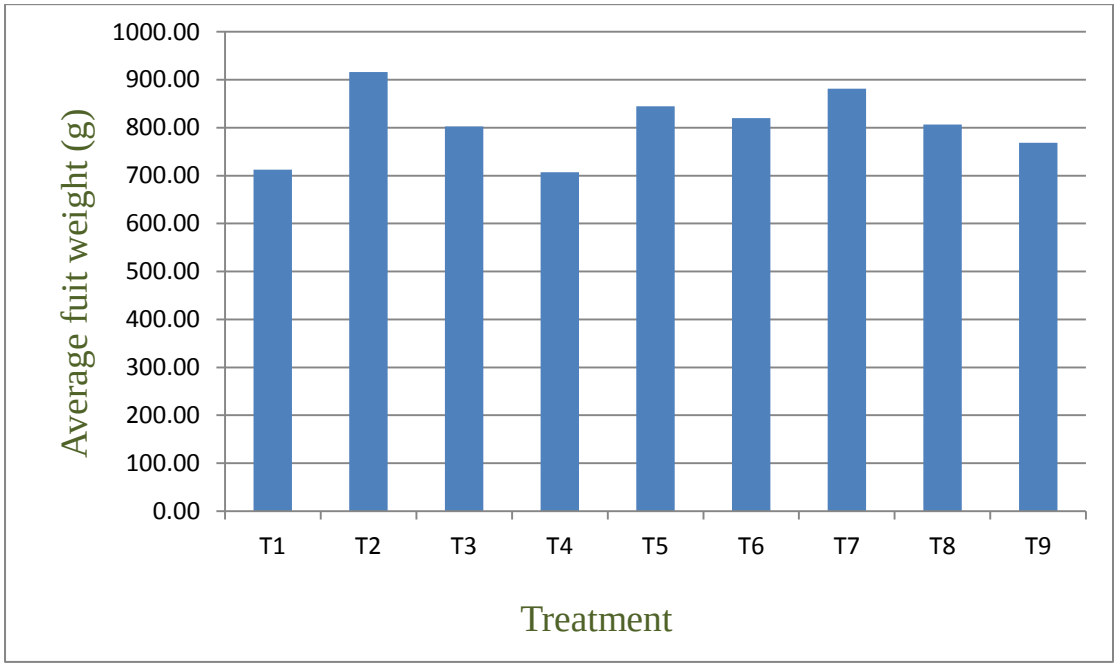


Fig. 4.16: Average fruits weight (g)

Table 4.9: Effect of various mycorrhizal strains on no. of fruits per plant and fruit yield per plant (kg)

Treatments	Doses	No. of fruits per plant	Fruit yield per plant (Kg)
T_1	Untreated Control	6.53	4.65
T_2	Soil application with Myc100 @ 250 g/ha × 1 application @ 15 DAS	7.47	6.83
T_3	Soil application with RhizoMyco100 @ 250 g/ha × 1 application @ 15 DAS	7.97	6.39
T_4	Soil application with RhizoMyxo100 @ 250 g/ha × 1 application @ 15 DAS	7.77	5.48
T_5	Soil application with Bolt Gr. @ 10 kg/ha × 1 application @ 15 DAS	7.40	6.24
T_6	Soil application with Ratchet @ 300 ml/ha × 1 application @ 20 DAS	7.03	5.76
T_7	Soil application with Ratchet @ 300 ml/ha × 2 applications @ 20 and 50 DAS	7.27	6.40
T_8	Soil application with Ratchet @ 450 ml/ha × 1 application @ 20 DAS	7.47	6.18
T_9	Soil application with Ratchet @ 450 ml/ha × 2 application @ 20 and 50 DAS	7.07	5.42
GRAND MEAN		7.32	5.92
***SE.M.*±**		0.321242	0.259255
CD 5%		0.954458	0.770286

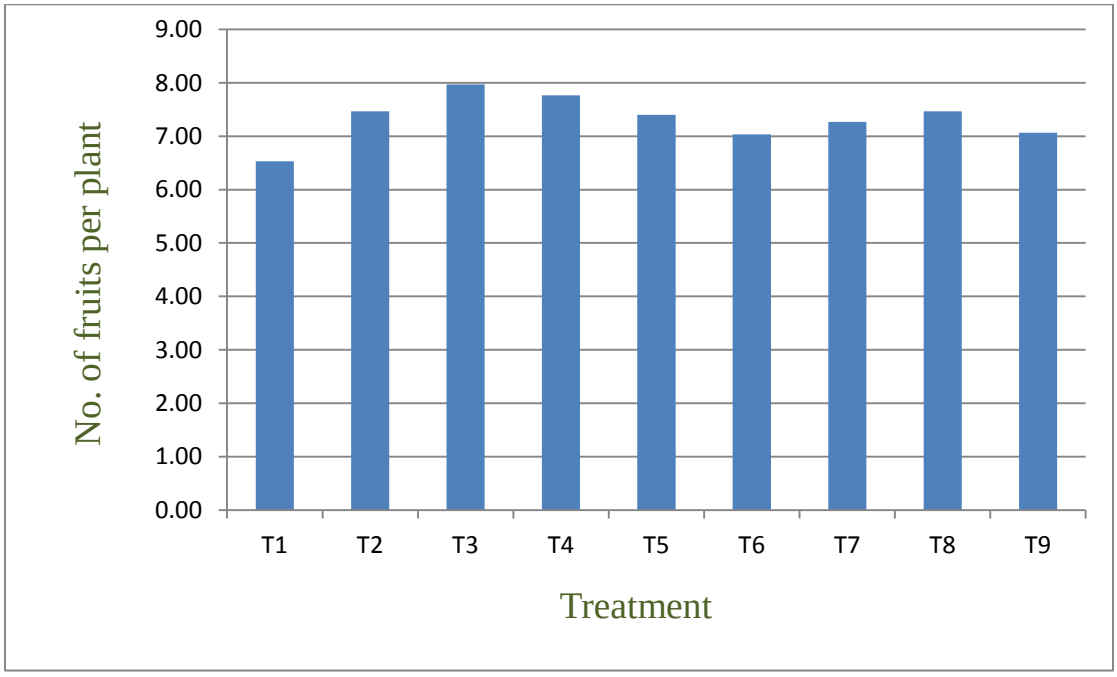


Fig. 4.17: No. of fruits per plant

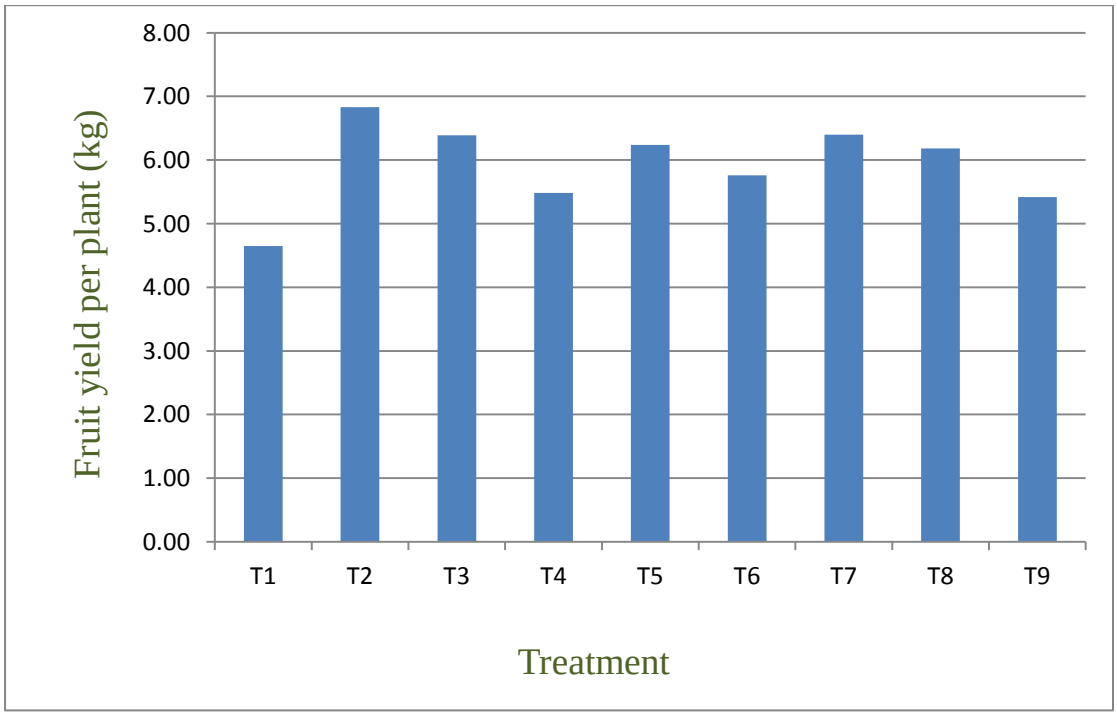


Fig. 4.18: Fruit yield per plant (kg)

Table 4.10: Effect of various mycorrhizal strains on fruit yield per plot (kg) and yield (q/ha)

Treatments	Doses	Fruit yield per plot (kg)	FruitYield (q/ha)
T_1	Untreated Control	46.56	369.53
T_2	Soil application with Myc100 @ 250 g/ha × 1 application @ 15 DAS	68.36	542.58
T_3	Soil application with RhizoMyco100 @ 250 g/ha × 1 application @ 15 DAS	63.92	507.37
T_4	Soil application with RhizoMyxo100 @ 250 g/ha × 1 application @ 15 DAS	54.89	435.69
T_5	Soil application with Bolt Gr. @ 10 kg/ha × 1 application @ 15 DAS	62.42	495.44
T_6	Soil application with Ratchet @ 300 ml/ha × 1 application @ 20 DAS	57.63	457.44
T_7	Soil application with Ratchet @ 300 ml/ha × 2 applications @ 20 and 50 DAS	64.03	508.17
T_8	Soil application with Ratchet @ 450 ml/ha × 1 application @ 20 DAS	61.84	490.84
T_9	Soil application with Ratchet @ 450 ml/ha × 2 application @ 20 and 50 DAS	54.23	430.39
GRAND MEAN		59.31	470.82
SE.M.±		2.594283	20.58797
CD 5%		7.708011	61.17

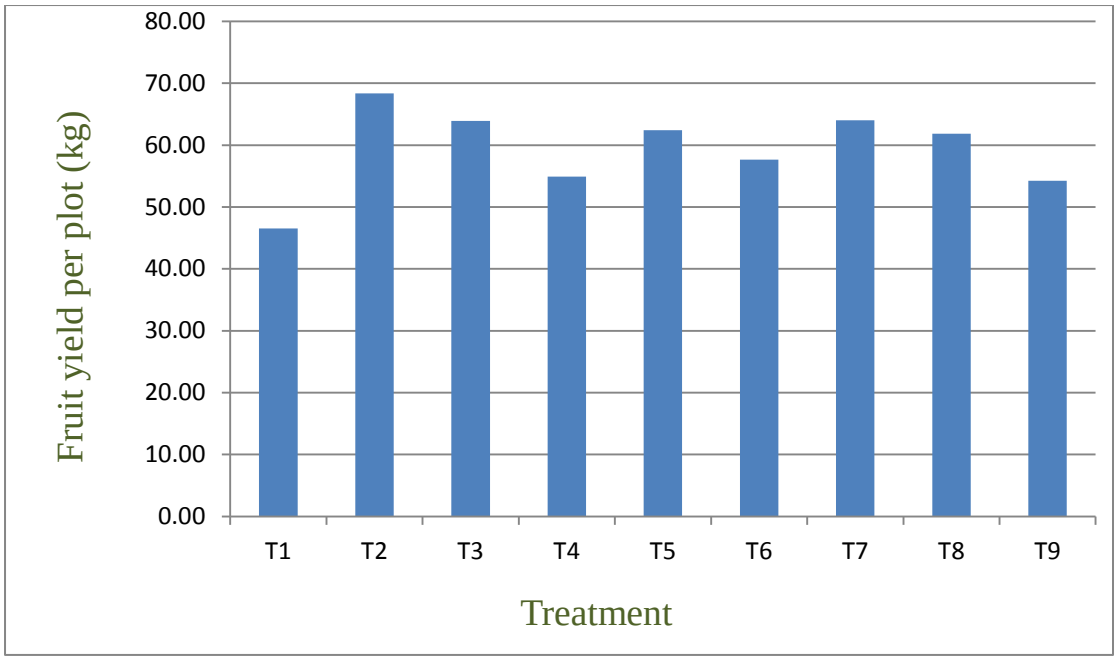


Fig. 4.19: Fruit yield per plot (kg)

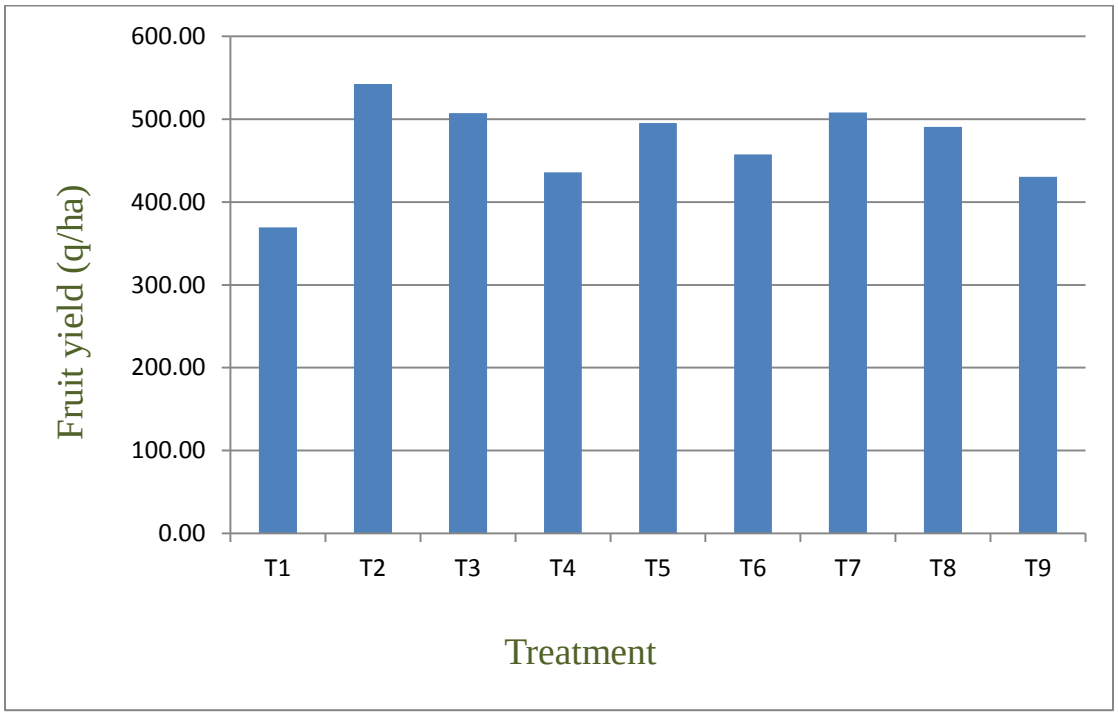


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Fig. 4.20: Fruit yield (q/ha)

Different stages of crop growth

Male flower

Female flower

Field view

Fruits of different treatments

T_1

T_2

T_3

T_4

T_5

T_6

T_7

T_8

T_9

CHAPTER-V

DISCUSSION

Bottle gourd is one of the excellent vegetable gifted by nature to human beings having composition of all the essential constituents that are required for good health and quality human life. The proper growth and development of crop is directly related to the economic yield of crop. Although chemical fertilizers have a considerable impact on increasing agricultural production but more use of chemical fertilizers may cause nutrient imbalance in soil leading to improper plant growth. Keeping in mind above facts use of mycorrhiza can be proved very useful in increasing agricultural production along with good soil health and reduced health hazards due to excessive use of chemicals (Milind *et al.,* 2011). Mycorrhiza can supplement very efficiently with chemical fertilizers in increasing agricultural production. In the present investigation, an attempt has been made to evaluate the response of various mycorrhizal strains on growth and yield characteristics of bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. In recent years, attempts have been made to use various mycorrhizal strains on growth and yield characteristics.

The results obtained from the present investigation entitled "Response of various Mycorrhizal strains on growth and yield characteristics of bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]" is discussed as under:

Days to first staminate flower anthesis

In bottle gourd, staminate flower came earlier than pistillate flower. Among the treatments, T_9 -Ratchet @ 450 ml/ha × 2 application @ 20 and 50 DAS treated plot recorded minimum no. of days to first staminate flower anthesis followed by T_8 - Ratchet @ 450 ml/ha of 1application × 1 application @ 20 DAS. Maximum no. of days to first staminate flower was observed in treatment T_2 -Myc100 @ 250 g/ha × 1 application @ 15 DAS treated plot followed by T_1 -Untreated Control. These results are resembled with the findings of Ortas *et al.* (2013).

Days to first pistillate flower anthesis

Mycorrhiza induces early pistillate flower anthesis, and is directly related with days to require in harvesting. Among the treatments, T_3 -RhizoMyco100 @ 250 g/ha × 1 application @ 15 DAS recorded minimum no. of days to first pistillate flower anthesis, which was followed by T_9 -Ratchet @ 450 ml/ha × 2 application @ 20 and 50 DAS treated plot. Maximum no. of days to first pistillate flower anthesis was observed in treatment T_2 -Myc100 @ 250 g/ha × 1 application @ 15 DAS treated plots, followed by T_1 -control plots. Findings are resembled with the findings of Ortas *et al.* (2013).

Days to 50% staminate flower anthesis

Different mycorrhizal strain induces early staminate and pistillate flowers. Minimum number of days to 50% staminate flowering recorded in two treatments T_7 -Ratchet @ 300 ml/ha × 2 applications @ 20 and 50 DAS and T_8 -Ratchet @ 450 ml/ha × 1 application @ 20 DAS with value of 50, followed by treatment T_6 -Ratchet @ 300 ml/ha × 1 application @ 20 DAS (50.67) and T_3 -RhizoMyco100 @ 250 g/ha × 1 application @ 15 DAS (51.00). Maximum number of days to 50% recorded in treatment T_2 -Myc100 @ 250 g/ha × 1 application @ 15 DAS.

Days to 50%pistillate flower anthesis

The plot treated with RhizoMyco100 @ 250 g/ha × 1 application @ 15 DAS *i.e*. treatment T_3 gave early 50% pistillate flower followed by treatment T_9 -Ratchet @ 450 ml/ha × 2 application @ 20 and 50 DAS. However maximum days for 50% pistillate flowering were observed in treatment T_1 that is control.

Node at which first staminate flower appears

In bottle gourd staminate flower are borne at lower nodes than pistillate flower. The data on this trait revealed that treatment T_9 -Ratchet @ 450 ml/ha × 2 application @ 20 and 50 DAS treated plot produced staminate flower at earliest node which was followed by T_5 -Bolt Gr. @ 10 kg/ha× 1 application @ 15 DAS. In contrast treatment T_4 -RhizoMyxo100 @ 250 g/ha × 1 application @ 15 DAS treated plant produced staminate flower on the higher node number. The results demonstrated that

RhizoMyxo was effective and desirable as it resulted into appears of staminate flowers at later nodes.

Node at which first pistillate flower appears

The data on the trait demonstrated that treatment T_5 -Bolt Gr. @ 10 kg/ha × 1 application @ 15 DAS produced pistillate flower on the earliest node followed by T_9 - Ratchet @ 300 ml/ha × 2 application @ 20 and 50 DAS gave almost same result. However, spray of RhizoMyxo100 @ 250 g/ha × 1 application @ 15 DAS *i.e.* treatment T_4 produced pistillate flower on higher node followed by T_3 - RhizoMyco100 @ 250 g/ha × 1 application @ 15 DAS.

No. of staminate flowers per plant

More no. of staminate flowers per plant is not desirable as they cause a decrease in no. of fruits per plant hence decrease the total yield. Less no. of staminate flowers per plant was observed in treatment T_8 -Ratchet @ 450 ml/ha × 1 application @ 20 DAS treatment plot. Which was followed by T_1 control treated plots. However highest no. of staminate flowers per plant was observed in treatment T_3 - RhizoMyco100 @ 250 g/ha × 1 application @ 15 DAS followed by T_6 -Ratchet @ 300 ml/ha × 1 application @ 20 DAS.

No. of pistillate flowers per plant

Highest no. of pistillate flowers per plant was observed in treatment T_2 - Myc100 @ 250 g/ha × 1 application @ 15 DAS treated plots followed by T_4 - RhizoMyxo100 @ 250 g/ha × 1 application @ 15 DAS. While treatment T_1 control plot produced least no. of pistillate flowers per plant followed by T_8 -Ratchet @ 450 ml/ha × 1 application @ 20 DAS**.** Myc100 @ 250 g/ha × 1 application @ 15 DAS treated plant have more no. of pistillate flowers per plant which is desirable as they cause an increase in no. of fruits per plant hence increase the total yield.

Sex ratio

We have requires the lower sex ratio as they cause higher yield. The treatment T_2 -Myc100 @ 250 g/ha × 1 application @ 15 DAS recorded lowest sex ratio followed by T_7 -Ratchet @ 300 ml/ha × 2 applications @ 20 and 50 DAS. Higher sex ratio was observed in absolutely control plot followed by T_5 - Bolt Gr. @ 10 kg/ha × 1 application @ 15 DAS.

Days to first fruit harvest

Days to first fruit harvesting was found to be statistically significant. Three treatment namely, T_3 -RhizoMyco100 @ 250 g/ha × 1 application @ 15 DAS, T_5 - Bolt Gr. @ 10 kg/ha × 1 application @ 10-15 DAS and T_9 - Ratchet @ 450 ml/ha × 2 application @ 20 and 50 DAS recorded minimum days for first fruit harvesting followed by treatments T_6 -Ratchet @ 300 ml/ha × 1 application @ 20 DAS and T_7 - Foliar application with Ratchet @ 300 ml/ha × 2 applications @ 20 and 50 DAS exhibited 60 days each, and these were statistically at par with each other. While maximum days for days to first fruit harvesting showed by treatment T_1 - untreated control.

Fruit length (cm)

The longest fruits were produced by the plot treated with treatment T_6 -Ratchet @ 300 ml/ha × 1 application @ 20 DAS followed by T_7 -Ratchet @ 300 ml/ha × 2 applications @ 20 and 50 DAS while shortest fruits were found in the treatment T_8 - Ratchet @ 450 ml/ha × 1 application @ 20 DAS. This result is resembled with the finding of Castillo *et al.* (2013) on the Chilean pepper plants and Nwangburuka *et al*. (2012).

Fruit diameter (cm)

By using different mycorrhizal strain fruit size significantly increased. Treatment T_6 -Ratchet @ 300 ml/ha × 1 application @ 20 DAS treated plot produced fruits with maximum diameter followed by T_5 - Bolt Gr. @ 10 kg/ha × 1 application @ 15 DAS. Treatment T_3 -RhizoMyco @ 250 g/ha × 1 application @ 15 DAS

followed by T_1 -control plot produced fruits with minimum diameter. The results were obtained in accordance with the finding of Nwangburuka *et al*. (2012).

Vine length (m)

Longer vine length is important feature because it is one of the important yield contributing traits. The data of longest vine length was observed in treatment T_2 - Myc100 @ 250 g/ha × 1 application @ 15 DAS followed by treatment T_6 -Ratchet @ 300 ml/ha × 1 application @ 20 DAS while shortest length vines were recorded in treatment T_1 *i.e.* control plot. Findings are resembled with the findings of Saha *et al*. (2013) on bitter gourd (var. Pusa Vishesh).

No. of primary branches on main axis of plant

The maximum no. of branches per plant was recorded in treatment T_2 - Myc100 @ 250 g/ha × 1 application @ 15 DAS treated plot and followed by treatment T_3 - RhizoMyco100 @ 250 g/ha × 1 application @ 15 DAS. In treatment T_1 -control plot no. of primary branches per plant was observed less followed by T_7 - Ratchet @ 300 ml/ha × 2 applications @ 20 and 50 DAS treated plot also recorded less no. of primary branches per plant. These findings are resembled with the findings of Hadad *et al*. (2012) and Bhuvaneswari *et al*. (2014) on chili.

No. of nodes on main axis of plant

More no. of nodes on main axis might be increase vine length and longer vine length cover large surface area and more no. of leaves will be there that is good for photosynthesis and accumulate more carbohydrates. The maximum no. of nodes per plant was recorded in two treatments *i.e.* T_2 - Myc100 @ 250 g/ha × 1 application @ 15 DAS and T_3 - RhizoMyco100 @ 250 g/ha × 1 application @ 15 DAS followed by T_6 - Ratchet @ 300 ml/ha × 1 application @ 20 DAS also gave almost similar result. In treatment T_9 -Ratchet @ 450 ml/ha × 2 application @ 20 and 50 DAS found minimum no. of nodes per plant. Results are resembled with the findings of Saha *et al*. (2013).

Average fruit weight (g)

From the perusal of data, the treatment effects were found to be statistically significant. Among all the treatments, T_2 -Myc100 @ 250 g/ha × 1 application @ 15 DAS treated plot recorded maximum average fruit weight followed by T_7 -Ratchet @ 300 ml/ha × 2 applications @ 20 and 50 DAS. While minimum average fruit weight were obtained in treatment T_4 - RhizoMyxo100 @ 250 g/ha × 1 application @ 15 DAS. These results are in agreement with the finding of Zhi-yu *et al.* (2008); Hadad *et al.* (2012) in tomato; Olawuyi *et al.* (2012) on okra; Castillo *et al.* (2013) on chilean pepper plants; Miceli *et al*. (2016) on mini-watermelon; Saha *et al*. (2013) in bitter gourd; Suhail (2013) on cucumber and Wang *et al*. (2008) on cucumber.

Number of fruit per plant

The application different mycorrhizal products resulted in increased number of fruits per plant significantly. Higher the number of fruits resulted more yield. The analysis of data demonstrated that maximum no. of fruits per plant were recorded in treatment T_3 - RhizoMyco100 @ 250 g/ha × 1 application @ 15 DAS and minimum no. of fruits were recorded in treatment T_1, *i.e.* control plot. Results are resembled with the findings of Olawuyi *et al*. (2012) on okra; Hadad *et al*. (2012) on tomato; Castillo *et al.* (2013) on chilean pepper plants; Suhail (2013) on cucumber and Adavi and Tadayoun (2014) on potato.

Fruit yield per plant (kg)

Due to the increased nutrient uptake by the use of mycorrhiza the yield per plant in experimental plot increased. The results demonstrated that treatment T_2 - Myc100 @ 250 g/ha treated plot produced highest fruit yield per plant followed by T_7 - Ratchet @ 300 ml/ha × 2 applications @ 20 and 50 DAS. The control plots observed lowest fruit yield/plant followed by T_9 -Ratchet @ 450 ml/ha × 2 application @ 20 and 50 DAS**.** Findings are resembled with the findings of Miceli *et al.* (2016) on mini-watermelon; Michalojc *et al*. (2015) on tomato; Adavi and Tadayoun (2014) on potato; Babaj *et al* (2014) on cucumber; Maboko *et al*. (2013) on tomato; Suhail (2013) on cucumber; Isfahani and Besharati (2012) on cucumber; Han *et al.* (2012)

and Olawuyi et *al*. (2014) on cucumber and Cardarelli *et al.* (2010) on zucchini plants.

Fruit yield per plot (kg)

The treatment effects were found to be statistically significant and the maximum yield/plot was recorded in the treatment T_2 -Myc100 @ 250 g/ha × 1 application @ 10-15 DAS followed by treatment T_7 Ratchet @ 300 ml/ha × 2 applications @ 20 and 50 DAS and the least total yield/plot was noticed in the treatment T_1 - untreated control. Findings are resembled with the earlier findings of Miceli *et al.* (2016) on mini-watermelon; Michalojc *et al*. (2015) on tomato; Adavi and Tadayoun (2014) on potato; Babaj *et al* (2014) on cucumber; Maboko *et al*. (2013) on tomato; Suhail (2013) on cucumber; Isfahani and Besharati (2012) on cucumber; Han *et al.* (2012) and Olawuyi et *al*. (2014) on cucumber and Cardarelli *et al.* (2010) on zucchini plants.

Fruit yield (q/ha)

The variation in total yield observed was significantly differed among the treatments and highest yield (542.58 q/ha) was found in treatment T_2 -Myc100 @ 250 g/ha × 1 application @ 10-15 DAS followed by treatment T_7 Ratchet @ 300 ml/ha × 2 applications @ 20 and 50 DAS, while the minimum total yield (kg/ha) was observed in treatment T_1 - untreated control (369.53 q/ha). These results are in agreement with the earlier finding of Miceli *et al.* (2016) on mini-watermelon; Michalojc *et al*. (2015) on tomato; Adavi and Tadayoun (2014) on potato; Babaj *et al* (2014) on cucumber; Maboko *et al*. (2013) on tomato; Suhail (2013) on cucumber; Isfahani and Besharati (2012) on cucumber; Han *et al.* (2012) and Olawuyi et *al*. (2014) on cucumber and Cardarelli *et al.* (2010) on zucchini plants.

CHAPTER-VI

SUMMARY AND CONCLUSION

A field experiment was conducted to study the "Response of various mycorrhizal strain on growth and yield characteristics of bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]", during Kharif season of 2016 at Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, BHU, Varanasi, to evaluate the response of various mycorrhizal strain at different concentrations on growth and yield parameters of bottle gourd.

The field experiment consisted of 9 treatments involving different mycorrhizal strain such as Myc100, RhizoMyco100, RhizoMyxo100 and Bolt Gr. @ 250 g/ha, 250 g/ha 250 g/ha and 10 kg/ha at 15 DAS respectively and two doses of Ratchet @ 300 ml/ha and @ 450 ml/ha at 20 DAS alone and at 20 and 50 DAS each respectively. The treatments included soil/foliar drenching with different strain of mycorrhiza.

A total of 20 characters including growth, yield and yield trait were studied. Growth and yield parameters included days to first staminate flower anthesis, days to first pistillate flower anthesis, days to 50% staminate flower anthesis, days to 50% pistillate flower anthesis, node at which first staminate flower appears, node at which first pistillate flower appears, no. of staminate flowers per plant, no. of pistillate flowers per plant, sex ratio, days to first fruit harvesting, vine length (m), number of primary branches on main axis, number of nodes on main axis, days to first fruit harvesting, fruit length (cm), fruit diameter (cm), average fruit weight (g), number of fruits per plant, fruit yield per plant (kg), fruit yield per plot (kg) and fruit yield (q/ha).

The results indicated that earliest days for anthesis of first staminate flowers were recorded in T_9 (Ratchet @ 450 ml/ha × 2 application @ 20 and 50 DAS) while T_2 (Myc100 @ 250 g/ha × 1 application @ 15 DAS) resulted in delayed appearance of staminate flowers. The minimum no. of days to first pistillate flowers anthesis was recorded in T_3 (RhizoMyco @ 250 g/ha × 1 application @ 15 DAS) and maximum number of days recorded for anthesis of pistillate flower in T_2 (Myc100 @ 250 g/ha ×

1 application @ 15 DAS).The present investigation shows that role of mycorrhiza strain in induction of early staminate and pistillate flowers.

The other parameters such as earliness in node at which first staminate flower appears was noted in treatment T_9 (Ratchet @ 450 ml/ha × 2 application @ 20 and 50 DAS) while treatment T_5 (Bolt Gr. @ 10 kg/ha × 1 application @ 15 DAS) shows the earliness in node at which first pistillate flower appears.

More no. of pistillate flowers per plant is desirable as because an increase in no. of fruits per plant ultimately increases the total yield. The analysis of data on number of pistillate flowers per plant showed that best treatment was T_2 (Myc100 @ 250 g/ha× 1 application @ 15 DAS) while in case of staminate flowers we require less no. of staminate flower because it help only for pollination, minimum no. of staminate flowers per plant and it was observed minimum in T_8 Ratchet @ 450 ml/ha × 1 application @ 20 DAS treatment plot.

The decrease in days to first fruit harvesting was recorded with different mycorrhizal application. Among the different treatment minimum number of day to first fruit harvesting recorded in T_3 (RhizoMyco @ 250 g/ha × 1 application @ 15 DAS), T_5 (Bolt Gr. @ 10 kg/ha × 1 application @ 10-15 DAS) and T_9 - Ratchet @ 450 ml/ha × 2 application @ 20 and 50 DAS.

Mycorrhiza application increased fruit length, among different mycorrhizal strain treatment T_6 (Ratchet @ 300 ml/ha × 1 application @ 20 DAS) significantly increases the fruit length. Maximum diameter of fruit produced by treatment T_6 (Ratchet @ 300 ml/ha × 1 application @ 20 DAS).

Mycorrhiza application significantly increase vine length among the different treatment. This is an important feature because it is one of the important yield contributing traits. Among all the treatments T_2 (Myc100 @ 250 g/ha × 1 application @ 15 DAS) was more effective as compare to other treatment to increase vine length. The maximum number of primary branches per plant was also recorded in T_2 (Myc100 @ 250 g/ha × 1 application @ 15 DAS) and the treatments T_2 (Myc100 @ 250 g/ha × 1 application @ 15 DAS) and T_3 (RhizoMyco @ 250 g/ha) also recorded

maximum number of nodes on main axis while maximum no. of fruits per plant was recorded in treatment T_3 (RhizoMyco100 @ 250 g/ha × 1 application @ 15 DAS).

The treatment T_2 (Myc100 @ 250 g/ha × 1 application @ 15 DAS) proved to be superior than all other products in case of yield parameters such as average fruit weight, fruit yield per plant, fruit yield per plot, fruit yield per hectare. Whereas control has proved to be minimum value in case of yield parameters.

On a whole, it was observed that all the treated plots performed better over the untreated plot because of the soil drenching of the mycorrhizae based other products in the root zone might have resulted in the colonization leading to an increase in plant growth, early flowering, higher yield, better root growth, nutrient absorption, better vegetative growth, alteration in the secondary metabolites and adaptation to abiotic and biotic stresses which in turn as a whole resulted in improved overall performance.

Conclusion

In conclusion of the study, the mycorrhizae based products have shown significant potential for good vegetative growth as well as enhanced yield performance over the untreated treatment thus stressing the importance of symbiotic organisms in crop growth and resistance towards the stresses.

From present investigation it could be concluded that the best product for increasing all the growth and yield parameters was treatment T_2 (Myc100 @ 250 g/ha× 1 application @ 15 DAS), which showed very interesting result for almost all the characters as compared to other treatments and second most significant treatment was treatment T_3 (RhizoMyco @ 250 g/ha× 1 application @ 15 DAS). The above experimentation showed that mycorrhiza (Myc100 @ 250 g/ha) could be used in the farmer's field for the effective crop production.

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