Efficacy of *Azospirillum,* Phosphobacteria and Spent Mushroom Compost on the growth and yield parameters of *Abelmoschus esculentus* (L.) Moench

By

M. KANIMOLEE

(19PBO009)

Thesis submitted to the

Avinashilingam Institute for Home Science and Higher Education

For Women, Coimbatore – 641 043.

In Partial Fulfillment of the Requirement for the

Degree of Master of Science in Botany

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Signature of the Head of Department **Signature of the Supervisor**

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INTRODUCTION

CHAPTER I

INTRODUCTION

In India, vegetables form an indispensable part of daily diet because most of the people in India are vegetarian. So, far fulfilling their dietary requirements, most of them depend on vegetables. Many varieties of different vegetables are grown according to size, shape, color, yield etc. throughout the country. The world's second largest country in the production of vegetables is India and China ranks first. It is found that vegetables give higher yield when compared to other crops.

Vegetables grow faster and they give more yields in terms of quantity and also have good quality if grown organically. The term '**Vegetable'** includes all types of vegetables and their origin but does not include cereals and sun dried seeds like pulses, it also includes cob which contains grains, tubers and potatoes.

The excellent food choice for a healthy body is fresh vegetables that are naturally low in fat, salt and sugar. Vegetable provides energy, vitamins, minerals and fibres and there is growing evidence of additional health benefits from a range of phytonutrients (Joao Silva Dias, 2012). No single vegetable provides all these nutrients needed for our daily life. Various types of vegetables contain different types of energy rich nutritious value.

Most vegetables are short duration crops and they are cultivated more when compared to the other crops and can be raised throughout the year. Some of the vegetables like Potato, Brinjal, Spinach, Pumpkin, Lady's finger etc. can be grown twice and even thrice in a year. It is possible to cultivate several vegetables one after the other throughout the year if irrigation facilities are available. Vegetables can be cultivated even in a small plot or for a family even in the backyard of a house or through terrace gardening or by organic farming.

ORGANIC FARMING

In India, the organic farming system is widely practised from ancient times and it is mentioned in most of the Indian ancient literatures like Vedas, Ramayana, Mahabharata (Behera *et al.,* 2011). It is another type of farming system which aims at cultivating the land and raising crops in such a way, so that the soil is alive and in good health by use of organic wastes (crop, animal and farm waste, aquatic waste) and other biological materials along with beneficial microbes (Bio fertilizers) to release nutrients to crop for the sustainable production with increase in the quantity of yield and making the environment pollution free and they are eco-friendly in nature.

According to United states Department of Agriculture (USDA) study team on organic farming, "Organic farming is a system that avoids or largely excludes the use of chemically synthesized inorganic substances (such as fertilizers, hormones, pesticides and feed additives etc.) and there is maximum possible feasible will be expect due to regular crop rotations and use of their residues, animal manures, organic waste from off-farm, mineral fines, nutrient mobilization and plant protection"

FAO suggested that "Organic type of agriculture is a distinctive production of crops in a regular management system which upgrades and enhances the health of agro-ecosystem, which includes biodiversity, cycles of biological, soil structure and fertility enhancement and their biological activities and these are accomplished by using on farm agronomic, biological and mechanical methods in exclusion of all synthetic off-farm inputs".

NEED OF ORGANIC FARMING

The essential of organic farming is not only to increase the agricultural production but also increase them in sustainable manner as the population keeps on increasing. The scientist have realized that the "**Green revolution**" with high inputs use has reached a plateau and is now sustained with diminishing return of falling dividends (Behera *et al.,* 2011) Thus, there is a need to maintain the natural balance at all cost for occurrence of life and property. The obvious choice for that would be more relevant in the present era, when these agrochemicals which is produced from fossil fuels are non renewable and are diminishing in availability. It is very beneficial for economic status when there is possible foreign exchange in future.

CHARACTERISTICS OF ORGANIC FARMING

- Protecting the long term fertility of soils by maintaining organic matter levels, encouraging soil biological activity and careful mechanical intervention.
- Providing crop nutrients using relatively insoluble nutrient sources which are made available to the plant by the action of soil microorganisms.
- Nitrogen self-sufficiency through use of legumes and biological nitrogen fixation, as well as effective recycling of organic materials including crop residues and livestock manures.

- Weed, disease and pest control relying primarily on crop rotations, natural predators, diversity, organic manure, resistant varieties and limited thermal, biological and chemical intervention (Behera *et al.*, 2011)
- Careful attention on the impact of the farming system on the wider environment and the conservation of wildlife and natural habitats (Behera *et al.*, 2011). The extensive management of livestock, paying full regard to their evolutionary adaptations, behavioural needs and animal welfare issues with respect to nutrition, housing, health, breeding and rearing.

BIOFERTILIZERS

Biofertilizers are the substances that contain microorganisms, which help to increase the yield and promote the plants and trees growth by enriching the level of nutrients and it helps to restore the soil fertility (Sneha *et al.*, 2018). It comprises living organisms which include Mycorrhizal fungi, blue green algae and bacteria. Cyanobacteria are characterized by its property of nitrogen fixation, but the Mycorrhizal fungi withdraw minerals from organic matter for the plant to survive.

Plants absorb the nitrogen present in the soil through their roots in the form of ammonium and nitrates. The plants cannot utilize the di-nitrogen present in the atmosphere (80%). Thus, a bacteria called diazotrophs is needed that is helpful in the conversion of atmospheric Nitrogen (N_2) to Ammonia (NH_3). This conversion is called Nitrogen fixation (Carole Santi *et al.*, 2013). For instance, some bacteria convert insoluble forms of soil phosphorous into soluble forms. As a result, phosphorous will be available for plants.

TYPES AND FEATURES OF BIOFERTILIZERS

According to Carole Santi *et al.* (2013), based on the type of organism, the bio fertilizer can also be classified as follows

Bacterial biofertilizers	• E.g. Rhizobium, *Azospirillum*, *Azotobacter*, Phosphobacteria
Fungal biofertilizers	• E.g. Mycorrhiza.
Algal biofertilizers	• E.g. Blue green algae (BGA)
Actinomycetes biofertilizers	• E.g. *Frankia*

Bio-fertilizers are mostly cultured and multiplied in the laboratory. However, blue green algae can be mass multiplied in the field. The nitrogen fixing biofertilizers such as *Azotobacter, Nostoc, Anabaena* are free-living bacteria, *Rhizobium, Frankia, Anabaena azollae* are symbiotic micro-organisms and *Azospirillum* forms associative symbiosis in nature (Kumar *et al.,* 2017).

CHARACTERISTICS FEATURES OF COMMON BIOFERTILIZERS

***Rhizobium* :** *Rhizobium* is relatively more effective and widely used bio fertilizer. *Rhizobium*, in association with legumes, fixes atmospheric nitrogen**.** The legumes and their symbiotic association with the *Rhizobium* bacterium results in the formation of root nodules that fix atmospheric N (Kumar *et al.,* 2017). Rhizobium population in the soil is dependent on the presence of legumes crops in field, when the legumes are absent there is a reduction in the population of *Rhizobium*.

***Azospirillum* :** In the higher plant community, the *Azospirillum* have good associative symbiosis in the graminaceous plants (Kumar *et al.,* 2017). The *Azospirillum* have a close association with cereals and millets. Some of them are sorghum, maize, pearl millet, finger millet, foxtail millet and other minor millets and also fodder grasses.

***Azotobacter* :** It is a common soil bacterium. *A. chorcoccum* is present widely in Indian soil which is helpful in the seed germination and it enhances the root architecture (Bhardwaj *et al.*, 2014). Soil organic matter is the important factor that decides the growth of this bacterium.

Blue green algae : Blue green algae are referred to as rice organisms because of their abundance in the rice field and are able to fix atmospheric Nitrogen (Hillol Chakdar *et al.*, 2012). In tropical conditions, species comeing under the genera *Tolypothrix*, *Nostoc*, *Calothrix*, *Anabaenopsis* and *Plectonema* are huge in number. Most of the nitrogen fixation BGA is filamentous, consisting of chain of vegetative cell including specialized cells called heterocyst which function as a micro nodule for synthesis and N fixing.

Phosphate solubilizing bacteria (PSB) : Most of the soil bacteria and fungi secretes organic acids and lower the pH in their surroundings and these helps in the dissolution of phosphates present in the soil. The yield of Potato and Wheat are increased due to the inoculation of peat based cultures of some PSB like *Bacillus polymyxa* and *Pseudomonas striata* (Kumar *et al.*, 2017).

IMPORTANCE OF BIOFERTILIZERS

Biofertilizers are important for the following reasons (Kumar *et al.,* 2017)

1. The soil texture and yield of plants could be improved by the application of biofertilizers.
2. They do not allow pathogens to flourish.
3. They are eco-friendly and cost effective.
4. As the biofertilizers are natural fertilizers, it could protect the environment from pollutants.
5. Plant disease causing harmful substances present in the soil are destroyed by the application of biofertilizers.
6. Under semi- arid conditions, biofertilizers are more effective.

The use of biofertilizers will increase the yield of the vegetable as well as the fertility of the soil. The present study is on the growth of vegetable crop *Abelmoschus esculentus* (L.) Moench under different types of biofertilizers application.

Okra is also known as “Lady’s finger” or “Bamia pod” is one of the nutritious vegetable in North east African origin. Its rate of growth is good in a well-drained and in soil with rich manure. It is a perennial flowering plant in Malvaceae family.

The okra plant bears dark green pods measuring about 5 – 15 cm in length. It takes about 45 – 60 days to get ready to harvest fruits. The pods are handpicked after it gets matured and eaten as vegetable.

The plant is very useful for its medicinal purposes in both tropical and subtropical areas. Its medicinal uses are followed traditionally and they are reported in the medicinal field such as Unani, Ayurveda and Siddha. Okra is considered as a healthy food because of its Fibre content, Vitamin C and Folate components. It is a very good source of Potassium and Calcium (Sathish Kumar *et al.,* 2013).

The main objective of this study is

- To monitor the growth of the seedlings at different days interval by means of root length, shoot length, number of leaves, diameter of leaves, number of lateral roots, number of flowers and number of fruits

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Literature related to the organic farming using different type of fertilizers that is relevant to the present study are reviewed and presented in this chapter.

Nuruzzaman *et al*. (2003) had conducted experiment on okra plant and its crop growth rate (CGR) was calculated at 15 day interval starting from 45 days to 105 days. He concluded that the usage of *Azotobacter* and *Azospirillum* fixes and supplies the atmospheric nitrogen to the plants, where it increases the crop growth rate (CGR).

Jilani *et al*. (2007) in his experiments used the Biological Potassium Fertilizer (BPF) and NP as fodder that gave maize growth, yield and nutrients uptake equal to that of full use of NPK. They also found that bio power + effective microorganisms (EM) + Half NP, was effective in giving more economic return.

Ahlawat *et al*. (2007) in his experiment has used the Spent Mushroom substrate for *Capsicum* crop. They concluded that cultivation of *Capsicum* with aerobically recomposted SMS could significantly increase the growth of the fruit yield and quality of the crop over FYM and control treatments along with lower infections of Pathogens. Thus, SMS is helpful in the production of crop which is organic in nature.

Sharma (2009) conducted an experiment using organic manures like vermicompost, farmyard manure and also chemical fertilizers on okra (*Abelmoschus esculentus* (L.) Moench) and onion (*Allium cepa*). In his study, he showed that the integrated use of vermicompost, farm yard manure and chemical fertilizers increased the yield, nutrient content and uptake of NPK by both okra and onion when compared to plots which received chemical fertilizers alone.

Mustafa Paksoy *et al*. (2010) in their experiment had concluded that both potassium (K) and humic acid (HC) has a great significance in the yield and nutrient uptake and growth parameters of vegetable crops. Humic acid not only increase the content of macro-nutrients, but also increase the content of micro-nutrients in plants.

Abd EI –Kader *et al*. (2010) showed that there is a significant effect on biometric characters such as plant height, fresh weight, dry weight, leaf area, no. of leaves, stem diameter, no. of branches per plant when combination of organic fertilizer treatment was used. The use of drip system in combination with plant residues and chicken manure also increases the okra yield.

Sheraz Mahdi *et al*. (2010) had concluded that selection of efficient location / soil specific strains for N-fixing, P, Zn- solubilizing and absorbing (Mycorrhizal) to suit different agro climatic conditions are essential. He also concluded that developing suitable alternate formulations viz liquid inoculants/ granular formulations for all bio inoculants, to carrier based inoculants is important.

Arshad (2011) from his experiment concluded that the use of both bio power and EM can be combined well with the suitable soil amendment. Both the fertilizers are useful to enhance the rice shoot biomass (*Oryza sativa*) and grain yield in the green manure amendment.

Tiamiyu *et al*. (2012) in their studies showed that the application of cow, sheep and poultry manure to the okra plant, shows great significance in terms of plant height, number of leaves per plant and fresh pod weight. The results obtained from the use of poultry manure shows great parameters when compared with other organic manures. In the absence of poultry manure, the application of sheep manure also gives greater fresh pod weight of okra production.

Sathish Kumar *et al*. (2013) in their experiment on *Abelmoschus esculentus* (L.) Moench has covered the medicinal properties of the plant which is highly suggested for its excellent antioxidant property and memory enhancing activity and also the extract is used as good medicine for Alzheimer's disease. It also has excellent quantity of cellulose, which can be used as cellulosic raw materials in cellulose based industries.

Allah Bakhsh Gulshan *et al*. (2013) in his study showed that the yield and yield components of okra were enhanced by the application of animal manure. The application organic manures increase the chemical properties of the soil when compared to control. The animal manure is highly recommended for field application to reduce the mineral deficiency in the soil.

Mal *et al*. (2013) in his investigation had concluded that in okra, plant the maximum growth, yield attributing characters and fruit yield was found in the integrated applications of fertilizers as compared to recommended dosage of chemical fertilizers and organic manures alone. It is due to the effect of N,P,K from FYM usage and recommended dose of NPK along with diazotrophs in the presence of vermicompost.

Yadav *et al*. (2013) has reported that organic farming can provide the quality foods and it is not affecting the soil environment. The seeds of chick pea inoculated with *Rhizobium* + PSB increase the yield of grain and grain protein content and also the level of total nitrogen and phosphorous uptake.

Ritika (2014) in her study has concluded that biofertilizers and organic manures are the alternate source that supplies nutrient requirement to crops. Biofertilizers such as *Azotobacter*, *Azospirillum*, Phosphobacteria and *Rhizobacter* are very important for the growth of the plant. The use of these biofertilizers not only increases the economic development, but also contributes to a sustainable ecosystem and holistic well-being of the country.

Roy *et al*. (2015) in their studies have concluded that both substrates of oyster mushroom and button mushroom compost are the good source of biofertilizer when they are applied to the *Capsicum annum* crop. They are much useful in the field to increase the crop production and also acts as a soil conditioner.

Amin Farnia (2015) has reported that using different types of biofertilizers can increase the production of Maize. The selection of supernitroplus biofertilizers and siloking cultivar lead to an increase in the growth of maize crop when compared with other biofertilizers.

Kirti Choudhary *et al*. (2015) have concluded that maximum growth, highest yield and yield attributing characters of okra are achieved by the application of biofertilizers and chemical fertilizers. The results obtained from Shivran *et al*. (2017) have shown that the use of biofertilizers and zinc levels enhanced the equality of broccoli when compared to control. They also concluded that inoculation of *Azotobacter*+ PSB with 30 kg of Zinc sulphate ($Zn\ So_4$) is highly recommended for the production of broccoli under Lucknow conditions.

Yakkala *et al.* (2015) had reported that maximum germination percentage by the variety Bhendi Anjali followed by Shakti and Arka Anamika.

Utpal Maity *et al*. (2016) had concluded that plant growth regulators have the potential to show a significant increase in the growth, yield and quality of okra. In their investigation the growth regulators i.e., GA_3 (Gibberellic acid) and IBA (Indole- 3- butyric acid) have the effect of increasing growth, development and yield of okra with increase in their concentration level. GA_3 is found to be a superior growth regulator as compared to IBA doses.

Anisa *et al*. (2016) in their studies on okra, concluded that the biofertilizers when combined with Farm yard manure (FYM) were the best combination to increase the yield of crop. They also obtained good yield by the use of FYM, inorganic (3/4) fertilizers and biofertilizers.

Sindhu (2016) in her studies briefly explained about the nutritional values of okra. It helps to cure various types of ailments and diseases. It also determines how food bioactives from such foods as okra can influence human health.

Mohammad Moneruzzaman Khandaker *et al*. (2017) had used different types of fertilizers like poultry manure, goat, rats and rabbit manure and NPK fertilizers. In this, they have shown significant increase in plant growth in terms of leaf area, chlorophyll content, No. of flowers, Number and weight of pod, photosynthetic rate especially in poultry manure. NPK fertilizers is good for early harvesting, while the use of organic manure like poultry manure can reduce the production cost, but increase soil physical properties as it is friendly to the environment.

Suchitra Rakesh *et al*. (2017) had conducted an experiment on okra using panchagavya at different level of concentrations like 1%, 3%, 5% and 7%. The growth and yield parameters increased at 3% concentration when panchagavya is used as a spray after proper dilution. Cows urine provide N, curd provides *Lactobacillus* which acts as a biocatalyst to digest organic manures. These contents stimulate the growth and yield of all vegetables crops.

Sivagama sundari (2017) have shown that the microbial inoculants and the process of fixation of N_2 have a great impact on soil fertility. She attempted this study to isolate and identify the strains that are effective for promoting the plant growth in okra.

Kumar *et al*. (2018) have concluded that the number of fruits/ plant increases when higher level of NPK biofertilizer treatment was used. Also the maximum fresh fruit weight was higher in the treatment where the usage of 100%RDF+*Azospirillum.* This was due to enhanced uptake of water and nutrients by *Azospirillum*.

Vaibhav *et al*. (2018) had suggested that MSWVC had a greater significance in the effect of biochemical, physiological and yield response of *A. esculentus* when amended with upto 60% MSWVC. An increase in the rate of photosynthesis, stomatal conductance and improved antioxidant response was seen with a greater significance in the parameters like leaf area, total biomass and yield responses when compared to control. Thus, MSWVC was found to be very much useful for the soil fertility in agricultural applications.

Rukshana *et al*. (2018) concluded that inoculation of PSB improves the yield character by solubilisation and increased availability of P from insoluble phosphorous. The inoculation of VAM in soil also significantly plays an important role in P recycling, mobilization and uptake by plants thereby having a greater root extension, higher nutrient uptake, higher photosynthesis and yield attributes.

Adekiya *et al*. (2018) had conducted an experiment on *Abelmoschus esculentus* (L.) Moench with urea fertilizers and maize cob ash to study the effect on the chemical properties, growth, yield and composition of the plant. At last, they concluded that treatment with urea fertilizer applied at 60 kg ha^{-1} in combination with maize cob ash applied at 3 t ha^{-1} produced the highest value of okra yield while urea fertilizer applied at $120kg^{-}ha^{-1}$in combination with maize cob ash applied at 3 t ha^{-1} showed better N, K, Ca, Cu, Fe contents in the okra plant.

Orluchukuru (2018) in his study determined the response of okra variety to poultry manure and spent mushroom substrate and showed that best growth and yield were obtained from the plots treated with poultry droppings. Thus, he concluded that poultry manure shows greater efficiency when compared to SMS.

Nunes *et al*. (2018) had shown that in okra plants the management of the crop is more effective than the use of organic fertilizers to increase its productivity. The spacing between the crops is more important when biofertilizers are used.

Hanafi *et al*. (2018) conducted an experiment on SMS substrate and concluded that this substrate is used as a fertilizer as it is rich in nutrient content. It is also helpful in several applications such as soil amendment and enrichment, animal feedstock, fertilizer, energy production, waste water treatment, dye- decolourization and ammonia emission reduction.

Shashank *et al*. (2019) in their experiment reported that different types of fertilizers used at certain concentrations on okra plant showed better growth and it was found that at 100% RDF +50% VC, the growth, seed yield and quality of okra was better than the control.

Adekiya *et al*. (2019) in their study have revealed that allocation of green manures (pawpaw, Neem, *Moringa* and Mesquite) reduced soil bulk density and increased the nutrients like N, P, K Ca, Mg, growth and yield of okra when compared to control. Mesquite increases the growth and yield of okra by the increasing the availability of N & K in the soil. *Moringa* had the best fruit quality in terms of K, Ca, Fe, Zn, Cu and Vitamin C content. However, these green manures are very much useful in the good production of okra plants.

Akhila *et al* (2019) in their studies concluded that the use of chemical fertilizers at higher amount had a greater negative impact on the soil, but the same can be maintained by the use of organic manures and fertilizers that could increase the available NPK in soil and maintain the nutrients in okra fruit.

Renugupta *et al*. (2019) has reported that integrated use of manures viz. FYM and vermicompost along with chemical fertilizers increased the yield, content and uptake of NPK by okra significantly over the use of chemical fertilizers alone. Significantly there is higher improvement of soil fertility and plots receiving either FYM or vermicompost in combination with chemical fertilizers than the plots that received chemical fertilizers alone.

MATERIALS & METHODS

CHAPTER III

MATERIALS AND METHODS

The plant taken for the current study was *Abelmoschus esculentus* (L.) Moench that belongs to the family Malvaceae. Growth studies were carried out under different treatments of biofertilizers namely *Azospirillum*, Phosphobacteria and Spent Mushroom Compost against untreated control at different stages of growth of the plant.

Collection of the seeds

Seeds of *Abelmoschus esculentus* (L.) Moench were obtained from Tamil Nadu Agricultural University, Coimbatore.

Morphology of the plant

Abelmoschus esculentus (L.) Moench (**Plate 1, 2 & 3**)

Systematic position

Kingdom	-	Plantae
Class	-	Magnoliopsida
Order	-	Malvales
Family	-	Malvaceae
Genus	-	*Abelmoschus*
Species	-	*A. esculentus* (L.) Moench

Description

- The taxonomists had found about 50 species in the genera *Ablemoschus* (biology of okra)
- Okra are specially found in the tropical region of the world and it belongs to the Malvaceae family.
- It is an upright annual herbaceous plant which is about 3-6 feet tall and it has hibiscus like flowers.
- It has a woody stem, erect and much branched. Numerous short twigs attached to the stem are distinguished.
- The leaves have different shapes even on the same plant. They are stalked heart shaped large with thick limb and dark green on top and grey at the bottom.
- The leaves are alternate, lobed palmate, hirsute and serrate.

- The basal leaves are almost entire, while the upper ones are present divided lobes (lobes 4 to7) with toothed margins.
- Okra flowers are solitary and showy, 4-8 cm in diameter. They are arising from the axils of the leaves.
- The calyx consists of 5 petals white or yellow with red or purple spots on the base. The flowers are solitary, axillary having epicalyx (up to 10), Hermaphrodite and actinomorphic.
- There are 5 valvate, distinct or basally connate sepals.
- The flowers last for only one day and each blossoms develops a small green pod.
- The fruit or pod are hairy on the outside and they are tapering 10 angled capsule 10-25cm in length (except in the dwarf varieties) that contains numerous oval dark-coloured seeds.


Plate 1 Habit of *Abelmoschus esculentus* (L.) Moench Plate 2 Flower of Lady's finger

Origin and Distribution:

Okra first originated in Ethiopia and was cultivated by the Egyptians in 12th century BC (Benchasri, 2012). Okra is then spread throughout tropical and subtropical areas of Africa. India is the second largest producer of okra in India. It is also used as a vegetable in Brazil, West Africa and many other countries. In India, major okra growing states are Uttar Pradesh, Bihar, Assam, Karnataka and West Bengal.

Okra is also distributed worldwide in tropical, subtropical and warm temperate regions. Apart from India, okra is well developed in the countries like Pakistan, Middle East, Greece, Turkey, South America and USA (Dhaliwal, 2017).

Plate 3 Plant showing the development of fruit

FOOD VALUE

Okra is a very good source of nutrients such as Vitamins, Calcium, Potassium and other Minerals. Okra is largely consumed for the control of goitre because it has high content of Iodine. The okra seed flour is used for a very long time by the Egyptians for the preparation of quality dough (Priya Singh *et al.*, 2014)

The Okra fruits contain Carbohydrates, Proteins, Thiamine, Riboflavin, Vitamin, Calcium and Iron. Proteins play an important role in human nutrition. "Okra" has been called "a perfect villager's vegetable" because of its robust and dietary fibre and distinct seed protein balance of both Lysine and Tryptophan aminoacids (Habtamu Fekadu *et al.*, 2015)

HEALTH BENEFITS

The plant consists of Carbohydrates, Proteins, Fat and Fibre. It also contains Vitamin C, Vitamin K and Vitamin E. Apart from these, it is also rich in calcium, phosphorous, manganese, copper, iron and zinc. The following are some of the health benefits that help us to maintain a good health.

1. **Promotes heart health**

Okra contains a component called pectin, which helps in lowering the bad cholesterol. The bad cholesterol is the cause of heart disease and it is controlled when there is a higher consumption of okra plants.

2. **Regulates blood sugar**

The higher fibre content in the okra helps to release the sugars slowly into the blood where the digestion occurs slowly. Thus, it has a great significance in the diabetics (Alessandra Durazzo *et al.*, 2018)

3. **Fights cancer**

When compared to other vegetables, the okra contains higher amount of antioxidant that helps to prevent the cells from oxidative damage and lowers the risk of cancer. Thus higher fibre content helps in healthy digestive system and also prevents the colon cancer.

4. **Prevents Anaemia**

The plants are rich in Vitamin K, Folate and Iron, thus these components helps in promoting the blood health and it ensures the prevention of anaemia.

5. **Boost immunity**

As the amount of Vitamin C is higher in quantity, it helps to boost up the immunity thus, helps in the prevention of common infections. Thus 100 grams of the okra contains nearly about 40% of Vitamin C.

6. **Beneficial in pregnancy**

The important mineral that is required for the subsequent development of foetus is folate or folic acid. The okra contains higher amount of folate which helps the foetus in the proper development of neurological system.

Collection of biofertilizers

The biofertilizers namely *Azospirillum* and Phosphobacteria were obtained from TNAU, Coimbatore. The Spent Mushroom Compost was collected from the Mushroom cultivation at Department of Botany, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore.

Trichoderma viride was added as a biocontrol agent for controlling the disease. The application of *Trichoderma* is beneficial as it helps in reducing the fertilizer application as well as increases the yield of the crop.

Azospririllum

Azospirillum is well known for its nitrogen-fixing capacity and ability of phytohormone production. *Azospirillum* helps in fixing atmospheric nitrogen and benefit the host plants by the supplying vitamins and growth hormone. *Azospirillum* inoculation increases the growth, nitrogen uptake and yield in number of crops. The recommended dosage of *Azospirillum* is 5kg/hectare.

Phosphobacteria

Phosphobacteria is the organism that helps in converting the insoluble phosphorus int an available form to the plants. Next to nitrogen, Phosphorus is the second most important nutrient required by crop plants. The phosphate solubilizing bacteria (PSB) solubilize the insoluble phosphates and make them available for crop plants in the rhizosphere region (Mallikarjuna Rao *et al.*, 2014). The recommended dose of phosphobacteria is 10 kg/hectare.

Spent Mushroom Compost

Mushrooms possess high nutritional value and they are being used as a potential medicinal source in recent times. One of the important species of mushroom cultivated for food is Pleurotus. Spent Mushroom Compost is the substrate obtained after harvesting the mushroom. SMC is a source of humus formation that helps in increasing the nutrient availability to the growing crops which in turn increases the yield of the crop. **T**he average pH of fresh mushroom compost is 6.6, which is an excellent pH for any compost used as an organic fertilizer or soil amendment. It is mainly used as a mulch and soil conditioner to improve ornamental and vegetable garden.

Methods

Experiment in Grow Bags

The seeds obtained from TNAU, Coimbatore were soaked in different organic fertilizers overnight. Later, the seeds were sown in Grow bags (30cm×30cm×45cm sized bags) containing garden soil and cocopeat in the ratio 1:1. The treated bags were maintained in triplicates. The effect of different biofertilizers on the growth and yield parameters of *Abelmoschus esculentus* (L.) Moench were assessed.

The growth parameters at different stages of growth of the plants were analyzed. Neem extract was sprayed at intervals to control the growth of insects. The different organic fertilizer treatments given were:

T_0 – Control
T_1 – *Azospirillum*
T_2 – Phosphobacteria
T_3 - Spent Mushroom Compost

Growth Parameters

To measure the growth parameters, plant samples were uprooted carefully on 15th, 30th and 45thday and the following parameters were recorded for all the treatments.

1. Root length (cm)
2. Shoot length (cm)
3. Number of lateral roots
4. Number of leaves
5. Diameter of leaves (cm)

Root Length

The plants were taken from control bag and other treatment bags and washed to get rid of adhering soil particles. Then, the length of the roots were measured with the help of a scale from root collar point to root tip and expressed in centimetre. Three seedlings were randomly selected from each treatment and their root length was measured using cm scale and recorded in cm/seedling.

Shoot Length

To measure the shoot length of the plants, the measurement was taken from the shoot collar point to shoot apex and expressed in centimetre. Three seedlings were randomly selected from each treatment and their root length was measured using cm scale and recorded in cm/seedling. Three readings were taken for statistical analysis.

Number of lateral root

The number of lateral roots arising from the main primary root was measured.

Number of leaves

The number of leaves present was recorded in the uprooted plants.

Diameter of leaves

The diameter of the leaves were measured for all the treatments along with the control plant and expressed in centimetre.

Yield parameters

Number of buds

The number of buds formed in all the grow bags was calculated.

Number of fruits

The number of fruits obtained on 45th day and 60th day were calculated for *Abelmoshus esculentus* (L.) Moench

STATISTICAL ANALYSIS

The data obtained from various morphological observations as well as yield parameters were subjected to statistical analysis as per the procedure of Panse and Sukhatme (1978).

RESULTS & DISCUSSION

Chapter IV
RESULTS AND DISCUSSION

The experiment was conducted in lady's finger plant (*Abelmoschus esculentus* (L.) Moench with a control and three different treatments (Plate 4) namely Phosphobacteria, *Azospirillum* and Spent Mushroom Compost (SMC) and the growth parameters of the plant were estimated.

The germination and initial leaflet formation of the lady's finger is seen in Plate 5. The parameters such as shoot length, root length, number of lateral roots, leaves and diameter of leaves were measured on the 10 (Plate 6 & 7) and 15 (Plate 8 & 9) days after sowing (DAS). Buds started forming after 15 days, so the number of buds formed was also measured on the 30th and 45th days. On the 45th day, the number of fruits formed was also measured and statistically analyzed. The growth parameters as well as the yield parameters were statistically analyzed and the results are tabulated.

Ten days after the seeds were sown, measurement of shoot length, root length, number of lateral roots formed, number of leaves formed and diameter of the leaves were calculated and tabulated (Table 1). The shoot length was significantly higher in the grow bag in which Spent Mushroom Compost (SMC) was used. The value obtained was 13.0 ± 1.9 cm (Fig.1).

Plate 4

Seeds of *Abelmoschus esculentus* (L.) Moench sown in Grow Bag

Plate 5

Seedling growth of *Abelmoschus esculentus* (L.) Moench after 6 days in control and treatments

Table 1

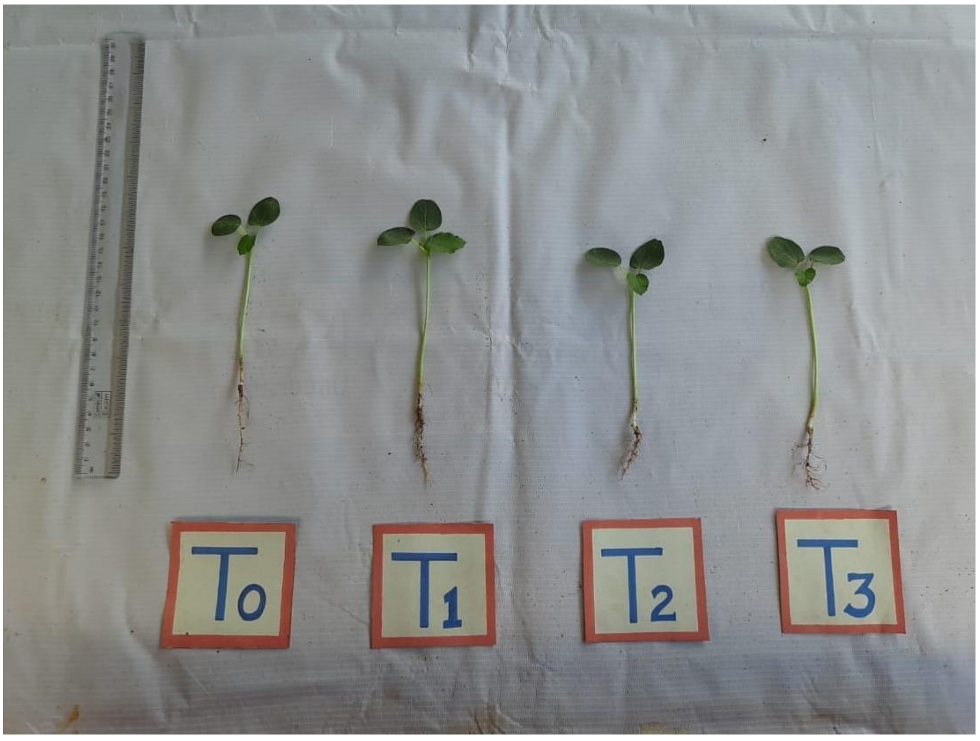
Growth parameters of *Abelmoschus esculentus* (L.) Moench on the 10th day after the seeds were sown

BAGS	PARAMETERS				
	Shoot length (cm)	**Root length (cm)**	**No. of lateral roots**	**No. of leaves**	**Diameter of leaves (cm)**
T_0	11 ± 1	6.2 ± 0.6	14.7 ± 1.5	3.3 ± 0.6	2.0 ± 0.6
T_1	12.4 ± 0.9	**7.6 ± 0.6**	13.0 ± 1.0	**4.0 ± 1.0**	2.5 ± 0.6
T_2	10.2 ±1.0	5.0 ± 0.5	**21.3 ± 1.5**	3.3 ± 0.6	**2.6 ± 0.6**
T_3	**13.0 ± 1.9**	5.0 ± 1.0	19. ±1.0	3.7 ± 1.2	2.3 ± 0.6
SED CD(P<0.5)	1.0341 2.3848	0.6988 1.6115	1.0541 2.4308	0.7071 1.6306	0.4601 1.0609

Plate 6

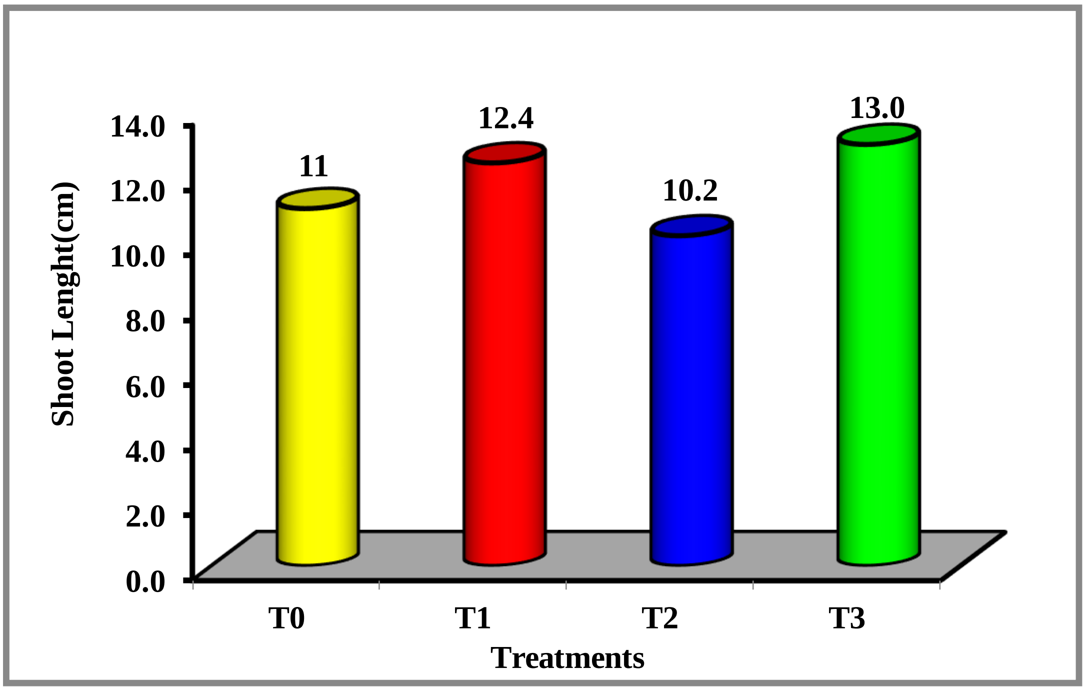
Growth of *Abelmoschus esculentus* (L.) Moench after 10 days in control and treatments

Plate 7



Measurement of morphological parameters on the 10^{th} day

Figure 1



Shoot Length

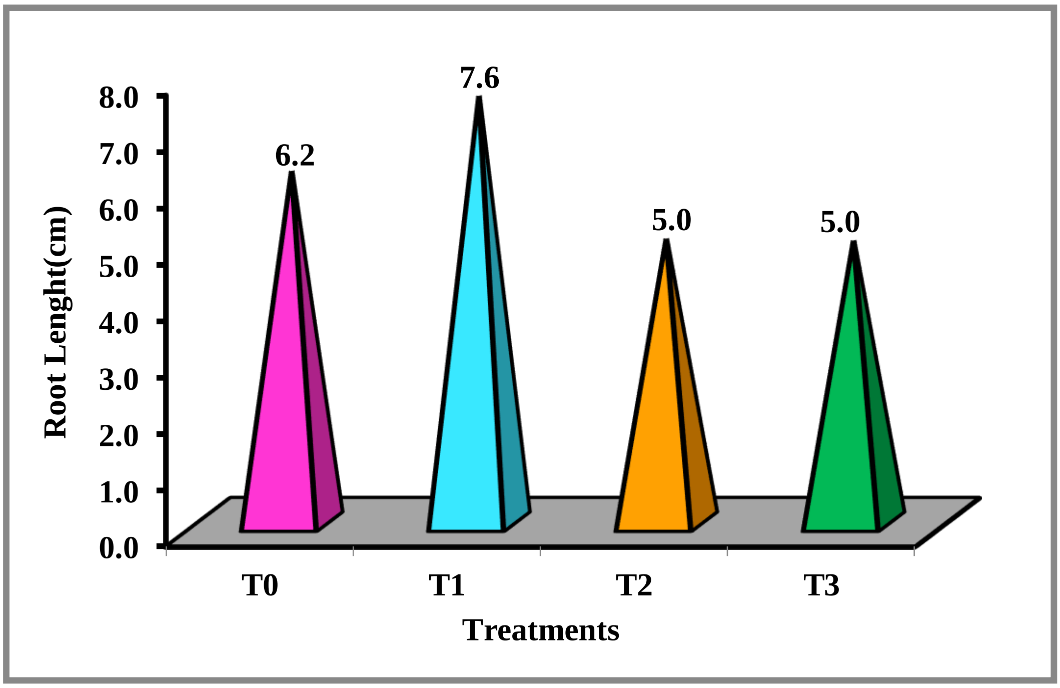
T_0 – Control

T_1 – Phosphobacteria

T_2 – *Azospirillum*

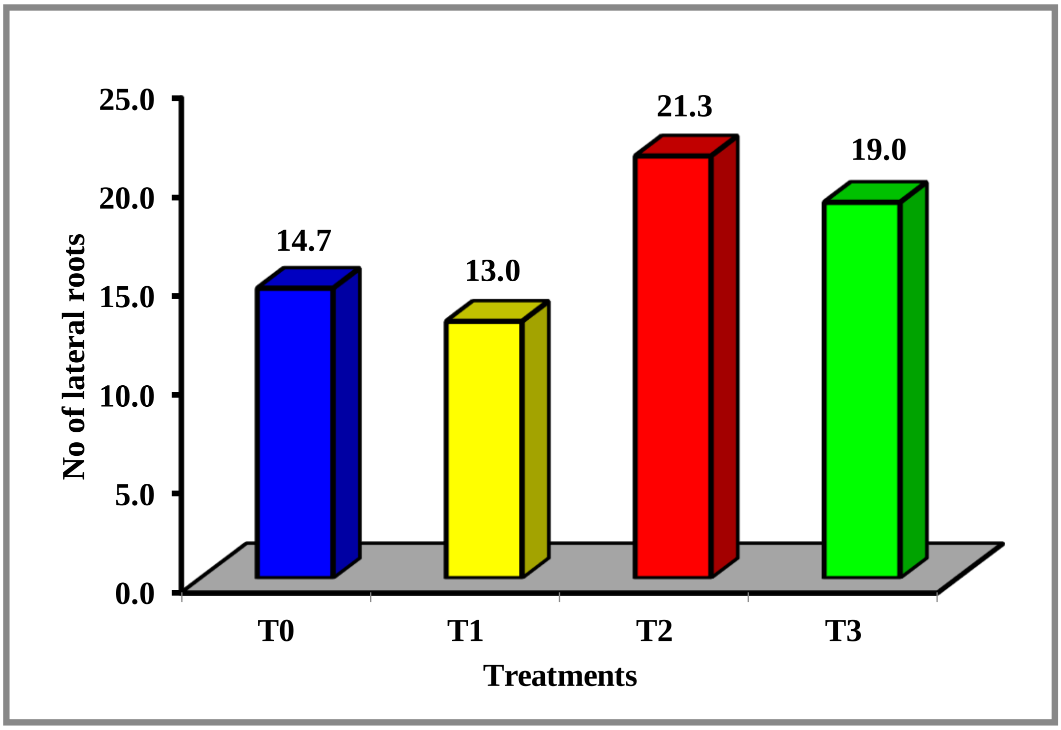
T_3 - Spent Mushroom Compost

Figure 2 Root Length



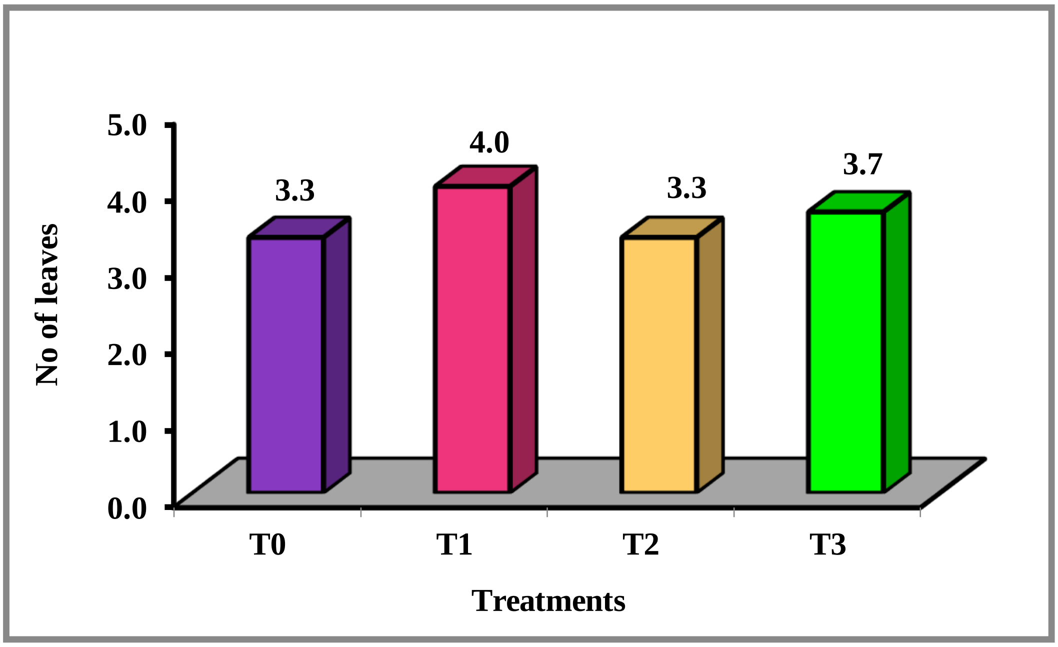
The root length of the lady's finger plant was found to be higher in plants treated with Phosphobacteria (Fig.2) and the reading observed was 7.6 ± 0.6 cm. The number of lateral roots formed on the 10th day was significantly higher in plants treated with *Azospirillum* (T_2) and value recorded was 21.3 ± 1.5 (Fig.3). The number of leaves and the diameter of the leaves on the 10th day were higher in T_1 and T_2 respectively. The measurement observed were 4.0 ± 1.0 (Fig.4) and 2.6 ± 0.6 cm (Fig.5).

Figure 3



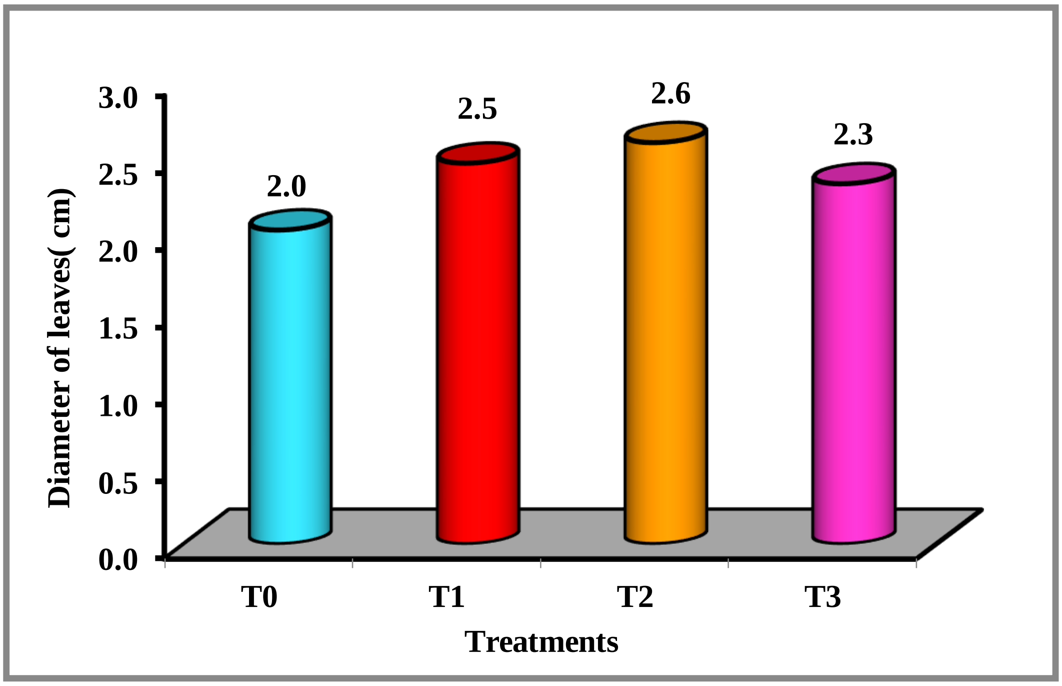
No. of lateral roots

Figure 4



No. of Leaves

Figure 5



Diameter of Leaves

On the 15th day (Table 2), the shoot length was found to be significantly higher in T_3 i.e. the lady's finger plant that was grown using Spent Mushroom Compost. The reading was observed to be 14.7 ±0.8cm (Fig.6). The root length on the 15th day was higher in T_1 (9.0 ± 1.5cm; Fig.7).

Table 2

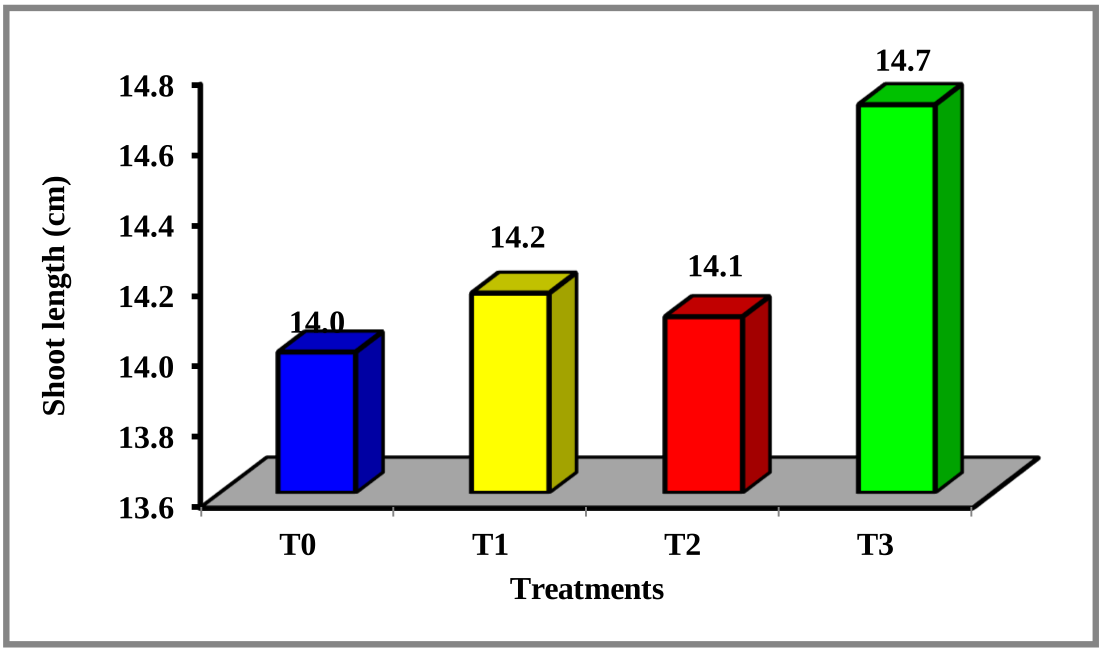
Growth parameters of *Abelmoschus esculentus* (L.) Moench on the 15th day

BAGS	PARAMETERS				
	Shoot length (cm)	**Root length (cm)**	**No. of lateral roots**	**No. of leaves**	**Diameter of leaves (cm)**
T_0	14.0 ±1.8	6.7 ± 1.5	22.7 ± 2.5	**4.3 ± 0.6**	**3.7 ± 0.8**
T_1	14.2 ± 2.0	**9.0 ± 1.5**	22.0 ± 2.0	3.7 ± 0.6	**3.7 ± 0.4**
T_2	14.1 ± 1.4	8.2 ± 1.2	**23.0 ± 2.6**	3.3 ± 1.2	2.8 ± 0.4
T_3	**14.7 ±0.8**	7.0 ±1.0	21.3 ± 3.1	3.8 ± 0.3	3.1 ± 0.4
SED CD(P<0.5)	1.4516 3.3475	1.0847 2.5014	2.1082 4.8615	0.5893 1.3588	0.4333 0.9993

Plate 8

Growth of *Abelmoschus esculentus* (L.) Moench after 15th day in control and treatments

Figure 6



Shoot Length

T_0 – Control

T_1 – Phosphobacteria

T_2 – *Azospirillum*

T_3 - Spent Mushroom Compost

Figure 7 Root Length

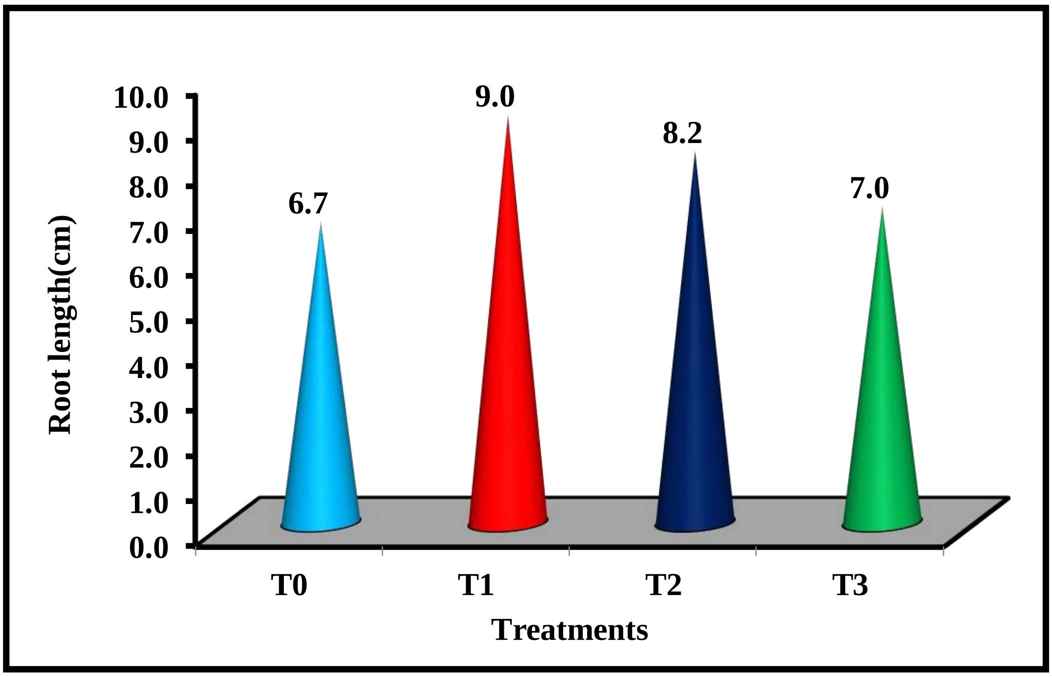
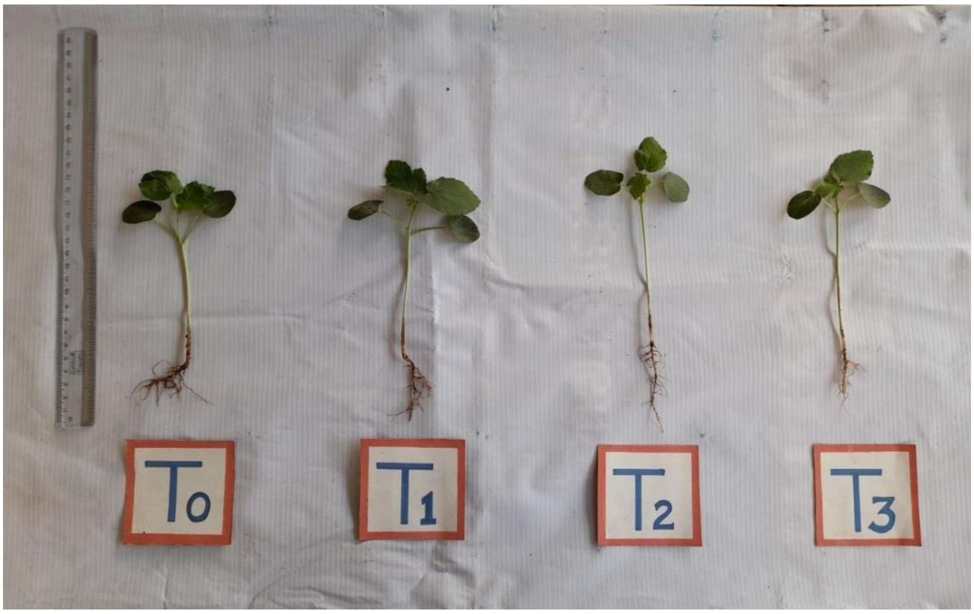
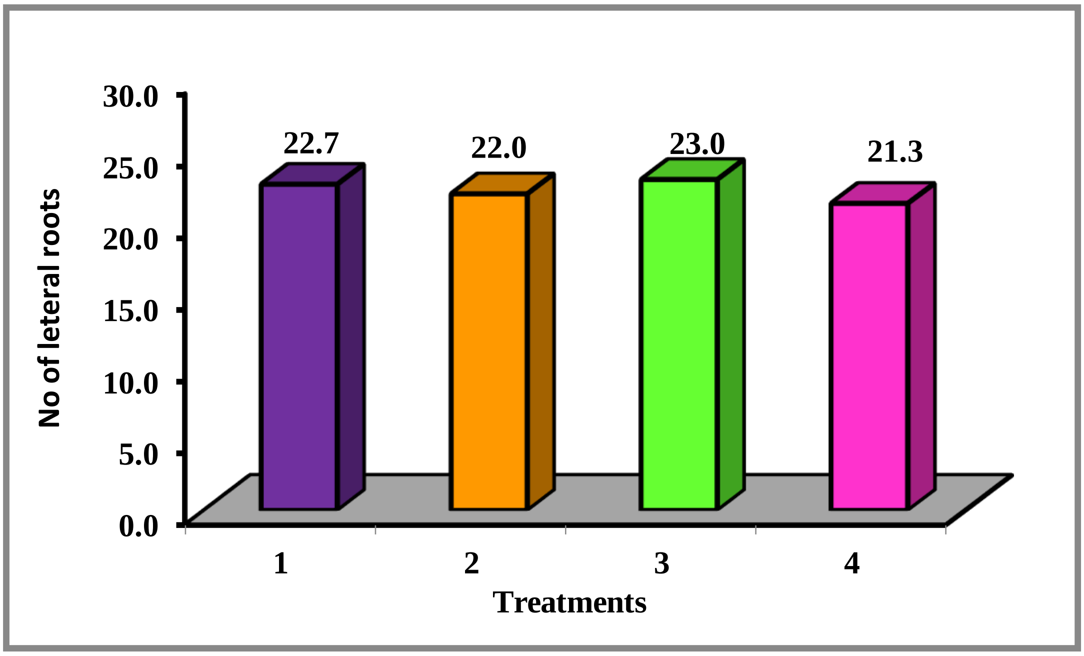


Plate 9



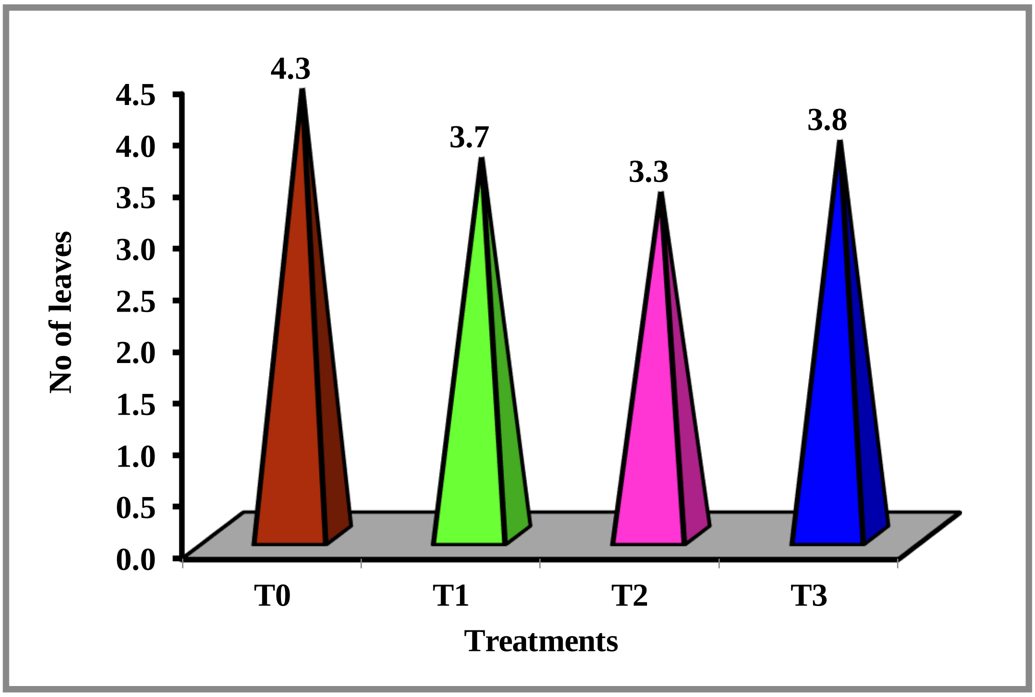
Measurement of morphological parameters on the 15th day

Figure 8



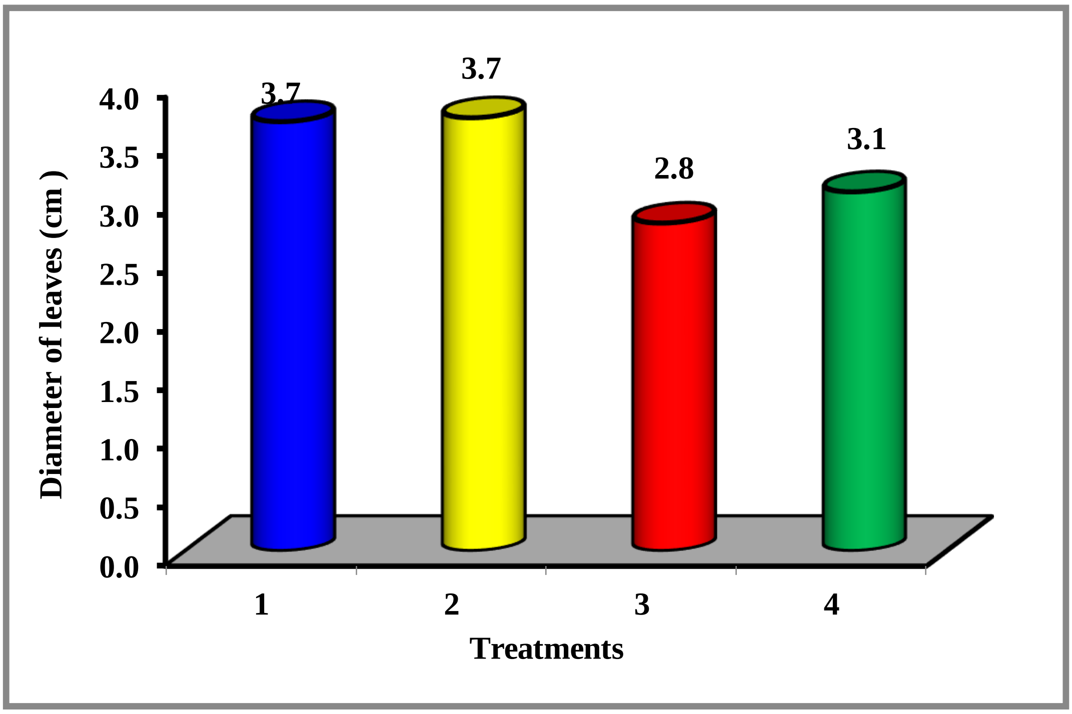
No. of lateral roots

Figure 9



No. of Leaves

Figure 10



Diameter of Leaves

The number of lateral roots was found to be maximum in plants treated with *Azospirillum* on the 15th day and the value was 23.0 ± 2.6 (Fig.8). Significantly higher number of leaves (Fig.9) and diameter of leaves (Fig.10) were observed in control plant on the 15th day and the values were found to be 4.3 ± 0.6 and 3.7 ± 0.8 cm respectively. The diameter of the leaves was found to be similar in both control plants and plants treated with Phosphobacteria.

On the 30th day (Table 3; Plate 10 & 11), the shoot length and root length was found to be significantly higher in $T_1$and the values were 26.0 ±2.1cm and 13.7 ± 1.2 cm i.e. the plant supplemented with Phosphobacteria (Fig.11 & 12).

Plate 10

Growth of *Abelmoschus esculentus* (L.) Moench after 30th day in control and treatments

The number of lateral roots formed on the 30th day was comparatively higher in T_2 than the control plant and other biofertilizer treated plants. The observation was 35.7 ± 5.0 (Fig.13). The number of leaves alone was found to be higher in control plant on the 30th day. The value recorded was 7.2 ± 1.5 (Fig.14).

Plate 11

Measurement of morphological parameters on the 30th day

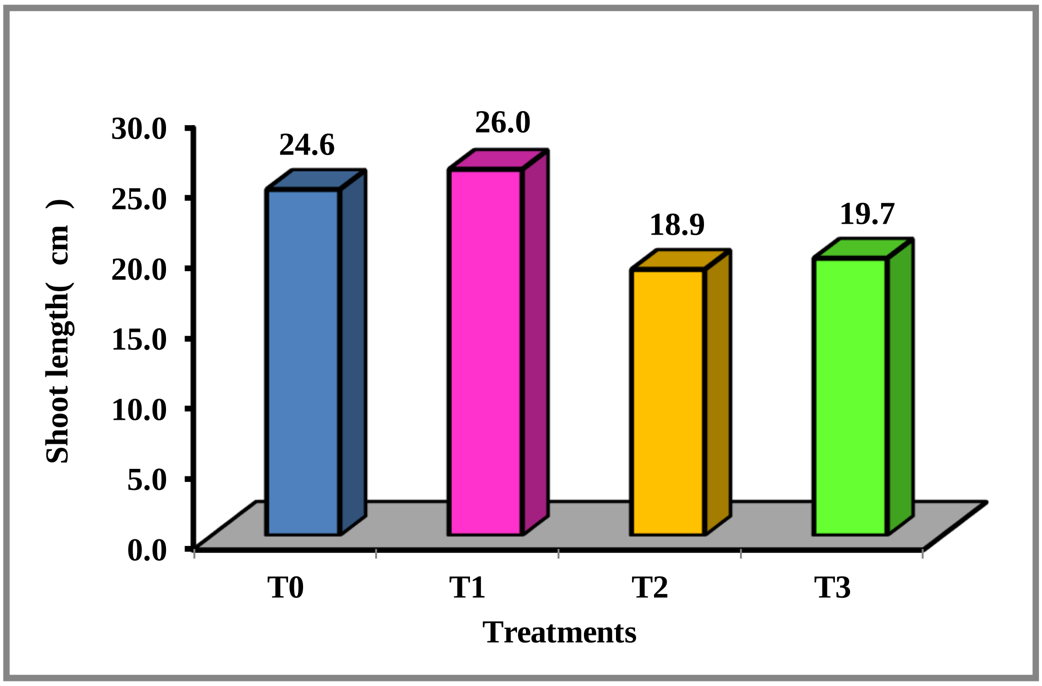
The diameter of the leaves and the number of buds formed were found to be significantly higher in plants treated with Phosphobacteria (T_1). The values for the same were 5.3 ± 0.6 cm (Fig.15) and 2.7 ± 1.5 (Fig.16) respectively.

Table 3

Growth parameters of *Abelmoschus esculentus* (L.) Moench on 30th day

BAGS	**PARAMETERS**					
Treatments	**Shoot length (cm)**	**Root length (cm)**	**No. of lateral roots**	**No. of leaves**	**Diameter of leaves (cm)**	**No. of buds**
T_0	24.6 ± 4.3	12.0 ± 1.3	25.3 ± 4.5	**7.2 ± 1.5**	5.0 ± 2.0	2.0 ± 1.0
T_1	**26.0 ±2.1**	**13.7 ± 1.2**	26.3 ± 2.1	6.2 ± 0.9	**5.3 ± 0.6**	**2.7 ± 1.5**
T_2	18.9 ± 0.7	13.0 ± 0.5	**35.7 ± 5.0**	4.0 ±0.2	5.0 ± 1.0	1.3 ± 0.6
T_3	19.7 ±1.2	10.3 ± 1.8	33.0 ± 1.7	4.0 ± 0.6	5.0 ± 1.0	1.7 ± 1.2
SED CD(P<0.5)	2.0225 4.6640	1.0384 2.3946	2.9721 6.8537	0.7728 1.7821	1.0274 2.3692	0.9129 2.1051

Figure 11



Shoot Length

T_0 – Control

T_1 – Phosphobacteria

T_2 – *Azospirillum*

T_3 - Spent Mushroom Compost

Figure 12 Root Length

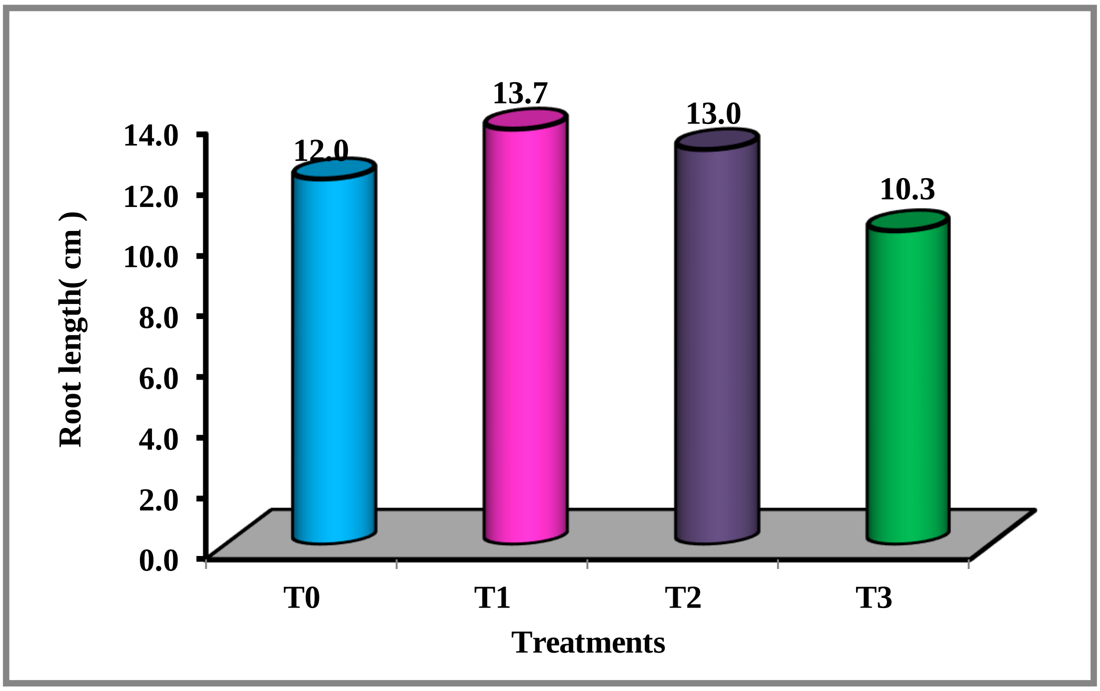
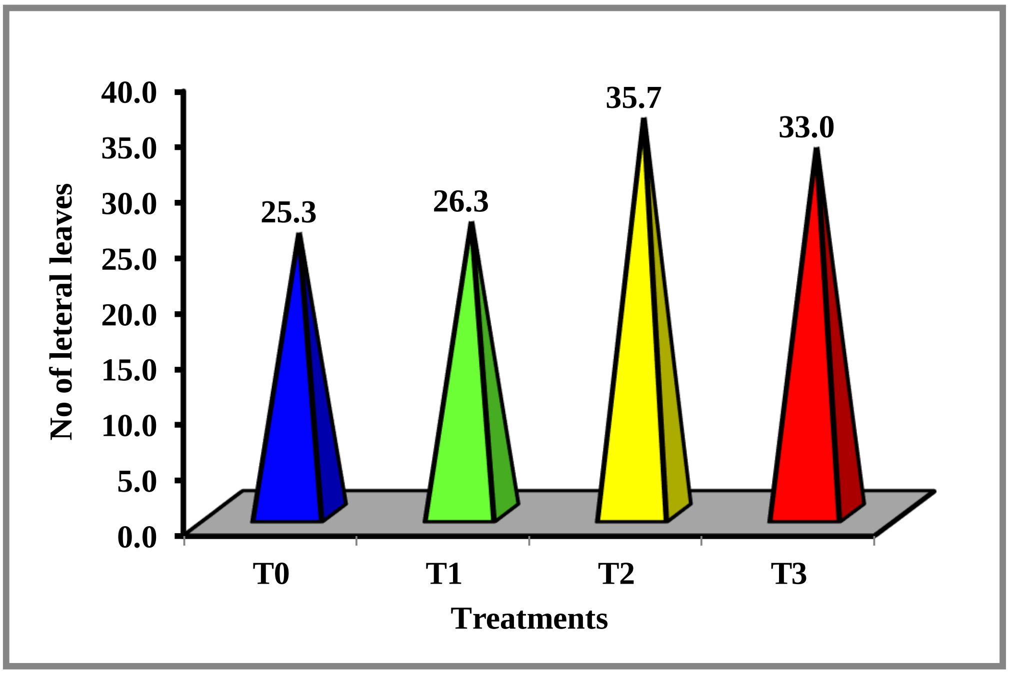
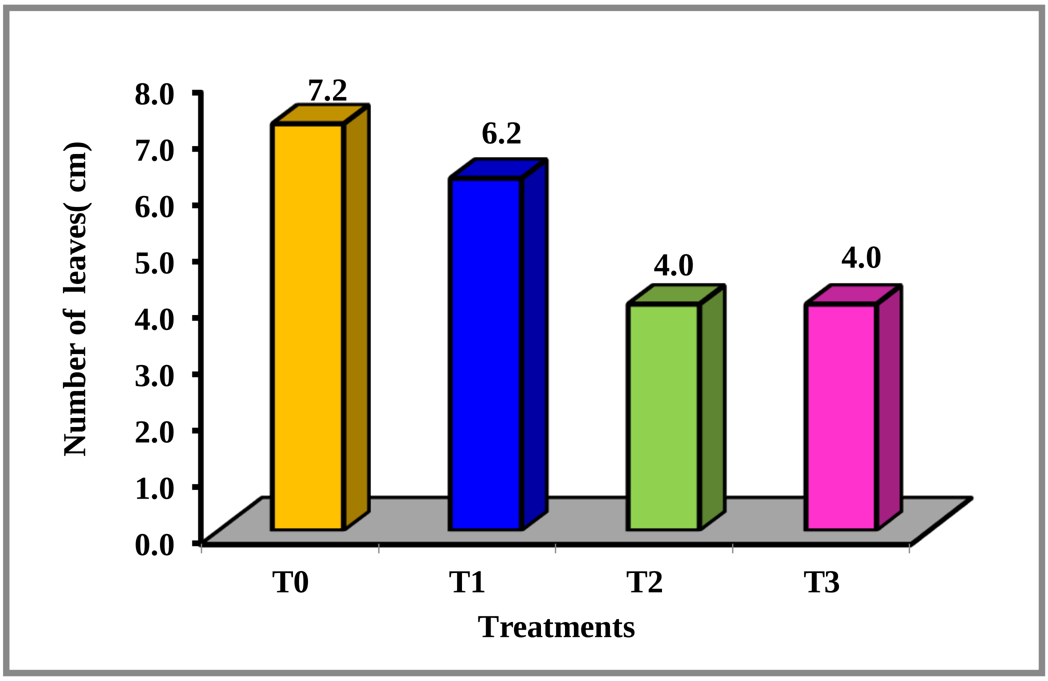


Figure 13



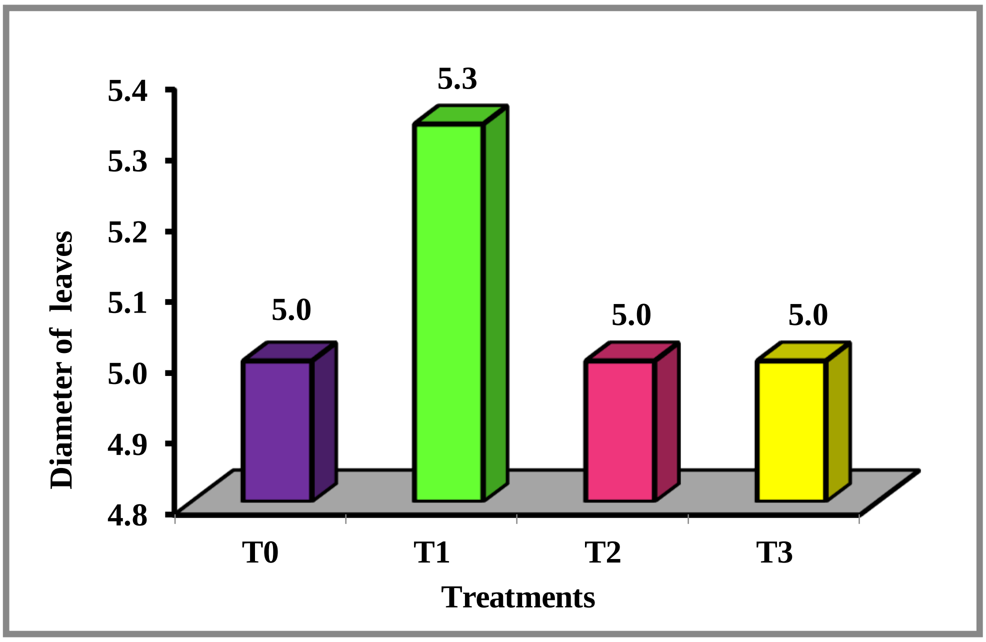
No. of lateral roots

Figure 14



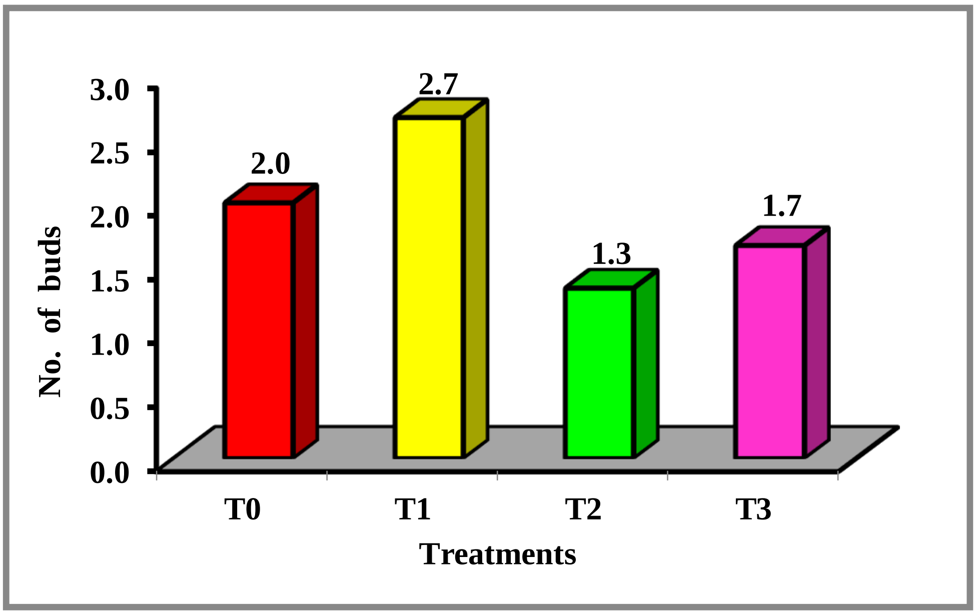
Number of Leaves

Figure 15



Diameter of Leaves

Figure 16



No. of buds

Plate 12 shows the growth of *Abelmoschus esculentus* (L.) Moench in control and biofertilizer treated lady's finger plants after 38 days. The grow bags shows flowering stage of the plants.

Plate 12

Growth of *Abelmoschus esculentus* (L.) Moench in control and treatments after 38 days showing flowering

On the 45th day, the morphological and yield parameters were observed and tabulated (Table 4; Plate 13 & 14). The morphological parameters observed were shoot length, root length, number of lateral root, number of leaves and diameter of leaves. The reproductive parameters or the yield parameters observed were number of buds and number of fruits formed on the 45th day.

Plate 13

Growth of *Abelmoschus esculentus* (L.) Moench after 45 days in control and treatments

Plate 14

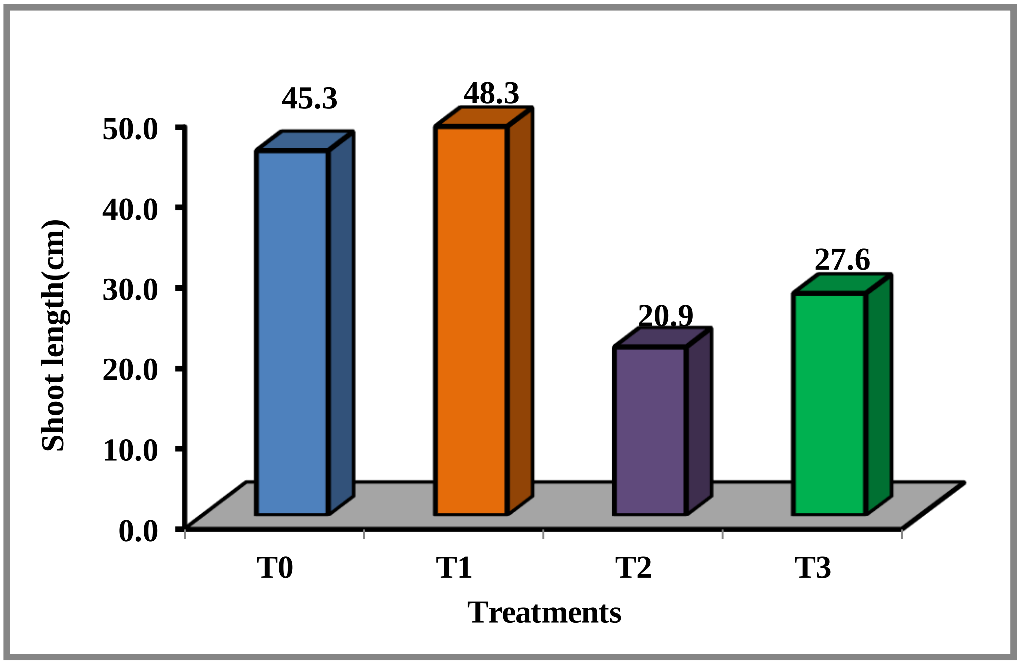
Measurement of morphological parameters on the 45^{th} day

Table 4

Growth parameters of *Abelmoschus esculentus* (L.) Moench on 45th day

BAGS	PARAMETERS						
	Shoot length (cm)	**Root length (cm)**	**No. of lateral roots**	**No. of leaves**	**Diameter of leaves (cm)**	**No. of buds**	**No. of Fruits**
T_0	45.3 ± 5.0	13.3 ± 1.5	45.0 ± 5.0	11.3 ± 3.1	12.8 ± 1.4	2.3 ± 0.6	2.0 ± 1.0
T_1	**48.3 ± 1.5**	**22.7 ± 2.1**	**62.7 ± 5.9**	**12.0 ±1.0**	**13.3 ± 1.0**	2.3 ± 1.5	**2.7 ± 1.2**
T_2	20.9 ± 2.3	15.7 ±1.5	58.3 ± 7.6	6.7 ± 1.5	4.6 ± 0.9	**2.7 ± 1.2**	2.3 ±2.3
T_3	27.6 ± 1.8	15.1 ± 1.7	55.3 ± 9.5	7.0 ±1.0	5.0 ± 4.0	2.0 ± 1.0	2.0 ± 1.0
SED CD(P<0.5)	2.4447 5.6376	1.4061 3.2426	5.8878 13.5775	1.5092 3.4803	1.8222 4.2021	0.9129 2.1051	1.2019 2.7715

Figure 17



Shoot Length

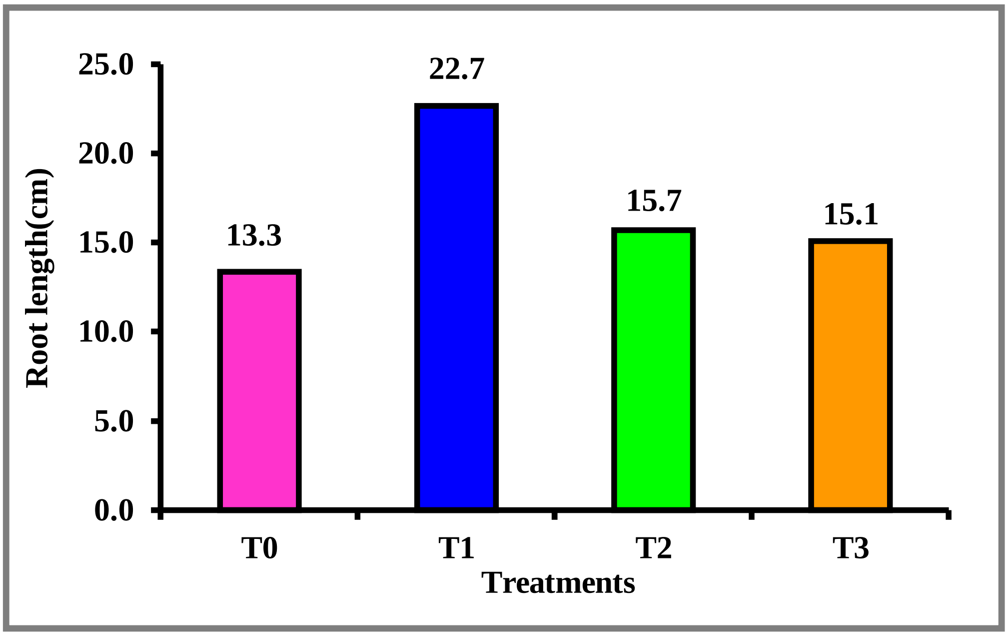
T_0 – Control

T_1 – Phosphobacteria

T_2 – *Azospirillum*

T_3 - Spent Mushroom Compost

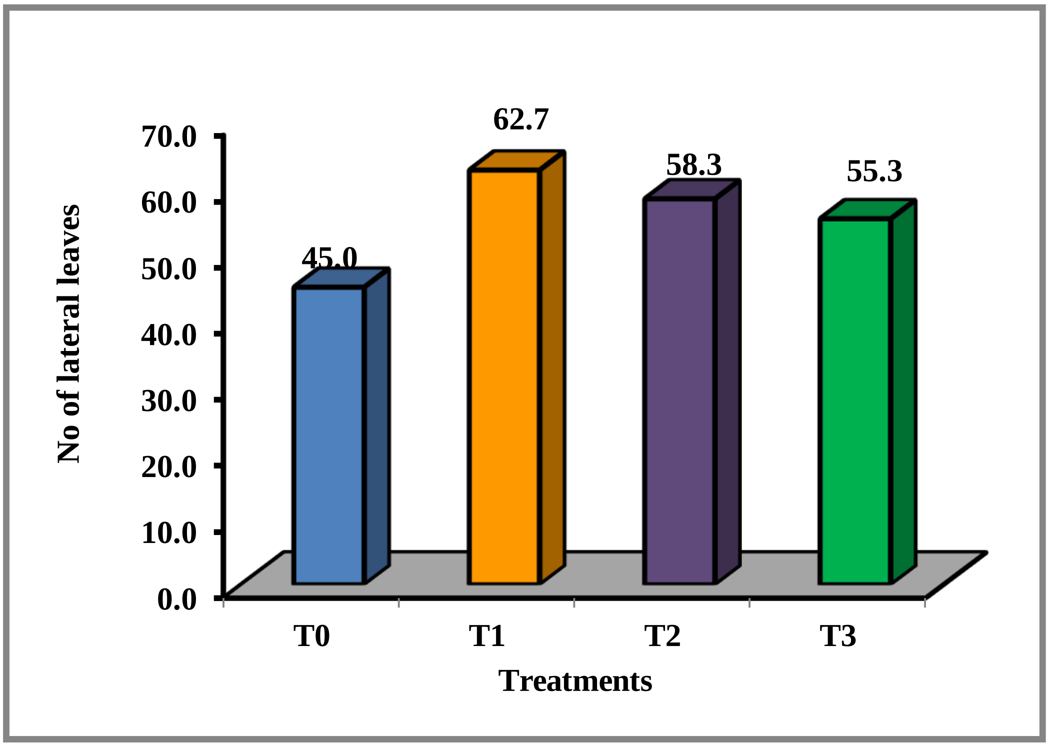
Figure 18



Root Length

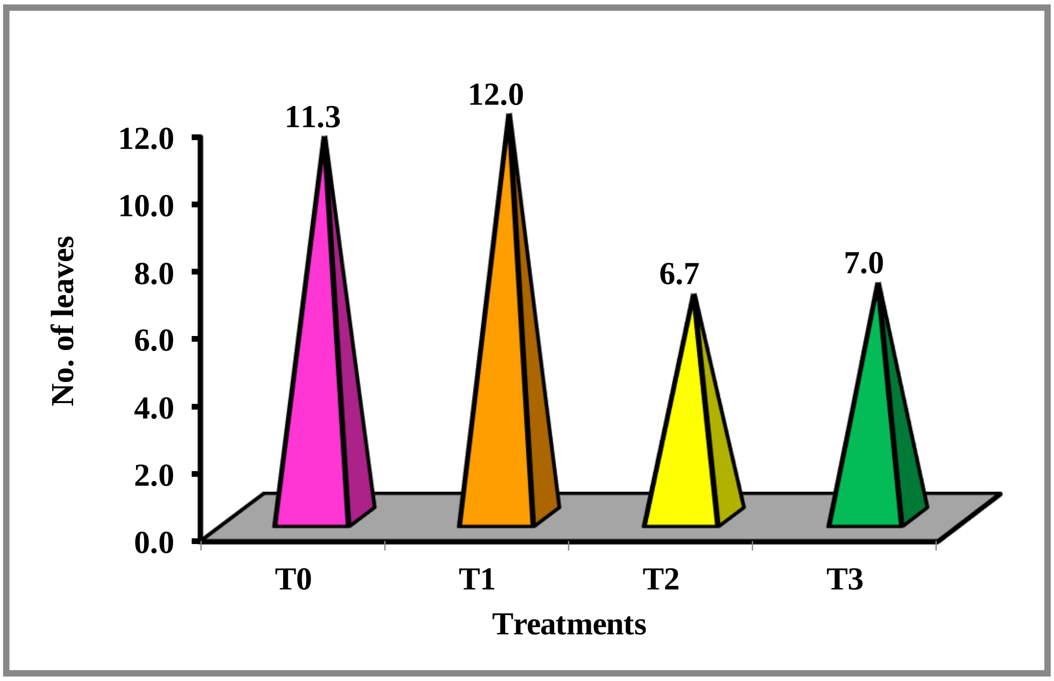
As far as the morphological parameters are concerned all the growth parameters namely shoot length (Fig.17), root length (Fig.18), number of lateral roots (Fig.19), number of leaves (Fig.20) and diameter of leaves (Fig.21) were significantly higher in plants treated with Phosphobacteria (T_1) on the 45th day. The values recorded were shoot length (48.3 ± 1.5 cm), root length (22.7 ± 2.1 cm), number of lateral roots (62.7 ± 5.9), number of leaves (12.0 ±1.0) and diameter of leaves (13.3 ± 1.0 cm) respectively.

Figure 19



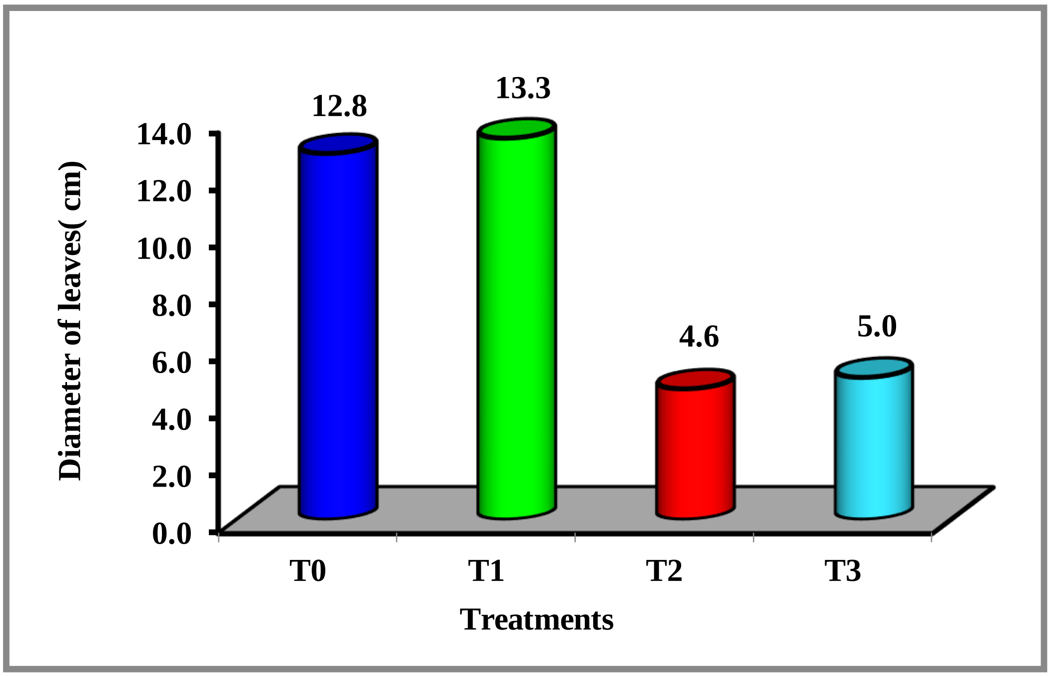
No. of lateral roots

Figure 20



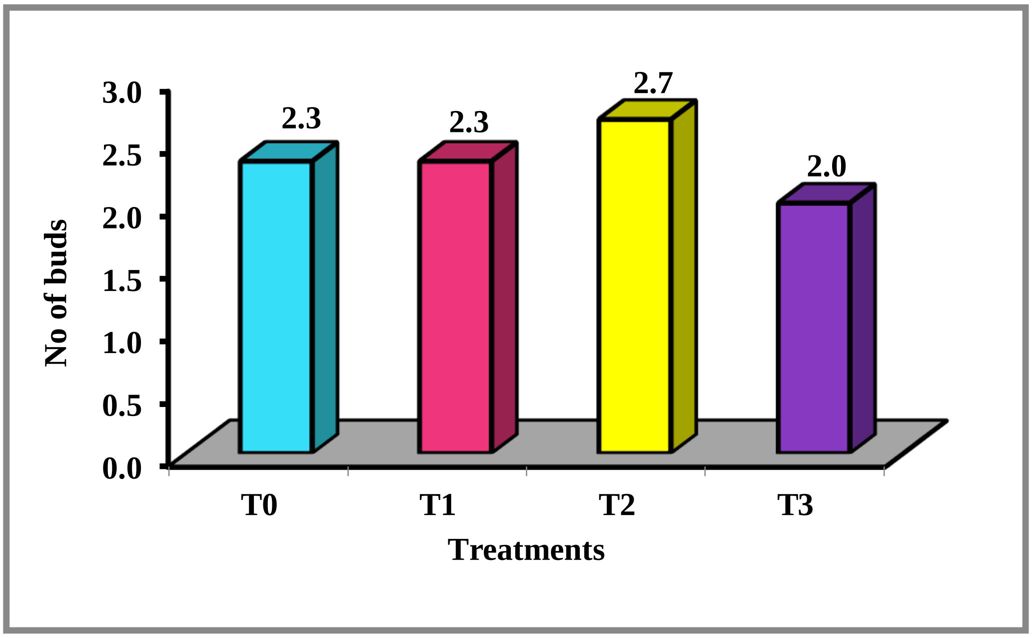
No. of Leaves

Figure 21



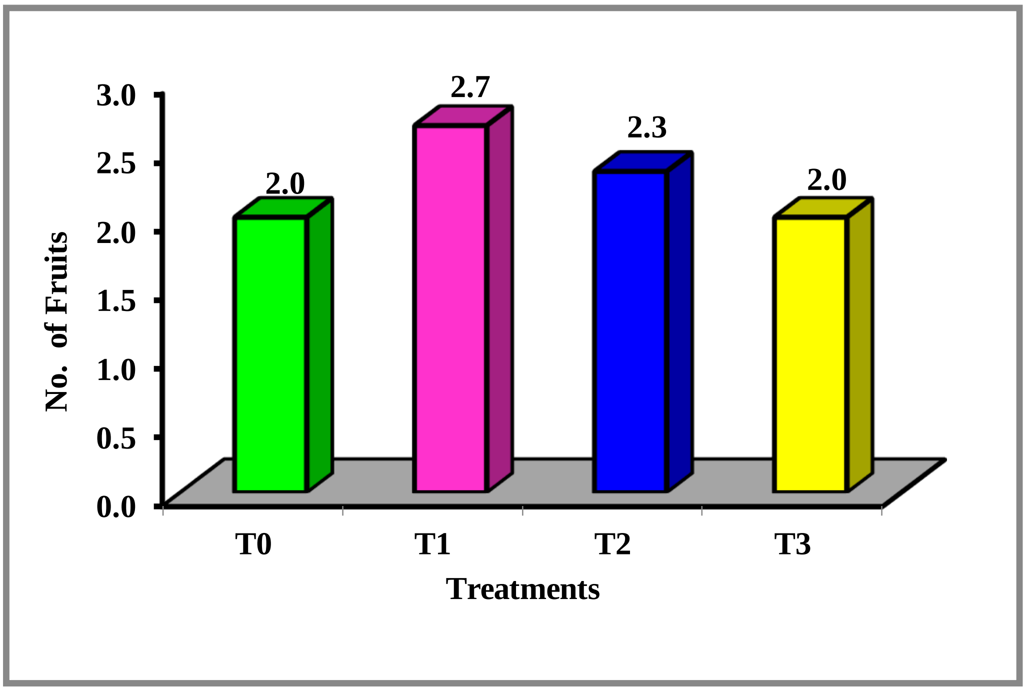
Diameter of Leaves

Figure 22



No. of buds

Figure 23



No. of Fruits

The yield parameters namely, the number of buds formed and number of viable fruits formed was found to be significantly higher in T_2 and T_1 respectively. The readings observed were 2.7 ± 1.2 (Fig.22) and 2.7 ± 1.2 (Fig.23). The effect of bacterial bio-fertilizer on the yield of sunflower had shown a positive effect on the growth and yield (Dhanasekar and Dhandepani, 2012). In the current study, the application of Phosphobacteria has shown better growth in terms of both morphological as well as yield parameters in *Abelmoschus esculentus* (L.) Moench.

Plate 15 shows the dispersal of seeds after maturity and Plate 16 shows the seeds obtained from the plants that can be utilized for further growth. The study on the influence of chemical fertilizers and bio-fertilizers on dry matter yield and NPK uptake by Cabbage (Singh *et al*., 2013) had shown a significant variation in dry matter yield/ plant due to the inoculation of *Azospirillum*. The maximum dry matter yield obtained might be due to the ability of *Azospirillum* to produce some growth promoting substances involved in increasing the accumulation of food in plant.

Plate 15

Seed dispersal

Plate 16

Seeds

The studies carried out by Uma Maheswari and Elakkiya (2014) have shown that combined inoculation of liquid bio-fertilizers such as *Rhizobium*, *Azospirillum* and *Azotobacter* could enhance the growth parameters as well as the biochemical constituents.

Application of biofertilizers such as *Azospirillum* and Phosphobacteria had shown an increase in growth and yield of the vegetable crops taken for study. This result is in accordance with the work carried out by Mounika *et al.* (2017) and Rahimi *et al*. (2009) in Coriander ; Mehta *et al*.,(2012) in fenugreek.

Bio-fertilizers are used to hasten the biological activity of the plants to improve the availability of plant nutrient (Kumari *et al*., 2015). The work on the growth and establishment of cashew grafts under greenhouse condition by Shankarappa *et al.* (2017) have shown that the bio- fertilizers used increased the growth and nutrient uptake of the cultivar.

The results on the application of microbial inoculants to onion produced maximum plant height, number of leaves per plant and fresh weight of plant. This result is on par with the current study, where the use of organic fertilizers such as *Azospirillum* and Phosphobacteria has resulted in increased growth parameters of lady's finger. These results also correlate with the findings of Rather *et al*. (2003) Yadav *et al*. (2005) and Jha *et al*., (2006).

Earlier studies by Srivastava (2017) have shown that integration of bio-fertilizers significantly improved the yield of Kalmegh.

The effect of bacterial bio-fertilizer on the yield of sunflower had shown a positive effect on the growth and yield (Dhanasekar and Dhandepani, 2012). These results are in correlation with the current result on *Abelmoschus esculentus*.

In the present study on lady's finger, the use of Spent Mushroom Compost has not shown a significant growth in terms of shoot length, root length and other morphological parameters. This is a trial in which the plants were grown only in grow bags. To prove the efficacy of the biofertilizers and the SMC, the plants should be grown under field soil, so that the nutrient availability to the plants would be better in the field conditions

SUMMARY & CONCLUSION

Chapter V
SUMMARY AND CONCLUSION

The experiment was conducted in lady's finger plant in grow bags under control and three different biofertilizer treatments namely, Phosphobacteria, *Azospirillum* and Spent Mushroom Compost (SMC). The seedling formation after germination started on the 5^{th} day of growth. The parameters tested for morphological characters were shoot length, root length, number of lateral roots, number of leaves and diameter of leaves on the 10^{th}, 15^{th}, 30^{th} and 45^{th} day after sowing. The reproductive characters such as formation of number of buds and later number of fruits formed were estimated for the test plant in control and other three biofertilizer treatments.

On the 10^{th} and 15^{th} day, the shoot length seemed to be significantly higher in Spent Mushroom Compost (T_3) grown lady's finger plants. The root length and the number of leaves on the 10^{th} day were found to be significantly higher in Phosphobacteria applied plants. The number of lateral root formed and diameter of the leaves were more in *Azospirillum* (T_2) treated plants on the 10^{th} day.

On the 15^{th} day, the root length and number of lateral roots formed were found to be significantly higher in Phosphobacteria and *Azospirillum* treated plants respectively. The number of leaves and the diameter of the leaves were found to increase in control plant (T_0) on the 15^{th} day.

On the 30^{th} day, Phosphobacteria showed significant increase in shoot length, root length, diameter of the leaves and number of buds. The lateral root formation was higher on the 30^{th} day in *Azospirillum* treated plants, whereas the number of leaves formed was significantly higher in control plants.

On the 45^{th} day, shoot length, root length, number of lateral roots, number of leaves, diameter of leaves and number of fruits were found to significantly increase in plants treated with Phosphobacteria (T_1). Azospirillum showed an increase in the number of bud formation on the 45^{th} day of growth of lady's finger plant.

The use of biofertilizers and organic fertilizers is essential for environmental safety, protection and sustainability. So, the current study is an initiative carried out in small grow bags which can be taken further for field work.

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