STUDY ON NUTRIENT USE EFFICIENCY OF OKRA IN SOIL AND SOILLESS MEDIA USING FERTIGATION

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DECLARATION

I hereby declare that this project entitled **"STUDY ON NUTRIENT USE EFFICIENCY OF OKRA IN SOIL AND SOILLESS MEDIUM USING FERTIGATION"** is a bonafide record of project work done by us during the course of study and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Place: Tavanur
Date: 01/02/2018

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CERTIFICATE

Certified that this project report, entitled **"STUDY ON NUTRIENT USE EFFICIENCY OF OKRA IN SOIL AND SOILLESS MEDIUM USING FERTIGATION"** is a record of project work done jointly by **Ann Annie Shaju, Ayisha Shareena N** and **Aksa V Reji** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to them.

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Ann Annie Shaju

Ayisha Shareena N

Aksa V Reji

Dedicated to
our loving parents

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CHAPTER I

INTRODUCTION

Agriculture is the basic source of food supply of all countries of the world. Due to heavy pressure of population in under developed and developing countries and its rapid increase, the demand for food is increasing at a fast rate. In India, with the growing population, the per capita availability of soil and water resources is diminishing day by day. This highlights the importance of optimizing the use of natural resources for crop production in the country. Technology which can improve the productivity, profitability and sustainability of our major farming systems are needed to increase production. To achieve these objectives, general approaches have been adopted in agriculture taking into consideration the prevailing environmental conditions by way of selection of more suitable crops and varieties, agronomic, cultural and engineering practices.

Kerala which lies in the tropical region is mostly subject to the type of humid tropical wet climate experienced by most of Earths rainforests. The abundance of water due to the 34 lakes and 44 rivers flowing through the state facilitates agriculture to a great extent and thus the economy of the state is dominated by agriculture.

Strengthening of Agriculture is usually attained through irrigation and fertilizer application. Over irrigation may be harmful in terms of its demerits and fertilizer application at doses higher than recommended lead to pollution of the environment. Suitable methods which are both eco and farmer friendly have to be developed.

Adoption of micro irrigation for crops is reported to get an increasing agricultural production. The benefits of micro irrigation which include water saving, precise application and water use efficiency make the system highly acceptable. Drip system is a type of micro irrigation that has the potential to save water and nutrients by allowing water to drip slowly to the root zone of the plants, either from above the soil surface or buried below the surface. Drip system distributes water through a network of pipes, tubings, valves, and emitters. The system deliver constant rate of discharge, which do not change significantly in the field. Judicious application of fertilizers and plant nutrients will enhance the system efficiency and ultimately the yield.

The productivity of a crop is influenced by the micro climate around it. The components of crop micro climate are light, temperature, air composition and the nature of root medium. Under open field conditions, it is not possible to have control over light, temperature and air composition. The only possibility under open field conditions is to manipulate the nature of rooting medium by tillage, irrigation, fertilizer application etc. Controlled environment agriculture i.e., greenhouse is one of the promising measures for supplying food under unfavourable environmental conditions.

A greenhouse is a framed or inflated structure covered with a transparent or translucent material, which protects plants from wind, precipitation, excess solar radiation, temperature extremes and considerable pest and disease attack. The micro climate control also implies superior quality of produce, free from floor and other objects in greenhouse. These objects in greenhouse in turn, emit long wave thermal radiation for which the cover material has lower transparency. As a result the solar energy is trapped in the greenhouse raising its temperature. This phenomenon is known as greenhouse effect.

Soil is usually the most common growing medium for plants. Soil acts as a reservoir to retain nutrients and water and it provides physical support for the plant through its root system. Well drained, pathogen free field soil of uniform texture is the least expensive medium for plant growth. But soil does not always occur in this perfect package. Some soils are poorly textured or shallow and provide an unsatisfactory root environment because of limited aeration and slow drainage. Presence of pathogenic organisms and nematodes are a common problem in field soil. When adverse conditions are found in soil and reclamation is impractical, some form of soilless culture may be justified.

Soilless culture system generally improves water use efficiency and thus reduces the demand of water. Protected cultivation using soilless culture tremendously reduces the water use and improves the water use efficiency. Gravel or sand is sometimes used in soilless system to provide plant support and retain some nutrients and water. The retention of nutrients and water can be further improved through the use of sphagnum peat, vermiculite, coir pith and perlite. Soilless culture in bag or pots with a light weight medium is the simplest, most economical and easiest method of soilless culture. The most common media used in soilless culture include coir pith, vermiculate, perlite etc.

Coir pith can be useful in soilless cultivation especially in areas facing different growing constraints such as water shortage, low fertility and poor soil drainage, unsuitable soil reaction, soil salinity, pest and other ecological problems. Besides the use of coir pith in agricultural fields or as water conservant in dry land, coir pith has gained importance as potting medium. Furthermore, its distinct features like water resistance and enhanced aeration enables the usage for various agricultural purposes. Coir pith is an excellent soil conditioner and is being expensively used as a soilless medium for agro-horticultural purposes such as planting lawns, gardens and planting vegetable gardens. Application of coir pith in soil helps in improving the structure and other physical and chemical properties of the soil. Because of its sponge like structure coir pith helps to improve aeration and retain water in root zone. Perlite is an inert, porous and light weight substance often used as a hydroponic substrate. It is the form of expanded volcanic rock and is usually white in colour. It provide good drainage and holds air. As perlite is relatively inexpensive and easy to use, it is a popular option for a growing medium among growers. Perlite should also be mixed with other mediums like peat moss since it does not retain water and will float to the top when plants are watered. Perlite as a growing medium is also easy to reuse and its longer life cycle is a great benefit when considering environmental impact. Vermiculite can also be used in soilless growing systems. These are beneficial in that little or no water or nutrients are wasted. Vermiculite is lighter than soil mediums. This is particularly important when growing indoors and when growing at height such as roof garden, greenhouse and grows rooms. Because of light weight it is very easy to carry, store and manage.

Vegetables are cultivated commonly as summer fallow in India. Irrigation is an essential practice for vegetable cultivation. Irrigation is frequently interrupted due to the scarcity of water during the season. Fertigation and drip irrigation is an effective method that can be resorted to improve the vegetable production. During summer season, the available water has to be used effectively and the soil moisture has to be conserved.

Vegetable production in Indian agriculture has wider scope for increasing the income of the marginal and small farmers. Vegetables have vast potential in gaining foreign exchange through the export. The vegetables growers are looking for new ways to achieve superior quality produce with higher yields. Among the vegetables grown, okra is an economically important crop grown in tropical and sub-tropical parts of the world. It is grown commercially in India, Turkey, Iran, Western Africa, Bangladesh, Japan, Brazil and southern United States. It is quite popular in India because of easy cultivation, dependable yield and adaptability to varying moisture condition. Okra is known by many local names in different part of the world. It is called Bhindi in India. Okra is cultivated for its green non fibrous fruits or pods containing round seeds. The fruits are harvested when immature and eaten as a vegetable. The roots and stem of okra are used for clarification of sugarcane juice. Okra provides an important source of vitamin, calcium, potassium and other minerals. The composition of edible okra is very useful against genito-urinary disorders and chronic dysentery.

Proper irrigation and nutrient management is essential for improving the productivity and quality of crops. Nutrient management involves managing all crop fertility inputs and other production practices to achieve efficient crop growth and water quality protection. Water and nutrients are the main factors of production in irrigated agriculture and are the major inputs in contributing higher productivity. Higher efficiency can be achieved by introducing advanced methods of water and fertilizer application. The method of fertilizer and irrigation application affects the efficiency of these inputs in arid and semi-arid regions. Improvement of the use efficiency of these valued inputs is of utmost importance because these are costly and scare. Under this poor condition the input use efficiency is very low. Micro irrigation systems are the most modern systems of irrigation where the irrigation efficiency is very high and it is very popular in arid and semi-arid conditions of the world. Of late, it is also becoming popular in the arid and semi-arid region of India particularly where canal irrigation systems are not developed. With the advent of this new method of irrigation system, traditional method of fertilization which is still in practiced by the farmers is being slowly replaced by fertigation. In drip irrigation, the wetted soil volume and thus the active root zone is reduced under drippers and this small volume does not allow the addition of all plant nutrients needed by the plants. Rather, fertilizer needed is to be applied frequently and periodically in small amount with the each irrigation to ensure adequate supply of water and nutrient in the root zone. Therefore, as a result of the shift from surface irrigation to drip method of irrigation, fertigation becomes the most common fertilization in the irrigated agriculture. The use of soluble and compatible fertilizers, good quality irrigation water, and application of actual crop and water need are the prerequisite of the successful fertigation.

Fertigation was first introduced in the late 1960's in Israel with the development of drip irrigation. It is the practice of supplying crops with fertilizers via the irrigation water. Fertigation, a modern agro-technique, provides an excellent opportunity to maximize yield and minimize environmental pollution by increasing fertilizer use efficiency. In fertigation timing, amounts and concentration of fertilizers applied are easily controlled. A large range of fertilizers, both solid and liquid, are suitable for fertigation depending on physicochemical properties of the fertilizer solution. Fertigation provides nitrogen, phosphorous and potassium as well as micro nutrients are applied directly to the root zone. The factors that governs the fertigation are soil types, crops, methods of irrigation used, water quality, types of fertilizers available, economic feasibility etc. The important components of a fertigation system include drip irrigation of suitable layout and fertigation equipment.

The impact of fertigation under different conditions on the performance of the growth and yield of Okra need to be assessed under this context.

Therefore, the present study entitled "Nutrient use efficiency of okra in soil and soilless media using fertigation" is taken up with the following objectives:

- To compare the effect of different fertigation treatments on the yield and growth parameters of okra in soil and soilless media inside and outside the poly house.
- To compare fertilizer use efficiency at different levels of fertigation.

CHAPTER II

REVIEW OF LITERATURE

Agricultural intensification can be attained through irrigation and fertilizer application along with protected cultivation. Micro climate inside polyhouse can be maintained at favourable conditions for plant growth and yield. Cultivation of crops under this condition and optimum fertigation levels show some significant effect on performance of crop which is becoming popular among Indian farmers. Climate that can be optimized by different ways is a beneficial impact of structure over open field cultivation.

The performance evaluation of crops at different fertigation levels were studied under different climatic condition for different crops. The productivity of crops is based on effective utilization of water and fertilizer, along with other agricultural inputs. Fertigation provides flexibility of fertilizer application, which enables three specific nutritional requirements of the crop to be met at different stages of its growth. In comparison with the conventional methods, it appears that fertigation gives higher crop yields with substantial saving in fertilizer usage.

A brief collection of literature relevant to the study are reviewed and presented below:

2.1 Drip Irrigation

Singh (2001) conducted studies on the emerging scenario of micro irrigation in India and reported that drip system permits the use of fertilizers, pesticides and other soluble chemicals along with the irrigation water. It has a high potential for use as it is a major component in adoption of precision farming.

James *et al*. (2007) defined micro irrigation as the slow application of water on or below the soil, by surface drip, subsurface drip, and bubbler or micro sprinkler systems. Water is applied as discrete or continuous drops, tiny streams, or miniature spray through emitters or applicators placed along a water delivery line adjacent to the plant row.

Schwankl *et al*. (2007) defined drip irrigation as an irrigation method that transfers the water under a definite pressure, after filtering, through pipe network into the soil surrounding the root system of plants in drops slowly and uniformly. Emitters are to drip the pressured water in the pipeline to the root of the crops evenly and steadily, so as to guarantee the water demand for crop growth. The quality of emitter has an important effect on the reliability, life span of the drip irrigation system and irrigation quality.

Yildrim and Gurol (2010) made accurate evaluation of pressure head distribution along a trickle irrigation lateral which can be operated under low pressure head. Simple mathematical expressions for computing three energy loss components – minor friction losses through the path of an inline emitter, the local pressure due to emitter connections and major friction losses which are quickly implemented in a simple excel spread sheet.

2.1.1 Impact of Fertigation

According to Bester *et al*. (1974), when fertigation was given on grape, it was observed that the crop growth was satisfactory with uniform berry size on bunches of grapes for all varieties with fertigation. Berry size were varying in different bunches, in all the varieties, resulting in prinking of small berries in conventional methods.

Fertigation allows nutrient placement directly into the plant root zone during critical periods of nutrient demand (Mickkelsen, 1989).

Kumar (2003) reported that major advantages of fertigation with drip irrigation are saving of water and labour, better timing, uniform distribution, less damage to crop and soil and ultimately higher yield. This method also offers precise application of water soluble fertilizers and other nutrients to the soil at appropriate times with desired concentration.

In general, greenhouse crops are grown intensively. As the mineral uptake is proportional to the total yield, the physical production levels involve high fertilizer inputs and the annual fertilizer application is 8-10 times greater than for open field vegetable crops (Sonneveld, 1993).

Apart from the high crop demand, the high fertilizer inputs are also believed to be necessary to maintain high osmotic pressure levels in the root environment, in order to prevent lush growth and to enhance product quality (Sonneveld, 1993).

However, organic manure is usually required in large quantity to sustain crop production and likely may not be available in small proportion for the small scale farmers (Nyathi and Campbell, 1995).

Fertilizer management is the most important agro technique which control development, yield and quality of a crop. Drip fertigation, is known to be the hi-tech and efficient way of applying fertilizers through irrigation system (Magen, 1995).

Nache (1996) reported that for efficient and uniform distribution of plant nutrients, the irrigation system must fulfill certain requirements like it must be designed correctly to operate efficiently and should ensure complete solubility of the fertilizers without leaving any residues and should supply nutrient solution at constant rate and pressure from the main flow line.

According to Khan *et al.* (1999), application of 100% of the recommended dose of water soluble fertilizers on potato gave highest tuber yield with maximum net returns compared to conventional method of application of furrow irrigation providing 100% normal fertilizers through fertigation was highly profitable.

Gopal (1999) conducted a study on fertigation of Chrysanthemum under high cost greenhouse revealed that fertigation with 80% recommended level of fertilizers resulted in maximum growth, early flowering and highest extent marketable flowers of good quality as compared to soil application of recommended level of fertilizers. Gowda *et al.* (1999) revealed that application of 80 % of the recommended dose of water soluble fertilizers on grape resulted in maximum number of canes, bunch weight and yield compared to conventional method of soil application of normal fertilizers with basin irrigation.

Srinivas (1999) conducted studies on fertigation in sapota revealed that application of 80% and 100% of the recommended level of water soluble fertilizers through fertigation were at par with each other and gave maximum number of fruits and fruit yield compared to all other treatments including control comprising dose application of recommended of normal fertilizers under rain fed conditions.

Singh *et al*. (2001) conducted field experiment to investigate the water and nutrient efficiency of sprouting broccoli growing on sandy loam soil using fertigation. The treatments include application of recommended fertilizer dose as soil application and irrigation through the drip irrigation as well as three levels of fertigation viz. 100%, 80%, 60% of the recommended fertilizer doses. Flood irrigation with recommended doses was considered as control. Yields obtained indicated substantial saving in the fertilizer applied to the extent of 25 to 30 %.

Veeranna *et al*. (2001) conducted fertigation studies to investigate the effect of broadcast application and fertigation of normal and water soluble fertilizers through furrow and drip irrigation methods on yield and water and fertilizer use efficiency in chilli. It was observed that fertigation with 80 % water soluble fertilizers at was effective in producing 31 % and 24.7 % higher yield over soil application of normal fertilizers at 100 % recommended level in furrow and drip irrigation method. The yield of chilly was increased to 42 %.

Khan (2001) conducted studies on fertigation in Gerbera with six treatments comprising of normal fertilizers and water soluble fertilizers and levels of 60, 80 and 100 % of recommended dose through drip irrigation application of 80 % water soluble fertilizers resulted in getting maximum plant height and plant spread, flower yield and flower diameter and highest percentage of marketable flowers.

Fertigation is the most efficient method of fertilizer application, as it application of the fertilizers directly to the plant roots (Patel and Rajput, 2002).

Sujatha *et al*. (2002) reported that fertigation with soluble fertilizers at 80%of recommended dose gave improved growth and flower production of gerbera under low cost polyhouse. They also reported significantly higher yield of gerbera.

Akande *et al*. (2003) reported that the use of phosphate significantly improved growth and yield of Okra (*Abelmoschus esculentus* L Moench) compared to application of each material separately. Zea mays L reported that maize yields obtained from application of a combination of synthetic fertilizer improved yield over that from manure alone.

Shukla and Naik (2003) stated that Okra plants respond well to fertilizer in terms of vegetative growth. Yet, okra plants do not tolerate over fertilization neither lack of fertilizer retards growth of okra plants. Lack of fertilizer and over fertilizing will give a negative effect on the growth of okra plant. It will further affect the yield produce by the plant. The rapid leaching of inorganic fertilizers into the sea is a serious problem to the environment and the organisms living in the sea, and also the use of inorganic fertilizers is too expensive to be ignored, thus, this study intends to provide an alternative method by determining proper fertilizer rate for optimum growth and yield on okra crop.

Manickasundaram (2005) reported that fertilizers supplied under traditional methods of irrigation are not effectively used by the crops. Through fertigation, water and fertilizers are efficiently used by the plant. Studies conducted in various commercial, horticultural and high value crops, revealed that adoption of this technology improves the yield and quality of crops. It is also highly beneficial to the farming community in reducing the cost of production. Further it helps in sustaining the soil health for better productivity and reducing environmental hazards.

Crop productivity in terms of responses to the fertilizer application can only be sustained if soil fertility levels are maintained to match with crops' requirement and in a proper rate (Jagadeeswaran *et al.*, 2005).

Akanbi *et al.* (2005) reported that the combined application of 4 Mt·ha-1 of maize straw compost and N mineral fertilizer at 30 kg·ha-1 improved plant growth and gave higher tomato (Lycopersicum esculentum). Okra requires nutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sodium (Na) and Sulphur (S) for fertility maintenance and crop production. These nutrients are specific in function and must be supplied to plants at the right quantity. Lack of sufficient amounts of these nutrients result in poor performance of the crop with growth been affected resulting to low yield.

When fertilizer is applied through drip irrigation, it was observed that yield has been increased and about 30% of the fertilizer could be saved (Sivanappan & Ranghaswami, 2005).

Kadam *et al.* (2005) conducted a field experiment to find out the effect of different water soluble fertilizers with different doses on the yield of cauliflower. Highest yields were recorded for 80 % recommended dose with 20 % savings in fertilizers when compared to conventional method.

Sharma (2005) conducted field experiment to study the effect of fertigation through water soluble fertilizers on growth, yield and quality of papaya. Plant height, stem grith and number of functional leaves were higher under 100 % fertigation level.

Among 18 essential plant nutrients, nitrogen (N), phosphorus (P) and potassium (K) are the most important nutrient and referred to as primary nutrients. The reason is because they are required by the plant in relatively large amounts compared to other nutrients. Aside from that, they are the nutrients that are most likely to be found to be limiting plant growth and development in soil systems if not available in adequate amount. In the commercial fertilizer, the ratio stated on the packaging bag refers to amount of an element is in the material (the guaranteed minimum quantity present) based on percentage by weight. All fertilizers are labeled with three numbers which give the percentage by weight of total nitrogen (N), citrate-soluble phosphorus (expressed as P2O5) and water-soluble potassium (expressed as K2O), respectively (Makinde and Ayoola, 2008).

Since organic manure is a slow releasing nutrient, the application of inorganic fertilizers at required rates gives a positive effect on crop yields and enhances yield improvement in agriculture food production (Akande *et al.*, 2010).

David *et al*. (2011) conducted a study to compare the effects of nitrogen fertigation and granular fertilizer application on growth and availability of soil nitrogen during establishment of high bush blueberry (*vaccinium corymbosum*). Treatments included four methods of nitrogen application (weekly fertigation, split fertigation, and two non-fertigated controls) and four levels of nitrogen fertilizer (0, 50,100, and 150 kg/ha). Fertigation treatments were irrigated by drip and injected with a liquid urea solution. Non- fertigated controls were fertilized with granular ammonium sulfate also applied as a triple-split, and irrigated by drip or micro sprinklers. Results indicate that fertigation may be less efficient at lower nitrogen rates than granular fertilizer application. But is also safer and promotes more growth when a high amount of nitrogen fertilizer is applied.

It is suggested that the use of chemical fertilizer has long-term negative effects to the soil properties and fertility (Akpan-Idiok *et al.,* 2012).

Jisha Chand (2014) conducted an experiment in naturally ventilated polyhouse with four fertigation levels viz., 110, 100, 90 and 80 per cent recommended dose to determine suitable fertigation dose for salad cucumber under naturally ventilated polyhouse cultivation. Fertigation levels significantly affected ($P<0.05$) cucumber yield. Plants that received 100 per cent recommended dose of fertigation (175:125:300 kg NPK ha-1) showed higher nutrient use efficiency of nitrogen, phosphorous and potassium (508.93, 712.50, 296.88 kg ha-1 respectively) and recorded significantly higher yield (89.06 t ha-1) with highest water use efficiency (6167.78 kg ha-1 cm-1). The economic analysis of cucumber production revealed that 100 per cent recommended dose of fertigation has resulted into maximum Benefit Cost (BC) ratio of 3.42. Both increased and decreased fertigation levels showed almost equal yield which is significantly less than 100 per cent recommended dose.

2.1.1.1 Fertilizers for Fertigation

Studies on fertigation in coffee conducted by Raghuramalu (1996) at the Central Coffee Research Station, Balehonur revealed that application of 120:90:120 kg NPK/ha through drip irrigation resulted in production of maximum number of bearing nodes, flower buds/bunch, fruit set, number of fruits per branch and yield of clean coffee, compared to soil application of 160:120:160 kg NPK/ha in four split doses.

Application of 150g of nitrogen and potassium through fertigation given by Srinivas (1999) into banana was found to be significantly superior and on part with 200g nitrogen and potassium as it resulted in getting higher plant height and bunch yield as compared to all other treatments. Application of soluble fertilizers through the drip irrigation could bring about substantial savings (20-25%) in fertilizer use.

Fertilizer studies conducted by Asokraj (2002) on sugarcane with soluble fertilizers shows that the highest yield of sugarcane was drip fertigation with water soluble fertilizer as 75% NPK recommended dose when compared to control surface irrigation and soil application of normal fertilizers at 100% NPK dose.

According to Asokraj (2002) when drip fertigation was given in banana (Nendran) with water soluble fertilizers at 125% NPK has registered the highest fruit yield of 35.09 t/ha, when compared to control 24.57 t/ha.

Kumar (2003) observed that when fertigation in banana (Robusta) was given with conventional fertilizers like urea and potash with 25 LPD with 100:30:150g NPK per plant has registered increased fruit yield of 61.05 % as compared to basin irrigation and soil application of conventional fertilizers (200:30:200g NPK per plant)

2.1.1.2 Fertigation Equipment

Ashwani (2001) reported that adoption of fertigation shows favourable results in terms of fertilizer use efficiency and quality of produce. Choice of water soluble fertilizers should be based on its properties in avoiding corrosion of pipes, softening of plastic pipe network and safety in field use.

Boman *et al*. (2004) reported that the flow rate of chemical from the pump however depends on the pressure in the irrigation main line. The higher the pressure differences in the main line, higher the flow rate in the pump.

In the dosmatic fertilizer injector, water in the main line, on its way through activates the dosmatic unit which takes up the required quantity of concentrate directly from the container. Dosmatic fertilizer injector mixes the concentrate with water inside it and water pressure forces the solution downstream to the main line. (Anonymous, 2008)

Fares *et al.* (2009) conducted studies on the injection rates and components of a fertigation system. Major advantages are accurate chemical application and easy adaptation for automation of injection system.

2.2 Growing Media

Dayananda *et al.* (2001) conducted an experiment to find out the desirable growing media and hydroponic system for cultivation of lettuce under controlled environment. Results revealed that the aggregate system had better mean values for all measured growth parameters while coir dust and paddy husk proved to be the best growing media for better plant growth and yield.

Hochmuth and Hochmuth (2003) reported that the cucumber and tomato are grown successfully in perlite media. Although the paper focuses on perlite media in lay flat-bags, most of the principles also pertain to other soilless media, such as peat- mix bags and rock wools slabs.

Bilderback *et al*. (2005) stated that Mineral soil or sand has been used for growing vegetables in greenhouses. Growing media have three main functions: 1) provide aeration and water, 2) allow for maximum root growth and 3) physically support the plant. Growing media should have large particles with adequate pore spaces between the particles.

Coir pith is a byproduct of the coir industry, producing more than 7.5 million tonnes annually in India. It can be used as fuel in loose form or in briquettes. This study investigates different physical properties of coir pith with respect to its moisture content (10.1 to 60.2 % w.b.) and particle size (0.098 to 0.925 mm). Porosity and particle density varied from 0.623 to 0.862 and from 0.939 to 0.605 g/cc respectively. Bulk density and static coefficient of friction against mild steel were in the range of 0.097 to 0.341 g/cc and 0.5043 to 0.6322 respectively. Models were developed for the above properties. (Neethi *et al.,* 2006)

Rajarathnam *et al.* (2007) carried out experiments with coir pith for its potential in serving as a growth substrate for the production of species of oyster mushroom. Amendment of coir pith with rice straw and horse gram plant residue tented to greatly modify the physical characteristics of inoculated mushroom. Changes in cellulose, hemicellulose and lignin condense of coir pith amended with rice straw were studied. Cellulose, hemicellulose and protease enzyme activities in the amended coir pith substrate showed continuous increase from inoculation till the end of fructification, whereas, laccase activity decreased during fructification, in consonance with decreased lignin degradation during fructification.

Worldwide, a high percentage of the hydroponic industry uses inorganic growing media such as rock wool, sand, perlite, vermiculite, pumice, clays, expanded polystyrene, urea formaldehydes and others (Sawan *et al*., 1999; Bohme *et al.,* 2001; San Bautista *et al.,* 2005;Bohme *et al.,* 2008), while only about 12% uses organic growing media such as peat, bark, wood residues (leaf mould, sawdust, barks), coir, bagasse, rice hulls and others.

There is no growing medium that can be labeled as the best since each particular medium has both advantage sand disadvantages. Several factors determine the type of growing medium appropriate for specific growing conditions. Although crop performance (yield and quality) is usually the primary factor in developing a growing medium, other traits such as cost, re-use or recycling potentials are critical for a sustainable production system. Various materials are used for substrate preparation such as peat, pine bark, sawdust, coco-fiber and cacao shell (Nurzynski, 2006; Grunert *et al.,* 2008).

The physical and chemical characteristics of the medium, together with the growing techniques (e.g., fertigation) employed, will determine the yield and quality of the vegetables that are produced (Grunert *et al.,* 2008).

The vast amount of solid waste (substrate and plant material) produced each year is one of the biggest problems associated with greenhouse horticulture in some European countries. The non-biodegradability of these mainly inorganic substrates (e.g., clay, perlite and mineral wool) causes environmental concern and has prompted the search for alternative growing media (Grunert *et al.,* 2008; Vaughn *et al.,* 2011).

Growing media are materials, other than soils in situ, in which plants are grown. These can include organic materials such as peat, compost, tree bark, coconut (*Cocosnucifera* L.) coir, poultry feathers, or inorganic materials such as clay, perlite, vermiculite, and mineral wool or mixes such as peat and perlite; coir and clay, peat and compost (Grunert *et al.,* 2008; Vaughn *et al.,* 2011)

Schmilewski (2009) revealed that appropriate particle size selection or combination is critical for a light and fluffy (well-aerated) medium that promotes fast seed germination, strong root growth and adequate water drainage. Various ingredients have been used to produce growing media for vegetable production. Throughout the world, the raw materials used vary based on their local availability.

Coir pith is a mass of heterogeneous particles having broadened physical characteristics. Bulk density was found to be high in small particles (150 μm) and it decreased as particle size increased (2000 μm). In smaller particles, high bulk density of coir pith was found (0.11g/cc) which are low compared to soil. Total porosity and aeration porosity of the coir pith mass formed of specific particle size showed direct relationship with particle size whereas water holding porosity had a negative relation. High bulk density showed by big particle had a low total porosity which would cause reduction in growth and distribution of roots of the plants grown on it. Water absorptive and particle size of coir pith showed a negative linear correlation. Smaller particle of coir pith which was compactly arranged and absorbed more water due to infinite micro pores than the coarser particles which contained larger but limited amount of macro pores. Both the surface area as well as specific surface area of coir pith particles decreased with the increase in the average size of the coir pith. As water retention in a medium depends mainly on the number and size of the pores and specific surface area of the medium, it was observed to be higher in the smaller sized particles. (Maragatham. 2010)

Nair (2011) stated that raw materials can be inorganic or organic, but growing media are often formulated from a blend of different raw materials in order to achieve the correct balance of air and water holding capacity for the plants to be grown as well as for the long-term stability of the medium.

Most vegetables are established from transplants grown in trays using growing media. Therefore, many studies have focused on vegetable seed germination and transplant establishment in various growing media (Nair *et al.*, 2011). However, the effects of growing medium on vegetable production (especially post-transplant) are not well known. The importance of growing medium choice, relative to other production factors, needs to be evaluated for hydroponic vegetable production. Several studies have investigated the effect of growing media on the yield of vegetables. However, only a few studies investigated the effects of the growing medium on the quality parameters of the crop.

Albaho *et al*.,(2013) investigated the suitability of some locally available materials in Kuwait for combinations of media were used as substrates viz. M1-35% peat moss/40% perlite/25% vermicompost, M2-25% peat moss/25%

perlite/25% vermicompost/25% coco peat,M3-100% coco peat and M4-50% perlite/50% peatmoss as control. Experiments were carried out in a cooled greenhouse. Experiments with cucumber cultivar 'Banan' revealed that the growing media M1 anaM2 are substrates for using the grow bag technique.

2.3 Polyhouse Cultivation

Backer (1989) reported that sweet pepper grown with alternative high and low humidity during day and night (vapour pressure deficit range 0.30 – 0.75 Kpa) under greenhouse gave more fruit set (16.7%) and more number of fruits (10.0/plant) as compared to continuous high (0.75 Kpa) or low humidity. There was no significant effect on fruit shape and maturity.

Ohigbu and Harris (1989) conducted experiment under polythene greenhouse condition, maximum yield of arrive tomato fruits (8.6 kg/m2) and total yield (9.4 Kg/m2) was obtained as compared to open conditions (6.6 Kg/m2 and 7.35 Kg/m2, respectively).

Mears (1990) had discussed the possibilities of greenhouse technology in India. The sub-continent which lies between 40° and 8° north of equator, with regions of extreme temperature conditions where open field cultivation is not feasible; greenhouse technology makes a significant contribution. The spectra of agro-climatic zones in India and the need for modern research in controlled environment, commercial use of greenhouses in plant production, plant culture etc. necessitates greenhouse systems. The evolution of environmental control systems along with greenhouse technology suitable for providing the plant environments under existing external agro-climatic condition is necessary in the area where the plants are to be produced.

More *et al*. (1990) reported that cucumber variety 'Poinset' gave a yield of 1.70 Kg/plant under polyhouse as compared to fewer yields in open conditions, during winter months under North Indian conditions due to low temperatures.

Nimje *et al*. (1993) conducted studies on U-V stabilized plastic film covered, pipe framed greenhouses (20mx5m wide), the day temperature was higher and night temperature was lower than that of outside. Solar radiation entering the greenhouse was 30-40% lowers than that reaching the soil surface outside. A winter crop of tomatoes performed better in the field than greenhouse. However, okra and capsicum gave significantly higher yields (2.5-3 folds) in the greenhouse than outside, including in winter. The yield of a winter crop was 13% higher in the greenhouse than outside. Biomass production inside the greenhouse was at least 6 fold higher than outside.

Gomez and Hernandez (1994) conducted a comparative study among capsicum cultivars. They were assessed for flowering days, beginning of cropping and full cropping, yield in each of four harvests and total yield, percentage of fruits in four different weigh groups. Cultivars Vidi and Elisa gave the higher total yields. (30,030, and 30,468 Kg/ha, respectively), almost twice as high as for cultivar Fiuco (16,268 Kg/ha) in the first harvest; in this harvest Elisa and Fiuco yielded 6738 and 3417 Kg/ha, respectively.

Rai *et al.* (1995) studied shelf life of capsicum grown under protected and open conditions. Six hybrids along with one open pollinated variety were grown in polyhouse and open conditions for studying their shelf life. The shelf life of capsicum fruits harvested from polyhouse was more than that of fruits harvested from open conditions. The maximum shelf life of 16 days was recorded in Arun F1 growing in polyhouse, while it was only ten days in fruits produced in open conditions.

Vonzabeltitz (1999) reported that the main advantage with greenhouse farming is that the production can be got throughout the year, which is not possible in the open field farming due to heavy rainfall and wind, especially in tropical regions.

Morphological development like plant height, number of branches per tomato plant, leaf area expansion rate and leaf area index was positively favoured due to the warmer climate inside the polyhouse in spite of lower amount of PAR. (Pandey *et al.,* 2004)

Montero and Anton (2003) reported that the lower amount of incident PAR under poly house as compared to the open field was due to the greater inference of the roof of poly house against the incoming solar radiation. Although poly house permits easy entrance of short wave radiation, it traps the outgoing long wave radiation. As a result the air temperature inside the poly house gradually increases due to the greenhouse effect. The warm air inside the poly house induces soil warming. Therefore, soil temperature was also higher under poly house than open field.

Anac (2004) revealed that protected cultivation has a special importance in the agriculture of Turkey and occupies 42,000 ha, which accounts 50% of the total land as glass and plastic greenhouses. From that 95% of the vegetables, 4% ornamentals and in the remaining seedlings and fruits are grown. Fertigation is the main fertilization system in modern commercial greenhouses. Excess fertilizer use is a very widespread practice, in especially conventional greenhouses.

Crop water requirement of drip irrigated tomatoes grown in greenhouse in tropical environment has been investigated in the past. Greenhouse farming system performed better than open farming systems in terms of crop yield, irrigation water productivity and fruit quality (Harmanto *et al*., 2004)

Mahajan *et al*. (2006) reported a two year study conducted during 2002-2004 at Department of Soil and Water Engineering, Punjab Agricultural University, Ludhiana to investigate the effect of irrigation and fertigation on Greenhouse tomato. It was found that Drip irrigation at 0.5 x Epan along with fertigation of 100% recommended nitrogen resulted an increase in fruit yield by 59.5% over control (recommended practices) inside the Greenhouse and by 116.2% over control (recommended practices) outside the Greenhouse, respectively. The drip irrigation at 0.5xEpan irrespective of fertigation treatments gave a saving of 48.1% of irrigation water and resulted in 51.7% higher fruit yield as compared to recommended practices inside the Greenhouse. Total root length was more in drip irrigated crop as compared to surface irrigated crop.

Santos *et al.* (2009) compared the effects of the protected cultivation and open field on growth of *Lactuca sativa* pants through morphological parameters. The morphological parameters evaluated were fresh and dry leaf matter, fresh and dry stem matter, leaf number, leaf area and absolute growth rate. The leaf fresh matter suffers significant effect, which for the treatment under protected cultivation was higher that the treatment carried out with plants in open field in all evaluated points. The plant dry matter production on 28th day after transplanting increased by 56.56%, when compared with open field condition. The leaf number shown significant difference on the 14th and 21st day after transplanting, in which the treatment under protected cultivation resulted in an increase of 64.2 % on 14th day after transplanting, when compared with open field condition.

Parvej *et al.* (2010) conducted an experiment in a covered polyhouse along with open field planting to compare the phonological development and production potential of two tomato varieties viz., BARI Tomato-3 and Ratan under poly house and open field conditions. Photosynthetically active radiation inside the poly house was reduced by about 40% compared to the outside (i.e., open field) while air and soil temperatures always remained higher. The above microclimatic variability inside poly house affected the growth and development of tomato plants. Plants in polyhouse had higher number of flower clusters/plant, flowers/cluster, flowers/plant, fruit clusters/plant, fruits/cluster, fruits/plant, fruit length, fruit diameter, individual fruit weight, fruit weight/plant and fruit yield over open field condition. Greenhouse tomato fruits were found to be superior to fruits of open field crop in view of fruit size, TSS content, ascorbic acid content and pH. Further, drip irrigation in greenhouse crop caused significant improvement in all the quality characteristics.

CHAPTER III

MATERIALS AND METHODS

Fertigation greatly influences the yield of a crop. The yield of crops varies with different levels of fertigation and also depends upon factors such as the media in which they grown (soil or soilless media) and the crop environment. In the present study an attempt was made to compare the performance of crop okra under three fertigation levels in soil and soilless media in protected and open field conditions. Materials used and methodology adopted for the study is briefly discussed in this chapter.

3.1 STUDY AREA

The study was conducted in a naturally ventilated polyhouse and open field in the research plot of the Department of Irrigation and Drainage Engineering, KCAET, Tavanur, Kerala. The study was conducted during 16th October 2017 to 1st January 2018 and the crop duration was three months. The polyhouse was oriented east–west with an overall area of 213 m^2 (26 m length and 8 m width). The open field was taken in the premises of the polyhouse.

Plate 3.1 Naturally Ventilated Polyhouse

3.2 FIELD EXPERIMENT

3.2.1 Climate

Agro–climatically, the area falls within the boundary of northern zone and central zone of Kerala. South-west monsoon contributes most part of the rainfall to this region. The average annual rainfall varies from 2500 mm to 2900 mm. The average maximum temperature of the study area is 31°C and the average minimum temperature is 26°C.

3.2.2 Treatment details

The experiment was laid out with twelve treatments, combination consisting of three fertigation levels and two growing media inside and outside the polyhouse in completely randomized design.

Fertigation levels

1. F_1 - 80 % of the fertilizer recommendation
2. F_2 - 100 % of the fertilizer recommendation
3. F_3 - 120 % of the fertilizer recommendation

Growing media

1. S_1 - Soil media inside the polyhouse
2. S_2 - Soil outside the polyhouse
3. S_3 - Soilless media inside the polyhouse
4. S_4 - Soilless media outside the polyhouse

Table 3.1 Treatment details

Sl.No	Treatments	Name	Description
1.	T_1	F_1S_1	80% of fertilizer recommendation and soil inside the polyhouse
2.	T_2	F_2S_1	100% of fertilizer recommendation and soil inside the polyhouse
3.	T_3	F_3S_1	120% of fertilizer recommendation and soil inside the polyhouse
4.	T_4	F_1S_2	80% of fertilizer recommendation and soil outside the polyhouse
5.	T_5	F_2S_2	100% of fertilizer recommendation and soil outside the polyhouse
6.	T_6	F_3S_2	120% of fertilizer recommendation and soil outside the polyhouse

7.	T_7	F_1S_3	80% of fertilizer recommendation and soilless media inside the polyhouse
8.	T_8	F_2S_3	100% of fertilizer recommendation and soilless media inside the polyhouse
9.	T_9	F_3S_3	120% of fertilizer recommendation and soilless media inside the polyhouse
10.	T_{10}	F_1S_4	80% of fertilizer recommendation and soilless media outside the polyhouse
11.	T_{11}	F_2S_4	100% of fertilizer recommendation and soilless media outside the polyhouse
12.	T_{12}	F_3S_4	120% of fertilizer recommendation and soilless media outside the polyhouse

Experimental Design

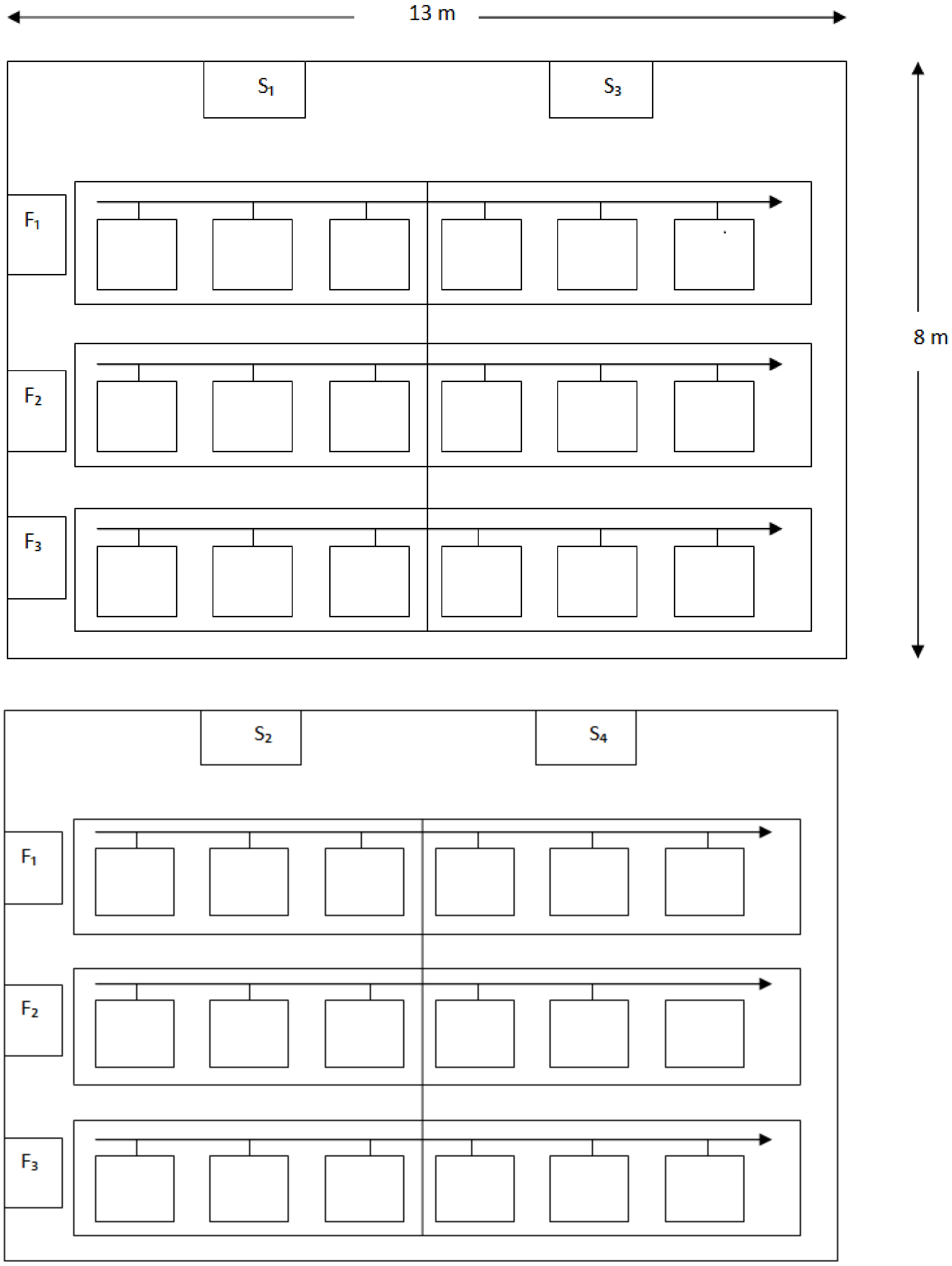

Figure 3.1 Layout of the experiment

Thirty six grow bags were used inside the polyhouse and open field respectively. Grow bags were made of UV stabilized polyethylene. Drainage holes were provided on both sides of the grow bags, towards the bottom to allow drainage. Twelve grow bags were placed on each bed. The experiment consist of three fertigation levels, 80% of recommended fertigation was applied to first row. 100% of recommended fertigation was applied to second row and 120% of recommended fertigation was applied to the third row. Each bed contain twelve grow bags of were filled with soil and six with soilless media.

3.3 CULTURAL OPERATIONS

3.3.1 Field preparation

Land preparation was done inside the naturally ventilated polyhouse and open field. Polyhouse was divided into two parts and we are considering only half portion for our purpose. Four raised beds of 10 m length, 1.0 m width and 0.25 m height were made; only three beds were used for cultivating Okra. The beds of the same dimensions were made in the open field also.

3.3.2 Crop details

Okra variety *Varsha Upahar* was chosen for this study. Sowing was done on 16th October 2017. A spacing of 45×60 cm recommended for okra in the package of practice recommendation: crops (KAU 2011) was adopted.

3.3.3 Growing media

3.3.3.1 Perlite

Perlite is an inert, porous, and lightweight substance often used as a hydroponic substrate. Perlite as a growing medium is most recognizable as little white rocks. It is a type of volcanic glass that, when heated to a certain temperature, expands to several times its size. As perlite is relatively inexpensive and easy to use, it is a popular option for a growing medium among growers. It can be used on its own or in a mixture with another growing medium. Perlite as a grow medium is also easy to reuse therefore its longer life cycle is a great benefit when considering environmental impact.

It offers both excellent water retention and drainage capabilities – both important in hydroponic gardening. Additionally, perlite also provides proper aeration which is necessary for healthy root growth in plants. It is an inert and sterile medium which means it is safe to use without the fear of tracking in pests, which is always risk with the soil. Perlite has a neutral pH level but will take on the acidity or alkalinity of the nutrient solution it is placed in. In terms of plant health, perlite as a growing medium strengthens the root growth and also acts as a terrific insulator to protect plants from temperature changes.

Plate 3.2 Perlite

3.3.3.2 Vermiculite

Vermiculite is the name of a group of hydrated laminar minerals (aluminium-iron magnesium silicates) which look like mica. Vermiculite is generally neutral 7.0 but is dependent upon the source from around the globe and its reaction is alkaline. It is very lightweight and mixes easily with other mediums.

It increases water and nutrient retention and aerates the soil, resulting in healthier, more robust plants. Perlite may also be found in plotting soils, but vermiculite is far superior for water retention. It will accelerate the growth and promotes anchorage for tender young root systems. It will also enable the plant to more easily absorb the ammonium, potassium, calcium and magnesium necessary for vigorous growth.

Plate 3.3 Vermiculite

3.3.3.3 Coir pith

Coir pith or coir dust, a highly lignocellulosic material, which is produced in enormous quantities as a by-product of coir fibre extraction industries. High content of lignin in coir pith causes very slowly decomposition. Coir pith takes decades to decompose there by posing environmental hazard and disposal problem. Coir waste after degradation can be effectively used is recommended for use at the beginning of the growing season, because phosphorus availability is crucial for the establishment of root system at this stage.

As manure for increasing yield of crops, coir pith has some advantages such as; it is a 100% renewable source and light in weight. It is completely environment friendly and has very good water holding capacity. It is highly suitable for better root system. It is easy to handle and uniform in composition. Additional nutrients and microorganisms can be incorporated into the medium so as to enhance the plant growth. It is free from harmful microorganism including pathogen. It has excellent drainage and air porosity. It is long lasting and cost effective. It has ideal pH and high cation exchange capacity and low EC.

Coir pith obtained from mechanical processing of unretted husk is richer in nutrients. The unique property of this waste material is the high water holding capacity. Apart from this, it is found to contain some amount of major secondary and micro nutrients. The higher potassium content of the pith indicates the

Plate 3.4 Coir pith before preparation

Plate 3.5 Coir pith after preparation

3.3.4 Preparation of growing media

Coir pith, vermiculate and perlite are mixed at the ratio of 3:1:1 (by volume) for the preparation of soilless media. Soil is mixed with dried cow dung at the ratio of 3:1 (by volume). 72 number of grow bags are used for the cultivation, out of this 36 bags are filled with soil and remaining with soilless media.

Plate 3.6 Mixing of Growing Media

3.4 IRRIGATION SYSTEM

The plants were irrigated daily through drip irrigation system. Water source is a filter point well from which water was pumped to an overhead tank and conveyed through the main line of 63 mm diameter PVC pipes. PVC pipes of 50 mm diameter were used as sub mains and low density polyethylene laterals of 12 mm diameter were connected to the sub mains. End caps were provided at the end of laterals. Cutoff valves were provided at starting point of each lateral for controlling irrigation. One lateral was provided for one bed inside and outside the polyhouse. Inline drippers of 4 lph were fixed on the laterals at a spacing of 45 cm.

3.5 FERTIGATION EQUIPMENT

3.5.1 Dosmatic fertigation unit

Dosmatic fertigation unit was used for the study. These are piston or diaphragm pumps which are driven by the water pressure of the irrigation system. The injection rate is proportional to the flow rate of water in the system. A high degree of control of the fertigation injection rate is possible. Dosmatic fertigation unit was a self-priming unit and operated on hydraulic pressure. Operating pressure for this fertigation unit is 0.3–5 Kgf/cm^2. The experimental setup for dosmatic fertigation unit is shown in Plate 3.6.

Dosmatic fertigation unit was connected as a bypass assembly to the main line. A suction pipe with a screen filter was provided in the centre of the fertigation unit and suction pipe with its filter was dipped into the container having the solution. The suction was created by the piston arrangement maintaining a pressure difference.

The required quantity of fertilizers was taken in the container and mixed thoroughly with water proportionately. The water pressure forces the solution downstream to the main line. The water in the mainline on its way through, due to its pressure activates the dosmatic unit which in turn takes up the required quantity of solution directly from the container.

Plate 3.7 Dosmatic Pump

3.5.2 Fertilizers

Fertilizers used for the study were Rajphos (0:50:0), Urea (46:0:0), 19:19:19, Potassium Nitrate or Boon-45 (13:0:45) and Mono Ammonium Phosphate (12:61:0). Rajphos contains 50% phosphorus was applied as basal dose. Nitrogen fertilizers like Urea are most commonly available and readily soluble in water. Urea is white crystalline solid containing 46% nitrogen. Urea has the highest nitrogen content of all solid nitrogenous fertilizer in common use. 19:19:19 is water soluble fertilizer contributing nitrogen 19%, phosphorus 19% and potassium 19%. It contains balanced nutrient NPK applications to improves vegetative and reproductive activities in the plant system, in increasing biomass production and improves bearing of flowers and fruits, and improves quality. Potassium Nitrate provides excellent green-up in low temperature conditions. It is also water soluble fertilizer contributing nitrogen 13% and potassium 45%. It increases yields and improves quality in vegetables, field crops, fruit and nut trees. It is virtually free from chloride, sodium and other harmful elements for plants. Mono Ammonium Phosphate is fully water soluble fertilizer, a highly efficient source of phosphorus and nitrogen for plants.

3.5.3 Fertigation scheduling

Macro nutrients were applied as water soluble fertilizers through fertigation system using dosmatic pump both in poly house and open field. Duration of the crop is 90 days, so the fertigation was scheduled as 17 splits with the frequency of once in three days from 25th day after planting to 76th day after planting. Neem cake was applied in three doses during crop period in poly house and open field at a rate of 2 g/plant.

Table 3.2 Fertilizer recommendation of Okra

Sl. No	Days of fertigation	Fertilizer to be applied(water soluble)	Quantity	
			Kg/ha	g/plant
		Basal dose P	18.75	5.10
1	3rd day to 18th day after planting(6 split doses)	19:19:19	3.30	0.90
		13:0:45	3.30	0.90
		Urea	5.20	1.40
		12:61:0	0.00	0.00
2	21st day to 54th day after planting(12 split doses)	19:19:19	1.70	0.54
		13:0:45	9.30	2.50
		Urea	0.36	0.13
		12:61:0	0.51	0.20
3	57th to 90th day after planting(12 split doses)	19:19:19	1.70	0.54
		13:0:45	9.30	2.50
		Urea	2.10	0.67
		12:61:0	0.51	0.20

Source: Harithagriha krishi sahay, State Horticultural Mission, Kerala.

3.5.4 Pest and disease management

Okra yield is usually reduced due to sucking insects and pests. Common problem for polyhouse okra are aphids mealy bugs, scale, thrips, and white flies. Tatamida was sprayed twice during the crop period at a rate of 2ml/ 3 liters of water on the leaves for controlling sucking insects.

3.5.5 Nutrient use efficiency

The fruit yield obtained for each treatment was divided by quantity of nutrients applied for the respective treatments. Yield and quantity of nutrients were expressed in Kg/ha.

The nutrient use efficiency was computed by the following formula:

$$NUE = \frac{Yield\ (Kg\ per\ ha)}{Total\ quantity\ of\ nutrient\ applied\ (Kg\ per\ ha)}$$

3.5.5.1 Nitrogen fertilizer use efficiency

$$NFUE = \frac{Yield\ (Kg\ per\ ha)}{Total\ quantity\ of\ nitrogen\ applied\ (Kg\ per\ ha)}$$

3.5.5.2 Phosphorus fertilizer use efficiency

$$PFUE = \frac{Yield\ (Kg\ per\ ha)}{Total\ quantity\ of\ phosphorus\ applied\ (Kg\ per\ ha)}$$

3.5.5.3 Potassium fertilizer use efficiency

$$KFUE = \frac{Yield\ (Kg\ per\ ha)}{Total\ quantity\ of\ potassium\ applied\ (Kg\ per\ ha)}$$

3.6 COLLECTION OF EXPERIMENTAL DATA

3.6.1 Biometric parameters

For analysing the growth pattern of crop, three plants were selected randomly from each treatment and were tagged to record the various observations at 10 days interval from 30th day after planting. The parameters and procedures followed are given as follows; height of the plant, number of leaves per plant and yield.

3.6.1.1 Height of the plant

Average height of the randomly selected plants grown under each treatment was taken. The measurement was taken from the surface of the growing medium to the shoot tip for the selected plants at 30, 40, 50 and 60 day after planting.

3.6.1.2 Number of branches

Number of branches per plant was noted at 10 days interval in selected plants from 30 days after planting.

3.6.1.3 Number of leaves

Number of leaves per plant was counted in randomly selected 3 plants at 30, 40, 50 and 60 day after planting.

3.6.2 Weather parameters

Light intensity, temperature and relative humidity inside polyhouse and open field was measured in the morning, afternoon, evenings in the months in the months of October, November and December.

3.6.2.1 Light intensity

Light intensity inside polyhouse and that in open field was measured by using equinox digital light meter in the morning, evening daily in the months of October, November, December and expressed as mean monthly data.

3.6.2.2 Temperature

The maximum and minimum air temperature inside polyhouse and that in open field was measured by using equinox digital temperature and humidity meter in the morning, evening daily in the months of October, November, December and expressed as mean monthly data.

3.6.2.3 Relative humidity

Relative humidity inside polyhouse and that in open field was measured by using equinox digital temperature and humidity meter in the morning, evening daily in the months of October, November, December and expressed as mean monthly data.

3.6.3 Yield

Harvesting of the crop was done treatment wise after attaining maturity. After the first harvest, other harvests were done at an interval of two days. The first yield was taken 40th day after planting. Total of the 11 harvests gave the total yield

36.4. Statistical analysis

Statistical analysis was done by three way ANOVA using SPSS software.

CHAPTER IV

RESULTS AND DISCUSSION

Results observed from the field study on the nutrient use efficiency of okra in soil and soilless media under different levels of fertigation in a naturally ventilated polyhouse and open field were analyzed, and the details are discussed under various headings in this chapter.

4.1 Biometric parameters

The various crop growth parameters such as flower initiation, plant height, number of leaves, number of branches etc. were measured and monitored during the crop growth period.

4.1.1 Flower initiation

First flowering was observed 35 days after planting in treatment T_4. The early flowering in T_4 indicates level of fertigation effect on plants. Majority of the plants started flowering 45 days after planting.

4.1.2 Plant Height

The data on plant height at 30, 40, 50 and 60 days after planting was influenced by different levels of fertigation and growing media in polyhouse and open field are presented in Table 4.1.

At 30 DAP, among the treatments plant height was maximum for T_1 and minimum for T_{10}. The maximum plant height was observed in T_3 and minimum in T_{12} at 40 DAP. At 50 DAP, the plant height was maximum for T_3 and minimum for T_{11}. At 60 DAP, the plant height was maximum for T_1 and minimum for T_{10} andT_{11}. At all stages of growth, plant height was significantly higher in polyhouse as compared to open field.

The results of higher growth rate in the polyhouse structure were reported by Maurer (1981) in bell pepper and More *et al*. (1990) in cucumber. Plant height in soil was significantly superior over soilless media.

Table 4.1 Average height of plants in each treatment at different stages of crop growth in okra

Treatments	**Plant Height (cm)**			
	30 DAP	40 DAP	50 DAP	60 DAP
T_1	32.00	64.90	128.67	178.00
T_2	25.76	60.33	122.33	174.67
T_3	29.17	66.33	133.67	174.00
T_4	20.00	62.66	104.17	117.00
T_5	26.00	56.00	78.67	109.17
T_6	22.00	57.00	94.33	107.50
T_7	19.50	34.50	54.49	99.49
T_8	24.00	43.50	82.50	132.50
T_9	23.50	35.50	57.50	95.00
T_{10}	12.45	29.00	48.50	56.00
T_{11}	12.50	25.00	44.00	56.00
T_{12}	13.50	24.00	48.00	63.75

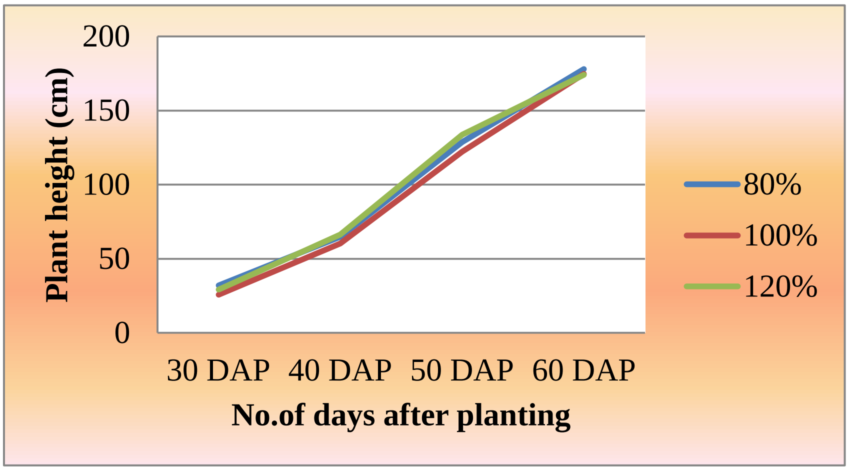

Figure 4.1 Influence of different levels of fertigation on plant height at different stages of crop growth in soil inside polyhouse.

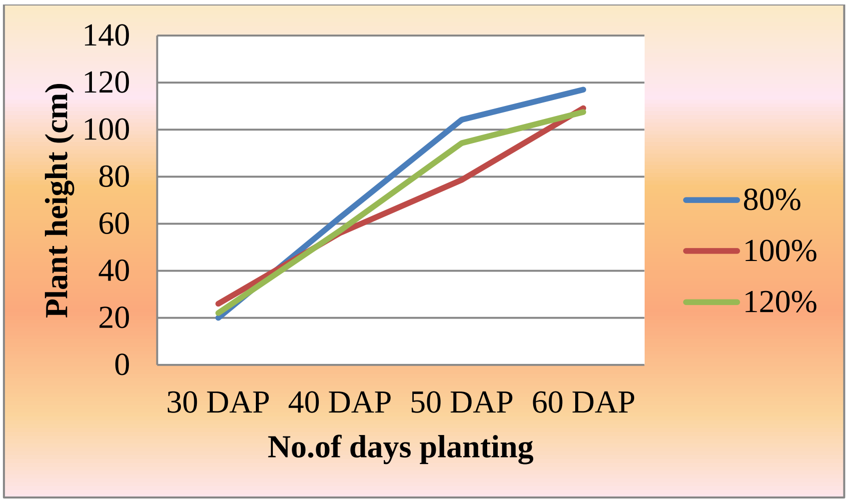

Figure 4.2 Influence of different levels of fertigation on plant height at different stages of crop growth in soil in open field

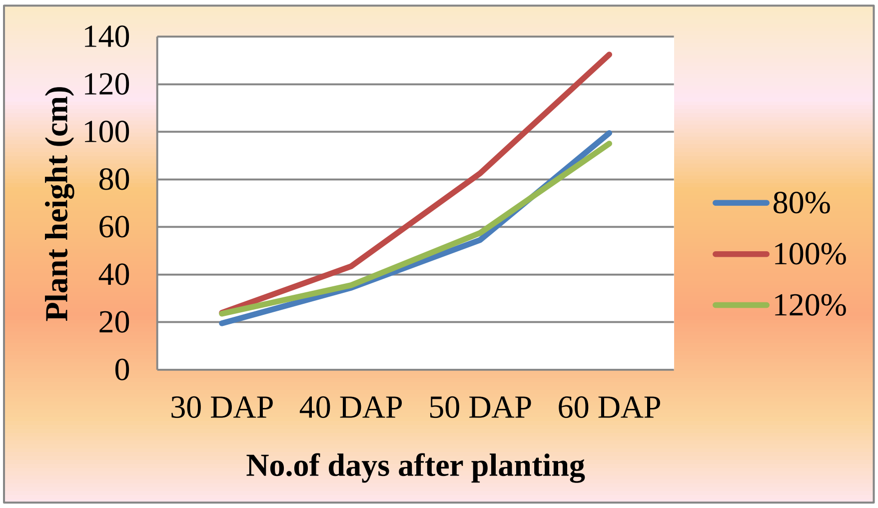

Figure 4.3 Influence of different levels of fertigation on plant height at different stages of crop growth in soilless media inside polyhouse.

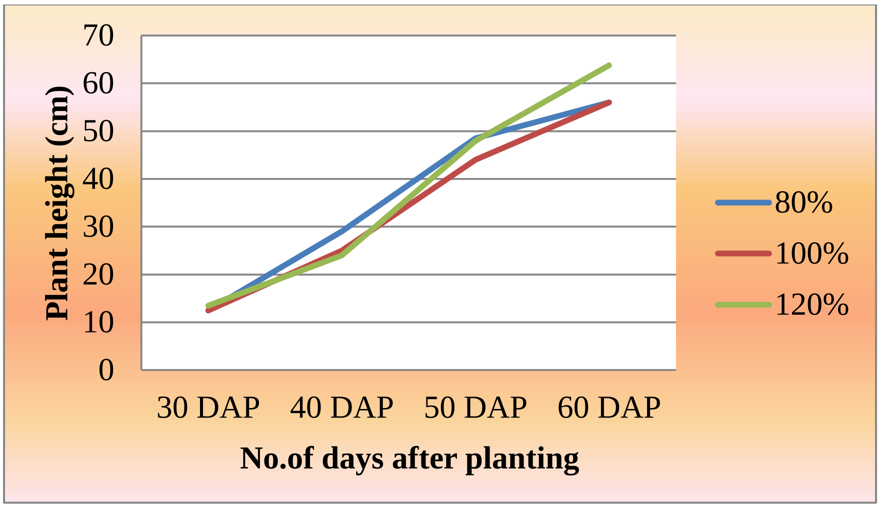

Figure 4.4 Influence of different levels of fertigation on plant height at different stages of crop growth in soilless media in open field.

4.1.3 Number of branches

The data on number of branches at different stages of crop growth is influenced by growing environment as given in Table 4.2 and fig.4.5.

Table 4.2 Number of branches as influenced by different treatments at different stages of crop growth in okra

Treatments	Number of branches			
	30 DAP	40 DAP	50 DAP	60 DAP
T_1	0	2	2	3
T_2	0	1	2	3
T_3	0	2	3	4
T_4	0	3	5	6
T_5	0	3	5	7
T_6	0	3	5	7
T_7	0	0	2	3
T_8	0	0	2	2
T_9	0	0	2	3
T_{10}	0	0	2	3
T_{11}	0	1	2	3
T_{12}	0	0	2	3

From Table 4.2, it is clear that number of branches is more in open field than in polyhouse at all growth stages. The more number of branches in open field as compared to protected structures was noticed by Rajasekar *et al.* (2013) in which it was reported that cluster bean, bhindi and cucumber had more number of branches per plant in open field than in shade net during both seasons. This indicates that this crop must require more light intensity for better growth and development (Marcelis and Hofman-Eijer, 1993).

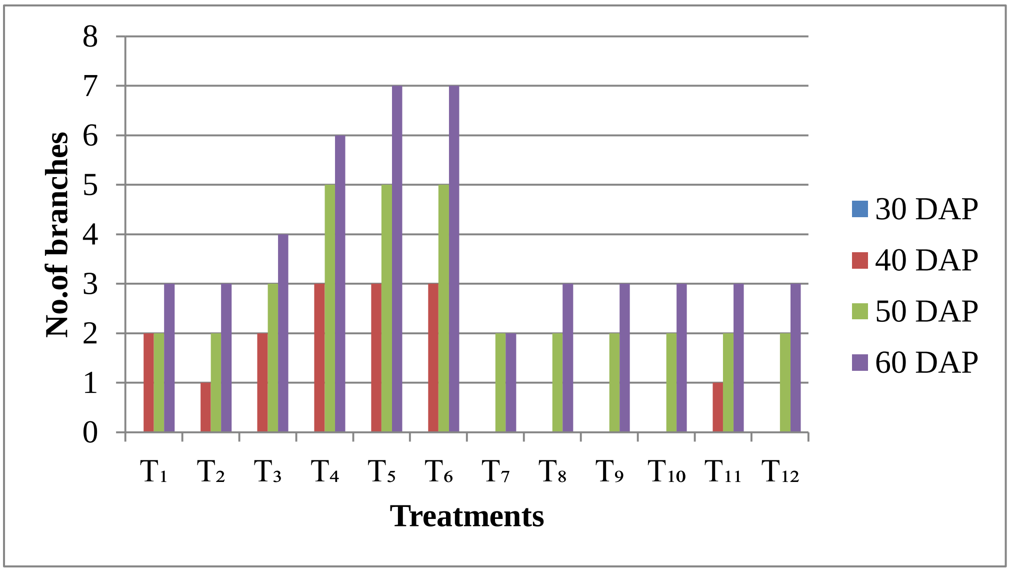

Figure 4.5 Number of branches as influenced by different treatments at different stages of crop growth in okra

4.1.4 Number of Leaves

The data on number of leaves as influenced by different treatments are presented in Table 4.3.

Table 4.3 Number of leaves per plant in each treatment at different stages of crop growth in okra

Treatments	**Number Of Leaves / Plants**			
	30 DAP	40 DAP	50 DAP	60 DAP
T_1	12	19	21	32
T_2	11	18	20	28
T_3	10	18	30	37
T_4	10	15	19	36
T_5	11	26	35	40
T_6	11	21	29	38
T_7	6	9	15	20
T_8	6	9	17	21
T_9	7	10	14	21
T_{10}	7	9	14	22
T_{11}	8	12	17	21
T_{12}	8	10	17	21

From table 4.3, it can be observed that the number of leaves increased with crop growth and reached maximum value 40 at the maturity stage. At 30 DAP, the maximum number of leaves was observed for the treatment T_1 i.e., 80% fertigation level in soil media inside polyhouse. The minimum number of leaves was observed for the treatments T_7 i.e., 80% fertigation level in soilless media inside the polyhouse and T_8 i.e., 100% fertigation level in soilless media inside the polyhouse. At 40 DAP, maximum number of leaves was observed for treatment T_5 and minimum for treatment T_9 and T_{10}. The maximum number of leaves was observed also in T_5 and minimum for T_9 and T_{10} at 50 DAP. At 60 DAP, maximum number of leaves was observed for T_5 and minimum for T_7. Sharma

(2005) conducted field experiment to study the effect of fertigation through water soluble fertilizers on growth, yield and quality of papaya and reported that plant height, stem girth and number of functional leaves were higher for 100% fertigation level which is agreed with our result.

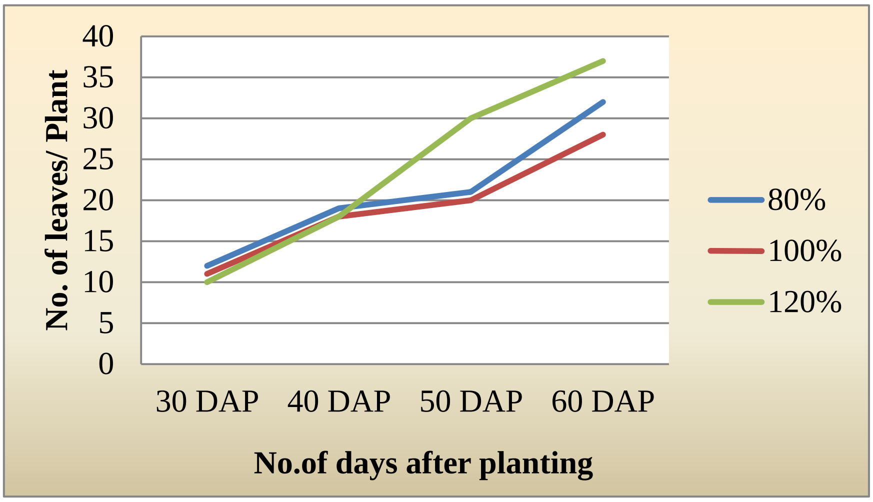

Figure 4.6 Number of leaves as influenced by different levels of fertigation at different stages of crop growth of okra in soil inside polyhouse

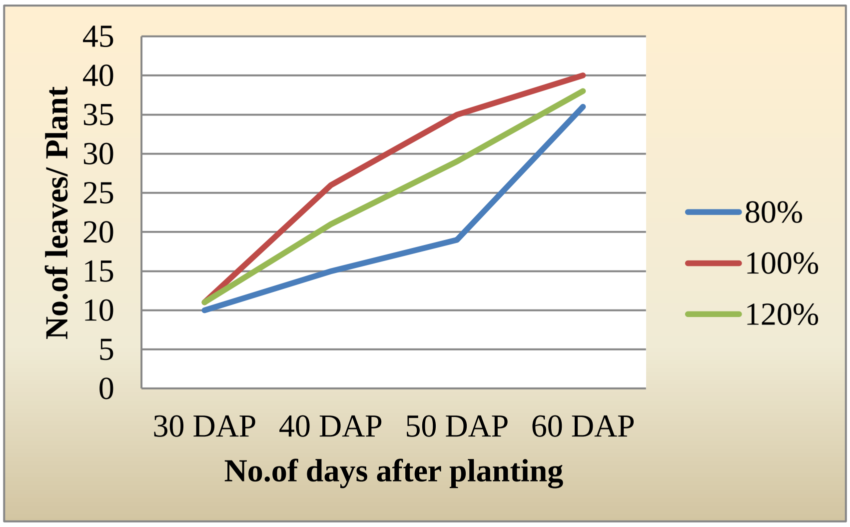

Figure 4.7 Number of leaves as influenced by different levels of fertigation at different stages of crop growth of okra in soil in open field

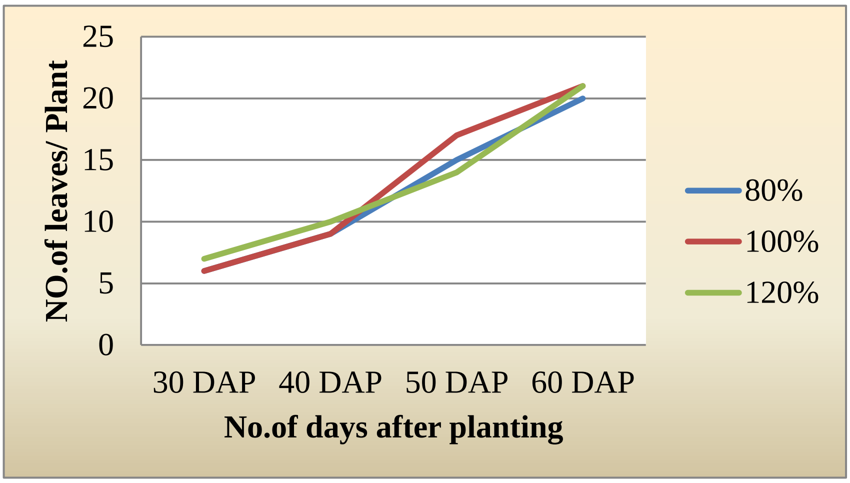

Figure 4.8 Number of leaves as influenced by different levels of fertigation at different stages of crop growth of okra in soilless media inside polyhouse

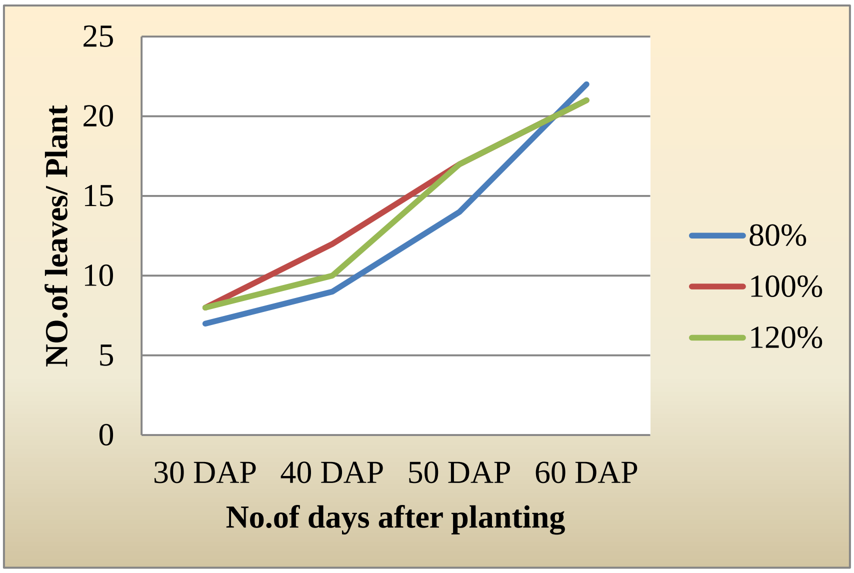

Figure 4.9 Number of leaves as influenced by different levels of fertigation at different stages of crop growth of okra in soilless media in open field

Shukla and Naik (2003) stated that Okra plants respond well to fertilizer in terms of vegetative growth. Yet, Okra plants do not tolerate over fertilization neither lack of fertilizer retards the growth of Okra plants. Lack of fertilizer and over fertilizing will give a negative effect on the growth of Okra plant.

4.2 Yield parameters

The observation on yield was taken first 40 days after planting and later the yield was taken at three days interval. The average yield influenced by different treatments is shown in Table 4.4, Table 4.5, fig. 4.10 and fig. 4.11.

Table 4.4 Yield (Kg/ plant) in soil inside the polyhouse and open field

Treatment	T_1	T_2	T_3	T_4	T_5	T_6
Yield	0.70	0.74	0.72	0.96	0.97	0.93

Table 4.5 Yield (Kg/plant) in soilless media inside the polyhouse and open field

Treatment	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
Yield	0.61	0.66	0.70	0.52	0.56	0.52

Table 4.4 and Table 4.5 shows crop yield inside polyhouse and open field. The maximum yield was observed for treatment T_5 and minimum for T_{12}. The treatment T_4 was on par with T_5. There was no significant difference in yield of okra in different levels of fertigation under same growing condition. The treatment T_2 was on par with T_3 and treatment T_{10} was on par with T_{12}. In soil, it is observed that the yield of okra was more in open field as compared to polyhouse. But in case of soilless media, the yield was more in polyhouse as compared to open field. The maximum yield was observed for 100% of fertilizer recommendation. Both increased and decreased fertigation levels showed almost equal yield which is significantly less than 100% recommended dose. So 80% recommended dose can be suggested for 20% savings in fertilizers.

Nair *et al*. (2017) that application of water soluble fertilizers through fertigation at recommended or reduced rate will not affect the yield by weekly or bi-weekly fertigation interval. Patel and Rajput (2003) and Varughese *et al.* (2014) also observed highest yield in okra with 100% fertigation of the recommended dose. These higher yields were due to better growth and yield parameters like days to flowering, plant height, and number of fruits per plant and fruit length.

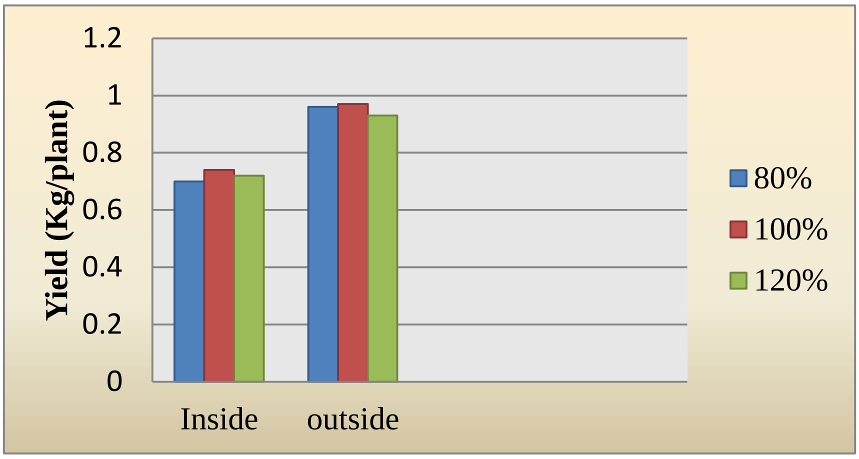

Figure 4.10 Variation of crop yield between polyhouse and open field in soil under different levels of fertigation

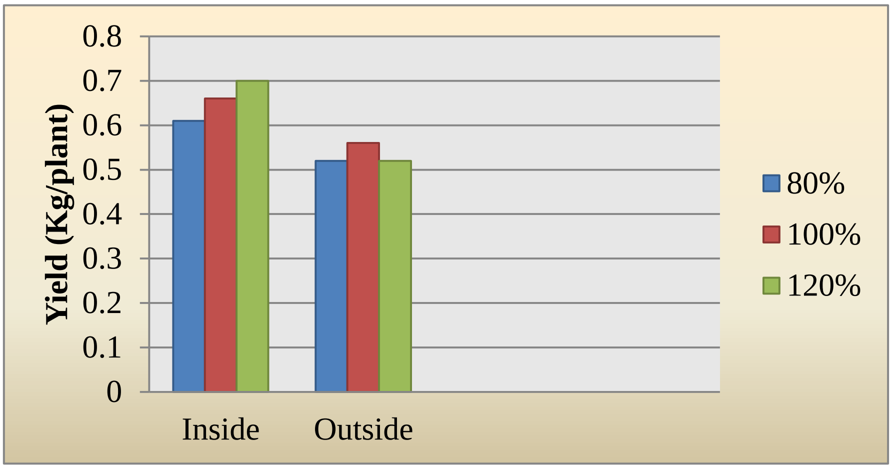

Figure 4.11 Variation of crop yield between polyhouse and open field in soilless media under different levels of fertigation

Plate 4.1 Yield after first harvest

4.2.1 Statistical Analysis of yield

Table 4.6 ANOVA table

Source	Type III Sum of Squares	Df	Mean Square	F	Sig
Corrected Model	0.872	11	0.079	3.819	0.003
Intercept	18.662	1	18.662	8990152	0.000
Treatment	0.034	1	0.034	10619	0.215
Medium	0.509	1	0.509	24.516	0.000
Block	0.006	2	0.003	0.141	0.869
treatment * medium	0.317	1	0.317	15.290	0.001
treatment * block	0.003	2	0.002	0.076	0.927
medium * block	0.002	2	0.001	0.040	0.961
treatment* medium*block	0.001	2	0.001	0.033	0.968
Error	0.498	24	0.021		
Total	20.032	36			
Corrected Total	1.370	35			

The yield observed from each treatment is represented in Table 4.4 and Table 4.5. Based on this statistical analysis of yield data were done by analysis of variance (ANOVA) in Least Significant Difference (LSD). Total degrees of freedom were 36. Evaluating the significant value for each source, medium and combination of treatment and medium was found to be significant i.e., the yield from the soil and soilless media inside polyhouse and open field shows significant variation. Also the yield from soil and soilless media shows significant variation.

4.3 WEATHER PARAMETERS

Growth, development, productivity and post-harvest quality of any crop is largely depends on the interaction between the plant genetics and the environmental conditions under which they are grown. Environment is the aggregate of all external conditions which influences the growth and development of crop, which play the dominant role in the crop production. Each crop has its own set of environmental conditions under which it grows best (Reddy *et al*., 1999). Generally crops are not profitable unless they are adapted to the region in which they are produced. Raising a crop successfully means the crop must be productive and economical to grow under prevailing conditions.

Observed weather parameters viz. light intensity, maximum and minimum temperature, relative humidity for the months of October, November and December are presented and discussed under.

4.3.1 Light intensity

Light intensity plays a significant role in crop growth and development. Light intensity in the morning, afternoon and evening inside polyhouse and open field in the months of October, November and December are given in table 4.7.

Table 4.7 Light intensity inside polyhouse and open field

Stage	Light intensity (lux)					
	Morning		After noon		Evening	
	Polyhouse	Open field	Polyhouse	Open field	Polyhouse	Open field
1st week	7632.86	30842.86	13572.86	58332.86	4345.71	15468.57
2nd week	10276.67	45157.14	18836.19	79014.29	4396.48	14997.14
3rd week	11393.81	35465.71	21064.76	85885.71	3063.33	23297.14
4th week	11054.76	36061.43	17803.33	74428.57	3087.14	11182.86
5th week	10317.62	30450.00	20817.14	92085.71	4149.52	17870.00
6th week	11047.62	34828.57	14820.48	60122.86	4046.19	16204.29

7th week	14548.57	34850.00	12977.62	53800.00	2340.81	7699.143
8th week	10158.38	26688.57	19627.62	73774.29	3049.52	9411.429

The maximum light intensity was recorded under open field in the afternoon during fifth week after planting and minimum relative humidity was recorded under naturally ventilated polyhouse in the evening seventh week after planting. There is a significant difference between light intensity inside polyhouse and that in the open field. Light intensity in open field is much higher than that inside polyhouse. This may due to shade inside polyhouse. This results in greater difference between yield inside polyhouse and open field.

4.3.2 Maximum and Minimum Temperature

Maximum and minimum temperature in the morning, afternoon and evening inside polyhouse and open field in the months of October, November and December are given in table 4.8.

Table 4.8 Mean maximum and minimum temperatures

Month	Time	Temperature (°C)			
		Polyhouse		Open field	
		Maximum	Minimum	Maximum	Minimum
October	Morning	29.84	29.63	30.13	29.83
	Afternoon	34.18	33.80	33.21	32.95
	Evening	30.80	30.60	29.86	29.67
November	Morning	30.40	30.09	31.18	30.76
	Afternoon	36.93	36.40	36.62	36.02
	Evening	31.50	31.30	31.22	30.99
December	Morning	29.80	29.52	30.84	30.65
	Afternoon	36.34	35.80	34.66	34.15
	Evening	30.10	29.90	29.17	29.07

The maximum temperature (36.93ºC) was recorded under naturally ventilated polyhouse in the afternoon during the month of November and minimum temperature (29.07^{o}C) was recorded under open field in the evening during the month of December. Temperature inside the polyhouse was slightly higher than that in the open field in the afternoon and evening in all the three months. But the temperature in the open field was slightly higher than that inside polyhouse in the morning in all the three months. The higher temperatures inside the polyhouse may be due to greenhouse effect. All the radiation entering the greenhouse will contribute to the potential elevation of the greenhouse above that of the external air (Day and Bailey, 1999).

4.3.3 Relative humidity

Atmospheric moisture plays a significant role in crop growth and development. Relative humidity in the morning, afternoon and evening inside polyhouse and open field in the months of October, November and December are given in Table 4.9.

Table 4.9 Variation of relative humidity inside polyhouse and open field

Month	Time	Relative humidity	
		Polyhouse	Open field
October	Morning	75.43	76.09
	After noon	61.22	64.54
	Evening	72.36	74.12
November	Morning	75.72	72.23
	After noon	50.79	51.60
	Evening	67.43	68.84
December	Morning	73.38	72.85
	After noon	54.56	50.41
	Evening	68.99	71.61

Relative humidity increases the net energy of crop growth and prolongs the survival of crops under moisture stress condition, which leads to optimum utilization of nutrients. It also maintains turgidity of cells (Reddy *et al*., 1999).

The maximum relative humidity (76.09%) was recorded under open field in the morning during the month of October and relative humidity (50.41%) was recorded under open field in evening during the month of December.

4.4 Nutrient use efficiency

The nutrient use efficiency in okra is shown in Table 4.10.

Table 4.10 Nutrient use efficiency

Treatment	Yield (Kg)	NFUE	PFUE	KFUE
T_1	0.70	87.50	225.80	41.92
T_2	0.74	72.55	194.74	33.79
T_3	0.72	59.01	266.67	31.17
T_4	0.96	117.07	309.67	57.48
T_5	0.97	95.09	255.26	44.29
T_6	0.93	76.23	344.44	40.26
T_7	0.61	74.39	196.77	36.52
T_8	0.66	64.70	173.68	30.13
T_9	0.70	57.38	259.26	30.30
T_{10}	0.52	63.41	167.74	31.13
T_{11}	0.56	54.90	147.37	25.57
T_{12}	0.52	42.62	192.60	22.51

From fig. 4.12 it is clear that nitrogen FUE was highest for T_4 and then for T_5 and T_1. Phosphorus FUE and potassium FUE were also greater in T_4. The figure gives a clear indication on the difference in ranges of each efficiency. Potassium was applied in greater quantities compared to the nitrogen and phosphorus and hence KFUE is in low ranges. In soilless culture use of drip irrigation with fertigation allows growers to improve the synchronization between nutrient application and crop nutrient uptake which leads to higher water and fertilizer use efficiencies (Metin *et al.*, 2010)

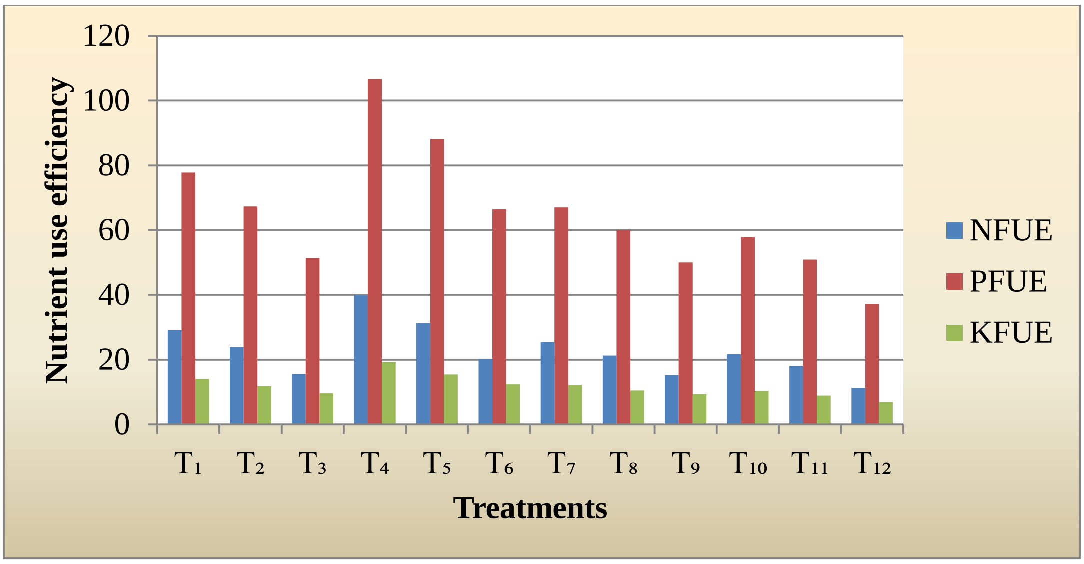

Figure 4.12 Variation of nutrient use efficiency for different treatments

CHAPTER V

SUMMARY AND CONCLUSION

The study was conducted in a naturally ventilated polyhouse and open field in the research plot of the Department of Irrigation and Drainage Engineering, KCAET, Tavanur, Kerala, during the period 16^{th} October 2017 to 01^{st} January 2018. The present study was undertaken with the objective to determine the nutrient efficiency of Okra in soil and soilless media under varied fertigation levels. The statistical design was based on completely randomized design consisting of twelve treatments and three replications. Yield parameters are compared statistically.

Three levels of fertigation (80%, 100% and 120%) were applied to the crops in soil and soilless media inside the greenhouse as well as in open field. The twelve treatments showed significant differences in the case of average yield. The maximum yield was observed for the treatment T_5 (0.97kg/plant), which had the fertigation at the level of 100%, in soil media in the open field. Minimum yield was observed from treatment T_{10} (80% fertilizer recommendation in soilless medium in open field) which was on par with T_{12} (120% fertilizer recommendation in soilless media in open field) with a yield of 0.52kg/plant.

The data on height of the plant and number of leaves after 60 DAP as influenced by different treatments was observed. The result revealed that plant height and number of leaves at 60 DAP differ significantly with respect to the different treatment over control. With respect to the height of the plant, it is seen that the maximum height (178 cm) was observed in treatment T_1 (80% fertilizer recommendation in soil inside the polyhouse) and minimum height was observed in treatment T_{10} (80% fertilizer recommendation in soilless media, in open field). This was on par with treatment T_{11} (100% fertilizer recommendation in soilless media in open field) with a height of 56 cm.

With respect to the number of leaves, maximum number of leaves was observed in treatment T_5 (100% fertilizer recommendation in soil media in open field) and minimum number of leaves was observed for T_7 (80% fertilizer recommendation in soilless media inside the polyhouse).

By comparing the results, it was observed that yield obtained in open field significantly differ from that of polyhouse. The higher yield of Okra in open field may be because of the more number of branches per plant found in open field condition. The increased number of branches in open field may be due to high light intensity in open field condition.

Yield obtained in soil was superior over the soilless medium. The combination and proportion of soilless media used need to be modified.

The maximum yield was observed for 100% of fertilizer recommendation. Both increased and decreased fertigation levels showed almost equal yield which is significantly less than 100 per cent recommended dose. So 80% recommended dose can be suggested for 20% savings in fertilizers.

The result obtained from statistical analysis confirms the results.

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ABSTRACT

A field experiment was conducted in a naturally ventilated polyhouse and open field in the research plot of the Department of Irrigation and Drainage Engineering, KCAET, Tavanur during October 2017- January 2018 to study the nutrient use efficiency of Okra in soil and soilless media using fertigation. The experiment was done with 12 treatments consisting of combination of 3 fertigation level in soil and soilless media under polyhouse and open field with 3 replications. The maximum yield was observed for the treatment having 100% fertigation in soil outside the polyhouse (T_5). The minimum yield was observed for the treatment having 120% fertigation in soilless media outside the polyhouse. It was observed that the biometric parameters do not significantly differ for different fertigation levels. The maximum nutrient efficiency was observed for treatment has 80% fertigation level in soil outside the polyhouse (T_4) and minimum for treatment having 120% fertilizer recommendation in soilless outside polyhouse. By statistical analysis, it was observed that, the growing environment and the media in which the crop grown influences its yield.