AGRO TECHNIQUES FOR CONTAINER GROWN YARDLONG BEAN

(*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)

by

ANJANA, S

(2015-11-031)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"AGRO TECHNIQUES FOR CONTAINER GROWN YARDLONGBEAN (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"AGRO TECHNIQUES FOR CONTAINER GROWN YARDLONGBEAN (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)"** is a record of research work done independently by Ms. Anjana, S (2015-11-031) 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 her.

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LIST OF ABBREVIATIONS

ASM	Available soil moisture
Bag^{-1}	Per bag
BCR	Benefit cost ratio
Cm	Centimeter
cm^3	Cubic centimetre
CPE	Cumulative pan evaporation
DAS	Days after sowing
et al.	Co- workers
Fig.	Figure
FYM	Farmyard manure
G	Gram
g $plant^{-1}$	Gram per plant
Ha	Hectare
IW	Irrigation water
KAU	Kerala Agricultural University
Kg	Kilogram
kg ha^{-1}	Kilogram per hectare

LIST OF ABBREVIATIONS (CONTINUED)

L^{-1}	Per litre
Max.	Maximum
M	Metre
Min.	Minimum
Ml	Millilitre
Mm	Milli meter
N	Nitrogen
No.	Number
NS	Non significant
OC	Organic carbon
P	Phosphorus
P_2O_5	Phosphate
$Plant^{-1}$	Per plant
RD	Recommended dose
SEm	Standard Error of mean
RH	Relative humidity
SE	Standard error

LIST OF ABBREVIATIONS (CONTINUED)

Sl.	Serial
t ha^{-1}	Tonnes per hectare
viz.	Namely

LIST OF SYMBOLS

₹ - rupees

@ - at the rate of

% - per cent

Introduction

1. INTRODUCTION

Conventional system of vegetable cultivation has its limits in Kerala in the light of declining farm land availability and labour shortage. According to Indian Council of Medical Research, annual requirement of vegetables for a four member family is 300- 350 kg (ICMR, 2010). As the agricultural commodities coming from neighbouring states can contain hazardous pesticide residues, production of safe to eat vegetables at home is gaining popularity across the state. It is estimated that a model terrace garden of a three-cent house could produce an average of 250 kg pesticide - free vegetables every year (John *et al.*, 2015).

Among the fresh vegetables, yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt) is one of the most popular vegetable crops grown in Kerala occupying an area of 6714 ha (FIB, 2016). The crop is a warm season vigorous trailing annual which produces very long slender pods. It grows to a height of four metres and the pods may be succulent light green, dark green or brownish red in colour. It is a rich and inexpensive source of vegetable protein and the pods are highly nutritive containing 23 to 26% digestible protein and high dietary fibre (Ano and Ubochi, 2008).

Container gardening is a way to offer affordability and accessibility of fresh and organic vegetable for family consumption. Moreover, it helps in reduction of money spent on buying vegetables from outside. Many fruits and vegetables can be produced with the right growing containers and growing media irrespective of the spaces. The potting media usually used for container cultivation is soil, sand and farmyard manure in the ratio 1: 1: 1. However, majority of urban dwellers especially those living in very small holdings or apartments lack the basic requirements for farming viz., quality growth media for filling the containers or growbags. In the light of incidents reported earlier on poor quality of growth media supplied by various agencies has necessitated the urgent need for standardizing and developing a growth media for commonly grown vegetables in urban farming. As yardlong bean is one of the most preferred vegetables in every household, it is essential to formulate an ideal growth medium by organic means.

Sand being a costly and scarcely available input, it is essential to find a cheaper alternative for preparing the growth medium. Coir pith improves soil conditions like drainage and stimulates growth of most of the crops when used as rooting media. It can be used as an alternative to peat in growth medium attributing to its desirable physical and chemical properties (Savithri and Khan, 1994). High water holding capacity along with its air filled porosity makes it an ideal growth medium. In this context, the possibility of utilising coir pith which is available in plenty and help in enhancing the moisture availability as a substitute for sand need to be studied.

Yardlong bean responds well to applied nutrients. At present, there is a lack of separate nutrient recommendation for yardlong bean grown organically in containers. The adhoc NPK recommendation for yardlong bean as per Packages of Practices Crops, Kerala Agricultural University is 30: 30: 20 kg ha^{-1} (KAU, 2011). Field studies revealed that application of excess organic manures may lead to excess vegetative growth. However, the effect of higher dose of organic nutrition in containers is not studied. Even though, yardlong bean is a leguminous crop, for initial growth and establishment it needs a starter dose of nitrogen and split doses of nutrients improves the response of applied nutrients.

Irrigation is one of the key factors for increasing the productivity of any crop. It is vital for yardlong bean and water stress may drastically reduce the crop yield in containers. Padmanabhan and Swadija (2015) reported that daily irrigation is necessary for vegetables grown in containers on house terraces. However, substitution of growth media with coir pith having high water holding capacity can reduce the irrigation frequency. Different levels of irrigation have significant effect on green pod yield (Geetha and Varugheese, 2001). Excess irrigation often leads to over growth of vegetative parts.

Being a trailer, the performance of yardlong bean under different trailing methods varies. As part of maximum space utilisation, several low cost structures that could be easily installed on terraces, balconies, or kitchen gardens are widely used among the urban residents. The performance of the crop grown in such structures has to be compared with that of the conventional trailing methods so as to find a suitable trailing method for container grown yardlong bean.

In this backdrop, the present investigation was undertaken with the following objectives.

- To identify an ideal growth medium
- To standardise nutrient schedule, irrigation interval and trailing method

so as to formulate an agronomic package for container grown yardlong bean.

Review of literature

2. REVIEW OF LITERATURE

Container gardening in urban areas is an inexpensive way of growing organic vegetables. It can be done anywhere in a house irrespective of spaces with the right growing containers and growth media. Yardlong bean is one of the most preferred vegetable crops in households. However, the production and productivity of any crop is based on the management practices adopted. Being a trailer, trailing pattern as well as irrigation can also influence the production and productivity of yardlong bean. Hence, the present study was envisaged to identify an ideal growth medium, to standardise nutrient schedule, irrigation interval and trailing method for yardlong bean so as to formulate an agronomic package for container grown yardlong bean. The available literatures related to the study from various sources are reviewed in this chapter. Since research work done on container cultivation is limited, similar works under field conditions is also reviewed.

2.1 URBAN FARMING

Majority of urban dwellers take up farming in the useful space or terrace of one's house for production of organic safe vegetables. Considering the growing preference of urban residents for organic food, the use of inorganic fertilizers, insecticides and fungicides were dispensed with. Padmanabhan and Swadija (2003) reported that urban families who have least cultivable land could rely on terrace cultivation of vegetables through which fresh, hygiene vegetables can be produced at low cost utilising household bio waste and family labour. Sreedaya (2004) reported that in order to attain vegetable self sufficiency from the terrace for a four member family, 60 per cent of the area should be utilised for fruit vegetables and 20 per cent for leafy tuberous vegetables.

John *et al*. (2015) stated that terrace cultivation was adopted by 96 per cent of the residents in Thiruvananthapuram district and 50 to 75 per cent of the terrace area were utilized for cultivation by majority of households (49 per cent). The findings of the study also revealed that available space utilization was important for nearly 82 per cent of people and non poisonous produce for consumption is preferred by 61 per cent of people.

Urban farming moderate air temperature through shading, absorption and cooling effect (Katayama *et al*; 1993; McPherson *et al*; 1994; Avissar, 1996; Dimoudi and Nikolopoulou, 2003; Wong *et al*., 2003; and Shashua-Bar *et al*., 2009). Urban agriculture can be an alternative for climate change adaption by reducing urban energy footprint (Oberndorfer *et al*., 2007 and De Zeeuw, 2011). It can decrease pressure on agricultural land (Specht *et al*., 2013). Urban farming is a process of utilising novel scientific farming techniques for year round production of high quality fresh organic food in very limited areas like terraces and balconies (Agarwal and Sinha, 2017).

2.2 CONTAINER CULTIVATION

Container gardening is a farming model where a family unit or household produces fruits and vegetables in special containers for personal consumption. It provides accessibility and affordability to fresh and highly nutritious vegetables for family consumption (Deveza and Holmer, 2002). Growing vegetables in containers is a good approach to obtain healthy plants in case of poor soil conditions and limited space (Miles, 2010).

According to Deveza and Holmer (2002), the benefits of container gardening are effective utilization of space, convenience and time, environmental friendly, economical and personal growth and development. Many fruits and vegetables can be produced irrespective of the spaces with the right growing containers and growing media. The additional advantage of container gardening is that it can save money spend for buying vegetables from outside. It also helps in reduction of air pollution.

Cantliffe (1993) reported an increase in plant leaf area, shoot and root biomass with increase in container size. NeSmith and Duval (1998) and Judd *et al.* (2015) observed that root volume varies with the size of the container. According to John *et al.* (2015), main container used for growing crops is plastic sac/ bag. Other containers include clay pots, plastic pots, plastic trays, soil and plastic sheet, baskets and cement pots. Most widely cultivated vegetables in containers are amaranthus, cowpea, bhindi, chilli, tomato, brinjal, snake gourd, bitter gourd and cucumber. Banana, tapioca, colocasia are also grown in containers in a smaller extent.

2.3 GROWTH MEDIUM FOR CONTAINER CULTIVATION

Growth medium is one of the key factors to successful container gardening (Deveza and Holmer, 2002). Container gardening requires a specific soil mixture as ordinary garden soil lacks the properties essential for healthy plant growth. The most commonly used mixture for container gardening is soil:sand:FYM in the ratio 1: 1: 1.

2.3.1 Effect of farmyard manure as a component of growth medium in container gardening

Most of the nutrient elements essential for plant growth can be supplied through organic manures. In organic manure treated plots of bhindi, yield attributes like fruit number plant^{-1}, fruit weight, fruit length and fruit yield were found to be higher (Raj, 1999). According to Dileep (2005), organic manures contain growth promoting principles like enzymes and hormones, besides plant nutrients essential for improvement of soil fertility and productivity. Organic manure application increased available P content of soil due to native P solubilisation and release of organic acids (Sharma *et al.*, 2009). According to Eifediyi and Remison (2010), addition of organic manure activates microbial activities.

The most common and readily available organic manure is farmyard manure (FYM) constituting urine, straw and dung (Gaur, 1994). According to Banerjee (1998), water holding capacity, soil aeration, permeability and biological properties were improved on addition of organic manures.

The constituent composition of FYM varies its nutrient content. The average nutrient content of well rotten FYM was found to be 0.5 per cent nitrogen, 0.2 per cent phosphorus and 0.5 per cent potassium (Gaur *et al.*, 1971). Krishnaswamy *et al.* (1984) observed that the availability of phosphorus from the native as well as applied sources increased on addition of FYM. Meerabai and Raj (2001) noticed that an average dressing of 25 t ha^{-1} FYM provides 112 kg N, 56 kg P_2O_5 and 112 kg K_2O. An increase in organic carbon, microbial biomass and coefficient was noticed on application of FYM (Mastol *et al.*, 2006).

Incorporation of organic matter (both crop residue and FYM) reduces bulk density (Khaleel *et al.*, 1981), improves infiltration rates (Acharya *et al.*, 1988). It enhances water retention capacity and soil structure (Bhagat and Verma, 1991). FYM enhanced soil fertility status (Hemalatha *et al.*, 2000).

The nitrogen content and organic carbon of the soil increased through the continuous application of FYM (Kanwar and Prihar, 1982). According to Gaur (1984), a small fraction of phosphorus, potash and less than 30 per cent of nitrogen in organic manure may be available to the immediate crop and rest to subsequent crops.

Organic carbon content of soil increased by FYM application (Havanagi and Mann, 1970). According to Udayasooriyan *et al.* (1988), continuous application of organic manures carbon content of soil increased from 0.91per cent to 1.58 per cent.

According to Gomes *et al.* (1993), FYM has an enhanced efficiency in increasing yield. Application of FYM enhanced growth and increased root biomass production in soyabean (Acharya *et al.*, 1988 and Benbi *et al.*, 1998). The plant height, leaf area index and dry matter production in bhindi was found to be higher in organically treated plots (Raj, 1999). Ribeiro *et al.* (2000) reported that cattle manure (20 t ha^{-1}) increased the yield over mineral fertilizer.

Cerna (1980) observed that FYM improved the plant and vegetative dry mass in capsicum. The growth parameters like plant height and number of leaves were higher on application of FYM in potato (Sahota, 1993). Joseph (1998) reported an increase in root weight plant^{-1} and dry matter production in snakegourd on addition of FYM. Similar increase in dry matter production on application of FYM was observed by Senthilkumar and Sekar (1998) in bhindi. In tomato, addition of FYM significantly increased number of branches plant^{-1} and plant height (Sharma and Sharma, 2004).

Gomes *et al.* (1993) observed efficiency of FYM in enhancing soil chemical properties and producing higher yield over urea and castor cake. The yield attributing characters of snakegourd like length, weight and number of fruits were higher on application of FYM (Joseph, 1998). Application of FYM increased the fruit yield in bhindi (Senthilkumar and Sekar, 1998). Application of FYM had a positive influence on the fresh and dry weight of tomato (Yadav *et al.*, 2003) A study conducted by Sharma and Abraham (2010) reported a significant difference in dry matter production and plant height on application of FYM in blackgram at maturity.

Organic farming gave higher total returns due to premium price when compared to other systems (Bharadwaj, 1995). Purushottamkumar and Puri (2002) recorded higher net returns in french bean on application of FYM.

2.3.2 Effect of coirpith as a component of growth medium in container gardening

Coirpith is a light fluffy non fibrous corky material from coconut husk. It is a by - product of coir fibre industry. Coirpith is also known as coir dust, coir fibre pith, cocopeat (Hume, 1949). According to Menon (1987), coirpith constitutes about 70 per cent of coconut husk. It is a waste product from coconut derived from the mesocarp of coconut consisting of dust and fibres (Arenas *et al*., 2002).

Coirpith is a cheap moisture retentive material. According to Nagarajan *et al.* (1985), one tonne of coirpith is generated as a waste material from 1000 coconut husks. Corpith has the capacity to absorb water slowly eight times by weight (Menon, 1987). Rajanna (1988) reported that coirpith has a bulk density of 0.1525g cm^{-3}, particle density of 0.4916g cm^{-3}, porosity of 76.77 per cent and pH of 5.8. The same author also reported that coirpith possess a mean water holding capacity of 625 per cent. Coirpith possess a high water retention capacity of 600- 800 per cent and can be a maximum of 1100 per cent (Coir board, 2016). It possesses a wider C: N ratio of 58:1 to 112:1. Coirpith contains high amount of lignin and cellulose (Coir board, 2016).

Coirpith improves soil conditions like drainage and stimulates growth of horticultural crops when used as rooting media (Hume, 1949). Coirpith rehydrates easily as it is hydrophilic in nature (Cresswell, 1992). It can be used as an alternative to peat in growth medium attributing its desirable physical and chemical properties (Bragg *et al*., 1993 and Savithri and Khan, 1994). Coirpith can be used as an effective soil ameliorant. It was also found that coirpith can improve CEC of soil. Coirpith can retain larger amounts of nutrients due to its higher CEC and it also possess high contents of exchangeable Na, K, Ca and Mg in its adsorption complex (Verhagen and Papadopoulos, 1997). Application of coir pith to soil can improve hydraulic conductivity, porosity, and water infiltration rate and nutrient storage capacity (Prabhu and Thomas, 2002).

Michel (2010) reported that coirpith exert a favourable air to water balance in the root zone for a longer period of time. The favourable air to water balance can enhance crop duration. In an investigation conducted by John *et al.* (2015) to find out effect of growth media for cultivation of vegetables, the best growth medium identified for bhindi and brinjal was coirpith mixed with cowdung in the ratio 1: 1.

A decreased hydraulic conductivity and noticeably increased capillary porosity was observed by Loganathan *et al.* (1979) when coirpith was applied to red sandy soils. The organic carbon content of the soil increased on continuous application of coir dust (Nambiar *et al.*, 1983). Bhowmic and Debanath (1985) reported increased water holding capacity of soil on application of coirpith. Nagarajan *et al.* (1990) noticed that coirpith can be used as an soil ameliorant in tropical farming. According to Cresswell (1992) coirpith can be used as an organic component of growth media attributing to its desirable properties like high water holding capacity, excellent drainage, absence of weeds, greater physical resiliency, renewability, slower decomposition, acceptable pH, CEC, EC and easier wettability than peat. Meerow (1995) reported that coirpith requires less liming as it possess a high pH. Plant height and root fresh mass was found to higher when chrysanthemum was grown in cocopeat (Sreerama *et al.*, 1999). A higher fruit number and yield is observed in tomato when grown in cocopeat substrate (Luitel *et al.*, 2012).

Knight (1991); Handreck (1993) and Offord *et al.* (1998) reported coirpith can be used as an alternative for peat in growth medium and thereby conserve peat ecosystem. According to Reghuvaran and Ravindranath (2013), coirpith is a poor conductor of heat and can reduce soil temperature. They also opined that coirpith can be used as an ideal growth medium for plant growth.

Loganathan *et al.* (1979) observed that there was an increase in germination percentage and plant stand in groundnut on application of coirpith. Venkatakrishnan and Ravichandran (1996) observed that the height, number of branches plant^{-1} and root growth of sesame plants increased on application of coirpith.

According to Loganathan *et al.* (1979), an increased yield of groundnut was observed when coirpith was added to red sandy soil. An increased yield of groundnut was observed on application of coirpith (Durai and Rajagopal, 1983). Nagarajan (1986) observed an increase in growth and yield of groundnut on application of coirpith along with recommended dose of NPK. An appreciable increase in yield was noticed when recommended level of nutrients along with raw coirpith was applied to groundnut (Nagarajan *et al.*, 1991). Jayapaul *et al.* (1996) stated that soil incorporation of coirpith can increase in yield, protein content and oil content of soyabean. Baskar (1996), reported that potting mixture composed of coirpith and soil in the ratio 75: 25 increased yield of yardlong bean. The weight of the growth medium can be reduced considerably when coirpith was used as a component of growth medium in containers (Joshua *et al.*, 2012).

Meerow (1994) stated that high quality coir dust can be a better substitute for sedge – peat and an increase in shoot, root growth and growth index of Anthurium and *Ravenea rivularis* was recorded in coirpith based media. A study conducted by Meerow (1995), recorded a higher growth index, top and root weight when *Ixora coccinia* and *Pemas lanceolata* were grown in coirpith based media than peat based media. Coirpith was also used in hydroponic production of tomato (Caraveo- Lopez *et al.*, 1996). Evans and Stamps (1996) observed early flowering when *Tagetes* was grown in cocopeat. Rao (1999) observed that cocopeat can be utilised in germination of seeds, nursery raising, soil conditioning, cultivation of glass house plants etc. Joshua *et al.* (2012) opined that coirpith can be used as an effective rooting medium since it promotes root growth.

Acalypha and *Bougainvillea* when grown in cocopeat recorded a higher rooting percentage (Lokesha *et al*., 1988). Warrier *et al*. (1998) reported that coirpith can be used a rooting medium for vegetative propagation of *Eucalyptus* using single noded cuttings. Coirpith was found to be a suitable growth medium in horticultural plants like *Begonia semperflorens* (Saravan and Nambisan, 1995), *Gerbera jamesonii* (Pillai *et al*., 1999). *Chrysanthemum* (Sreerama *et al*., 1999). A study conducted by Rajamani *et al*. (1999) reported that orchid *Vanda rothschildiam* grown in coirpith based growth medium recorded higher production of flowers.

2.3.3 Effect of sand as a component of growth medium in container gardening

Sand is typically selected as a growth media component to improve the drainage and porosity. Medium to course sized particles can increase porosity. Sand has to be washed and sterilized before using it in the growing medium (Miller and Jones, 1995). A reduction in aeration and drainage is observed when small sand particles are lodged in existing pore spaces. According to Gordon (2004), the most serious disadvantage of using sand as a component in growth media is its weight, since it causes problems with handling and increases the cost of shipping. In general, 0.05 to 0.25 mm sized sand particles will block drainage holes and decrease aeration (Wilkerson, 2011).

2.4 NUTRIENT SOURCES

2.4.1 Oil cake as a nutrient source for container gardening

The residues left after the extraction of oil from oil seeds are referred as oil cakes. Oil cakes are the by-products of oil seeds crops. Groundnut cake possesses 7.3 per cent nitrogen, 1.5 per cent phosphorus and 1.3 per cent potassium (Sankaranarayanan, 2004).

Baliah *et al.* (2016) stated that oilcakes are important and rapidly acting organic nitrogenous manures. It possesses a small amount of phosphorous and potassium. On application of oilcakes to crops, nitrogen becomes quickly available in about a week or ten days. Oil cakes can enhance soil structure, aeration and water holding capacity of soil (Joshi *et al.*, 2016).

According to Chinnaswamy (1967), application of groundnut cake and FYM resulted in an enhanced growth in tomato plants. Biswas *et al.* (1969) stated that groundnut cake when applied in a rice fallow rotation for ten years enhanced the water holding capacity of soil. On application of neem cake, maximum plant height was noticed in brinjal (Som *et al.*, 1992). Application of Neem cake provides organic carbon and potash to the soil (Sahrawat and Mukherjee, 1997). The available N content in soil was found to be highest on neem cake application in bhindi on comparison with FYM, poultry manure and compost. (Asha, 1999). Application of fermented groundnut cake increased number of branches in tomato (Soumya, 2015).

Application of oilcake increased growth in chilli, tomato and egg plant seedlings (Mashkoor *et al.*, 1980). Incorporation of oilcake during the land preparation resulted in higher yield of bhindi, brinjal and chilli (Islam and Haque, 1992). Neem cake can stimulate biocontrol agents leading to suppression of diseases like damping off and can lower plant parasitic nematodes (Abbasi *et al.*, 2005). Asha (2006) observed that neem cake applied plots recorded the highest green yield of 15.07t ha^{-1} in amaranthus compared to enriched vermicompost.

Lokanadhan *et al.* (2012) observed that neem seed cake reduces the nitrogen loss by nitrification inhibition when used as a soil amendment and also enriches the soil with organic matter. Baliah *et al.* (2016) reported that application of neem cake recorded higher shoot length, taller root system, highest fresh weight and dry weight in bhindi.

The plant height, number of branches and dry matter accumulation were higher on application of neem cake in chilli and was found to be on par with Package of Practices recommendation of Kerala Agricultural University (Sharu, 2000). According to Arunkumar (2000), higher yield was noticed on application of oilcakes compared to chemical fertilizers. Aridoss *et al.* (2004) stated that increased plant growth on application of oilcakes attributed to its higher NPK content.

According to Nandini (1998), application of ground nut cake equivalent to 75 kg N ha^{-1} recorded higher yield per plot in bhindi. Nitrogen content in groundnut cake was found to be 6.13 per cent (Pillai, 2012). On application of fermented groundnut cake, fruit length was found to be maximum in tomato. An increased fruit girth, fruit weight and yield $plant^{-1}$ was observed on application of incubated groundnut cake + PGPR mix 1 (Soumya, 2015).

2.4.2 Bone meal as a nutrient source for container gardening

Bone meal is a rich source of available phosphorus for crops than phosphates (Warren *et al.*, 2009). A slight reduction in soil pH on application of bone meal was reported by Svoboda *et al.* (2010). It is rich in P and contains about 20 per cent P_2O_5.

Bone meal can be a possible alternative to phosphate fertilizers (Jeng *et al.*, 2006; Svoboda *et al.*, 2010; Chen *et al.*, 2011; Brod *et al.*, 2012 and Nogalska *et al.* 2012). Phosphorus is present as apatite form in bone fraction and soluble organic form in meat fraction (Nogalska and Zalewska, 2013).

Deydier *et al.* (2003) noticed soil pH improved on application of bone meal. Bone meal application increased N availability, activity of microorganisms thus improving enzymatic activity nutrient availability and elemental cycling (Mondini *et al.*, 2008). Warren *et al.* (2009) reported that bone meal can be used as a liming material.

The positive influence on phosphorus content on application of bone meal in various crops was reported by Ylivainio *et al*. (2008) and Nogalska *et al*. (2012). A four year study conducted by Nogalska and Zalewska (2013) to assess the direct and residual effect on increasing dose of meat and bone meal revealed that available phosphorus level was increased on application of meat and bone meal. Nogalska *et al*. (2014) reported that bone meal is an important phosphorus as well as nitrogen fertilizer for rapeseed and cereals.

2.4.3 Wood ash as a nutrient source for container gardening

The wood ash is a by-product of combustion of woods has potential use as a fertilizer.

Wood ash can be utilised as a soil amendment for raising pH and a source of nutrients like potassium (Erich, 1990). According to Tsutomu and Erich (1990), the nutrient release from wood ash varies with the nutrient and the average nutrient release percentages were 5.7 per cent potassium, 40 per cent magnesium, 48 per cent calcium, 74 per cent sodium. On application of wood ash in soil, the equivalent fraction of K, Mg decreased and equivalent fraction of Ca increased. Wood ash is an appreciable alternative liming agent which possesses a moderate amount of P and K. Wood ash mainly contains calcite, and possesses minor amounts of K and Na carbonates (Ulery *et al*., 1993).

Wood ash also possesses readily soluble neutral salts in various concentrations, like sulphates and chlorides of K and Na. Application of loose wood ash reduces acidity and increases base saturation (Eriksson 1998). Wood ash enhances the microbial activity in soil (Fritze *et al.,* 1994). Mahler *et al*. (2008) observed that wood ash could be used as a low analysis K fertilizer and/or a liming agent in agricultural applications. Application of wood ash increased maize yield (Mbah *et al.*, 2010).

The residue powder left after the combustion of woods contains calcium carbonate as its major component. Bougnom *et al.* (2011) reported that wood ash contains trace elements, nutrients and lime and application of wood ash as a supplement to organic fertilizers improves depleted soils.

2.5 NUTRIENT LEVELS

Application of nutrients in the correct dose is important in realising optimum yield of any crop. Being a perennial legume, yardlong bean might respond differently to applied nutrients. According to Dart *et al.* (1977), an enhanced early vegetative growth was observed on application of small quantity of nitrogen. Minchin *et al.* (1981) noticed an increase in NPK had a positive influence on plant height, number of leaves plant^{-1} and dry matter at 50 per cent flowering. Cuckoorani (2013) observed that different levels of NPK had no influence on number of branches plant^{-1}. Soumya (2015) reported that nutrient levels failed to influence number of branches in tomato. Giles (2016) noticed an increase in number of primary branches and productive branches on application of 150 per cent recommended dose of N and K.

Naeem *et al.* (2002) noticed early flowering with increase in NPK levels in chilli. Similar results were reported by Abdel-Mawgoud *et al.* (2005) in common bean. Cuckoorani (2013) reported higher number of leaves, leaf area index and plant height on application of 125 per cent dose of NPK in bhindi. Cuckoorani (2013) in bhindi and (Soumya, 2015) in tomato recorded higher number of inflorescence on application of 125 per cent recommended dose of NPK.

Tripathy *et al.* (1993) noticed that NPK each at 30 kg ha^{-1} gave higher yield in spine gourd. Geetha (1999) observed no significant influence on dry matter production at different levels of N and K. Naeem *et al.* (2002) observed that different doses of NPK influenced days to flowering, days to fruiting, number of branches per plant, plant height (cm), number of fruits per plant, length of fruit (cm) and total yield (kg ha^{-1}). Abdel-Mawgoud *et al.* (2005) reported that increasing level of NPK resulted in a positive response in the vegetative growth and increased pod yield in common bean. Cuckoorani (2013) in bhindi and (Soumya, 2015) in tomato recorded early flowering on application of 100 and125 per cent recommended dose of NPK.

Increasing N levels increased yield of common bean (Barbosa and Silva, 2000). Farkade and Parar (2002) observed increase in yield with increase in N and P in french bean. Increased NPK levels increased days for harvesting in common bean (Abdel-Mawgoud *et al.,* 2005). Ahmed *et al.* (2007) reported that an increase in nitrogen application resulted in maximum fruit length, fruit weight, vine length and yield of cucumber. Jilani *et al*. (2009) noticed that NPK had positive influence on growth and yield of cucumber as it increased cucumber production.

Geetha (1999) observed that different levels of N and K had no significant influence on dry matter production. K and P levels significantly influenced total dry matter (TDM) content where application of 100 per cent of recommendation of both P and K recorded higher value in cowpea (Choudhary and Kumar, 2013).

A significant increase in number of pods up to 60 kg ha^{-1} in black gram was reported by Mishra (1993). An increase in N content with increased level of nutrient was reported by Gill *et al*. (1972) and Faroda and Tomer (1975). Geetha (1999) also observed increased uptake of nutrients due to increased tapping of nutrients from the soil. According to Suja (2006), increasing N levels from 30 to 60 kg ha^{-1} showed no influence on pod yield of yardlong bean. Cuckoorani (2013) reported application of 125 per cent recommended dose of NPK recorded higher number of flowers and fruits, total fruit yield fruit yield plant^{-1} An increase in number of fruits was also observed from zero P to 60 kg ha^{-1}. Giles (2016) noticed increased yield on application of 150 per cent recommended dose of N and K.

Higher availability of nutrients might have helped in better proliferation of root system (Cuckoorani, 2013). These findings are in agreement with the report of Giles (2016) who observed an increase in root volume under higher nutrient levels of N and K in yardlong bean. Increase in P levels also improved the root parameters and root shoot ratio as reported by Basirat *et al.* (2011).

Application of N and P both at 150 kg ha^{-1} recorded higher growth and yield parameters (Barrios *et al.*, 2014). Increasing nitrogen to 150 per cent recommended level had no influence in yield. Soumya (2015) recorded higher fruit yield on application of 125 per cent recommended dose of NPK. In the same study, 100 per cent recommended dose of NPK recorded higher fruit set percent in tomato. Different levels of NPK influenced the growth and yield of tomato, where increased levels of NPK resulted in higher growth performance than recommended NPK level. But it did not reflect in yield of tomato (Jayasinghe *et al.*, 2016).

Cuckoorani (2013) in bhindi and (Soumya, 2015) in tomato reported that application of 125 per cent recommended dose of NPK to growth media recorded higher net income.

Application of 100 per cent recommended dose of NPK to growth media recorded higher BCR by Cuckoorani (2013) in bhindi and (Soumya, 2015) in tomato.

2.6 TIME OF APPLICATION OF NUTRIENTS

According to George (1981), split application of N 20 kg ha^{-1} as basal dose and 10 kg ha^{-1} at vegetative stage recorded maximum plant height at all stages of cowpea. Kumar and Cheeran (1981) reported that split application of N was more advantageous over basal application. George (1981) also observed maximum number of leaves at mid pod filling stage and at maturity on application 20 kg N ha^{-1} as basal dose and 10 N kg ha^{-1} at vegetative stage in cowpea. Midan *et al.* (1985) and El-shobaky (2002) noticed that vegetative characters enhanced with split application of N in tomato.

Midan *et al.* (1985) and El-shobaky (2002) recorded higher fruit yield in tomato when nitrogen was applied in splits. Feleafel (2005) observed that application of nitrogen in six splits increased vegetative characters like number of branches, plant height, and leaves in brinjal. Similar findings were reported in sweet pepper by Ghoeinm (2005). Gull *et al.* (2006) reported that leaf size increased on application of nitrogen (40 kg ha^{-1}) as two splits ie., 50 per cent at sowing and 50 per cent at flowering in pea.

George (1981) reported that leaf area index varied with application of N 20kg ha^{-1} as basal dose and 10 kg ha^{-1} at vegetative stage in cowpea. Minchin *et al.* (1981) observed that application of nitrogen during vegetative and reproductive phase enhanced dry matter production in cowpea. Feleafel (2005) reported an increased dry weight in egg plant on application if nitrogen in splits. Gull *et al.* (2006) observed minimum number of days for flowering when 40 kg N ha^{-1} applied as two splits (75 per cent at sowing and 25 per cent at flowering). Split application of N recorded higher dry matter production in yardlong bean (Babu, 2015).

An increased number of branches, number of pods and pod yield in cowpea were observed on application of nitrogen during vegetative and reproductive phase (Minchin *et al.*, 1981). George and Singleton (1992) reported that split application of N during early vegetative and reproductive stages increased yield of soyabean. Split application of N at higher rates increased yield of cotton (Setatou and Simonis, 1995). Gull *et al.* (2006) reported that split application of nitrogen at 50 per cent sowing and 50 per cent flowering recorded higher number of pods in pea.

Feleafel (2005) observed an increase in total fruit yield on split application of nitrogen irrespective of nutrient level in brinjal. According to Gull *et al.* (2006), application of N 25 per cent at sowing and 75 per cent flowering in pea recorded higher pod weight per plant and pod yield plot. Babu (2015) reported increased pod weight, number of pods plant^{-1}, pod yield plant^{-1} and pod yield ha^{-1} on split application of N in yardlong bean.

2.7 TRAILING METHODS

Konser and Strider (1973) observed increased plant vine length in bittergourd when trailed on trellis. Yadav *et al.* (1989) reported that trailing had a positive influence on branching in pointed gourd. According to him, an increase in growth characters may be attributed to more penetration and better utilization of sunlight for producing maximum number of side branches and leaves. This is in turn might have increased photosynthetic activity and assimilation of photosynthates for enhanced plant growth. Sairaj (2001) reported that trailing systems had no influence on length vine while it influenced yield and yield parameters in cucumber. Pandals provide better microclimate. better photosynthesis and mobilization to fruits, and better fruit development. Pandals facilitates uniform spread of vine.

Rahman and Hussain (1989) reported earliness in flowering in bittergourd trailed on trellis. Kleiber *et al.* (1993) studied effect of trailing systems in Mustang cucumber grown in green house and found that trailing system determined orientation of laterals, leaf and fruit ratio.

A study conducted by Sairaj (2001) on Standardisation of population density and trailing systems in gherkin (*Cucumis sativus* L.) reported that different trailing systems influenced earliness, morphological characters and quality of fruits in gherkins. Plants trailed in pandal more number of branches and fruits. Plants grown on pandal exhibited faster, vigorous and longer vegetative growth resulting in late initiation of reproductive phase.

Trailing had a positive influence on growth characters in muskmelon (Patil *et al,* 1973) and in ridgegourd and sponge gourd (Saimbi, 1993). Similar results were also reported by Shantappa (2004) in bitter gourd. Early flowering, higher vine length, number of shoots, number of fruits and fruit yield was observed when pointed gourd was raised on bamboo pandal (Ara *et al.*, 2011).

In a study conducted by Renji (1998) on the response of slicing cucumber to different population densities, trailing systems and nutrients observed an early harvesting when grown on pandal system. Pandal system was not good enough for flowering in cucumber (Sairaj, 2001).

Konser and Strider (1973) observed higher marketable yields in bitter gourd when trailed on trellis system over ground culture. Rahman and Hussain (1989) observed more number of fruits per plant on trellis sytem over those without trellis. The fruit size and fruit weight were also higher when trailed on trellis system. Singh *et al.* (1989) and Yadav *et al.* (1989) noticed that vines of pointed gourd trailed on trellis system and bower system recorded earlier flowering and higher yields due to effective pollination and luxuriant plant growth. Russo *et al.* (1991) reported that when cucumber was trailed on trellis system enhanced marketable yield as well as total yield. He also reported that the average fruit weight was not affected by different trailing methods.

Increased yield when pointed gourd was trailed on pandal system was reported by Prasad and Singh (1987). According to Renji (1998), maximum fruit yield was obtained when cucumber was trailed on pandal system. Shetty and Wehner (1998) reported higher fruit quality of cucumber when trailed on trellis system. Trailing cucumber on pandal system recorded an increased fruit yield (Sairaj, 2001).

Trailing cucumber on pandal sytem enhanced growth and yield characters (Ravikumar, 2001). Hilli *et al*. (2009) observed an increase in growth and yield when ridgegourd was trailed on pandal system. Trailing cucurbits resulted in more number of fruits, seed yield and quality (Tomar and Yalamelle, 2016).

Trailing the crop (pointed gourd) on bamboo pandal recorded 200 per cent yield (Ara *et al*., 2011). Trailing the crop increased number of fruits and fruit yield in bottle gourd (Kalyanrao *et al*, 2012).

2.8 IRRIGATION

2.8.1 Effect of irrigation frequency on growth and yield of yardlong bean

Irrigation management is one of the main factors increasing productivity of any crop. The transport of plant nutrients to root surface is rapid under irrigated conditions besides better root growth (Rajput *et al*., 1991). An optimum irrigation schedule attributed to optimum moisture condition in crop root zone could enhance growth and yield characters in green gram (Trivedi *et al*., 1994). Different levels of irrigation have significant effect on green pod yield in yardlong bean (Geetha and Varugheese, 2001).

Water stress affects many aspects of plant growth (Kramer and Paul, 1969). Hsiao (1973) and Karamanos (1980) pointed that water stress in cowpea decreased leaf production, promoted senescence and abscission, decreased total leaf area per plant and biomass production

Singh and Lamba (1971) stated that irrigation at higher available soil moisture (ASM) appreciably increased number of leaves plant^{-1} in cowpea. Soil moisture stress in green gram lowered the number of leaves per plant (Ali and Alam, 1973). Lower level of moisture reduced the number of leaves in peas (Manning *et al*., 1977) and chickpea (Kuhad *et al*., 1988). Jyothi (1995) observed an increase in number of leaves in vegetable cowpea by irrigating the crop at 75 per cent ASM. The number of leaves of yardlong bean was also noticeably increased by providing irrigation at 75 per cent ASM in summer season. According to Mini (1997) frequent light irrigations given to yardlong bean resulted production of higher number of leaves per plant during summer season.

Drought stress at vegetative, flowering or pod - filling stage of cowpea influences leaf expansion and abscission (Akyeampong, 1983). Increasing frequency of irrigation remarkably increased the number of leaves in other pulse crops *viz*., Nandan and Prasad (1998) in green gram, Dabhi *et al*., (1998) in green gram. Geetha and Varughese (2001) reported that higher availability of moisture in the soil resulted in early flowering in yardlong bean. Babu (2015) reported that daily irrigation recorded maximum of number of leaves in yardlong bean.

According to Ramamurthy *et al.,* (1990), there is no noticeable influence on the number of branches in cowpea on irrigation. Similar result was obtained by Pani and Srivastava (1990) in pea. Mini (1997) reported that frequent light irrigations at a depth of 10mm depth have an appreciable effect on plant height and leaf area. According to Geetha (1999), growth characters of yardlong bean is not affected by different levels of irrigation frequencies.

A reduction in initiation and retention of floral buds was observed in green gram under moisture stress (Ali and Alam, 1973). Balakumaran (1981) in cowpea documented that varying moisture regimes had no influence on days for 50 per cent flowering in cowpea. According to Jyothi (1995), higher moisture availability is favourable for early flowering in yardlong bean.

The dry matter production in cowpea enhanced with higher ASM in the root zone (Singh and Lamba, 1971). Phogat *et al.* (1984) stated that an enhanced dry matter production was observed in cowpea with increased frequency of irrigation. Irrigation at 75 per cent field capacity resulted in maximum dry matter production in summer yardlong bean than irrigating the crop at 50 per cent of field capacity (Jyothi, 1995). Frequent light irrigations in summer also produced yardlong bean dry matter production (DMP) at all growth stages (Mini, 1997). A reduction in dry weight of leaf, stem and roots of cluster bean was noticed under soil moisture deficit (Shubra *et al.*, 2003). Jukte *et al.* (2007) stated that maximum dry matter production and maximum leaf area were recorded in french bean when irrigated at IW/CPE of 0.8 and 1.0.

Patel (1979) reported that noticeable increase in number and weight of green pods per plant at 80 to 100 per cent available soil moisture (ASM) and a 12.87 per cent higher green pod yield when compared to 60 to 100, 40 to 100 and 20 to 100 per cent ASM in green gram. Balakumaran (1981) noticed that an increased wetness significantly increased the number and weight of pods in summer cowpea. A noticeable reduction in fresh pod yield of yardlong bean is observed when plant is subjected to moisture stress ten days after the emergence until the peak period of vegetative stage (Diputado and del Rosario, 1985). Abdelazim (1988) reported that frequent irrigation intervals enhanced plant height while prolonged irrigation intervals reduced grain yield in cowpea. Yusuf *et al.* (1980) reported pod yield of chickpea was limited by water sress at critical stages. Mingcai *et al.* (2004) observed significant yield loss in soya bean under that water deficit stages. He also reported that assured irrigation at critical stages increased the green pod yield.

A reduction in yield under water stress was reported in broad bean (El Nadi, 1970) and haricot beans (El Nadi, 1975). Irrigation influenced the pod length and number of seeds pod^{-1} in yardlong bean (Subramanian *et al.*, 1993). According to Jyothi (1995), an increase in soil wetness increases pod and haulm yield of yardlong bean during summer season. Geetha and Varughese (2001) reported that pod yield was significantly influenced by irrigation levels. Okon (2013) observed that water stress in cowpea reduced the growth parameters like leaf area and seedling height. Babu (2015) reported increased total dry matter production on daily irrigation.

Ziska and Hall (1983); Akyeampong (1983) and Ziska *et al.* (1985) reported that soil water deficit during flowering and pod-filling affects grain yield of cowpea. As irrigation interval is reduced, an increase in green pod yield of lablab was noticed Pulekar *et al.* (1993). Saeed and El Nadi (1997) investigated the effect of irrigation on growth and yield of alfalfa and forage sorghum and found out that dry matter production was consistently lower for the stressed plants. According to Benjamin and Neilsen (2006), water stress in soyabean had no impact on its relative root distribution while it affected root system of chickpea and field pea where the roots grew deeper in the soil. Hamidou *et al.* (2007) stated that a reduction in root volume was noticed in various cowpea genotypes subjected to water stress. Babu (2015) reported that various irrigation levels influenced the number of days for 50 per cent flowering in yardlong bean.

Kramer and Paul (1969); El Nadi (1975); Saeed and El Nadi (1996); Saeed and El Nadi (1997); Abdelazim (1988) and Mingcai *et al.* (2004) observed that reduction in growth varied with the duration, magnitude of water stress and stage of crop growth during which the crop suffered from water stress.

Akyeampong (1985) reported a higher seed yield in cowpea with frequent irrigation. Subramanian *et al.* (1993) reported that varying irrigation did not have an impact on P content of cowpea. Jyothi (1995) observed that when yardlong bean was irrigated at 75 per cent field capacity, there was a noticeable increase in uptake of N, P and K. The uptake of N, P, K was higher in yardlong bean on daily irrigation (Mini, 1997). According to Geetha, (1999) different levels of irrigation did not have an impact on N and K uptake in yardlong bean. Husman *et al.* (2000) reported that frequent irrigation increased seed yield in durum wheat. Ali and Ahmed (2007) noticed that water stress adversely affected crop growth and production.

Jyothi (1995) reported that treatments with moisture stress had the highest content of N, P and K in soil. Geetha (1999) stated that in post experiment soil nutrient status there was no noticeable variation due to different irrigation treatments. Babu (2015) reported an increased P content in soil on daily irrigation.

Patel (1979) observed that irrigating summer cowpea at 80 to 100 per cent ASM gave maximum net profit. Irrigating yardlong bean at 75 per cent field capacity throughout the crop period registered highest income and benefit cost ratio (Jyothi, 1995). Geetha (1999) reported that different irrigation levels had no influence on net income and benefit cost ratio. According to Babu (2015), irrigation at wider intervals recorded higher net income in yardlong bean.

Materials and methods

3. MATERIALS AND METHODS

The investigation entitled "Agro techniques for container grown yardlong bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)" was undertaken at College of Agriculture, Vellayani during the period 2015-2017. The primary objectives of the study were to identify an ideal growth medium; to standardise nutrient schedule; irrigation interval and trailing method in containers so as to formulate an agronomic package for container grown yardlong bean.

The study was conducted as two separate experiments in containers. The materials used and the methods adopted for the studies are briefly described below.

3.1 EXPERIMENT DETAILS

3.1.1 Location

The experiments were conducted in the Instructional Farm attached to College of Agriculture, Vellayani, Kerala, located at 8° 25' 46" N latitude and 76° 59' 24" E longitude and at an altitude of 29 m above the mean sea level.

3.1.2 Climate and Season

The experimental site experienced a humid tropical climate. The growth media evaluation and nutrient studies were carried out during the *rabi* season of 2016 with crop period extending from August to December 2016.

The study on trailing methods under various irrigation frequencies was carried out during summer season of 2017 with the crop period extending from January to May 2017.

The data on weekly mean maximum and minimum temperatures, relative humidity, total rainfall and evaporation during the study period obtained from Class B Agromet Observatory of College of Agriculture, Vellayani are presented in Appendix 1 and 2 and illustrated graphically in Fig. 1 and 2.

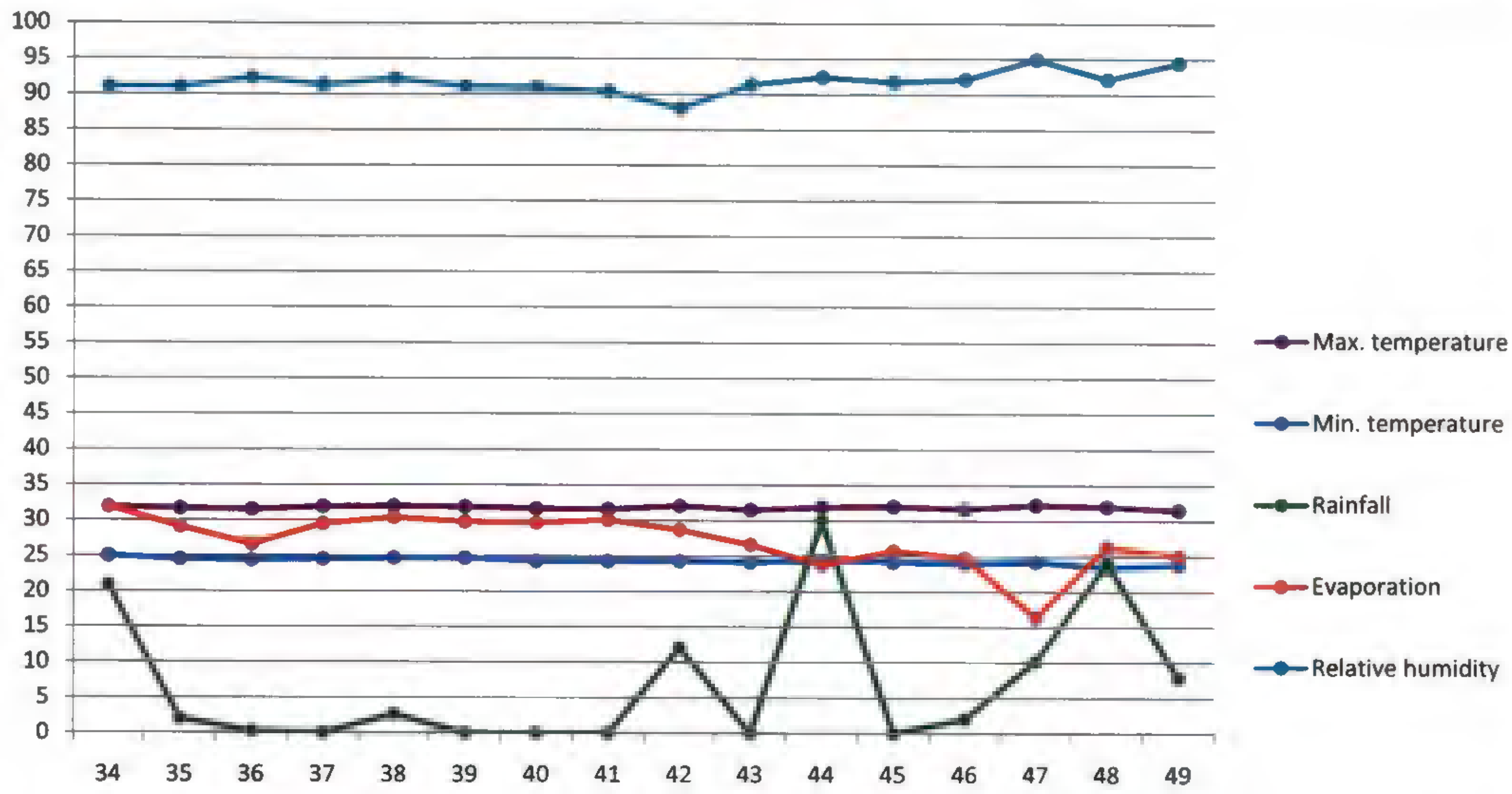


Fig .1 Weather data during cropping period (August - December, 2016)

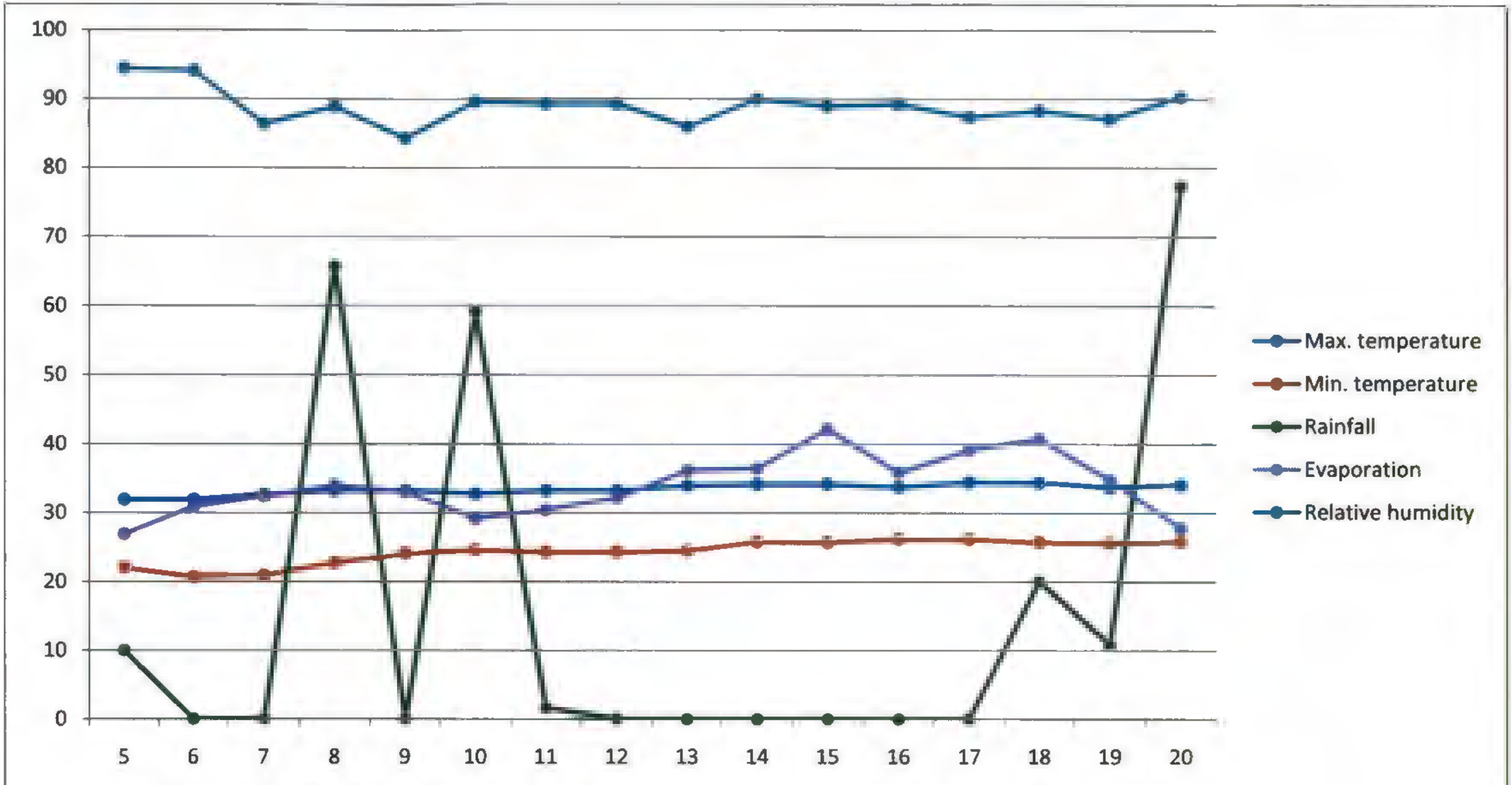


Fig. 2 Weather parameters during cropping period (January - May, 2017)

3.2 MATERIALS

3.2.1 Crop and Variety

Yardlong bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt) variety *Githika* , released from the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani was selected for the study. The characters of the variety are given in Table 1.

Table1. Characters of yardlong bean variety *Githika*

Characters	**Description**
Parentage	Selection from Vellayani Local
Growth habit	Indeterminate, climbing
Immature pod colour	Light green
Days to 50% flowering	40-43 days
Productivity	26-28 t ha^{-1}
Duration	105-110 days

3.2.2 Seeds

Breeder seeds of yardlong bean variety *Githika*, obtained from the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani was used for the study.

3.2.3 Containers

UV stabilized growbags of size 39 cm x 26 cm and capable of holding 15 kg potting mixture were used for experiment I and II.

3.2.4 Growth media

Growth media used was a combination of soil, sand, coir pith and farmyard manure (FYM) in various proportions according to the treatments.

3.2.5 Manures

The organic manure source used for potting mixture preparation was well decomposed FYM (1.5% N, 0.72% P_2O_5, 0.31% K_2O). Groundnut cake (5.786% N), fermented groundnut cake (4.665% N), bone meal (20% P_2O_5) and wood ash (2% K_2O) were used as nutrient sources for nitrogen, phosphorus and potassium respectively. Lime and neem cake each at 10 g $growbag^{-1}$ was applied uniformly to all growbags before transplanting.

3.2.6 Trellis system

A trellis system for trailing the plants was erected by fixing two poles on either sides of the row and these two poles are connected by three rows of kera rope as presented in Plate 1.

3.2.7 Pandal system

Conventional pandal was erected at a height of 2 m using wooden poles and top portion was tied with kera rope in a criss cross pattern as presented in Plate 2.

3.2.8 Trailing stand

A trailing stand (Plate 3) was locally fabricated using 30 x 30 cm galvanised weld mesh having a height of 210 cm. The circumference of the stand was 180 cm and the interval between two mesh was 30 cm.

3.3 METHODS

3.3.1 EXPERIMENT I

Growth media evaluation and nutrient studies for container grown yardlong bean

3.3.1.1 *Design and Layout*

Design : Completely Randomised Design (CRD)

Plate 1. Trellis sytem

Plate 2. Pandal system

Plate 3. General view of experiement I

Plate 4. Trailing stand

Treatments : 18

Replications : 3

3.3.1.2 Treatments

Treatments included three growth media, three levels of nutrient and two time of application.

Growth media (M) - 3

M_1: soil: sand: FYM (1:1:1)

M_2: soil: sand: coirpith: FYM (1:0.75:0.25:1)

M_3: soil: sand: coirpith: FYM (1:0.50:0.50:1)

Nutrient levels (N) - 3

N_1: 100% recommended dose of NPK

N_2: 150% recommended dose of NPK

N_3: 200% recommended dose of NPK

Time of application (T) -2

T_1: Full NPK as basal

T_2: Half N, full P & K as basal+ half N as fermented groundnut cake at fortnightly interval up to 50% flowering in two splits (30 and 45 DAS)

The nutrient recommendation for yardlong bean is N: P_2O_5: K_2O @ 30:30:20 kg ha^{-1} as per the Package of Practices Recommendations Crops (KAU, 2011). The nutrient schedule is followed as per the Package of Practices Recommendations Crops.

Treatment combinations

$m_1n_1t_1$ $m_2n_1t_1$ $m_3n_1t_1$

$m_1n_1t_2$ $m_2n_1t_2$ $m_3n_1t_2$

$m_1n_2t_1$ $m_2n_2t_1$ $m_3n_2t_1$

$m_1n_2t_2$ $m_2n_2t_2$ $m_3n_2t_2$

$m_1n_3t_1$ $m_2n_3t_1$ $m_3n_3t_1$

$m_1n_3t_2$ $m_2n_3t_2$ $m_3n_3t_2$

The chemical characteristics of different growth media are summarized in Table 2.

Table 2. Chemical characteristics of different growth media

Particulars	M_1	M_2	M_3	Method used
Organic C (%)	3.34	3.73	3.8	Walkley and Black rapid titration method (Jackson, 1973)
Available N (%)	0.075	0.079	0.085	Alkaline $KMnO_4$ method (Subbiah and Asija, 1956)
Available P (%)	0.04	0.039	0.042	Bray's colorimetric method (Jackson, 1973)
Available K (%)	0.015	0.019	0.018	Ammonium acetate method (Jackson, 1973)
Soil reaction (pH)	7.35	6.98	7.13	pH meter with glass electrode (Jackson, 1973)
Electrical conductivity ($dS\ m^{-1}$)	1.3	1.6	1.3	Digital conductivity meter

3.3.1.3 Crop management

All cultural practices were carried out as per the Package of Practices Recommendations Crops (KAU, 2011).

3.3.1.3.1 Land preparation and Layout

The experimental site was cleared and black polythene mulch sheet was spread on the site. UV stabilized growbags were filled with potting media prepared as per the treatments. Uniform quantity of potting media (9kg) was taken in each grow bag. The growbags were placed at a spacing of 1.5 m between rows and 0.5 m between plants. Trellis system was erected for trailing the crop. The layout plan of the experiment is given in Fig. 3.

3.3.1.3.2 Sowing and establishment

Seeds were sown in protrays filled with a mixture of vermiculite and perlite and the seedlings were transplanted one week after emergence @ one seedling growbag^{-1}.

3.3.1.3.4 Application of manures

The nutrient requirement for each plant in a growbag kept at a spacing of 1.5 x 0.45 m was calculated on the basis of plant population. The manures were applied as per the nutrient levels and time of application (details given in Table 3). Uniform mulching with dry leaves (100 g) was given to all grow bags from 25 DAS.

3.3.1.3.5 After cultivation

The weeds were removed from the growbags by hand weeding as and when they appeared and the plants were irrigated uniformly.

3.3.1.3.6 Plant protection

As a prophylatic measure, application of Oxuron against pest was done at weekly intervals. Bordeaux mixture was given against Anthracnose at 30 DAS.

$m_3n_1t_2$	$m_3n_3t_2$	$m_3n_1t_1$	$m_1n_1t_1$	$m_2n_2t_2$	$m_3n_2t_1$	$m_2n_1t_1$	$m_3n_1t_1$	$m_2n_1t_2$
$m_2n_2t_2$	$m_2n_2t_1$	$m_1n_3t_2$	$m_3n_1t_2$	$m_2n_1t_1$	$m_2n_3t_2$	$m_1n_3t_1$	$m_3n_2t_2$	$m_3n_1t_1$
$m_3n_1t_1$	$m_2n_1t_2$	$m_3n_3t_1$	$m_2n_2t_2$	$m_3n_3t_1$	$m_2n_1t_2$	$m_1n_1t_2$	$m_3n_1t_2$	$m_1n_1t_1$
$m_2n_1t_2$	$m_3n_1t_1$	$m_2n_3t_1$	$m_3n_3t_1$	$m_3n_1t_2$	$m_3n_1t_1$	$m_2n_2t_2$	$m_1n_3t_1$	$m_2n_3t_2$
$m_3n_2t_1$	$m_2n_1t_1$	$m_1n_1t_2$	$m_3n_1t_1$	$m_3n_3t_2$	$m_1n_1t_1$	$m_2n_3t_1$	$m_2n_1t_2$	$m_3n_2t_1$
$m_1n_3t_1$	$m_3n_3t_1$	$m_1n_3t_1$	$m_3n_2t_1$	$m_1n_2t_2$	$m_1n_3t_1$	$m_3n_3t_2$	$m_1n_1t_2$	$m_1n_2t_1$
$m_3n_3t_2$	$m_2n_3t_2$	$m_3n_2t_2$	$m_1n_3t_1$	$m_1n_3t_2$	$m_1n_2t_1$	$m_3n_2t_2$	$m_1n_1t_1$	$m_2n_1t_1$
$m_1n_2t_2$	$m_1n_3t_1$	$m_3n_2t_1$	$m_1n_2t_1$	$m_2n_2t_1$	$m_3n_3t_1$	$m_3n_1t_2$	$m_3n_3t_1$	$m_3n_3t_2$
$m_2n_3t_1$	$m_1n_2t_1$	$m_3n_3t_2$	$m_2n_1t_1$	$m_3n_2t_1$	$m_3n_2t_2$	$m_1n_3t_2$	$m_2n_3t_1$	$m_1n_3t_1$
$m_3n_2t_2$	$m_2n_2t_2$	$m_1n_2t_1$	$m_3n_2t_2$	$m_2n_1t_2$	$m_2n_1t_1$	$m_1n_2t_1$	$m_3n_3t_2$	$m_2n_2t_2$
$m_3n_3t_1$	$m_1n_1t_2$	$m_2n_1t_2$	$m_3n_3t_2$	$m_2n_3t_1$	$m_2n_2t_2$	$m_3n_3t_1$	$m_2n_2t_1$	$m_1n_2t_2$
$m_1n_1t_2$	$m_3n_2t_1$	$m_2n_2t_2$	$m_2n_3t_2$	$m_3n_2t_2$	$m_3n_3t_2$	$m_1n_1t_1$	$m_1n_3t_2$	$m_1n_1t_2$
$m_1n_3t_2$	$m_2n_3t_1$	$m_1n_2t_2$	$m_1n_3t_2$	$m_3n_1t_1$	$m_1n_2t_2$	$m_2n_3t_2$	$m_1n_2t_1$	$m_3n_2t_2$
$m_2n_3t_2$	$m_1n_1t_1$	$m_2n_2t_1$	$m_2n_1t_2$	$m_1n_1t_2$	$m_2n_3t_1$	$m_2n_2t_1$	$m_2n_1t_1$	$m_3n_1t_2$
$m_2n_2t_1$	$m_1n_3t_2$	$m_2n_1t_1$	$m_1n_1t_2$	$m_1n_2t_1$	$m_2n_2t_1$	$m_1n_2t_2$	$m_3n_2t_1$	$m_2n_3t_1$
$m_1n_2t_1$	m_3n_1t	$m_2n_3t_2$	$m_1n_2t_2$	$m_1n_1t_1$	$m_1n_1t_2$	$m_3n_1t_1$	$m_1n_2t_2$	$m_2n_2t_1$
$m_1n_1t_1$	$m_3n_2t_2$	$m_3n_1t_2$	$m_2n_2t_1$	$m_1n_3t_1$	$m_1n_3t_2$	$m_2n_1t_2$	$m_2n_3t_2$	$m_3n_3t_1$
$m_2n_1t_1$	$m_1n_2t_2$	$m_1n_1t_1$	$m_2n_3t_1$	$m_2n_3t_2$	$m_3n_1t_2$	$m_3n_2t_1$	$m_2n_2t_2$	$m_1n_3t_2$

Fig. 3 Layout of experiment I

Table 3. Growth media, nutrient levels and time of application of manures as per treatments

Sl No	Treatments	Growth media (9 kg bag^{-1})	Nutrient levels (g growbag^{-1})			Time of application
			N (groundnut cake)	P_2O_5 (bone meal)	K_2O (wood ash)	
1	$m_1n_1t_1$	soil: sand: FYM (1:1:1)	40	10	70	full NPK as basal
2	$m_1n_1t_2$	soil: sand: FYM (1:1:1)	40	10	70	½ N + full P & K as basal+ ½ N at fortnightly intervals
3	$m_1n_2t_1$	soil: sand: FYM (1:1:1)	60	15	105	full NPK as basal
4	$m_1n_2t_2$	soil: sand: FYM (1:1:1)	60	15	105	½ N + full P & K as basal+ ½ N at fortnightly intervals
5	$m_1n_3t_1$	soil: sand: FYM (1:1:1)	80	20	140	full NPK as basal
6	$m_1n_3t_2$	soil: sand: FYM (1:1:1)	80	20	140	½ N + full P & K as basal+ ½ N at fortnightly intervals
7	$m_2n_1t_1$	soil: sand: coirpith: FYM (1:0.75:0.25:1)	40	10	70	full NPK as basal
8	$m_2n_1t_2$	soil: sand: coirpith: FYM (1:0.75:0.25:1)	40	10	70	½ N + full P & K as basal+ ½ N at fortnightly intervals
9	$m_2n_2t_1$	soil: sand: coirpith: FYM (1:0.75:0.25:1)	60	15	105	full NPK as basal
10	$m_2n_2t_2$	soil: sand: coirpith: FYM (1:0.75:0.25:1)	60	15	105	½ N + full P & K as basal+ ½ N at fortnightly intervals

Table 3. Growth media, nutrient levels and time of application of manures as per treatments (continued)

11	$m_2n_3t_1$	soil: sand: coirpith: FYM (1:0.75:0.25:1)	80	20	140	full NPK as basal
12	$m_2n_3t_2$	soil: sand: coirpith: FYM (1:0.75:0.25:1)	80	20	140	½ N + full P & K as basal+ ½ N at fortnightly intervals
13	$m_3n_1t_1$	soil: sand: coirpith: FYM (1:0.5:0.5:1)	40	10	70	full NPK as basal
14	$m_3n_1t_2$	soil: sand: coirpith: FYM (1:0.5:0.5:1)	40	10	70	½ N + full P & K as basal+ ½ N at fortnightly intervals
15	$m_3n_2t_1$	soil: sand: coirpith: FYM (1:0.5:0.5:1)	60	15	105	full NPK as basal
16	$m_3n_2t_2$	soil: sand: coirpith: FYM (1:0.5:0.5:1)	60	15	105	½ N + full P & K as basal+ ½ N at fortnightly intervals
17	$m_3n_3t_1$	soil: sand: coirpith: FYM (1:0.5:0.5:1)	80	20	140	full NPK as basal
18	$m_3n_3t_2$	soil: sand: coirpith: FYM (1:0.5:0.5:1)	80	20	140	½ N + full P & K as basal+ ½ N at fortnightly intervals

3.3.1.3.7 Harvesting

Harvesting commenced from 47 DAS. Subsequent harvests of green pods were done on alternate days from all the treatments and fresh weight was recorded separately.

3.3.2 EXPERIMENT II

Studies on trailing pattern of yardlong bean under various irrigation frequency

3.3.2.1 *Design and Layout*

Design : Completely Randomised Design (CRD)

Treatments : 6

Replications : 3

3.3.2.2 Treatment details

The best potting medium and the best nutrient schedule from experiment I was selected for experiment II. Soil, sand, coirpith and FYM in 1: 0.5: 0.5: 1 (M_3) was identified as the best medium. Best nutrient schedule identified was 100% recommended dose of NPK (N_1) where half N, full P & K were given as basal and half N as fermented groundnut cake at fortnightly interval up to 50% flowering (T_2). The available NPK content and organic carbon content of the best medium were 0.083%, 0.041%, 0.017% and 3.76% respectively.

Treatments included three trailing methods and two levels of irrigation frequency.

Trailing methods (R) - 3

R_1: pandal system

R_2: trellis system

R_3: trailing stand

Irrigation (I) - 2

I_1: daily irrigation

I_2: irrigation when plant is at temporary wilting stage

Treatment combinations

$r_1 i_1$ $r_1 i_2$

$r_2 i_1$ $r_2 i_2$

$r_3 i_1$ $r_3 i_2$

3.3.2.3 Crop management

Same as 3.3.1.3

3.3.2.3.1 Land preparation and Layout

Same as 3.3.1.3.1

3.3.2.3.2 Sowing

Same as 3.3.1.3.2

3.3.2.3.4 Application of manures

Recommended dose of NPK (N_1) where half N (20 g groundnut cake), full P (10 g bone meal) & K (70 g wood ash) were uniformly applied as basal and half N (20 g as fermented groundnut cake) at 30 and 45 DAS up to 50% flowering (T_2). Neem cake was applied @ 10g plant^{-1}uniformly to all growbags as basal.

3.3.2.3.5 After cultivation

Same as 3.3.1.3.5

$r_i i_1$	$r_i i_2$	$r_i i_1$	$r_i i_2$	$r_i i_1$	$r_i i_2$	$r_i i_1$	$r_i i_2$	$r_i i_1$
$r_i i_2$	$r_i i_1$	$r_i i_2$	$r_i i_1$	$r_i i_2$	$r_i i_1$	$r_i i_2$	$r_i i_1$	$r_i i_2$
$r_2 i_1$	$r_2 i_2$	$r_2 i_1$	$r_2 i_2$	$r_2 i_1$	$r_2 i_2$	$r_2 i_1$	$r_2 i_2$	$r_2 i_1$
$r_2 i_2$	$r_2 i_1$	$r_2 i_2$	$r_2 i_1$	$r_2 i_2$	$r_2 i_1$	$r_2 i_2$	$r_2 i_1$	$r_2 i_2$
$r_3 i_1$	$r_3 i_2$	$r_3 i_1$	$r_3 i_2$	$r_3 i_1$	$r_3 i_2$	$r_3 i_1$	$r_3 i_2$	$r_3 i_1$
$r_3 i_2$	$r_3 i_1$	$r_3 i_2$	$r_3 i_1$	$r_3 i_2$	$r_3 i_1$	$r_3 i_2$	$r_3 i_1$	$r_3 i_2$

Fig. 4 Layout of experiment II

3.3.2.3.6 Irrigation

The irrigation study started at 25 DAS. The soil moisture content at field capacity, temporary wilting and permanent wilting point were found out. Moisture of the media was brought to field capacity in all growbags. The quantity of water used for daily irrigation was one litre, for bringing the moisture content to field capacity for irrigation on daily basis. In treatment with irrigation when plant shows temporary wilting, the growbags were irrigated on alternate days and quantity of water for irrigation was calculated based on the core method and was found to be 2 L. The methods used to find out moisture content of moisture constants are given in Table 4. Water requirement for irrigation on daily basis and at temporary wilting stage was found to be the same.

Table 4. Methods used to find out moisture contents

Moisture constant	Moisture content (%)	Method used
Field capacity	22	Pressure plate apparatus (Hillel, 1971)
Permanent wilting point	8	
Temporary wilting point	10	Core method (Gupta and Dakshinamoorthi, 1980)

3.3.2.3.7 Plant protection

Prophylatic application of Oxuron was done against pest incidence at weekly intervals.

3.3.2.3.8 Harvesting

Same as in 3.3.1.3.7

3.4 OBSERVATIONS (For experiment I and II)

3.4.1 Growth attributes

The observations were recorded from all the three observational plants from each treatment and the mean values were worked out.

3.4.1.1 Primary branches plant^{-1} at 30 and 45 DAS

The number of branches arising from the main stem at an interval 30 and 45 DAS were counted and the mean was worked out.

3.4.1.2 .Functional leaves plant^{-1} at 30 and 45 DAS

The mean number of functional leaves plant^{-1} from the observational plants was recorded at 30 and 45 DAS.

3.4.1.3 Crop duration

The duration of the crop from sowing up to the end of the cropping period i.e., till vegetable yield came below economic level was recorded and expressed in days.

3.4.2 Yield attributes and yield

3.4.2.1 Days for 50 per cent flowering

The date for flowering of 50 per cent of the observational plants in growbags was recorded and the period was expressed as number of days.

3.4.2.2 Number of pods plant^{-1}

The pods obtained from each of the observational plants were counted and the average was worked out.

3.4.2.3 Pod yield plant^{-1}

The pods obtained from the observational plants were weighed separately and averages were worked out in g.

3.4.2.4 Pod yield harvest^{-1}

The pod yield obtained from each treatment was recorded separately and tabulated harvest wise and expressed in g.

3.4.2.5 Total dry matter yield plant^{-1}

At final harvest, the observational plants were uprooted carefully without damaging the roots, dried under shade separately and oven dried at $80 \pm 5^{\circ}$ C until two consecutive weights were same . The final weight were recorded and expressed in g.

3.4.2.6 Number of pickings

Number of pickings of immature green pods from each treatment during the total crop period was recorded.

3.4.2.7 Harvest Index

Harvest index was calculated using the formula:

$$\text{Harvest index} = \frac{\text{Economic yield (g plant}^{-1})}{\text{Biological yield (g plant}^{-1})} \quad \text{(Donald,1962)}$$

3.4.3 Root studies at final harvest

3.4.3.1 Root weight

After the final harvest, the observational plants were uprooted and the fresh weight of the roots were recorded and expressed in g.

3.4.3.2 Root volume

The root volume was measured by water displacement method in a graduated cylinder and the volume expressed in cm^3.

3.4.3.3 Root shoot ratio

After the final harvest, dry weight of shoots and roots were recorded and expressed as ratio.

3.4.4 Pest and disease incidence

Major pests and diseases observed during the crop period was recorded.

3.4.5 Chemical analysis

3.4.5.1 Plant analysis (NPK content and uptake at harvest)

After the final harvest, the plant samples were analyzed for major nutrients. The nitrogen content in plant sample was estimated by the modified micro kjeldhal method (Jackson, 1973). The phosphorus content in plant samples was determined colorimetrically using vanadomolybdo phosphoric yellow colour method (Jackson, 1973) and potassium content was determined by flame photometry method (Jackson, 1973). The nutrient uptake was calculated as the product of the respective nutrient content in percentage and total dry matter yield $plant^{-1}$ and expressed as g $plant^{-1}$.

3.4.5.2 Growth media analysis before and after the experiment

3.4.5.2.1 Organic carbon

The estimation of organic carbon was done before and after the experiment using Walkley and Black rapid titration method (Jackson, 1973) and expressed as percentage.

3.4.5.2.2 Available NPK

The growth media were analyzed for available NPK before and after the experiment. Growth media samples collected from each of the treatment were dried, powdered and sieved through 2 mm sieve and analysed for N, P and K. Available N content was determined by Alkaline potassium permanganate method (Subbiah and Asija, 1956), available P_2O_5 content by Bray's colorimetric method (Jackson, 1973) and available K_2O by Ammonium acetate method (Jackson, 1973).

3.4.5.3 Characterization of best growth medium identified from experiment I

3.4.5.3.1 pH

The pH of the best growth medium was estimated using pH meter with glass electrode (Jackson, 1973).

3.4.5.3.2 Electrical Conductivity (EC)

The electrical conductivity of the best growth medium was estimated using conductivity meter and expressed as dSm^{-1}.

3.4.5.3.3 Organic Carbon

Same as 3.4.5.2.1

3.4.5.3.4 Available NPK

Same as 3.4.5.2.2

3.4.6 Economic analysis

The economics of cultivation of the crop was worked out and the net income and benefit cost ratio (BCR) were calculated as follows

3.4.6.1 Net income

The net income was calculated by subtracting cost of cultivation from gross income and expressed in ₹ bag^{-1}

3.4.6.2 Benefit: Cost ratio (BCR)

BCR was worked out as the ratio of gross income to the cost of cultivation.

$$\text{B: C ratio} = \frac{\text{Gross income (₹bag}^{-1}\text{)}}{\text{Cost of cultivation (₹bag}^{-1}\text{)}}$$

3.4.7 Statistical analysis

The data generated from the experiment were statistically analysed using Analysis of Variance technique for Completely Randomised Design (CRD) (Panse and Sukhatme, 1985) and significance was tested by 'F' test (Snedecor and Cochran, 1975). The data after statistical analysis were used for interpretation.

Results

4. RESULTS

The investigation entitlted “Agro techniques for container grown yardlong bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)” was undertaken at College of Agriculture, Vellayani during the period 2015-17 to identify an ideal growth medium; to standardise nutrient schedule; irrigation interval and trailing method so as to formulate an agronomic package for container grown yardlong bean.

The study was conducted as two separate experiments in containers. The experimental data were analyzed statistically and the results are presented below.

4.1 GROWTH MEDIA EVALUATION AND NUTRIENT STUDIES FOR CONTAINER GROWN YARDLONG BEAN

4.1.1 Growth attributes

4.1.1.1 Number of Primary Branches plant^{-1} at 30 and 45 DAS

The data on number of primary branches plant^{-1} as influenced by treatments are presented in Table 5 a, 5 b and 5 c.

The different growth media had significant influence on number of primary branches plant^{-1} at 30 and 45 DAS, while different nutrient levels and time of application had no influence on it. At 30 DAS, growth media M_3 {soil: sand: coirpith: FYM in 1: 0.5: 0.5: 1} registered higher number of primary branches plant^{-1} (3.02) and was on par with M_2 {soil: sand: coirpith: FYM in 1:0.75:0.25:1} (2.97). At 45 DAS, the same media produced higher number of primary branches plant^{-1} (4.19) and was on par with M_2 (4.11).

The interaction effects were significant at 30 DAS where M x N, N x T, M x T and M x N x T combinations differed with treatments. Among the M x N interactions, m_2n_1 recorded higher number of primary branches plant^{-1} (3.5) which was on par with m_3n_3, m_3n_2 and m_1n_2. Regarding N x T combinations, n_3t_1 produced higher number of primary branches plant^{-1} (3.11) which was on par with

n_2t_1, n_2t_2, n_1t_1, n_1t_2. In the case of M x T interactions, m_2t_1 recorded the maximum number of primary branches plant^{-1} (3.33) which was on par with m_3t_1 and m_3t_2. Among the M x N x T interactions, $m_2n_3t_1$ recorded higher number of primary branches plant^{-1} (3.66) which was on par with $m_2n_1t_1$, $m_3n_2t_2$, $m_3n_3t_1$, $m_1n_2t_1$, $m_3n_3t_2$, $m_2n_1t_2$.

The interaction effects were significant at 45 DAS where M x N and M x T interactions differed among treatments. Among the M x N interactions, m_3n_3 recorded higher number of primary branches plant^{-1} (4.66) which was on par with m_3n_1, m_2n_2. In the case of M x T interactions, m_3t_1 recorded the maximum number of primary branches plant^{-1} (4.38) which was on par with m_2t_1 and m_3t_2. The three factor interaction could not influence number of primary branches plant^{-1}.

4.1.1.2 Functional Leaves plant^{-1} at 30 and 45 DAS

Observations on number of functional leaves plant^{-1} at 30 and 45 DAS as influenced by treatments are presented in Table 5 a, 5 b, 5 c.

The different growth media had significant influence on functional leaves plant^{-1} at 30 and 45 DAS, however different nutrient levels, time of application and their interactions did not exert any influence on functional leaves plant^{-1} at 30 and 45 DAS.

At 30 DAS, growth media M_3 {soil: sand: coirpith: FYM in 1: 0.5: 0.5: 1} registered higher number of functional leaves plant^{-1} (20.64) which was on par with M_2 {soil: sand: coirpith: FYM in 1:0.75:0.25:1}. At 45 DAS, the same trend was observed in 30 DAS where M_3 recorded higher number of functional leaves plant^{-1} (59.25) which was on par with M_2 (56.42).

4.1.1.3 Crop duration

The data on crop duration as influenced by treatments are shown in Table 5 a, 5 b, 5 c. The results revealed that the growth media exerted a favourable influence on duration of the crop and time of application had no influence on it.

Table 5 a. Effect of growth media, nutrient levels and time of application on number of primary branches plant^{-1}, number of functional leaves plant^{-1}, crop duration

	Number of primary branches plant^{-1}		Number of functional leaves plant^{-1}		Crop duration (days)
Treatments	30DAS	45DAS	30DAS	45DAS	
Growth media					
M_1	2.52	3.66	16.39	55.03	103.75
M_2	2.97	4.11	20.22	56.42	104.30
M_3	3.02	4.19	20.64	59.25	104.34
SEm(±)	0.11	0.11	0.82	1.03	0.13
CD (0.05)	0.325	0.312	2.342	2.957	0.37
Nutrient levels					
N_1	2.80	3.88	19.86	58.00	104.00
N_2	3.00	3.94	18.75	56.97	104.15
N_3	2.72	4.13	18.64	55.73	104.23
SEm(±)	0.11	0.11	0.82	1.03	0.13
CD (0.05)	NS	NS	NS	NS	NS
Time of application					
T_1	2.96	4.05	18.54	56.54	104.02
T_2	2.72	3.92	19.63	57.26	104.24
SEm(±)	0.09	0.09	0.67	0.84	0.10
CD (0.05)	NS	NS	NS	NS	NS

Table 5 b. Interaction effect of growth media, nutrient levels and time of application on number of primary branches plant^{-1}, number of functional leaves plant^{-1}, crop duration

	Number of primary branches plant^{-1}		Number of functional leaves plant^{-1}		Crop duration (days)
Treatments	30DAS	45DAS	30DAS	45DAS	
M x N					
m_1n_1	2.25	3.50	19.17	55.75	103.92
m_1n_2	3.00	3.66	14.75	55.25	103.09
m_1n_3	2.33	3.83	15.25	54.10	104.23
m_2n_1	3.50	4.00	20.08	56.92	104.05
m_2n_2	2.83	4.41	20.25	56.67	104.73
m_2n_3	2.58	3.91	20.33	55.67	104.12
m_3n_1	2.66	4.16	20.33	61.33	104.03
m_3n_2	3.16	3.75	21.25	59.00	104.64
m_3n_3	3.25	4.66	20.33	57.42	104.34
SEm(±)	0.20	0.19	1.41	1.78	0.22
CD (0.05)	0.563	0.540	NS	NS	0.641
N x T					
n_1t_1	2.77	4.11	19.61	59.17	103.98
n_1t_2	2.83	3.66	20.11	59.33	104.02
n_2t_1	3.00	3.83	18.06	56.94	103.90
n_2t_2	3.00	4.05	19.44	57.00	104.41
n_3t_1	3.11	4.22	17.94	55.57	104.17
n_3t_2	2.33	4.05	19.33	55.89	104.29
SEm(±)	0.16	0.15	1.15	1.48	0.18
CD (0.05)	0.460	NS	NS	NS	NS
M x T					
m_1t_1	2.50	3.44	15.78	54.51	103.63
m_1t_2	2.55	3.88	17.00	55.56	103.86
m_2t_1	3.33	4.33	19.67	55.94	104.27
m_2t_2	2.61	3.88	20.78	56.89	104.39
m_3t_1	3.05	4.38	20.16	59.17	104.21
m_3t_2	3.00	4.00	21.11	59.33	104.47
SEm(±)	0.16	0.15	1.15	1.48	0.18
CD (0.05)	0.460	0.441	NS	NS	NS

Table 5 c. Interaction effect of M x N x T on number of primary branches plant^{-1}, number of functional leaves plant^{-1}, crop duration

	Number of primary branches plant^{-1}		Number of functional leaves plant^{-1}		Crop duration (days)
Treatments	30DAS	45DAS	30DAS	45DAS	
M x N x T					
$m_1n_1t_1$	2.00	3.66	18.83	54.00	103.91
$m_1n_1t_2$	2.50	3.33	19.50	57.50	103.93
$m_1n_2t_1$	3.33	3.33	13.50	55.50	102.70
$m_1n_2t_2$	2.66	4.00	16.00	55.00	103.47
$m_1n_3t_1$	2.16	3.33	15.00	54.03	104.28
$m_1n_3t_2$	2.50	4.33	15.50	54.17	104.18
$m_2n_1t_1$	3.50	4.16	19.83	55.50	104.11
$m_2n_1t_2$	3.50	3.83	20.33	58.33	103.99
$m_2n_2t_1$	2.83	4.50	19.67	57.17	104.51
$m_2n_2t_2$	2.83	4.33	20.83	56.17	104.95
$m_2n_3t_1$	3.66	4.33	19.50	57.17	104.03
$m_2n_3t_2$	1.50	3.50	21.17	56.17	104.22
$m_3n_1t_1$	2.83	4.50	20.17	61.83	103.93
$m_3n_1t_2$	2.50	3.83	20.50	60.83	104.13
$m_3n_2t_1$	2.83	3.66	21.00	58.17	104.49
$m_3n_2t_2$	3.50	3.83	21.50	59.83	104.79
$m_3n_3t_1$	3.50	5.00	19.33	57.50	104.21
$m_3n_3t_2$	3.00	4.33	21.33	57.33	104.47
SEm(±)	0.28	0.26	2.00	2.52	0.32
CD (0.05)	0.796	NS	NS	NS	NS

Among the two factor interactions, m_2n_2 recorded longer duration (104.73 days) and was on par with m_3n_2, m_3n_3, m_1n_3, m_2n_3, m_3n_1 and m_2n_3, while other two and three factor interactions were found non significant.

4.1.2 Yield attributes and yield

4.1.2.1 Days For 50 Per cent flowering

The data on days for 50 per cent flowering as influenced by treatments are depicted in Table 6 a, 6 b, 6 c.

Different growth media had significant influence on number of days for 50 per cent flowering. M_2 {soil: sand: coirpith: FYM mixed in the ratio 1: 0.75: 0.25: 1} recorded earlier flowering (41.03 days) and was on par with M_1 {soil: sand: FYM in 1: 1: 1} (41.05 days).

The different nutrient levels failed to influence days for 50 per cent flowering while time of application had significant influence on it. Between the time of application, T_1 (full NPK as basal) recorded the lower days for 50 per cent flowering (40.52 days) compared to T_2.

All the two factor interactions remarkably influenced days for 50 per cent flowering. In the case of M x N interactions, m_2n_2 recorded earlier flowering and was on par with m_3n_3 while n_2t_1 recorded earlier flowering among N x T interactions and m_2t_1 recorded the least days to attain 50 % flowering among M x T interactions.

The combined interactions of the three factors exerted a significant influence on days for 50 per cent flowering where $m_2n_2t_2$ recorded lower days for 50 % flowering while $m_3n_1t_2$ recorded delayed flowering.

Table 6 a. Effect of growth media, nutrient levels and time of application on days for 50 per cent flowering, number of pods plant^{-1} and pod plant^{-1}

Treatments	Days for 50 per cent flowering	Number of pods plant^{-1}	Pod yield plant^{-1}
Growth media			
M_1	41.05	47.73	845.15
M_2	41.03	48.11	838.02
M_3	41.25	48.51	862.74
SEm(±)	0.06	0.21	4.50
CD (0.05)	0.162	0.591	12.906
Nutrient levels			
N_1	41.15	48.50	849.49
N_2	41.11	48.31	848.59
N_3	41.11	47.54	847.82
SEm(±)	0.06	0.21	4.50
CD (0.05)	NS	0.591	NS
Time of application			
T_1	40.52	45.48	797.70
T_2	41.72	50.75	899.57
SEm(±)	0.05	0.17	3.67
CD (0.05)	0.132	0.483	22.355

Table 6 b. Interaction effect of growth media, nutrient levels and time of application on days for 50 per cent flowering, number of pods plant^{-1} and pod yield plant^{-1}

Treatments	Days to 50 per cent flowering	Number of pods plant^{-1}	Pod yield plant^{-1}
M x N			
m_1n_1	41.17	49.25	840.72
m_1n_2	41.08	47.62	848.08
m_1n_3	40.89	46.33	846.65
m_2n_1	40.96	48.12	832.85
m_2n_2	40.62	50.25	804.60
m_2n_3	41.52	45.95	876.60
m_3n_1	41.31	48.12	874.92
m_3n_2	41.61	47.08	893.10
m_3n_3	40.91	50.33	820.22
SEm(±)	0.10	0.36	7.79
CD (0.05)	0.280	1.024	NS
N x T			
n_1t_1	40.51	46.08	802.18
n_1t_2	41.78	50.91	896.81
n_2t_1	40.42	46.22	790.06
n_2t_2	41.79	50.41	907.13
n_3t_1	40.63	44.13	800.88
n_3t_2	41.58	50.94	894.77
SEm(±)	0.08	0.29	6.36
CD (0.05)	0.229	0.836	NS
M x T			
m_1t_1	40.49	45.11	793.98
m_1t_2	41.61	50.36	896.32
m_2t_1	40.48	45.66	796.44
m_2t_2	41.58	50.55	879.59
m_3t_1	40.58	45.66	802.69
m_3t_2	41.97	51.36	922.80
SEm(±)	0.08	0.29	6.36
CD (0.05)	NS	NS	18.253

Table 6 c. Interaction effect of M x N x T on days for 50 per cent flowering, number of pods plant^{-1} and pod yield plant^{-1}

Treatments	Days to 50 per cent flowering	Number of pods plant^{-1}	Pod yield plant^{-1}
M x N x T			
$m_1n_1t_1$	40.71	48.00	816.10
$m_1n_1t_2$	41.64	50.50	865.33
$m_1n_2t_1$	40.29	45.50	769.67
$m_1n_2t_2$	41.88	49.75	926.50
$m_1n_3t_1$	40.48	41.83	796.17
$m_1n_3t_2$	41.31	50.83	897.13
$m_2n_1t_1$	40.65	46.75	814.37
$m_2n_1t_2$	41.27	49.50	851.33
$m_2n_2t_1$	39.74	49.00	751.17
$m_2n_2t_2$	41.51	51.50	858.03
$m_2n_3t_1$	41.06	41.25	823.80
$m_2n_3t_2$	41.97	50.66	929.40
$m_3n_1t_1$	40.17	43.50	776.07
$m_3n_1t_2$	42.44	51.33	973.77
$m_3n_2t_1$	41.22	44.16	849.33
$m_3n_2t_2$	42.00	52.75	936.87
$m_3n_3t_1$	40.34	49.33	782.67
$m_3n_3t_2$	41.47	50.00	857.77
SEm($\pm$)	0.14	0.51	11.02
CD (0.05)	0.396	1.448	31.614

4.1.2.2 Number of Pods Plant^{-1}

Observations on number of pods plant^{-1} are shown in Table 6 a, 6 b, 6 c.

The data revealed that different growth media, nutrient levels and time of application influenced number of pods produced plant^{-1}. M_3 {soil: sand: coirpith: FYM in the ratio 1: 0.5: 0.5: 1} registered higher number of pods (48.51) plant^{-1} and was on par with M_2 {soil: sand: coirpith: FYM in the ratio 1:0.75:0.25:1} (48.11). Regarding nutrient levels, application of 100 % recommended of nutrients (RDN) (N_1) registered higher number of pods plant^{-1} (48.50) and was on par with 200% RDN (N_2) (48.31). Between the time of application, T_2 (Half N, full P & K as basal+ half N as fermented groundnut cake at fortnightly interval up to 50% flowering) recorded more number of pods plant^{-1} (50.75) when compared to T_1.

The interaction effect M x N and N x T exerted profound influence on number of pods plant^{-1}. The combination m_3n_2 recorded higher number of pods plant^{-1} and was on par with m_2n_3. n_2t_2 recorded higher number of pods plant^{-1} and was on par with n_1t_2 and n_3t_2 among N x T interactions. The three factor interaction significantly influenced number of pods plant^{-1}, where $m_3n_2t_2$ recorded higher number of pods plant^{-1} which was on par with $m_3n_1t_2$ and $m_2n_2t_2$.

4.1.2.3 Pod Yield Plant^{-1}

The data on pod yield plant^{-1} depicted in Table 6 a, 6 b, 6 c. revealed that different growth media and time of application had profound influence on pod yield plant^{-1} while the different nutrient levels had no significant influence on it.

The growth medium M_3 {soil: sand: coirpith: FYM mixed in the ratio 1: 0.5: 0.5: 1 by weight} recorded significantly superior pod yield (862.75 g) plant^{-1}. Between the time of application, T_2 (Half N, full P & K as basal+ half N as fermented groundnut cake as fortnightly interval up to 50% flowering) recorded higher pod yield plant^{-1} (899.57 g) when compared to T_1 .

The two factor interaction of M and T influenced pod yield where, m_3t_2 registered higher pod yield plant^{-1} while other two factor interaction had no influence on pod yield. The higher order interaction between the main factors of M, N and T noticeably influenced pod yield plant^{-1} where $m_3n_1t_2$ recorded higher pod yield and was significantly superior over other treatment combinations.

4.1.2.4 Pod Yield Harvest^{-1}

The data on pod yield per harvest (Table 7) indicated that pod yield gradually increased as harvest progressed. The maximum pod yield was obtained around thirteenth harvest irrespective of the treatment combinations. After attaining maximum yield, the pod yield harvest $^{-1}$ slowly declined until final harvest.

4.1.2.5 Total Dry Matter Yield Plant^{-1}

Observations on total dry matter yield plant^{-1} are presented in Table 8 a, 8 b, 8 c.

Total dry matter yield plant^{-1} was remarkably influenced by different growth media, time of application, while different nutrient levels had no influence on it. The growth medium M_3 {soil: sand: coirpith: FYM mixed in the ratio 1: 0.5: 0.5: 1} recorded superior total dry matter yield plant^{-1} (490.46 g). Between the time of application, T_2 (Half N, full P & K as basal+ half N as fermented groundnut cake as fortnightly interval up to 50% flowering) recorded higher total dry matter yield plant^{-1} (511.39 g) when compared to T_1 .

The interaction effect of M and T influenced total dry matter yield plant^{-1} where m_3t_2 recorded higher total dry matter yield plant^{-1} over other combinations. In the case of M x N x T interactions, $m_3n_1t_2$ recorded significantly superior total dry matter yield plant^{-1} over other treatment combinations.

Table 7. Effect of growth media, nutrient levels and time of application on pod yield $harvest^{-1}$*

Treatments	Harvest number										
	1	2	3	4	5	6	7	8	9	10	11
$m_1n_1t_1$	16.2	17.5	19.5	23.5	26.3	32.3	36.57	44.6	48.3	54.1	59.3
$m_1n_1t_2$	17.2	21.3	26.44	29.3	34.24	38.1	46.13	48.5	53.2	59.2	67.3
$m_1n_2t_1$	12.3	15.2	19.3	21.5	25.4	35.1	46.4	50.3	57.6	65.4	73.5
$m_1n_2t_2$	18.5	20.5	27	31.3	39.2	44.6	52.2	57.4	63.3	67.2	71.2
$m_1n_3t_1$	16.2	19.3	21.4	26	31.2	37.4	40.6	52.5	56.2	60.3	63.4
$m_1n_3t_2$	16	18	24.2	29	33.6	39.3	44.2	49.2	57.3	65	71
$m_2n_1t_1$	17.2	19.52	22.5	35.3	44.2	47.1	49.5	53.18	58.4	62.1	68.5
$m_2n_1t_2$	14.5	19.2	25.1	30.2	37.3	44.3	51	55.4	60.3	63.5	70.2
$m_2n_2t_1$	12.3	14	19	23.1	29.33	37.25	49	58.2	68.1	76.2	77
$m_2n_2t_2$	13.6	18	25.2	31.2	38.5	46.3	50.2	55	61.2	64	67.3
$m_2n_3t_1$	10.5	16.3	21.2	24.2	33.3	42.3	47.5	52.2	55	59.2	62.5
$m_2n_3t_2$	19.7	21.5	29	32.4	41.6	46.2	53	58.4	64.3	69	71.3
$m_3n_1t_1$	16.26	18	21.3	34	45.3	46.3	50.2	55	57.4	61.3	68.3
$m_3n_1t_2$	19	26.4	33	35.2	42.2	47	52.4	57.3	60.3	70.2	72
$m_3n_2t_1$	16.32	24.2	29.13	32.3	45	49.4	55.23	60.22	64.2	69	72.2
$m_3n_2t_2$	20	28.5	31.3	38.2	46	53.2	61.2	65.3	68	75.2	77
$m_3n_3t_1$	14.5	17.3	20.2	28	39.3	47.4	50.2	55.3	65.2	68.3	75.3
$m_3n_3t_2$	11.5	22.2	27.5	33.5	46.2	48	56.3	61.2	66	70.2	73.2

*Data not statistically analysed

Table 7 continued. Effect of growth media, nutrient levels and time of application on pod yield harvest^{-1}*

Treatments	Harvest number									
	12	13	14	15	16	17	18	19	20	21
$m_1n_1t_1$	65.2	70.33	74.1	69.5	65.5	47.36	30.2	19.24	0	0
$m_1n_1t_2$	76.1	79.5	71.6	68.2	54.4	45.2	23.8	14.22	7.51	0
$m_1n_2t_1$	77.2	79.37	60.4	46.3	35.2	27.3	20.5	12.13	0	0
$m_1n_2t_2$	74.5	75.2	66.2	59.4	53.6	40.3	32.4	21.2	16.37	0
$m_1n_3t_1$	75.2	70.5	65.5	51.2	40.4	30	26.3	16.21	0	0
$m_1n_3t_2$	76.3	77.3	71.2	65.5	59.3	42.2	35.1	23.4	12.34	0
$m_2n_1t_1$	71.23	76.4	63.32	51.2	45.15	24.3	16.57	0	0	0
$m_2n_1t_2$	75.3	77	68.1	55.02	47.2	33.4	20.32	12	8.43	0
$m_2n_2t_1$	78.2	65.2	56.22	48.2	32.5	25.4	15.2	0	0	0
$m_2n_2t_2$	75	78.2	67	54.3	45	37.4	20	13.2	7.22	0
$m_2n_3t_1$	65	67.3	71.1	61.3	53.1	47.2	39.3	18.54	0	0
$m_2n_3t_2$	74.2	75.1	64.32	59	53.38	38.3	32	21.1	16.4	8.5
$m_3n_1t_1$	73.2	77.5	62.1	51.2	45.5	21.4	18.2	0	0	0
$m_3n_1t_2$	74.4	77	60.2	57.4	54.1	52.2	39.3	33.2	20.5	8.68
$m_3n_2t_1$	75	77.2	61	52	38.3	28	16.3	7.75	0	0
$m_3n_2t_2$	78.2	65	61.7	57.2	48.3	31.3	20.4	16	8.62	0
$m_3n_3t_1$	79.2	65.28	60.3	51	45.22	21.1	12.29	0	0	0
$m_3n_3t_2$	75	76.2	56.2	55.13	38.4	26.3	15	9.2	0	0

*Data not statistically analysed

Table 8 a. Effect of growth media, nutrient levels and time of application on total dry matter yield plant $^{-1}$, number of pickings and harvest index

Treatments	Total dry matter yield plant $^{-1}$ (g)	Number of pickings	Harvest index
Growth media			
M_1	480.46	19.05	0.387
M_2	476.40	19.08	0.386
M_3	490.46	19.27	0.394
SEm(±)	2.56	0.05	0.001
CD (0.05)	7.337	0.146	0.003
Nutrient levels			
N_1	482.93	19.14	0.392
N_2	482.41	19.16	0.388
N_3	481.97	19.10	0.388
SEm(±)	2.56	0.05	0.001
CD (0.05)	NS	NS	0.003
Time of application			
T_1	453.48	18.55	0.377
T_2	511.39	19.72	0.401
SEm(±)	2.09	0.04	0.001
CD (0.05)	5.991	0.119	0.003

Table 8 b. Interaction effect of growth media, nutrient levels and time of application on total dry matter yield plant $^{-1}$, number of pickings and harvest index

Treatments	Total dry matter yield plant $^{-1}$ (g)	Number of pickings	Harvest index
M x N			
m_1n_1	477.94	19.17	0.393
m_1n_2	482.12	19.08	0.382
m_1n_3	481.31	18.89	0.385
m_2n_1	473.46	18.96	0.387
m_2n_2	457.40	18.79	0.377
m_2n_3	498.34	19.51	0.395
m_3n_1	497.38	19.30	0.396
m_3n_2	507.72	19.61	0.404
m_3n_3	466.28	18.90	0.382
SEm(±)	4.43	0.09	0.002
CD (0.05)	12.708	0.253	0.006
N x T			
n_1t_1	456.03	18.51	0.380
n_1t_2	509.83	19.78	0.404
n_2t_1	449.14	18.52	0.372
n_2t_2	515.69	19.79	0.403
n_3t_1	455.29	18.62	0.380
n_3t_2	508.66	19.58	0.395
SEm(±)	3.62	0.07	0.002
CD (0.05)	NS	0.206	0.005
M x T			
m_1t_1	451.37	18.49	0.377
m_1t_2	509.55	19.60	0.396
m_2t_1	452.77	18.59	0.377
m_2t_2	500.03	19.58	0.395
m_3t_1	456.32	18.57	0.377
m_3t_2	524.60	19.97	0.411
SEm(±)	3.62	0.07	0.002
CD (0.05)	10.376	0.206	0.005

Table 8 c. Interaction effect of M x N x T on total dry matter yield plant $^{-1}$, number of pickings and harvest index

Treatments	Total dry matter yield plant $^{-1}$ (g)	Number of pickings	Harvest index
M x N x T			
$m_1n_1t_1$	463.94	18.71	0.389
$m_1n_1t_2$	491.93	19.63	0.397
$m_1n_2t_1$	437.55	18.29	0.365
$m_1n_2t_2$	526.70	19.88	0.398
$m_1n_3t_1$	452.61	18.48	0.378
$m_1n_3t_2$	510.01	19.30	0.393
$m_2n_1t_1$	462.96	18.64	0.382
$m_2n_1t_2$	483.97	19.27	0.392
$m_2n_2t_1$	427.03	18.07	0.360
$m_2n_2t_2$	487.78	19.50	0.395
$m_2n_3t_1$	468.32	19.06	0.390
$m_2n_3t_2$	528.35	19.97	0.400
$m_3n_1t_1$	441.18	18.17	0.369
$m_3n_1t_2$	553.57	20.44	0.423
$m_3n_2t_1$	482.83	19.22	0.391
$m_3n_2t_2$	532.60	20.00	0.416
$m_3n_3t_1$	444.94	18.33	0.372
$m_3n_3t_2$	487.63	19.47	0.393
SEm($\pm$)	6.26	0.13	0.003
CD (0.05)	17.972	0.358	0.008

4.1.2.6 Number of Pickings

The results from Table 8 a, 8 b, 8 c. revealed that different growth media and time of application had remarkable influence on number of pickings while different nutrient levels had no influence on it.

M_3 {soil: sand: coirpith: FYM mixed in the ratio 1: 0.5: 0.5: 1} recorded more number of pickings (19.27) compared to other growth media. Between the time of application, T_2 (Half N, full P & K as basal+ half N as fermented groundnut cake as fortnightly interval up to 50% flowering) recorded more number of pickings (19.72).

All two factor and three factor interactions exerted a favourable influence on number of pickings. Regarding interaction of M and N, m_3n_2 registered more number of pickings which was on par with m_3n_1. n_2t_2 recorded more number of pickings which was on par with n_1t_2 and n_3t_2 among N x T interactions. m_3t_2 was significantly superior over other combinations in the case of M x T interactions.

Among the three factor interactions, $m_3n_1t_2$ recorded more number of pickings and was on par with $m_3n_2t_2$.

4.1.2.7 Harvest Index

The data on harvest index as influenced by treatments are shown in Table 8 a, 8 b, 8 c.

The different growth media, nutrient levels, time of application and their interactions exerted noticeable influence on harvest index. M_3 {soil: sand: coirpith: FYM mixed in the ratio 1: 0.5: 0.5: 1} registered significantly superior harvest index (0.394) over other growth media. Application of 100 % RDN (N_1) registered higher harvest index (0.392) and between the time of application, T_2 (Half N, full P & K as basal+ half N as fermented groundnut cake as fortnightly interval up to 50% flowering) recorded higher harvest index (0.401).

In the case of two factor interactions (M x N, N x T and M x T), m_3n_2, n_1t_2 and m_3t_2 recorded significantly superior harvest index. M x N x T interactions influenced harvest index, where $m_3n_1t_2$ recorded higher harvest and was on par with $m_3n_2t_2$.

4.1.3 Root studies at final harvest

4.1.3.1 Root Weight

The data presented in Table 9 a, 9 b, 9 c. revealed that different growth media, nutrient levels, time of application and their interactions had significant influence on root fresh weight.

The growth medium, M_3 {soil: sand: coirpith: FYM mixed in 1: 0.5: 0.5: 1} registered higher root weight (38.85 g). Application of 200 % RDN (N_3) registered higher root weight (34.98 g) and was on par with 150 % RDN (N_2). Regarding time of application, T_1 (Full NPK as basal) recorded higher fresh root weight (38.55 g) when compared to T_2.

M x N, N x T, M x T exerted a favourable influence on root fresh weight. Among the M x N interactions, m_3n_2 registered higher root fresh weight which was on par with m_3n_1 and m_3n_3. n_3t_1 and $m_3t_1$was significantly superior over other combinations in the case of N x T and M x T interactions respectively.

M x N x T influenced root fresh weight where $m_3n_3t_1$ registered higher value and was on par with $m_1n_3t_1$.

4.3.2 Root Volume

Observations on root volume is presented in Table 9 a, 9 b, 9 c.

The different growth media, time of application and their interactions had no significant influence on root volume while nutrient levels had an influence on it. N_3 (200 % RDN) registered higher root volume (63.47 cm^3) and was significantly superior over other nutrient levels.

Table 9 a. Effect of growth media, nutrient levels and time of application on root weight, root volume and root shoot ratio

Treatments	Root weight (g)	Root volume (cm^3)	Root shoot ratio
Growth media			
M_1	29.35	59.82	0.092
M_2	32.01	59.71	0.133
M_3	38.86	59.85	0.144
SEm(±)	0.62	0.54	0.001
CD (0.05)	1.783	NS	0.004
Nutrient levels			
N_1	31.80	54.33	0.100
N_2	33.43	61.57	0.119
N_3	34.99	63.47	0.151
SEm(±)	0.62	0.54	0.001
CD (0.05)	1.783	1.558	0.004
Time of application			
T_1	38.56	59.67	0.150
T_2	28.26	59.92	0.097
SEm(±)	0.51	0.44	0.001
CD (0.05)	1.456	NS	0.003

Table 9 b. Interaction effect of growth media, nutrient levels and time of application on root weight, root volume and root shoot ratio

Treatments	Root weight (g)	Root volume (cm^3)	Root shoot ratio
M x N			
m_1n_1	28.67	54.59	0.110
m_1n_2	28.66	61.47	0.090
m_1n_3	30.73	63.41	0.077
m_2n_1	28.11	54.05	0.084
m_2n_2	31.83	61.56	0.140
m_2n_3	36.09	63.51	0.175
m_3n_1	38.63	54.36	0.105
m_3n_2	39.80	61.68	0.127
m_3n_3	38.14	63.51	0.201
SEm(±)	1.08	0.94	0.002
CD (0.05)	3.088	NS	0.007
N x T			
n_1t_1	33.07	54.21	0.104
n_1t_2	30.53	54.46	0.095
n_2t_1	31.93	61.50	0.132
n_2t_2	34.93	61.64	0.106
n_3t_1	50.67	63.29	0.213
n_3t_2	19.31	63.66	0.089
SEm(±)	0.88	0.77	0.002
CD (0.05)	2.521	NS	0.006
M x T			
m_1t_1	37.92	59.66	0.088
m_1t_2	20.79	59.99	0.096
m_2t_1	35.95	59.66	0.196
m_2t_2	28.07	59.75	0.070
m_3t_1	41.80	59.69	0.165
m_3t_2	35.91	60.01	0.124
SEm(±)	0.88	0.77	0.002
CD (0.05)	2.521	NS	0.006

Table 9 c. Interaction effect of M x N x T on root weight, root volume and root shoot ratio

Treatments	Root weight (g)	Root volume (cm^3)	Root shoot ratio
M x N x T			
$m_1n_1t_1$	40.72	54.37	0.130
$m_1n_1t_2$	16.63	54.81	0.090
$m_1n_2t_1$	27.28	61.33	0.058
$m_1n_2t_2$	30.05	61.61	0.122
$m_1n_3t_1$	45.76	63.26	0.076
$m_1n_3t_2$	15.70	63.55	0.077
$m_2n_1t_1$	22.67	54.08	0.097
$m_2n_1t_2$	33.54	54.01	0.070
$m_2n_2t_1$	33.58	61.38	0.211
$m_2n_2t_2$	30.07	61.73	0.069
$m_2n_3t_1$	51.59	63.50	0.280
$m_2n_3t_2$	20.59	63.51	0.070
$m_3n_1t_1$	35.83	54.17	0.084
$m_3n_1t_2$	41.43	54.55	0.126
$m_3n_2t_1$	34.93	61.79	0.127
$m_3n_2t_2$	44.66	61.57	0.127
$m_3n_3t_1$	54.65	63.11	0.282
$m_3n_3t_2$	21.63	63.91	0.120
SEm($\pm$)	1.52	1.33	0.003
CD (0.05)	4.367	NS	0.010

4.3.2 Root Shoot Ratio

The data on root shoot ratio in Table 9 a, 9 b, 9 c. revealed that root shoot ratio was significantly influenced by different growth media, nutrient levels and time of application and their interactions

The growth medium, M_3 {soil: sand: coirpith: FYM mixed in the ratio of 1: 0.5: 0.5: 1} registered higher root shoot ratio (0.144). Application of 200 % RDN (N_3) registered higher root shoot ratio (0.151) and between the time of application, Full NPK as basal (T_1) recorded higher root shoot ratio (0.150).

All two factor and three factor interactions significantly influenced root shoot ratio. Among two factor interactions, m_3n_3, n_3t_1 and m_2t_1 recorded significantly superior values over other combinations. In the case of M x N x T interactions, $m_3n_3t_1$ recorded higher value and was on par with $m_2n_3t_1$.

4.4 PEST AND DISEASE INCIDENCE

Pest incidence was comparatively less and minor attack by pod bug (*Riptorus pedestris*) and cowpea aphid (*Aphis craccivora*) were observed. Treatment wise variation was not observed in pest incidence. Anthracnose caused by *Colletotrichum lindemuthianum* was observed in isolated patches and the incidence was not influenced by treatments.

4.5 CHEMICAL ANALYSIS

4.5.1 Plant analysis

4.5.1.1 NPK content and uptake at final harvest

The data on NPK content and uptake at final harvest as depicted in Table 10 a, 10 b, 10 c, revealed that different growth media, nutrient levels and time of application had remarkable influence on plant N content and uptake. M_3 {soil: sand: coirpith: FYM mixed in the ratio 1: 0.5: 0.5: 1} recorded higher plant N content (2.45%) and uptake (12.06 g plant^{-1}). When compared to other nutrient levels, plant N content (2.49%) and uptake (12.07 g plant^{-1}) was found to be

Table 10 a. Effect of growth media, nutrient levels and time of application on plant NPK content (%) and uptake (g plant^{-1})

Treatments	N	N uptake	P	P uptake	K	K uptake
Growth media						
M_1	2.39	11.54	0.134	0.647	1.51	7.27
M_2	2.41	11.53	0.137	0.652	1.56	7.42
M_3	2.45	12.06	0.142	0.701	1.67	8.21
SEm(±)	0.009	0.08	0.001	0.005	0.01	0.08
CD (0.05)	0.024	0.230	0.002	0.014	0.044	0.218
Nutrient levels						
N_1	2.49	12.07	0.146	0.708	1.75	8.47
N_2	2.44	11.81	0.141	0.680	1.63	7.90
N_3	2.32	11.25	0.127	0.612	1.35	6.53
SEm(±)	0.009	0.08	0.001	0.005	0.01	0.08
CD (0.05)	0.024	0.230	0.002	0.014	0.044	0.218
Time of application						
T_1	2.40	10.93	0.138	0.628	1.58	7.18
T_2	2.43	12.49	0.138	0.706	1.58	8.09
SEm(±)	0.007	0.07	0.001	0.004	0.01	0.06
CD (0.05)	0.020	0.188	NS	0.011	NS	0.178

Table 10 b. Interaction effect of growth media, nutrient levels and time of application on plant NPK content (%) and uptake (g plant^{-1})

Treatments	N	N uptake	P	P uptake	K	K uptake
M x N						
m_1n_1	2.46	11.80	0.142	0.682	1.67	8.00
m_1n_2	2.44	11.83	0.141	0.684	1.65	7.97
m_1n_3	2.27	10.98	0.119	0.576	1.21	5.85
m_2n_1	2.50	11.89	0.147	0.697	1.76	8.36
m_2n_2	2.43	11.15	0.139	0.636	1.59	7.31
m_2n_3	2.31	11.55	0.125	0.624	1.32	6.57
m_3n_1	2.51	12.51	0.150	0.746	1.82	9.05
m_3n_2	2.44	12.46	0.142	0.721	1.65	8.41
m_3n_3	2.39	11.21	0.136	0.635	1.53	7.17
SEm(±)	0.01	0.14	0.001	0.008	0.02	0.13
CD (0.05)	0.042	0.398	0.004	0.024	0.08	0.377
N x T						
n_1t_1	2.48	11.36	0.147	0.669	1.75	7.99
n_1t_2	2.49	12.77	0.146	0.747	1.75	8.95
n_2t_1	2.43	10.95	0.141	0.634	1.63	7.36
n_2t_2	2.45	12.68	0.140	0.727	1.63	8.44
n_3t_1	2.29	10.49	0.127	0.580	1.35	6.18
n_3t_2	2.35	12.01	0.126	0.644	1.35	6.88
SEm(±)	0.01	0.11	0.001	0.007	0.02	0.11
CD (0.05)	NS	NS	NS	NS	NS	NS
M x T						
m_1t_1	2.37	10.75	0.135	0.610	1.51	6.84
m_1t_2	2.41	12.33	0.134	0.685	1.51	7.71
m_2t_1	2.39	10.87	0.137	0.622	1.56	7.06
m_2t_2	2.43	12.19	0.137	0.683	1.56	7.77
m_3t_1	2.44	11.18	0.142	0.652	1.67	7.63
m_3t_2	2.46	12.94	0.142	0.749	1.67	8.79
SEm(±)	0.01	0.113	0.001	0.007	0.02	0.11
CD (0.05)	NS	NS	NS	0.019	NS	NS

Table 10 c. Interaction effect of M x N x T on plant NPK content (%) and uptake (g $plant^{-1}$)

Treatments	N	N uptake	P	P uptake	K	K uptake
M x N x T						
$m_1n_1t_1$	2.44	11.37	0.143	0.664	1.67	7.77
$m_1n_1t_2$	2.48	12.24	0.142	0.700	1.67	8.23
$m_1n_2t_1$	2.44	10.70	0.141	0.622	1.65	7.24
$m_1n_2t_2$	2.45	12.96	0.141	0.746	1.65	8.71
$m_1n_3t_1$	2.24	10.17	0.120	0.544	1.21	5.50
$m_1n_3t_2$	2.30	11.79	0.119	0.609	1.21	6.19
$m_2n_1t_1$	2.50	11.60	0.147	0.682	1.76	8.17
$m_2n_1t_2$	2.50	12.17	0.147	0.712	1.76	8.55
$m_2n_2t_1$	2.42	10.35	0.139	0.595	1.60	6.83
$m_2n_2t_2$	2.44	11.95	0.138	0.678	1.59	7.79
$m_2n_3t_1$	2.27	10.66	0.125	0.588	1.32	6.18
$m_2n_3t_2$	2.35	12.44	0.125	0.660	1.32	6.96
$m_3n_1t_1$	2.51	11.12	0.150	0.662	1.82	8.03
$m_3n_1t_2$	2.50	13.91	0.149	0.830	1.81	10.07
$m_3n_2t_1$	2.43	11.79	0.142	0.686	1.65	8.00
$m_3n_2t_2$	2.46	13.13	0.142	0.756	1.65	8.83
$m_3n_3t_1$	2.38	10.62	0.136	0.608	1.54	6.85
$m_3n_3t_2$	2.41	11.79	0.135	0.663	1.53	7.48
SEm(±)	0.02	0.20	0.001	0.012	0.04	0.19
CD (0.05)	NS	0.563	NS	0.033	NS	0.533

superior in 100% RD NPK (N_1). Between the time of application, T_2 (Half N, full P & K as basal+ half N as fermented groundnut cake as fortnightly interval up to 50% flowering) recorded higher N content (2.43%) and uptake (12.48 g $plant^{-1}$) when compared to T_1. M x N interaction have significant impact on N content and uptake where m_3n_3 recorded higher N content and was on par with m_1n_1 and m_2n_1, while uptake was superior in m_3n_1 and was on par with m_3n_2. Regarding M x N x T combinations, N uptake was significantly superior for $m_3n_1t_2$.

Regarding P content and uptake, M_3 {soil: sand: coirpith: FYM mixed in the ratio 1: 0.5: 0.5: 1} registered higher P content (0.142%) and uptake (0.701 g $plant^{-1}$). Different nutrient levels have significant effect on plant P content and P uptake where 100% RD NPK (N_1) recorded higher P content (0.146%) and P uptake (0.708 g $plant^{-1}$). The time of application did not exert noticeable effect on plant P content while T_2 (Half N, full P & K as basal+ half N as fermented groundnut cake as fortnightly interval up to 50% flowering) recorded higher P uptake (0.706 g $plant^{-1}$) compared to T_1. The interaction of M x N appreciably influenced P content and uptake, where m_3n_1 recorded higher P content and was on par with m_2n_1. P uptake was higher for m_3n_1. However, the interaction between N x T and M x T was absent in the case of N, K content and their uptake. The three factor combinations did not exert any influence on P content, while P uptake was significantly superior for $m_3n_1t_2$.

The different growth media and nutrient levels had noticeable influence on K content and uptake. M_3 {soil: sand: coirpith: FYM in the ratio of 1: 0.5: 0.5: 1} registered higher K content (1.67%) and uptake (8.2 g $plant^{-1}$). Application of 100% RD NPK (N_1) recorded higher K content (1.75%) and K uptake (8.47 g $plant^{-1}$). The time of application did not exert any effect on plant K content while T_2 (Half N, full P & K as basal+ half N as fermented groundnut cake as fortnightly interval up to 50% flowering) recorded higher K uptake (8.09 g $plant^{-1}$) compared to T_1. With regard to M x N interactions, m_3n_1 recorded higher value for K content and was on par with m_2n_1 while K uptake was higher for m_3n_1. In the case of M x N x T combinations, $m_3n_1t_2$ registered superior value for K uptake.

4.5.2 Growth media analysis

4.5.2.1 Available NPK and Organic carbon content after experiment

The data on available NPK and Organic carbon content as influenced by treatments are shown in Table 11 a, 11 b, 11 c. and it revealed that different growth media, nutrient levels and time of application had significant influence on available N content after the experiment. The growth medium, M_1 {soil: sand: FYM in 1:1:1} registered higher available N content (0.111%) which was on par with M_2 {soil: sand: coirpith: FYM in 1:0.75: 0.25:1} (0.109%). Application of 200 % RDN (N_3) recorded higher available N content (0.109%). Between the time of application, Half N, full P & K as basal+ half N as fermented groundnut cake as fortnightly interval up to 50% flowering (T_2) recorded higher available N content (0.108%) and was on par with Full NPK as basal (T_1) (0.106%). Both the time of application was equally effective regarding available N content of growth media after the experiment.

Considering interactions, only N x T, M x T exerted a favourable influence on available N content after the experiment while M x N had no influence on it. Among the N x T interactions, n_3t_1 registered higher available N content which was on par with n_1t_2, n_2t_2 and n_3t_2. Regarding M x T interactions, m_1t_2 registered higher available N content which was on par with m_2t_1. The three factor interactions influenced available N content after the experiment, where $m_2n_3t_1$ registered higher available N content and was on par with $m_1n_3t_2$, $m_1n_3t_1$ and $m_1n_2t_2$.

Regarding available P content after the experiment, different growth media, time of application did not exert influence on P content, while time of application had significant influence on it. Application of 200 % RDN (N_3) registered higher available P content (0.054%) and was significantly superior over other treatments. Interaction effect had no influence on available P content after the experiment.

Table 11 a. Effect of growth media, nutrient levels and time of application on available NPK and organic carbon content (%)

Treatments	N content	P content	K content	OC content
Growth media				
M_1	0.111	0.045	0.056	3.66
M_2	0.109	0.044	0.056	4.08
M_3	0.101	0.045	0.053	4.56
SEm($\pm$)	0.001	0.001	0.001	0.02
CD (0.05)	0.002	NS	0.002	0.068
Nutrient levels				
N_1	0.105	0.036	0.049	3.95
N_2	0.106	0.045	0.054	4.04
N_3	0.109	0.054	0.062	4.30
SEm($\pm$)	0.001	0.001	0.001	0.02
CD (0.05)	0.002	0.003	0.002	0.068
Time of application				
T_1	0.106	0.045	0.055	3.98
T_2	0.108	0.045	0.055	4.22
SEm($\pm$)	0.001	0.001	0.001	0.02
CD (0.05)	0.002	NS	NS	0.056

Table 11 b. Interaction effect of growth media, nutrient levels and time of application on available NPK and organic carbon content (%)

Treatments	N content	P content	K content	OC content
M x N				
m_1n_1	0.107	0.037	0.050	3.39
m_1n_2	0.110	0.046	0.055	3.36
m_1n_3	0.116	0.054	0.063	4.23
m_2n_1	0.108	0.035	0.050	4.10
m_2n_2	0.108	0.043	0.054	4.11
m_2n_3	0.110	0.055	0.064	4.03
m_3n_1	0.100	0.036	0.047	4.38
m_3n_2	0.101	0.046	0.053	4.65
m_3n_3	0.102	0.055	0.059	4.65
SEm(±)	0.001	0.002	0.001	0.04
CD (0.05)	NS	NS	NS	0.118
N x T				
n_1t_1	0.101	0.036	0.048	3.63
n_1t_2	0.109	0.036	0.050	4.28
n_2t_1	0.105	0.046	0.054	4.06
n_2t_2	0.108	0.043	0.053	4.02
n_3t_1	0.110	0.054	0.062	4.25
n_3t_2	0.108	0.054	0.062	4.36
SEm(±)	0.001	0.001	0.001	0.03
CD (0.05)	0.003	NS	NS	0.096
M x T				
m_1t_1	0.109	0.047	0.056	3.60
m_1t_2	0.113	0.044	0.056	3.72
m_2t_1	0.110	0.045	0.056	3.84
m_2t_2	0.107	0.044	0.056	4.33
m_3t_1	0.097	0.045	0.052	4.51
m_3t_2	0.105	0.046	0.053	4.61
SEm(±)	0.001	0.001	0.001	0.03
CD (0.05)	0.003	NS	NS	0.096

Table 11 c. Interaction effect of M x N x T on available NPK and organic carbon content (%)

Treatments	N content	P content	K content	OC content
M x N x T				
$m_1n_1t_1$	0.106	0.038	0.049	2.68
$m_1n_1t_2$	0.109	0.036	0.051	4.09
$m_1n_2t_1$	0.108	0.047	0.055	3.26
$m_1n_2t_2$	0.112	0.044	0.054	3.47
$m_1n_3t_1$	0.114	0.055	0.063	4.85
$m_1n_3t_2$	0.117	0.052	0.062	3.61
$m_2n_1t_1$	0.107	0.036	0.049	3.94
$m_2n_1t_2$	0.108	0.034	0.051	4.27
$m_2n_2t_1$	0.106	0.045	0.055	4.19
$m_2n_2t_2$	0.110	0.041	0.053	4.02
$m_2n_3t_1$	0.118	0.053	0.064	3.38
$m_2n_3t_2$	0.102	0.056	0.063	4.69
$m_3n_1t_1$	0.091	0.033	0.046	4.28
$m_3n_1t_2$	0.109	0.038	0.047	4.48
$m_3n_2t_1$	0.102	0.047	0.053	4.73
$m_3n_2t_2$	0.101	0.045	0.053	4.58
$m_3n_3t_1$	0.098	0.054	0.058	4.53
$m_3n_3t_2$	0.106	0.055	0.060	4.77
SEm(±)	0.002	0.002	0.002	0.06
CD (0.05)	0.006	NS	NS	0.167

The available K content after the experiment was influenced by different growth media and nutrient levels while time of application had no noticeable influence on it. M_1 and M_2 registered higher available K content (0.056%) after the experiment. In the case of nutrient levels, 200 % RDN (N_3) registered higher available K content (0.062%) and was significantly superior over other treatments. Interaction effect did not exert any influence on available K content after the experiment.

The organic carbon content after experiment was remarkably influenced by different growth media, nutrient levels, time of application and their interactions. The growth medium, M_3 {soil: sand: coirpith: FYM mixed in the ratio 1: 0.5: 0.5: 1} registered higher Organic carbon content (4.55%). Application of 200 % RDN (N_3) registered higher N content (4.30%) and between the time of application, Half N, full P & K as basal+ half N as fermented groundnut cake as fortnightly interval up to 50% flowering (T_2) recorded higher organic carbon content (4.21%) compared to T_1.

All two factor interactions and three factor exerted a favourable influence on organic carbon content after the experiment. Among the M x N interactions, m_3n_2 and m_3n_3 registered higher organic carbon content. In the case of N x T interactions, n_3t_2 registered higher organic carbon content which was on par with n_1t_2. Among the M x T interactions, m_3t_2 recorded higher organic carbon content which was on par with m_3t_1. Regarding three factor interactions, $m_1n_3t_1$ recorded higher value and was on par with $m_3n_3t_2$, $m_3n_2t_1$ and $m_2n_3t_2$.

4.6 Economics of Cultivation

4.6.1 Net income and BCR

Data in Table 12 a, 12 b, 12 c. revealed that different growth media, nutrient levels and time of application and their interactions had profound influence on net income and BCR.

Table 12 a. Effect of growth media, nutrient levels and time of application on net income (₹ bag^{-1}) and BCR

Treatments	Net income	BCR
Growth media		
M_1	25.02	0.98
M_2	29.34	1.40
M_3	31.32	1.54
SEm(±)	0.27	0.01
CD (0.05)	0.774	0.037
Nutrient levels		
N_1	29.78	1.43
N_2	28.56	1.30
N_3	27.34	1.18
SEm(±)	0.27	0.01
CD (0.05)	0.774	0.037
Time of application		
T_1	25.50	1.17
T_2	31.62	1.44
SEm(±)	0.22	0.01
CD (0.05)	0.632	0.031

Table 12 b. Interaction effect of growth media, nutrient levels and time of application on net income (₹ bag^{-1}) and BCR

Treatments	Net income	BCR
M x N		
m_1n_1	25.92	1.05
m_1n_2	25.19	0.98
m_1n_3	23.94	0.89
m_2n_1	30.20	1.52
m_2n_2	27.33	1.30
m_2n_3	30.48	1.38
m_3n_1	33.22	1.72
m_3n_2	33.14	1.62
m_3n_3	27.60	1.27
SEm(±)	0.47	0.02
CD (0.05)	1.341	0.065
N x T		
n_1t_1	26.94	1.29
n_1t_2	32.62	1.57
n_2t_1	25.04	1.14
n_2t_2	32.07	1.45
n_3t_1	24.52	1.06
n_3t_2	30.16	1.30
SEm(±)	0.38	0.02
CD (0.05)	NS	NS
M x T		
m_1t_1	21.95	0.85
m_1t_2	28.09	1.09
m_2t_1	26.84	1.28
m_2t_2	31.83	1.52
m_3t_1	27.72	1.36
m_3t_2	34.93	1.72
SEm(±)	0.38	0.02
CD (0.05)	1.095	0.053

Table 12 c. Interaction effect of M x N x T on net income (₹ bag^{-1}) and BCR

Treatments	Cost of cultivation (₹ bag^{-1})	Net income	BCR
M x N x T			
$m_1n_1t_1$	24.52	24.44	0.99
$m_1n_1t_2$	24.52	27.40	1.11
$m_1n_2t_1$	25.69	20.49	0.79
$m_1n_2t_2$	25.69	29.90	1.16
$m_1n_3t_1$	26.86	20.91	0.77
$m_1n_3t_2$	26.86	26.96	1.00
$m_2n_1t_1$	19.77	29.09	1.47
$m_2n_1t_2$	19.77	31.31	1.58
$m_2n_2t_1$	20.94	24.13	1.15
$m_2n_2t_2$	20.94	30.54	1.46
$m_2n_3t_1$	22.11	27.31	1.23
$m_2n_3t_2$	22.11	33.65	1.52
$m_3n_1t_1$	19.27	27.29	1.41
$m_3n_1t_2$	19.27	39.15	2.03
$m_3n_2t_1$	20.44	30.52	1.49
$m_3n_2t_2$	20.44	35.77	1.75
$m_3n_3t_1$	21.61	25.35	1.17
$m_3n_3t_2$	21.61	29.85	1.38
SEm(±)	-	0.66	0.03
CD (0.05)	-	1.897	0.092

Among growth media, M_3 {soil: sand: coirpith: FYM in 1: 0.5: 0.5: 1} recorded higher net income (31.12) and BCR (1.54) and application of 100 % RDN (N_1) registered higher net income (29.78) and BCR (1.44). Between the time of application, T_2 (Half N, full P & K as basal+ half N as fermented groundnut cake as fortnightly interval up to 50% flowering) recorded higher net income (31.62) and BCR (1.45) compared to T_1.

Considering interactions, M x N, M x T and M x N x T exerted a favorable influence on net income. Among the M x N interactions, m_3n_1 registered higher net income and was on par with m_3n_2, while m_3n_1 recorded significantly superior value for BCR. Among the M x T interactions, m_3t_2 recorded superior net income and BCR.

In the case of M x N x T interactions, $m_3n_1t_2$ was significantly superior over other treatment combinations for net income and BCR.

4.2 CHARACTERISATION OF BEST GROWTH MEDIUM FROM EXPERIMENT I

The treatment combination $m_3n_1t_2$ {M_3 : soil: sand: coirpith: FYM in the ratio 1: 0.5: 0.5: 1} + 100 % RDN (N_1) + T_2 (Half N, full P & K as basal+ half N as fermented groundnut cake as fortnightly interval up to 50% flowering)} recording the highest pod yield plant^{-1} was identified as the best growth medium and analyzed for its chemical characters viz., pH, EC, available NPK and organic carbon content which is presented in Table 13. The best growth medium along with the best nutrient schedule was selected for the second study.

Table 13. Chemical characters of the best growth medium M_3 (soil: sand : coirpith: FYM: 1: 0.5: 0.5: 1)

Particulars	Content
EC ($dS\ m^{-1}$)	1.3
Organic Carbon (%)	3.8
Available Nitrogen (%)	0.085
Available Phosphorus (%)	0.042
Available Potassium (%)	0.018

4.3 STUDIES ON TRAILING PATTERN OF YARDLONG BEAN UNDER VARIOUS IRRIGATION FREQUENCY.

4.3.1 Growth attributes

4.3.1.1 Number of Primary Branches plant^{-1} at 30 DAS and 45 DAS

The data on number of primary branches plant^{-1} as influenced by treatments are presented in Table 14 a, 14b. The different irrigation frequency, trailing method and their interactions did not exert any influence on number of primary branches plant^{-1} at 30 DAS. However, the different irrigation frequency had significant influence on number of primary branches plant^{-1} at 45 DAS, while different trailing method and interaction had no influence on it.

At 45 DAS, daily irrigation (I_1) registered higher number of primary branches plant^{-1} (5.79) compared to I_2.

4.3.1.2 Functional Leaves Plant^{-1} at 30 and 45 DAS

Observations on number of functional leaves plant^{-1} at 30 and 45 DAS as influenced by treatments are shown in Table 14 a, 14b.

The different irrigation frequency exerted remarkable influence on number of functional leaves plant^{-1} at 30 and 45 DAS, while different trailing method and interaction had no impact on it.

At 30 DAS, daily irrigation (I_1) registered higher number of functional leaves plant^{-1} (24.51). At 45 DAS, the same treatment recorded higher number of functional leaves plant^{-1} (64.87).

4.3.1.3 Crop Duration

The data on crop duration as influenced by treatments are presented in Table 14 a, 14b.

Table 14 a. Effect of trailing method and irrigation on number of primary branches plant^{-1}, number of functional leaves plant^{-1}, crop duration

	Number of primary branches plant^{-1}		Number of functional leaves plant^{-1}		Crop duration (days)
Treatments	30DAS	45DAS	30DAS	45DAS	
Trailing method					
R_1	3.61	5.14	22.16	62.62	102.78
R_2	3.73	5.08	21.85	62.52	103.55
R_3	3.55	5.08	22.15	61.68	105.903
SEm(±)	0.08	0.06	0.25	0.66	0.17
CD (0.05)	NS	NS	NS	NS	0.526
Irrigation frequency					
I_1	3.77	5.79	24.51	64.87	104.63
I_2	3.49	4.42	19.59	59.67	103.52
SEm(±)	0.07	0.05	0.21	0.54	0.14
CD (0.05)	NS	0.1593	0.633	1.662	0.430

Table 14 b. Interaction effect of trailing method and irrigation on number of primary branches plant^{-1}, number of functional leaves plant^{-1}, crop duration

	Number of primary branches plant^{-1}		Number of functional leaves plant^{-1}		Crop duration (days)
Treatments	30DAS	45DAS	30DAS	45DAS	
r_1i_1	3.71	5.750	24.63	64.17	103.77
r_1i_2	3.51	4.547	19.69	61.08	101.80
r_2i_1	3.83	5.793	24.13	66.90	104.13
r_2i_2	3.63	4.377	19.56	58.13	102.96
r_3i_1	3.76	5.830	24.76	63.56	105.99
r_3i_2	3.34	4.347	19.53	59.81	105.82
SEm($\pm$)	0.11	0.09	0.36	0.97	0.24
CD (0.05)	NS	NS	NS	NS	NS

The different trailing method, irrigation frequency had noticeable influence on crop duration while their interaction effect had no influence on duration of the crop.

Trailing the crop on trailing stand (R_3) recorded longer crop duration (105.9 days) and was significantly superior over other trailing methods. Daily irrigation (I_1) registered longer crop duration (104.63 days) over irrigation when plant is at temporary wilting stage (I_2).

4.3.2 Yield Attributes and Yield

4.3.2.1 Days for 50 Per cent flowering

The data in Table 15 a, 15 b revealed that different trailing method, irrigation frequency influenced days for 50 per cent flowering while their interaction effect had no influence on it.

Trellis system (R_2) recorded earlier flowering (40.12 days) where R_3 (trailing stand) registered delayed flowering (41.80 days). Between irrigation intervals, daily irrigation (I_1) registered earlier flowering (41.32 days) when compared to I_2.

4.3.2.2 Number of Pods Plant^{-1}

Observations on number of pods plant^{-1} is depicted in Table 15 a, 15 b.

The different trailing method, irrigation frequency and interaction imparted a significant influence on number of pods plant^{-1}

The different trailing methods have exerted significant influence on number of pods plant^{-1} where trellis system (R_2) registered largest number of pods plant^{-1} (50.49) and was on par with trailing stand (R_3). Daily irrigation (I_1) recorded significantly more number of pods plant^{-1} (61.77) than irrigation when plant is at temporary wilting stage (I_2).

Table 15 a. Effect of trailing method and irrigation on days for 50 per cent flowering, number of pods plant^{-1} and pod yield per plant^{-1}

Treatments	Days for 50 per cent flowering	Number of pods plant^{-1}	Pod yield plant^{-1}
Trailing method			
R_1	40.68	39.54	626.39
R_2	40.12	50.49	832.03
R_3	41.80	49.27	814.53
SEm(±)	0.17	0.81	2.06
CD (0.05)	0.514	2.492	6.415
Irrigation frequency			
I_1	41.32	61.77	941.85
I_2	40.41	31.10	573.46
SEm(±)	0.14	0.66	1.68
CD (0.05)	0.420	2.035	5.238

Table 15 b. Interaction effect of trailing method and irrigation on days for 50 per cent flowering, number of pods plant^{-1} and pod yield per plant^{-1}

Treatments	Days to 50 per cent flowering	Number of pods plant^{-1}	Pod yield plant^{-1}
R x I			
r_1i_1	41.26	49.11	751.52
r_1i_2	40.11	29.98	501.28
r_2i_1	40.32	68.55	1,079.15
r_2i_2	39.92	32.44	584.91
r_3i_1	42.39	67.66	994.87
r_3i_2	41.21	30.89	634.19
SEm(±)	0.24	1.14	2.91
CD (0.05)	NS	3.524	9.072

Among the interactions, R x I, r_2i_1 (trellis system under daily irrigation) recorded higher number of pods plant^{-1} and was on par with r_3i_1.

4.3.2.3 Pod yield plant^{-1}

The data on pod yield plant^{-1} as influenced by treatments are presented in Table 15 a, 15 b.

The different trailing method, irrigation frequency and their interactions have exerted influence on pod yield plant^{-1}.

Trailing methods have remarkable impact on pod yield plant^{-1} where trailing on trellis system (R_2) registered higher pod yield plant^{-1} (832.03g). Irrigation on a daily basis (I_1) recorded significantly higher pod yield plant^{-1} (941.84 g) than irrigation when plant is at temporary wilting stage (I_2).

Among the interactions, R x I, r_2i_1 (trellis system under daily irrigation) recorded larger pod yield plant^{-1} and was significantly superior over other treatment combinations.

4.3.2.4 Pod Yield Harvest^{-1}

The data on pod yield harvest^{-1} (Table 16) revealed that pod yield was found to increase steadily and reaches a maximum around thirteenth harvest. It gradually decreases as harvest proceeds until the final harvest irrespective of the treatment combinations.

4.3.2.5 Total Dry Matter Yield Plant^{-1}

Table 17 a, 17 b presents the data on total dry matter yield plant^{-1} as influenced by treatments.

The different trailing method, irrigation frequency and their interactions significantly influenced total dry matter yield plant^{-1}.

Growing the crop on trellis system (R_2) registered higher total dry matter yield plant^{-1} (472.99 g) when compared to other trailing methods. Daily irrigation

Table 16. Effect of trailing method and irrigation on pod yield harvest^{-1}*

Treatments	Harvest number										
	1	2	3	4	5	6	7	8	9	10	11
r_1i_1	14.2	19	21.2	26.3	29.6	35.4	42.2	46.3	51	62.3	70
r_1i_2	12	14.4	19.3	21	36.3	32	34.5	38.2	42.2	42	47.3
r_2i_1	21	33	42.2	47.2	53	56.3	61	65	73.3	77.22	81
r_2i_2	12.3	14	17.2	21	24.2	27.5	29	31.2	39	45.2	51
r_3i_1	21	27	33.2	36.2	42.3	48.4	51.2	56	60	71.3	73.1
r_3i_2	12.1	16	21	22.2	25.6	28.2	30	33.2	37.4	42.1	43.5

*Data not statistically analysed

Table 16. continued. Effect of trailing method and irrigation on pod yield $harvest^{-1}$*

Treatments	Harvest number									
	12	13	14	15	16	17	18	19	20	21
r_1i_1	75.3	70	64.2	41.6	26	22	19.2	13	0	0
r_1i_2	51.5	45.2	25.3	22	20.2	17	11.6	0	0	0
r_2i_1	79	75.33	68.2	62.3	54.1	48	37.5	26	19.67	0
r_2i_2	54	59.2	51	41.3	30	18	14.2	11	0	0
r_3i_1	76	77.2	61	59.36	52	50.4	42	32.2	20	10.3
r_3i_2	52.2	56	59.5	64	32	17.4	18	16	12.1	0

*Data not statistically analysed

(I_1) registered significantly higher total dry matter yield plant^{-1} (535.42 g) than irrigation when plant is at temporary wilting stage (I_2).

r_2i_1 (trailing the crop on trellis system under daily irrigation) recorded higher total dry matter yield plant^{-1} and was on par with r_3i_1 (trailing stand under daily irrigation).

4.3.2.6 Number of Pickings

The data from Table 17 a, 17 b revealed that different trailing method and irrigation frequency profoundly influenced number of pickings while their interactions had no influence on number of pickings.

Trailing the crop on trailing stand (R_3) registered higher number of pickings (20.69). Daily irrigation (I_1) registered significantly more number of pickings (19.87) than irrigation when plant is at temporary wilting stage (I_2).

4.3.2.7 Harvest Index

The data on harvest index as influenced by treatments are depicted in Table 17 a, 17 b.

The data from Table revealed that different trailing method, irrigation frequency and interaction have remarkable influence on harvest index.

Trellis system (R_2) registered superior harvest index (0.359) compared to other trailing methods. Daily irrigation (I_1) registered significantly higher harvest index (0.355) than irrigation when plant is at temporary wilting stage (I_2).

Among the R x I interactions, r_2i_1 (trailing the crop on trellis system under daily irrigation) recorded higher harvest index which was significantly superior over other treatment combinations.

Table 17 a. Effect of trailing method and irrigation on total dry matter yield plant $^{-1}$, number of pickings and harvest index

Treatments	Total dry matter yield plant $^{-1}$ (g)	Number of pickings	Harvest index
Trailing method			
R_1	360.18	18.50	0.293
R_2	472.99	18.77	0.359
R_3	463.05	20.69	0.298
SEm(±)	1.27	0.09	0.007
CD (0.05)	3.964	0.331	0.021
Irrigation frequency			
I_1	535.43	19.87	0.355
I_2	328.72	18.77	0.278
SEm(±)	1.039	0.09	0.006
CD (0.05)	3.237	0.270	0.017

Table 17 b. Interaction effect of trailing method and irrigation on total dry matter yield plant $^{-1}$, number of pickings and harvest index

Treatments	Total dry matter yield plant $^{-1}$ (g)	Number of pickings	Harvest index
R x I			
r_1i_1	427.23	18.99	0.309
r_1i_2	293.13	18.02	0.276
r_2i_1	613.48	19.18	0.433
r_2i_2	332.51	18.36	0.285
r_3i_1	565.57	21.44	0.322
r_3i_2	360.53	19.93	0.273
SEm(±)	1.80	0.15	0.01
CD (0.05)	5.606	NS	0.030

4.3.3 Root studies at final harvest

4.3.3.1 Root Weight

The data on root dry weight as influenced by treatments are shown in Table 18 a, 18 b. and it revealed that different irrigation frequency had noticeable influence on root fresh weight while different trailing method had no influence on root fresh weight. The interaction effect was insignificant on root weight.

Daily irrigation (I_1) registered significantly higher root fresh weight (26.56g) than irrigation when plant is at temporary wilting stage (I_2).

4.3.2 Root Volume

The results from Table 18 a, 18 b revealed that different irrigation frequencies have exerted influence on root volume while different trailing method and interaction of trailing method and irrigation frequency had influence on it.

Daily irrigation (I_1) registered significantly higher root volume (45.88 cm^3) than irrigation when plant is at temporary wilting stage (I_2).

4.3.2 Root Shoot Ratio

Table 18 a, 18 b depicts data on root shoot ratio as influenced by the treatments.

Different trailing methods and irrigation frequency had remarkable influence on root shoot ratio while their interactions had no influence on it. Trailing on pandal system (R_1) recorded higher root shoot ratio (0.217) and was on par with trailing on trailing stand (R_3). Daily irrigation (I_1) registered significantly higher root shoot ratio (0.237) than irrigation when plant is at temporary wilting stage (I_2).

4.3.4 Pest and disease incidence

Pest incidence was relatively less and minor attack by blue butterfly (*Lampides boeticus*) and cowpea aphid (*Aphis craccivora*) were observed.

Table 18 a. Effect of trailing method and irrigation on root weight, root volume and root shoot ratio

Treatments	Root weight (g)	Root volume (cm^3)	Root shoot ratio
Trailing method			
R_1	21.56	37.41	0.217
R_2	23.19	35.75	0.209
R_3	20.22	33.91	0.183
SEm(±)	1.77	3.10	0.004
CD (0.05)	NS	NS	0.0131
Irrigation frequency			
I_1	26.56	45.88	0.237
I_2	16.75	25.50	0.169
SEm(±)	1.45	2.53	0.003
CD (0.05)	4.510	7.806	0.0107

Table 18 b. Interaction effect of trailing method and irrigation on root weight, root volume and root shoot ratio

Treatments	Root weight (g)	Root volume (cm^3)	Root shoot ratio
R x I			
r_1i_1	26.91	44.00	0.240
r_1i_2	16.22	30.83	0.195
r_2i_1	29.41	45.83	0.253
r_2i_2	16.97	25.66	0.165
r_3i_1	23.38	47.83	0.218
r_3i_2	17.06	20.00	0.148
SEm($\pm$)	2.51	4.39	0.006
CD (0.05)	NS	NS	NS

Treatment wise variation was not observed in pest incidence. Anthracnose caused by *Colletotrichum lindemuthianum* was observed in isolated patches. Anthracnose incidence was not influenced by treatments.

4.3.5 Chemical analysis

4.3.5.1 Plant Analysis

4.5.1 NPK content and uptake at final harvest

Data in Table 19 a, 19 b revealed that different trailing methods, irrigation frequency and their interactions did not exert any influence on N and K content while P content was profoundly influenced by irrigation frequency. Daily irrigation (I_1) registered significantly higher P content (0.135%) when compared to irrigation when plant is at temporary wilting stage (I_2).

The different trailing methods, irrigation frequency and their interactions had noticeable influence on NPK uptake.

Trailing on trellis system (R_2) recorded higher N uptake (12.09 g plant^{-1}), P uptake (0.539 g plant^{-1}) and K uptake (9.13 g plant^{-1}) and was on par with R_3.

Daily irrigation (I_1) registered higher N uptake (13.71 g plant^{-1}), P uptake (0.732 g plant^{-1}) and K uptake (10.48 g plant^{-1}) over irrigation when plant is at temporary wilting stage (I_2).

Interaction effect was profound for N, P and K uptake. r_2i_1 (trailing on trellis system) recorded superior N uptake (15.64 g plant^{-1}), r_3i_1 (trailing on trailing stand) registered higher P uptake (0.837 g plant^{-1}) and was on par with r_2i_1, K uptake (11.94 g plant^{-1}) recorded was higher for r_2i_1 and was on par with r_3i_1 .

Table 19 a. Effect of trailing method and irrigation on plant NPK content (%) and uptake (g plant^{-1})

Treatments	N	N uptake	P	P uptake	K	K uptake
Trailing method						
R_1	7.79	0.099	1.97	9.16	0.378	7.09
R_2	8.53	0.106	1.92	12.09	0.539	9.14
R_3	8.50	0.106	1.97	11.83	0.535	9.13
SEm(±)	0.06	0.006	0.05	0.08	0.03	0.26
CD (0.05)	0.173	NS	NS	0.262	0.085	0.797
Irrigation frequency						
I_1	9.39	0.135	1.96	13.71	0.732	10.48
I_2	7.17	0.072	1.96	8.35	0.236	6.43
SEm(±)	0.04	0.02	0.04	0.07	0.02	0.21
CD (0.05)	0.141	0.005	NS	0.214	0.070	0.651

Table 19 b. Interaction effect of trailing method and irrigation on plant NPK content (%) and uptake (g plant^{-1})

Treatments	N	N uptake	P	P uptake	K	K uptake
R x I						
r_1i_1	2.56	0.127	1.95	10.94	0.545	8.34
r_1i_2	2.52	0.071	1.99	7.39	0.210	5.85
r_2i_1	2.55	0.132	1.95	15.64	0.814	11.94
r_2i_2	2.57	0.079	1.90	8.54	0.264	6.33
r_3i_1	2.57	0.147	1.99	14.55	0.837	11.16
r_3i_2	2.53	0.064	1.97	9.11	0.234	7.09
SEm(±)	0.02	0.008	0.08	0.12	0.039	0.362
CD (0.05)	NS	NS	NS	0.370	0.121	1.127

Table 20 a. Effect of trailing method and irrigation on available NPK and organic carbon content (%)

Treatments	N content	P content	K content	OC content
Trailing method				
R_1	0.104	0.039	0.054	4.45
R_2	0.106	0.039	0.056	4.37
R_3	0.105	0.038	0.055	4.28
SEm(±)	0.002	0.001	0.002	0.10
CD (0.05)	NS	NS	NS	NS
Irrigation frequency				
I_1	0.106	0.041	0.056	4.41
I_2	0.104	0.036	0.054	4.32
SEm(±)	0.001	0.001	0.001	0.08
CD (0.05)	NS	0.003	NS	NS

Table 20 b. Interaction effect of trailing method and irrigation on available NPK and organic carbon content (%)

Treatments	N content	P content	K content	OC content
R x I				
r_1i_1	0.106	0.041	0.056	4.50
r_1i_2	0.102	0.037	0.052	4.40
r_2i_1	0.105	0.040	0.055	4.47
r_2i_2	0.107	0.038	0.057	4.27
r_3i_1	0.107	0.043	0.057	4.27
r_3i_2	0.103	0.034	0.053	4.30
SEm(±)	0.002	0.002	0.002	0.14
CD (0.05)	NS	NS	NS	NS

4.3.5.2 Growth Media Analysis

4.3.5.2.1 NPK and Organic carbon content after experiment

The data in Table 20 a, 20 b indicated that different trailing methods, irrigation frequency and their interactions had no influence on available N, K and organic carbon while irrigation frequency have remarkable influence on available P content where daily irrigation registered significantly higher value (0.041%) when compared to I_1.

4.3.6 Economics of cultivation

4.3.6.1 Net income and BCR

Data in Table 21 a, 21 b revealed that different trailing methods, irrigation frequency and their interactions had profound influence on net income and BCR.

Among trailing methods, trellis system (R_2) recorded higher net income (₹ 30.65) and BCR (1.59). Irrigation on a daily basis (I_1) registered higher net income (₹ 36.17) and BCR (1.78) over irrigation when plant is at temporary wilting stage (I_2).

Interaction effect was appreciable for net income where higher net income (₹ 45.48) and BCR (2.36) was registered with trailing the crop on trellis system, r_2i_1.

Table 21 a. Effect of trailing method and irrigation on net income (₹ bag^{-1}) and BCR

Treatments	Net income	BCR
Trailing method		
R_1	18.24	0.92
R_2	30.65	1.59
R_3	26.90	1.22
SEm(±)	0.13	0.007
CD (0.05)	0.418	0.021
Irrigation frequency		
I_1	36.17	1.78
I_2	14.35	0.70
SEm(±)	0.11	0.005
CD (0.05)	0.341	0.017

Table 21 b. Interaction effect of trailing method and irrigation on net income (₹ bag^{-1}) and BCR

Treatments	Cost of cultivation (₹ bag^{-1})	Net income	BCR
R x I			
r_1i_1	19.77	25.32	1.28
r_1i_2	19.77	11.16	0.56
r_2i_1	19.27	45.48	2.36
r_2i_2	19.27	15.82	0.82
r_3i_1	21.97	37.72	1.71
r_3i_2	21.97	16.08	0.73
SEm(±)	-	0.19	0.009
CD (0.05)	-	0.591	0.029

Discussion

5. DISCUSSION

The study entitled "Agro techniques for container grown yardlong bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)" was undertaken at College of Agriculture, Vellayani to identify an ideal growth medium; to standardise nutrient schedule; irrigation interval and trailing method so as to formulate an agronomic package for container grown yardlong bean. The investigation was conducted as two separate experiments. The results of the experiments are discussed briefly in this chapter.

5.1 EFFECT OF GROWTH MEDIA ON GROWTH AND YIELD CHARACTERS OF CONTAINER GROWN YARDLONG BEAN

Container cultivation is widely adopted in urban households for production of safe to eat vegetables. The results of the study to identify a suitable growth medium for container grown yardlong bean indicated that the various growth media tested had a significant influence on growth and yield characters of yardlong bean. The growth medium M_3 where soil, sand, coirpith and FYM were mixed in the ratio of 1: 0.5: 0.5: 1 by weight and M_2 {soil: sand: coirpith: FYM in 1:0.75:0.25:1} recorded higher values for all growth characters. These results indicate that coirpith can be effectively used for substituting sand to an extent of 50 per cent. However, a substitution up to 75 per cent was reported by Baskar (1996), where potting mixture composed of coirpith and soil in the ratio 75: 25 recorded an increased yield in yardlong bean. These media M_3 and M_2 registered higher number of primary branches, functional leaves plant^{-1} (30 and 45 DAS) and longer crop duration. This is in conformity with the results obtained by Venkatakrishnan and Ravichandran (1996) where an increase in height, number of branches plant^{-1} and length of root of sesame plants was observed on application of coirpith. Moreover, substitution of 50 per cent coirpith could considerably reduce the weight of the growth medium which has more relevance for container cultivation in urban house terraces where it can be easily handled. Similar observation was also made by Joshua *et al.* (2012).

Incorporation of coirpith as a component in growth medium has extended the crop duration considerably. This might be due to maintenance of a favourable air to water balance in the root zone for a longer period of time as reported by Michel (2010).

The number of pods plant^{-1} as well as pod yield was higher for M_3 {soil, sand, coirpith and FYM in 1: 0.5: 0.5: 1}. An increase in number of pods plant^{-1} could be attributed to the corresponding increase in the number of primary branches and functional leaves. Reddy (2005) observed a positive correlation between number of branches and pod yield in cowpea. Similar results were also reported by Knoieczny *et al.* (1994) in soyabean. The growth medium M_3 registered higher pod yield plant^{-1} and was significantly superior to other growth media, which corresponds to the higher initial available nutrient status (0.085 per cent N, 0.042 per cent P_2O_5, 0.018 per cent K_2O and 3.8 per cent OC) and favourable chemical properties viz., neutral pH of 7.13 and EC of 1.3 d S m^{-1}. Reghuvaran and Ravindranath (2013) reported that coirpith could reduce the temperature of the medium and improved growth as well as yield characters. Baskar (1996) reported potting mixture composed of coirpith and soil in the ratio 75: 25 recorded an increased yield in yardlong bean.

The number of pickings in M_3 was found to be higher which might be due to the extended crop duration. Similar trend was observed in total dry matter yield plant^{-1} and harvest index which again confirmed the observation that substitution of sand with coirpith could be a better alternative for container grown yardlong bean without affecting the growth characters and yield.

Root characters such as root weight and root shoot ratio were also found higher in M_3. The better physical and chemical properties of the growth medium might have contributed to improved root growth. The average root weight of yardlong bean in M_3

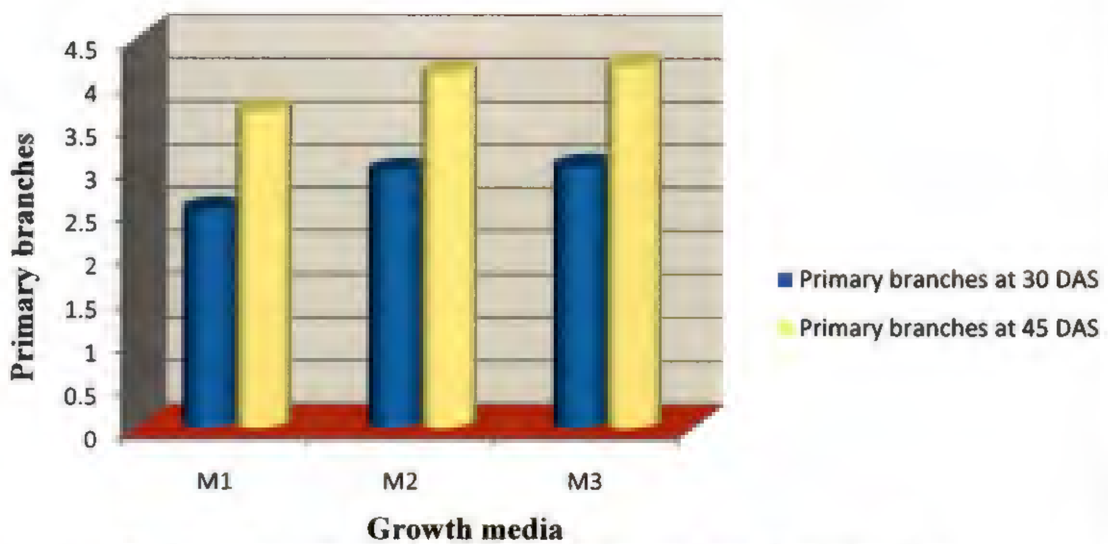


Fig. 5 Effect of growth media on primary branches plant^{-1} at 30 DAS and 45 DAS

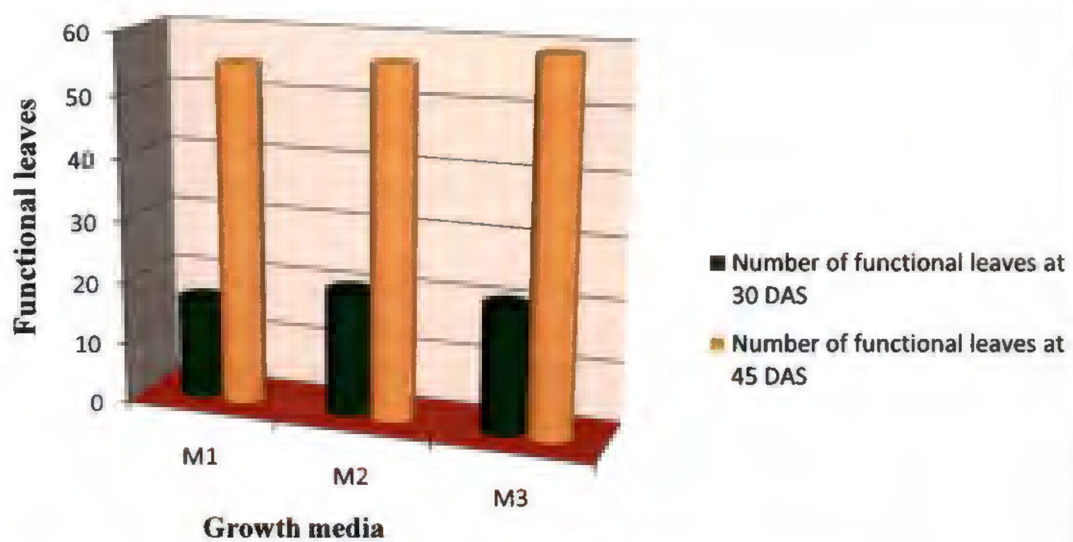


Fig. 6 Effect of growth media on functional leaves plant^{-1} at 30 DAS and 45 DAS

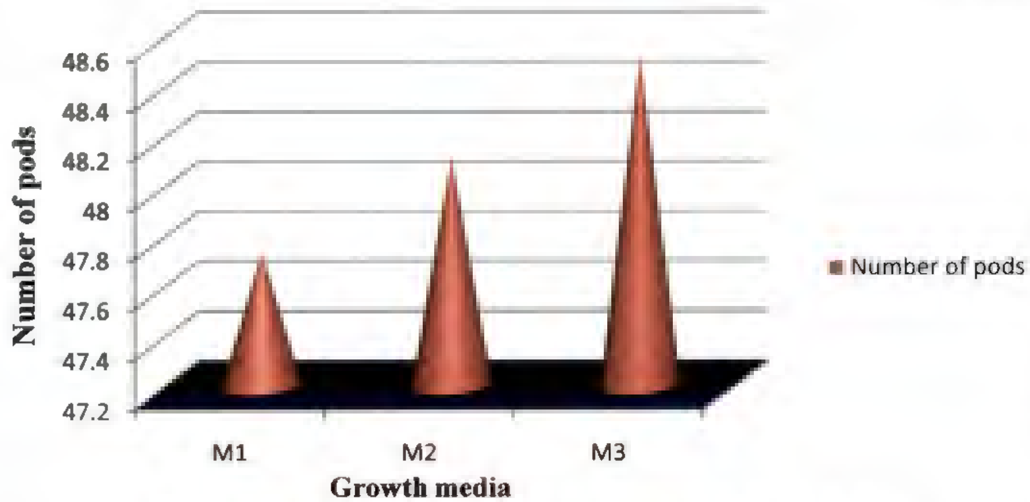


Fig. 7 Effect of growth media on number of pods plant^{-1}

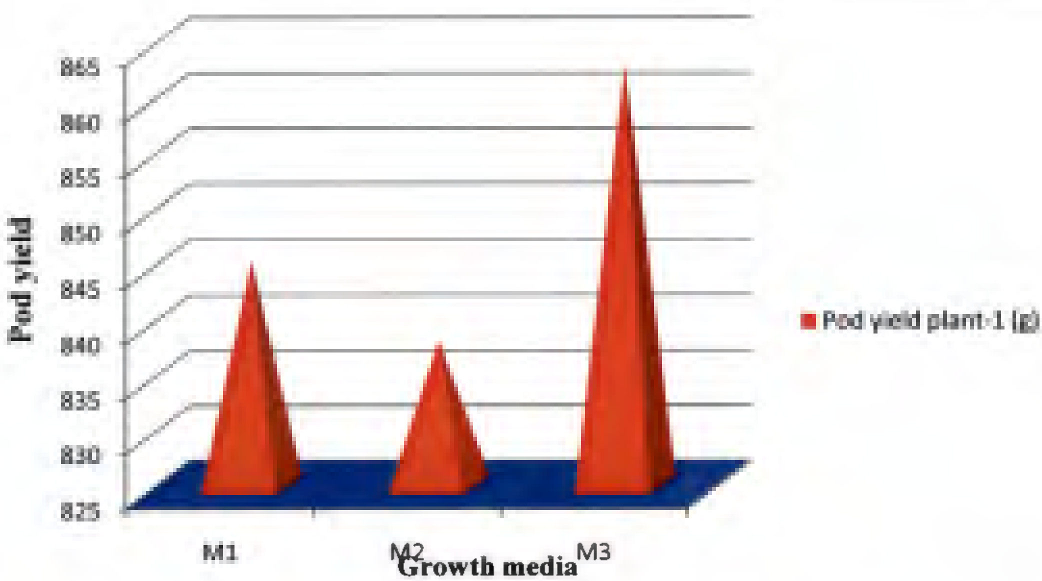


Fig. 8 Effect of growth media on pod yield plant^{-1} (g)

was 38.85 g plant^{-1} whereas the root weight of the same plant in soil based medium was 29.35 g only. This clearly indicated the superiority of coirpith as a rooting medium. The results are in conformity with the findings of Joshua *et al.* (2012). Root volume which normally may not vary much in containers of uniform size was not affected by any of the growth media tested. Similar result was reported by NeSmith and Duval (1998). However, Judd *et al.* (2015) reported that root volume varied with the size of the container rather than the content of the medium.

The NPK uptake of the plant was higher in M_3 (where 50 per cent sand was replaced with coirpith) since the total dry matter yield plant^{-1} was found to be higher in this medium. Babu (2015) also reported a similar increase in uptake of nutrients with increase in dry matter production of yardlong bean. The available NPK content after the harvest was lower in M_3 which could be attributed to higher uptake and dry matter production in this medium. Organic carbon content of the medium after the experiment was high in M_3, might be contributed by the coirpith in media replacing 50 per cent of sand.

The growth medium M_3 {soil: sand: coirpith: FYM in 1:0.5:0.5:1} registered higher net income and BCR due to higher pod yield realized in this treatment. Moreover the cost involved in growth medium preparation was only ₹ 14.25 bag^{-1} since 50 per cent sand was substituted with coirpith as against ₹ 15.76 bag^{-1} in the conventional growth medium.

5.2 EFFECT OF NUTRIENT LEVELS ON GROWTH AND YIELD CHARACTERS OF CONTAINER GROWN YARDLONG BEAN

Yardlong bean responds well to applied nutrients. As the harvest of yardlong bean is protracted, the response to nutrient levels may differ especially when grown in containers. The present recommended dose as per Package of Practices Recommendations Crops (KAU, 2011) is 30: 20: 20 N: P_2O_5: K_2O kg ha^{-1}. For formulating a nutrient recommendation for yardlong bean grown in containers, different nutrient levels of 100, 150 and 200 per cent recommended dose (RD) of NPK were evaluated. The results of the study indicated that different nutrient levels had no influence on growth characters. This was in conformity with the findings of Babu (2015) where different levels of nitrogen had no influence on growth parameters upto 60 DAS of yardlong bean. Duration of the crop was also unaffected by the different nutrient levels. On the contrary, Babu (2015) reported significant variation in crop duration with varying nutrient levels.

The number of days for 50 per cent flowering was not influenced by different nutrient levels. Similar finding was reported by Jyothi (1995) in yardlong bean. However, an increased number of pods plant^{-1} was noticed with the application of 100 per cent and 200 per cent RD of NPK (N_1 and N_3). A significant increase in number of pods up to 60 kg ha^{-1} in black gram was reported by Mishra (1993). However, the increase in number of pods has not reflected in the pod yield. This clearly indicated that increasing the nutrient levels did not have any influence on pod yield of container grown yardlong bean and 100 per cent RD of NPK was sufficient for attaining higher pod yield. Suja (2006) observed that increasing N levels from 30 to 60 kg ha^{-1} had no influence on pod yield of yardlong bean.

The different nutrient levels had no influence on the total dry matter yield plant^{-1}. Geetha (1999) observed no significant influence on dry matter production at different levels of N and K. Harvest index was higher for 100 per cent RD of NPK (N_1).

The root parameters viz., root weight, root volume and root shoot ratio varied with nutrient levels. All root characters were higher on application of 200 per cent RD of NPK which clearly indicated that excess nutrient supply has enhanced the root growth. Higher availability of nutrients might have helped in better proliferation of root system (Cuckoorani, 2013). These findings are in agreement with the report of

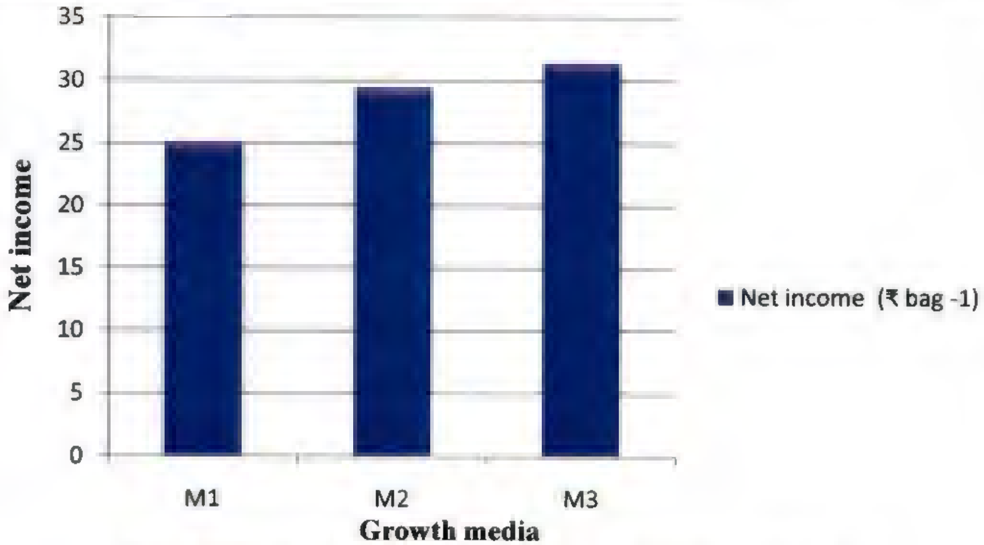


Fig. 9 Effect of growth media on net income (₹ bag $^{-1}$)

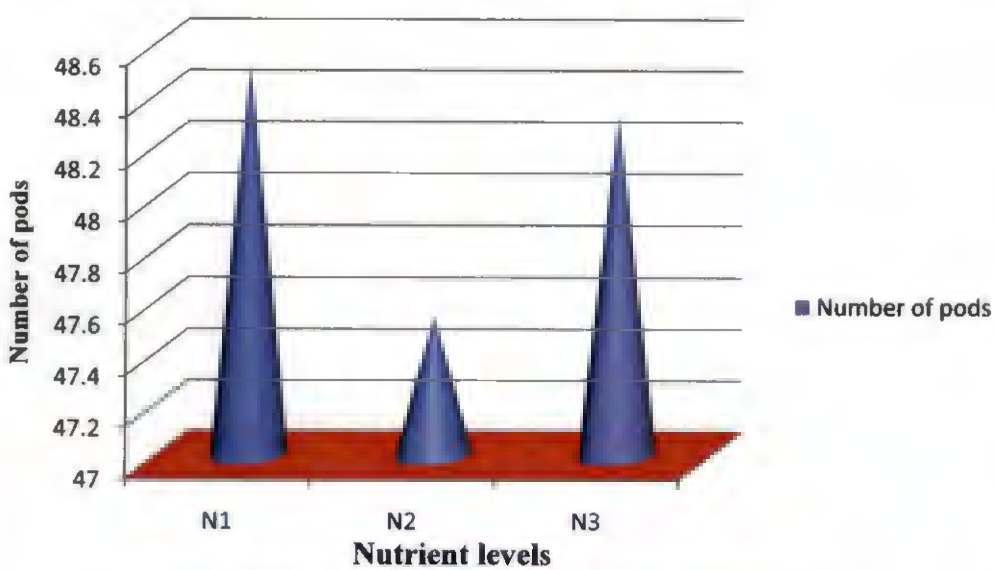


Fig. 10 Effect of nutrient levels on number of pods plant^{-1}

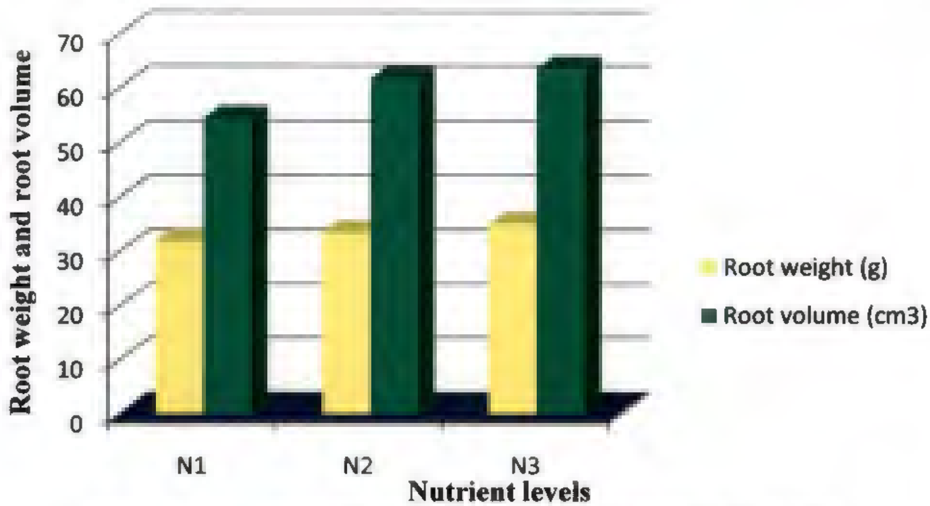


Fig. 11 Effect of nutrient levels on root weight (g) and root volume (cm^3)

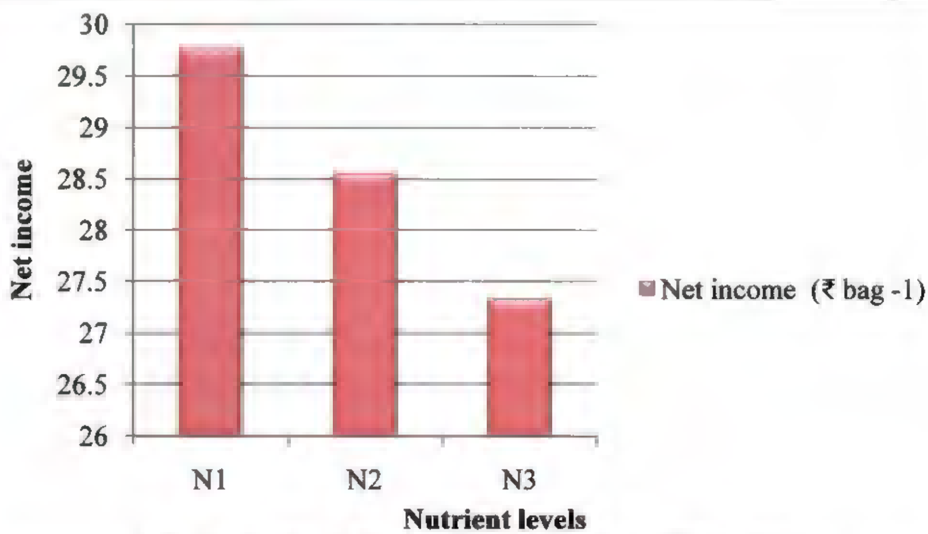


Fig. 12 Effect of nutrient levels on net income (₹ bag $^{-1}$)

Giles (2016) who observed an increase in root volume under higher nutrient levels of N and K in yardlong bean. Increase in P levels also improved the root parameters and root shoot ratio as reported by Basirat *et al*. (2011).

Application of 100 per cent RD of NPK also recorded higher plant nutrient content and uptake at final harvest. This increased uptake could be attributed to the higher dry matter production. This is in conformity with the findings of Babu (2015). Geetha (1999) also observed increased uptake of nutrients due to increased tapping of nutrients from the media.

Available NPK and organic carbon content of growth media after the experiment was found to be higher than the initial status of the media. Application of 200 per cent RD of NPK recorded higher values for available NPK and organic carbon content after the experiment. As the nutrient uptake was low at this level (N_3), the depletion of nutrients from the media was also less resulting in high available NPK and organic carbon content after the crop. Moreover, groundnut cake applied at higher dose also might have contributed to higher organic carbon content after the experiment. An increase in increase in N content with increased level of nutrient was reported by Gill *et al*. (1972) and Faroda and Tomer (1975).

Application of 100 per cent RD of NPK recorded higher net income and BCR. This might be due to the higher yield and lower cost of production (₹ 24.52 bag^{-1}) which resulted in higher net income and subsequently higher BCR.

5.3 EFFECT OF TIME OF APPLICATION ON GROWTH AND YIELD CHARACTERS OF CONTAINER GROWN YARDLONG BEAN

For formulating nutrient schedule, standardizing time of application of nutrients is as important as standardizing nutrient level. From the results of the study, it was observed that time of application had profound influence on number of pods and pod yield of yardlong bean. Between the time of application, T_2 was found superior with respect to most of the yield attributes *viz.*, number of pods plant^{-1}, pod yield plant^{-1}, total dry matter yield plant^{-1}, number of pickings and harvest index. However, it did not have any influence on growth characters and duration of the crop. On the contrary, Babu (2015) reported that split application of N had positive influence on growth characters and duration of yardlong bean.

Among the nutrients, only nitrogen was given in splits, while entire dose of P and K were applied as basal. In the present study, number of pods and pod yield plant^{-1} were higher in split application of N with supply of half N, full P & K as basal and remaining N as fermented groundnut cake at fortnightly interval up to 50% flowering (T_2). This is in conformity with the results reported by Babu (2015) in yardlong bean and Gull *et al.* (2006) in pea. Groundnut cake which is used as the nitrogen source has C: N ratio less than 10: 1 and is amenable for mineralization within one week after application. If entire dose of nitrogen was applied as basal, there were chances for leaching during periods of rainfall and plants may suffer from nitrogen deficiency. Moreover, as a legume, yardlong bean required a starter dose of nitrogen for quicker establishment. According to Misra and Ram (1971), application of smaller dose of starter nitrogen remarkably increased the yield of leguminous crops and split application of nitrogen ensured availability of nitrogen throughout the growing period. The higher availability and uptake of nutrients might have enabled the plant to produce more number of flower buds which in turn increased the number of pods.

The total dry matter yield plant^{-1} and harvest index were also found to be higher for T_2. This might be due to the constant availability of nutrients especially nitrogen throughout the cropping period which might have enhanced dry matter production as reported by Babu (2015). Split application of N also recorded more number of pickings compared to application of full NPK as basal. Yardlong bean is an indeterminate plant which will exhibit continued vegetative growth and pod formation up to the completion of its life cycle. Hence basal application of entire dose

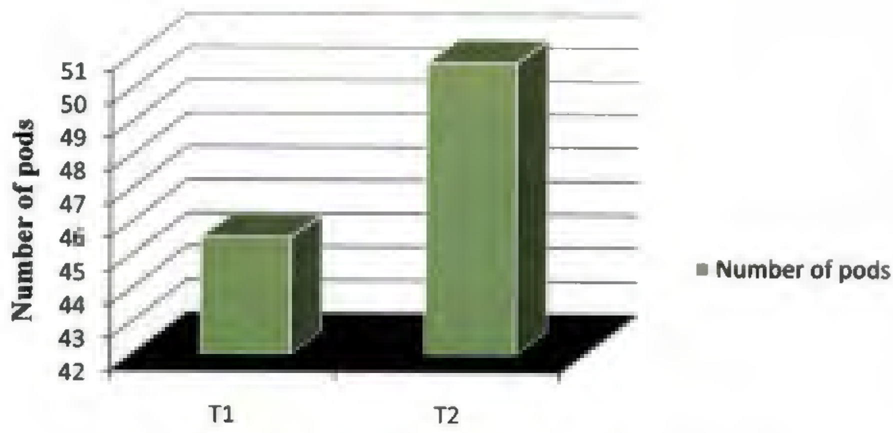


Fig. 13 Effect of time of application on number of pods plant^{-1}

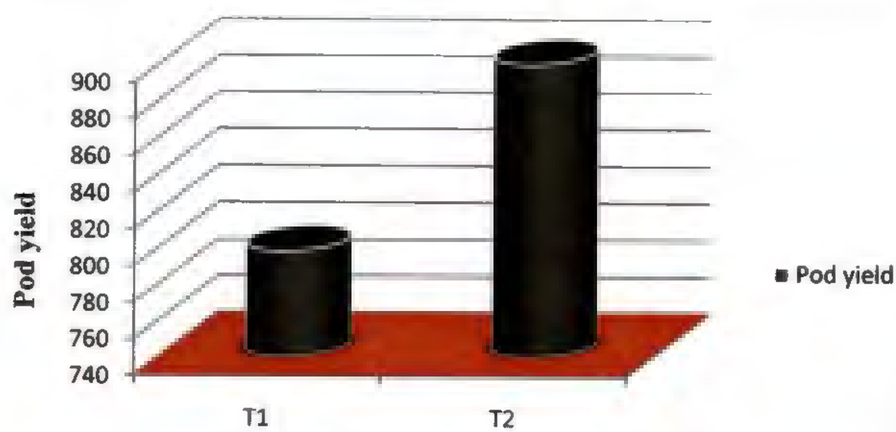
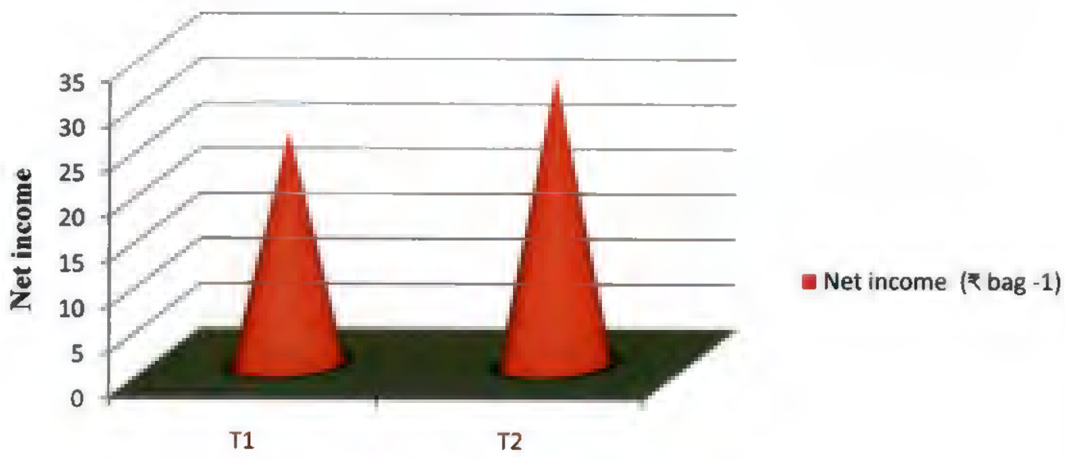


Fig. 14 Effect of time ofapplication on pod yield plant^{-1} (g)



Time of application

Fig. 15 Effect of time of application on net income (₹ bag $^{-1}$)

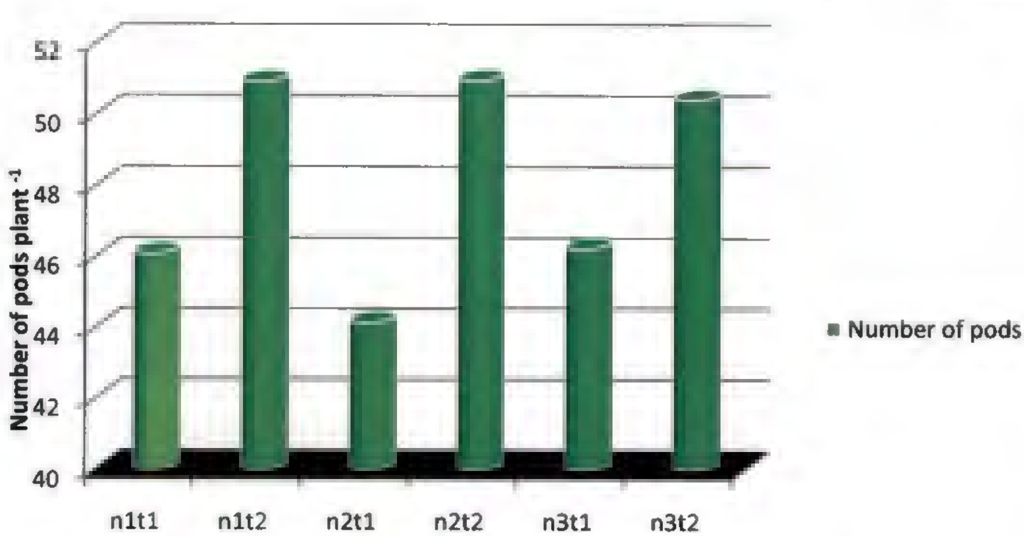


Fig. 16 Interaction effect of nutrient levels and time of application on number of pods plant^{-1}

of nitrogen may not be sufficient to meet the requirement in later crop growth stages and split application helped to prolong the reproductive phase of the crop.

The plant N content was significantly influenced by the time of application and split application recorded higher value when compared to T_1. The uptake of all the major nutrients was found to be higher in spilt application which corresponds to higher dry matter production. Higher dry matter production and availability of nutrients will lead to higher uptake (Babu, 2015).

The available N and organic carbon content of the media after the experiment were significantly influenced by time of application, where split application of N recorded higher organic carbon content over basal application of entire dose. An increase in organic carbon content might be due to low mineralization of groundnut cake applied in splits. Time of application significantly influenced economics of the experiment. Net income and BCR were higher for T_2 since the pod yield recorded was higher for this treatment.

5.4 INTERACTION EFFECT OF GROWTH MEDIA, NUTRIENT LEVELS AND TIME OF APPLICATION ON GROWTH AND YIELD CHARACTERS OF CONTAINER GROWN YARDLONG BEAN

Among the second order interactions, M x N interaction had significant influence on primary branches plant^{-1}, crop duration and days for 50 per cent flowering where m_2n_1 recorded higher number of primary branches plant^{-1}. The combination m_2n_2 registered longer crop duration and the least days for 50 per cent flowering. Higher number of pods was recorded in m_3n_2 where 50 per cent of sand was replaced by coirpith with 150 RD of NPK. However, the interaction effects had no influence on pod yield plant^{-1}. The same treatment combination (m_3n_2) could record higher total dry matter yield plant^{-1}, more number of pickings and higher harvest index. Analyzing the root characters, root weight and root shoot ratio were found to be higher in m_3n_3. Higher NPK content and uptake were recorded with m_3n_1

and it reflected the trend of main effects. Higher net income and BCR were recorded by m_3n_1 which also reflected the trend of main effects.

N x T interactions could markedly influence growth parameter like primary branches plant^{-1} while the number of leaves produced and duration was not affected by the interaction. Feleafel (2005) and Ghoeinm (2005) observed an increase in vegetative characters on split application of nitrogen irrespective of nutrient level. Higher number of pods was recorded at all nutrient levels when applied as half N, full P & K as basal and half N as fermented groundnut cake at fortnightly interval up to 50 per cent flowering. This might be due to ideal distribution of N during the entire growing period on split application especially during flowering and setting stages (Olieveira *et al*., 1971). From these findings, it can be concluded that whatever be the level of nutrient, split application of N helps in production of more number of pods which is one of the important yield contributing character. This is in conformity with the results of Feleafel (2005) in brinjal and Ghoeinm (2005) in sweet pepper where an increase in fruit number plant^{-1} was observed on split application of nitrogen. The same trend was observed in the case of number of pickings also.

The interaction effect of growth media and time of application have exerted significant impact on growth parameters and yield characters. Higher pod yield was registered by m_3t_2 which is a combination of medium composed of soil, sand, coirpith and FYM in the ratio 1: 0.5: 0.5: 1 by weight and split application of nitrogen. This clearly reflected the trend of main effects. The same treatment combination recorded higher total dry matter yield plant^{-1}, more number of pickings and higher harvest index. This might be attributed to the longer air to water balance provided by the coirpith and continued availability of nutrients throughout the cropping period by split application of nitrogen. Root characters viz., root weight and root shoot ratio were influenced by the interaction where m_3t_1 recorded higher root weight and m_2t_1 registered higher root shoot ratio. The results on root characters revealed that basal application of nutrients is favourable for development of healthy root system

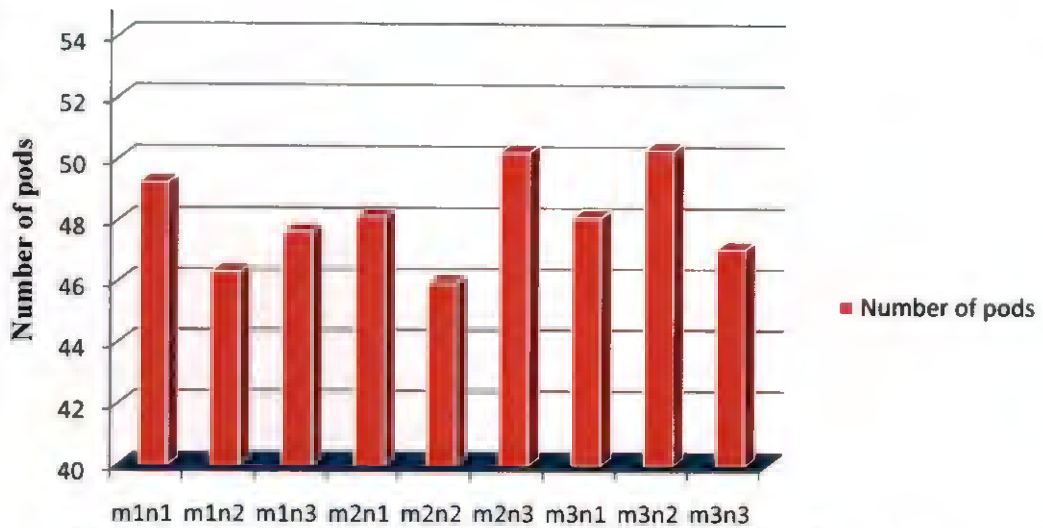


Fig. 17 Interaction effect of growth media and nutrient levels on number of pods plant^{-1}

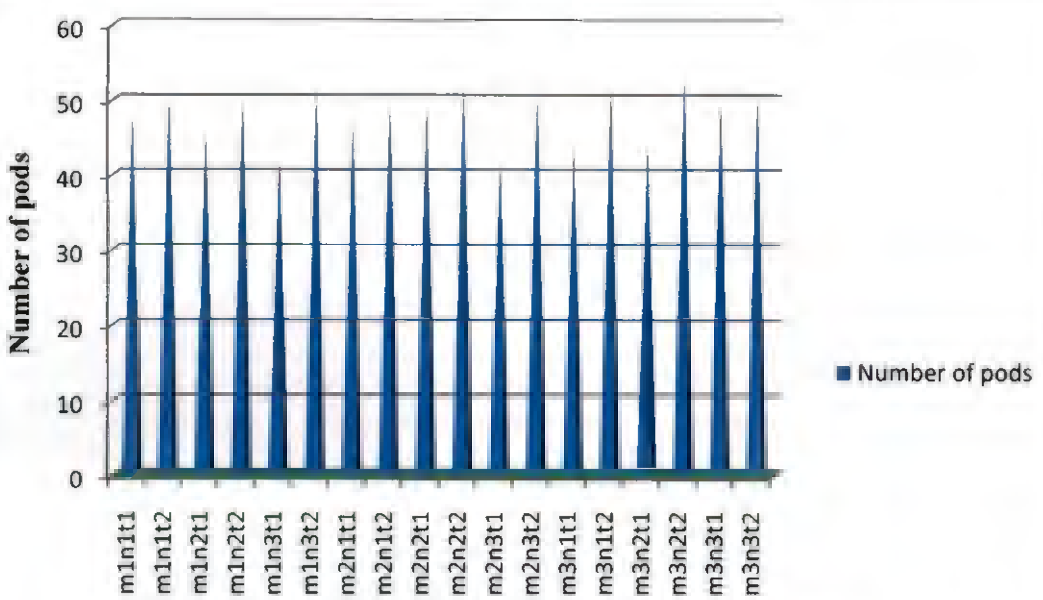


Fig. 18 Interaction effect of growth media, nutrient levels and time of application on number of pods plant^{-1}

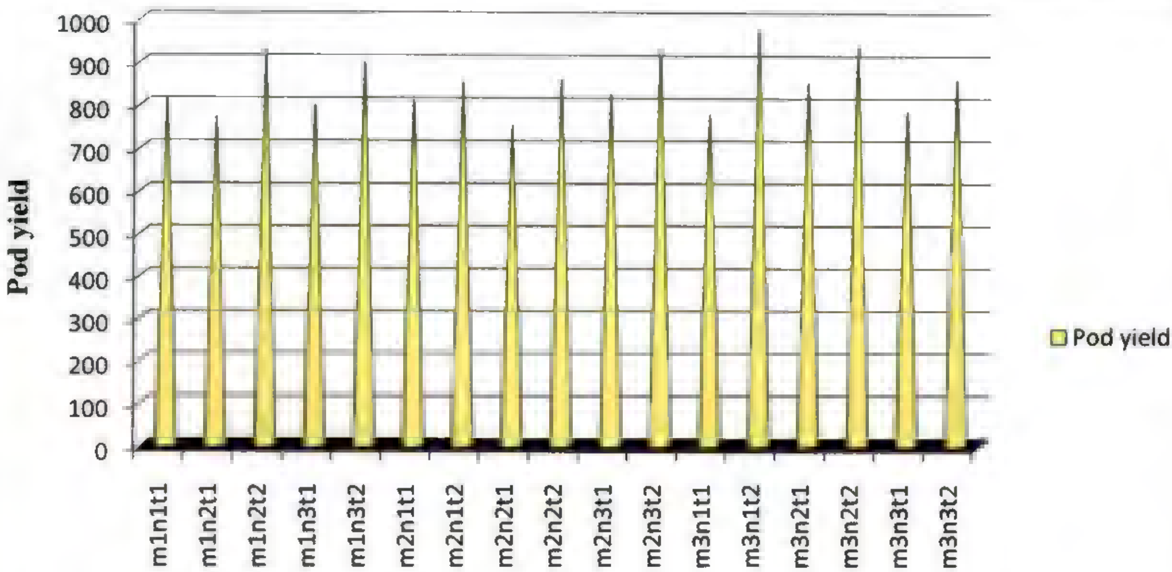


Fig. 19 Interaction effect of growth media, nutrient levels and time of application on pod yield plant^{-1} (g)

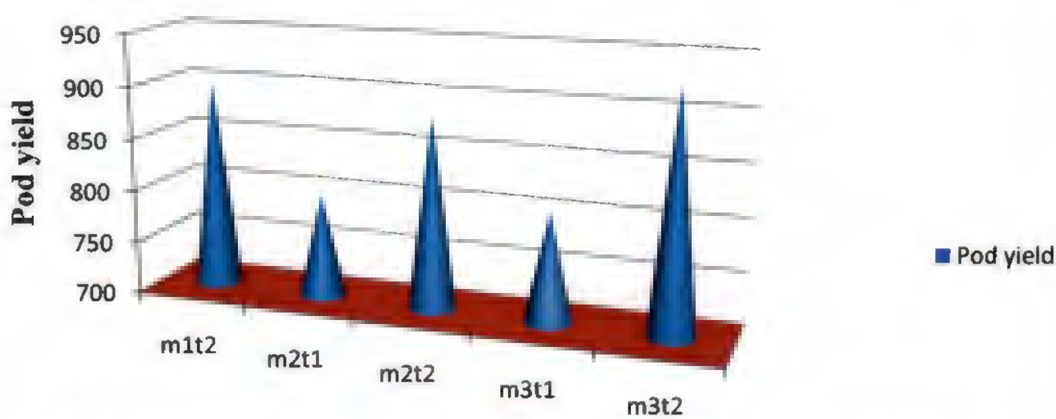


Fig. 20 Interaction effect of growth media and time of application on pod yield plant^{-1} (g)

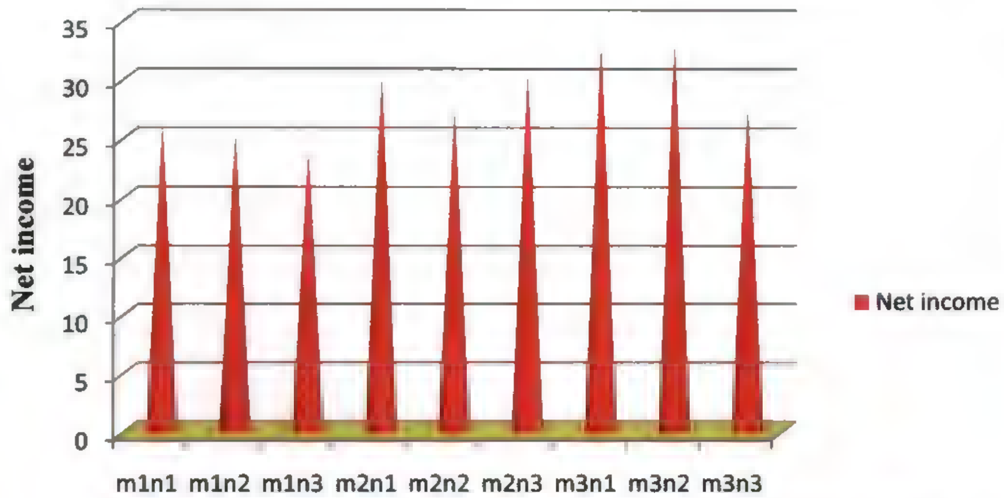


Fig. 21 Interaction effect of growth media and nutrient level on net income (₹ bag $^{-1}$)

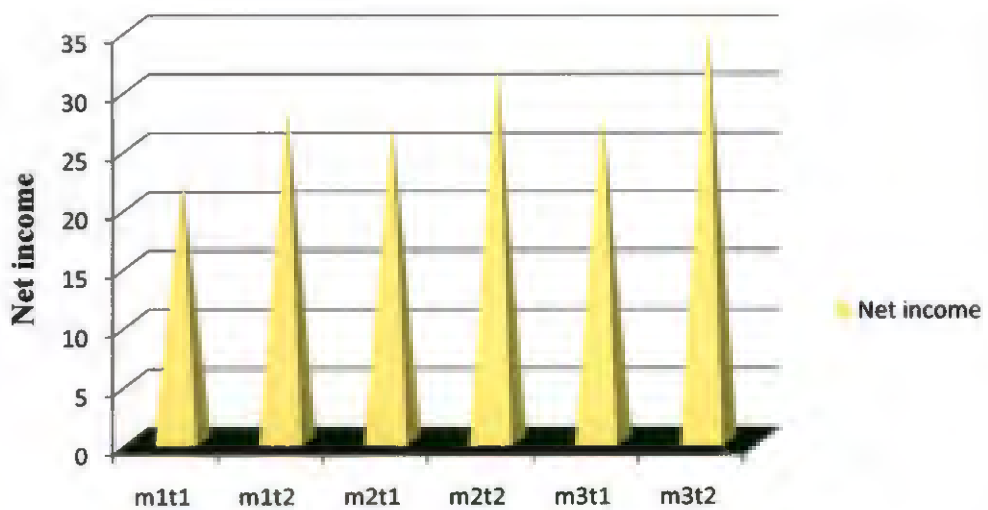


Fig. 22 Interaction effect of growth media and time of application on net income (₹ bag $^{-1}$)

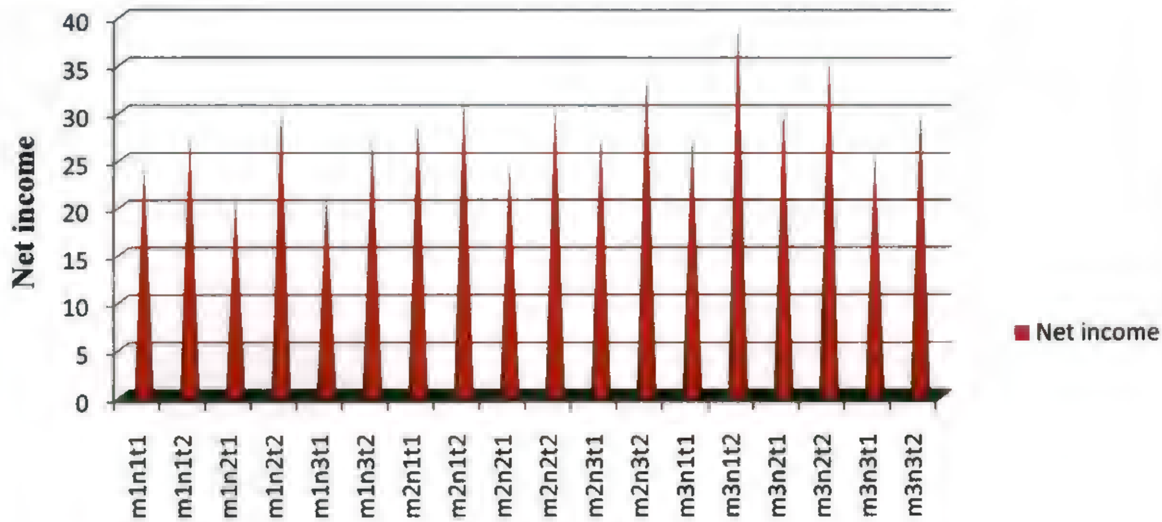


Fig. 23 Interaction effect of growth media, nutrient level and time of application on net income (₹ bag^{-1})

irrespective of the medium. The same treatment combination recorded higher P uptake since the total dry matter produced was higher. Higher net income and BCR were obtained in this combination as pod yield produced $plant^{-1}$ was higher.

Among the third order interactions, $m_3n_1t_2$ recorded higher pod yield which might be due to the enhanced number of pods $plant^{-1}$ and more number of pickings. The same treatment combination registered higher total dry matter yield and harvest index. NPK uptake was also higher in this treatment combination as the dry matter production was high in this combination. The higher pod yield in $m_3n_1t_2$ resulted in higher net income and BCR. This is in conformity with the results obtained by Nagarajan. (1986) where an increase in growth and yield of groundnut was observed by application of coirpith along with recommended dose of NPK. Hence it could be concluded that the medium prepared by substituting 50 per cent sand by coirpith with basal application of 20 g groundnut cake, 10 g bone meal and 70 g wood ash followed by top dressing with fermented groundnut cake was found to be the best growth medium and nutrient schedule.

5.5 EFFECT OF TRAILING METHODS ON GROWTH AND YIELD CHARACTERS OF CONTAINER GROWN YARDLONG BEAN

Study on trailing pattern of yardlong bean was conducted using the best medium M_3 {soil: sand: coirpith: FYM in 1:0.5:0.5:1} from the first experiment. The three trailing methods evaluated were pandal, trellis and trailing stand. The results of the study indicated that the different trailing systems did not have any influence on growth characters. Early flowering was recorded on trellis system while, trailing yardlong bean in trailing stand recorded delayed flowering, longer duration and consequently more number of pickings. Trailing the crop on trellis system recorded higher number of pods and subsequently high yield, which might be attributed to high light interception in trellis system which avoids mutual shading of leaves compared to pandal system. Higher light interception might have increased the photosynthetic

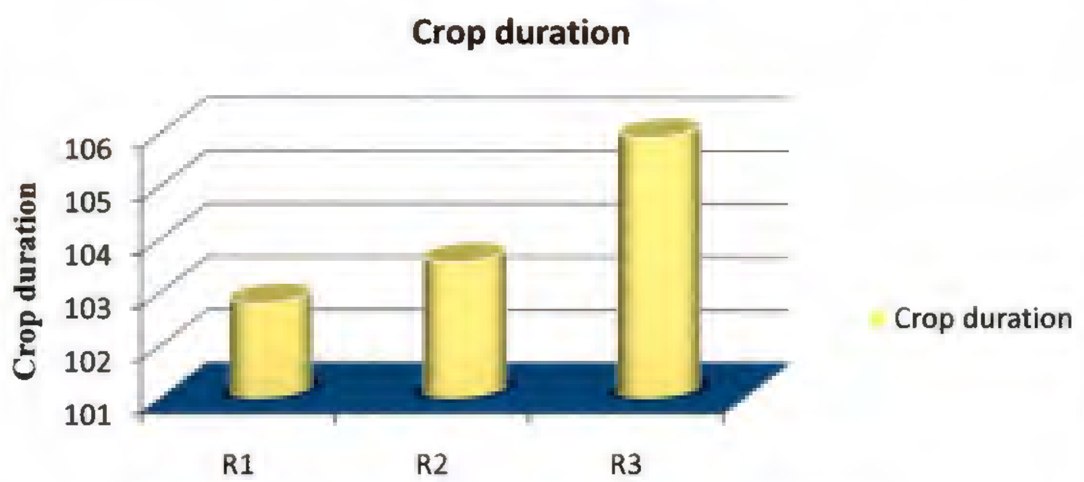


Fig. 24 Effect of trailing method on crop duration (days)

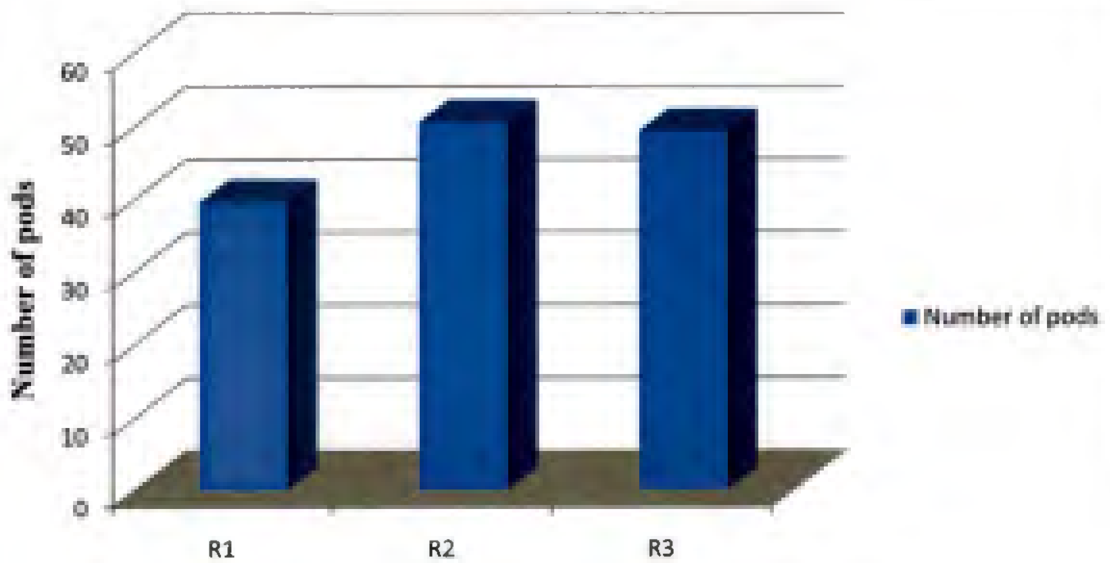


Fig. 25 Effect of trailing method on number of pods plant^{-1}

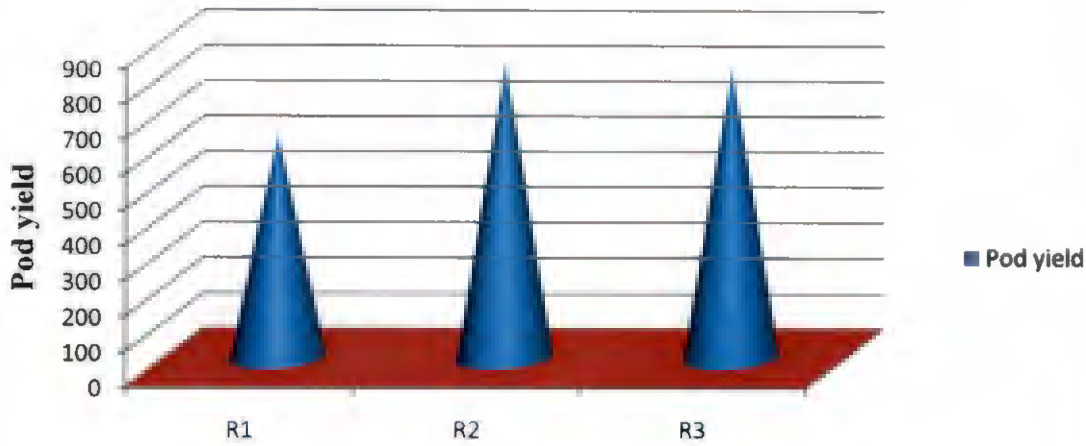


Fig. 26 Effect of trailing method on pod yield plant^{-1} (g)

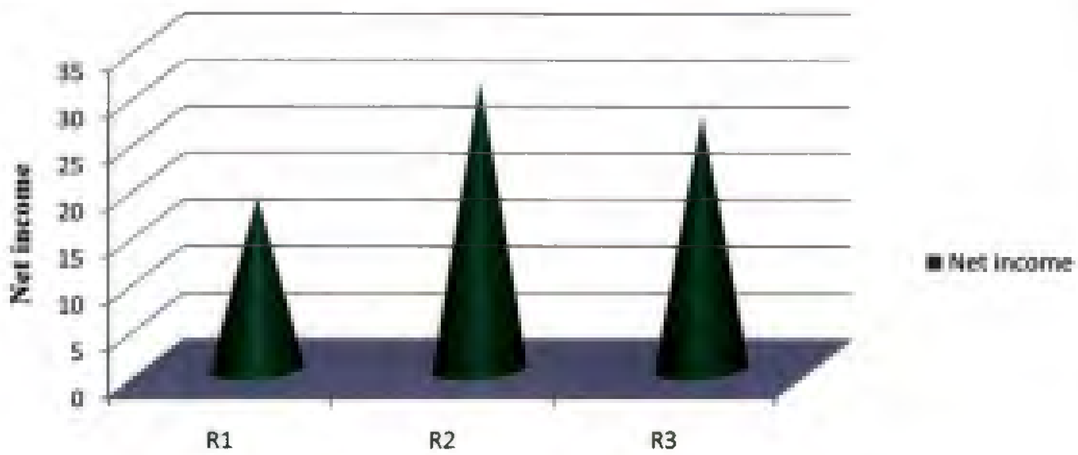


Fig. 27 Effect of trailing method on net income (₹ bag^{-1})

activity of the crop and increased the production, translocation and assimilation of photosynthates to growing points and stimulated the plants to flower early. Moreover, number of parasitic leaves in pandal system might have reduced yield. Trellis system of trailing recorded higher dry matter yield and harvest index. Regarding root parameters, pandal system recorded higher root shoot ratio. The N uptake was also higher when the crop was trailed in the trellis system, while trailing stand recorded higher P uptake. Both trailing stand and trellis system recorded higher K uptake. The nutrient content of the growth medium increased after the experiment; however, different trailing methods could not influence the available NPK and organic carbon content. Trailing yardlong bean in trellis system registered higher net income and BCR owing to the higher number of pods and pod yield.

5.6 EFFECT OF IRRIGATION INTERVALS ON GROWTH AND YIELD CHARACTERS OF CONTAINER GROWN YARDLONG BEAN

Irrigation management is one of the key factors increasing productivity of container grown yardlong bean. The study on irrigation interval was conducted during the summer season. The results of the study indicated that different frequencies of irrigation significantly influenced growth and yield characters. Between the irrigation frequencies, irrigation on a daily basis enhanced growth parameters like primary branches and functional leaves plant^{-1} as moist soil could ensure better nutrient availability and growth (Mohanty and Sharma, 1985, Prasad *et al.*, 1991). Chatterjee and Bhattacharya (1986) reported that absence of moisture stress at the critical stages and higher moisture regimes resulted in better growth. These results were also supported by the findings of Jayaraman (1994) and Trivedi *et al.* (1994). The number of leaves of yardlong bean was noticeably increased by providing irrigation at 75 per cent available soil moisture (ASM) in summer season (Jyothi, 1995). According to Mini (1997) frequent light irrigations given to yardlong bean resulted in production of higher number of leaves plant^{-1} during summer season. Being an indeterminate crop, pod yield was significantly influenced by crop duration and number of pickings. Daily irrigation had a positive influence on crop duration and inducing stress by increasing the irrigation interval reduced the crop duration in I_2. Similar finding of extended crop duration on daily irrigation was reported by Babu (2015) in yardlong bean. In treatments subjected to moisture stress, early flowering was observed. This might be due to the early initiation of flower buds in mild stress which is in conformity with the results obtained by Babu (2015) in yardlong bean.

The major yield attributes *viz.*, number of pods plant^{-1} (50.49) and pod yield plant^{-1} (941.84 g) were significantly superior in daily irrigation (I_1). The increased yield might be a direct reflection of improved growth parameters on daily irrigation. Adequate moisture availability throughout the growing period resulted in better growth and yield. Optimum moisture supply might have solubilized, mobilized and translocated the nutrients resulting in higher pod yield. According to Jyothi (1995) an increase in soil wetness increases pod and haulm yield of yardlong bean during summer season. Similar finding was reported by Mini (1997) in yardlong bean. Padmanabhan and Swadija (2015) opined that daily irrigation is required for vegetables grown in containers on house terraces.

Irrigation on a daily basis recorded higher dry matter yield and harvest index. Under moisture stress condition, a vapour gap would be formed around the roots, which might have reduced the availability of nutrients by their turgor pressure probably due to lesser contact between roots and water particles and causes a drastic reduction in dry matter production and uptake of nutrients (Phillips, 1966). The number of pickings was also higher in daily irrigation as the duration of the crop was higher. The availability of moisture throughout the growth period might have prolonged the reproductive phase of the crop which is in conformity with the results reported by Babu (2015).

Analyzing the root characters, root weight, root volume and root shoot ratio were significantly influenced by the irrigation interval. Daily irrigation recorded

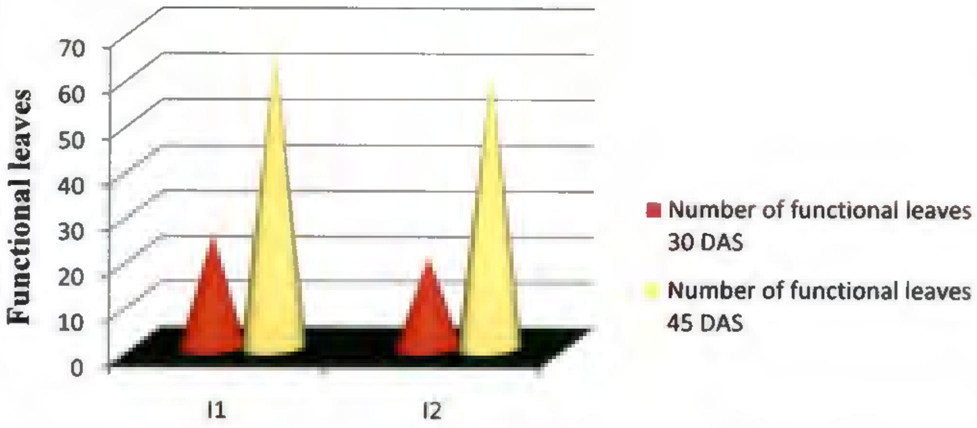


Fig. 28 Effect of irrigation on functional leaves plant^{-1} at 30 and 45 DAS

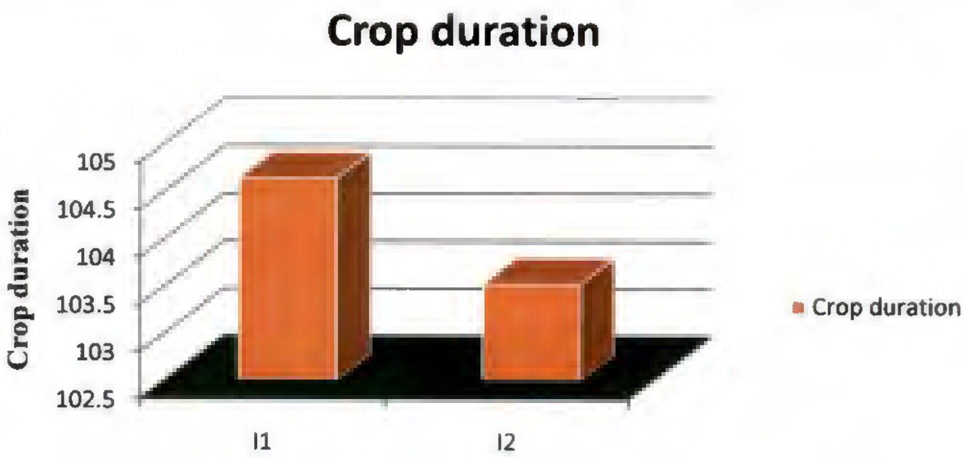


Fig. 29 Effect of irrigation on crop duration (days)

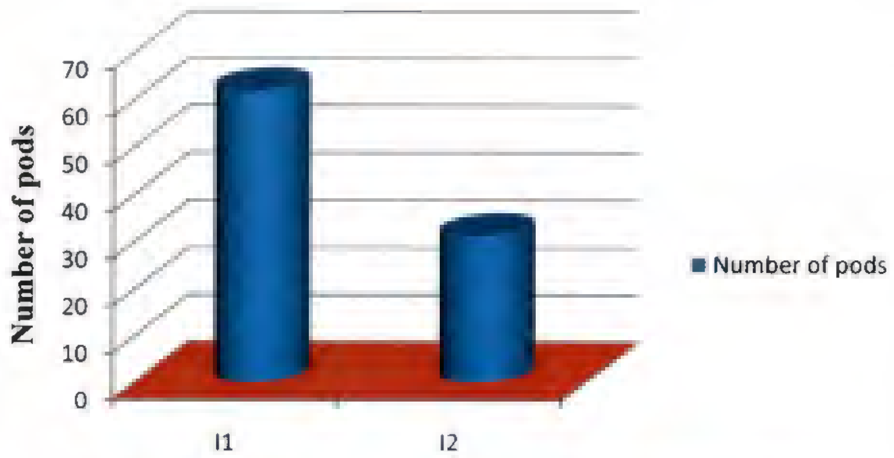


Fig. 30 Effect of irrigation on number of pods plant^{-1}

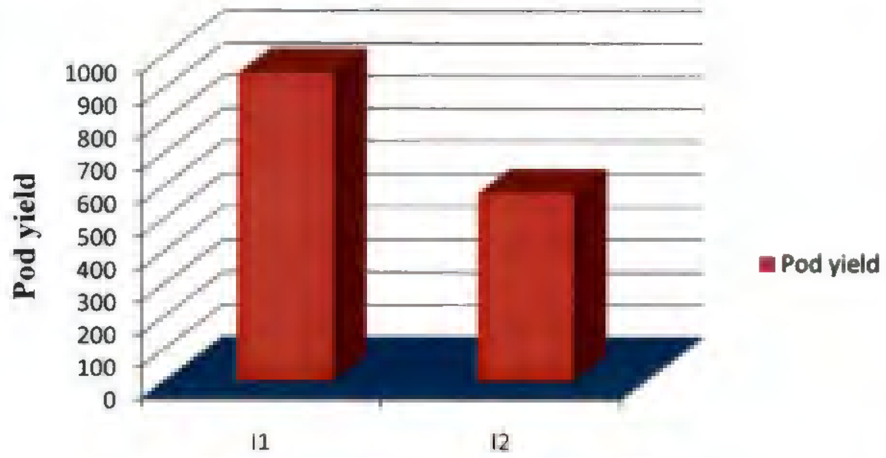


Fig. 31 Effect of irrigation on pod yield plant^{-1} (g)

Plate 5 Pod yield

higher values for root parameters. This might be attributed to the adequate moisture in the root zone which helped in development of healthy root system throughout the growth period. Similar result on increase in root weight and root volume under daily irrigation was observed by Babu (2015). A reduction in root volume observed in I_2 is corroborated by the finding of Hamidou *et al.* (2007) where a reduction in root volume was noticed in cowpea genotypes under water stress.

The NPK uptake was remarkably influenced by irrigation interval where daily irrigation recorded higher values. The increased dry matter production in daily irrigation resulted in higher nutrient uptake. This is in agreement with the findings of Mini (1997) and Babu (2015) in yardlong bean. Irrigation interval could significantly influence available P content of the media after the experiment. Daily irrigation recorded higher available P content after the experiment which might be due to the mineralization of applied P under favourable moisture regimes thereby increasing the available P content in the medium.

The economic parameters viz., net income and BCR were influenced by irrigation interval where daily irrigation recorded higher values. Irrigating the crop at 80 to 100 per cent available soil moisture resulted in maximum net income in yardlong bean (Patel, 1979).

5.7 INTERACTION EFFECT OF TRAILING METHODS AND IRRIGATION INTERVALS ON GROWTH AND YIELD CHARACTERS OF CONTAINER GROWN YARDLONG BEAN

The interaction of trailing methods and irrigation intervals did not have any influence on growth characters while it influenced the yield characters. Higher number of pods were registered by trellis system under daily irrigation (r_2i_1) followed by trailing stand under daily irrigation (r_3i_1). Higher pod yield plant^{-1} was also recorded by trellis system under daily irrigation. This reflected the trend of main effects. The same treatment combination registered higher dry matter yield and

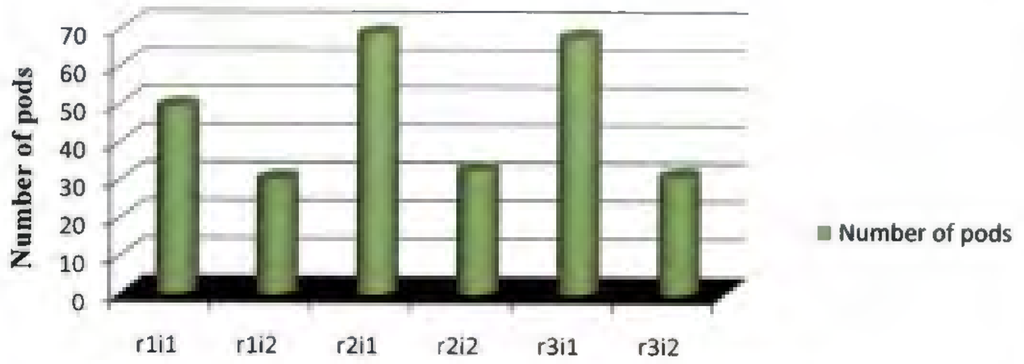


Fig. 32 Interaction effect of trailing method and irrigation on number of pods plant^{-1}

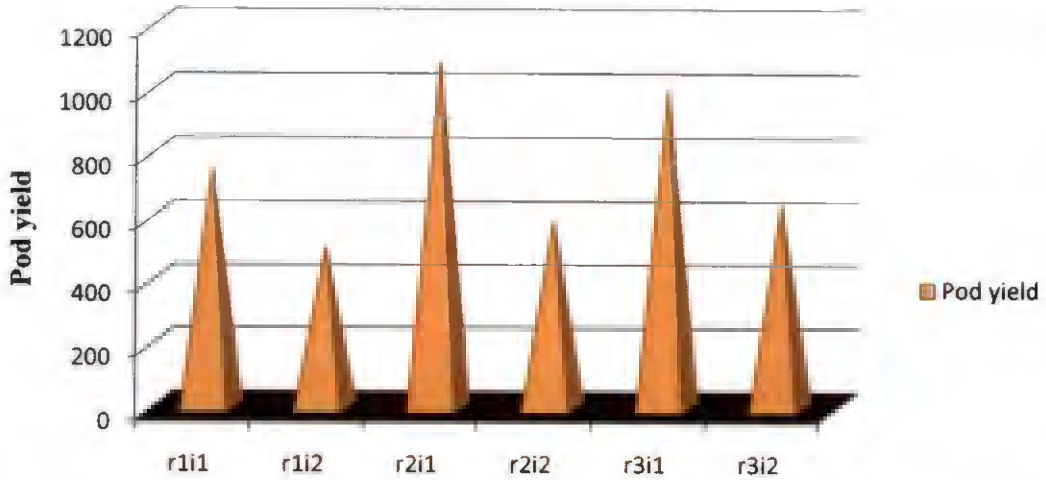


Fig. 33 Interaction effect of trailing method and irrigation on pod yield plant^{-1} (g)

harvest index. The interaction effect could not influence the root characters. However, N and K uptake were found to be higher in the same treatment combination which recorded higher dry matter yield. Higher K uptake was recorded by trailing the crop in the trailing stand under daily irrigation followed by trellis system under daily irrigation. Analyzing the economics of cultivation, net income and benefit cost ratio were found to be higher with the trellis system (R_2) and daily irrigation (I_1). The treatment combination r_2i_1 recorded the highest net income (₹ 45.48 bag^{-1}) and benefit cost ratio (2.36).

The study investigated five factors related to container grown yardlong bean viz., growth media, nutrient level, time of application, trailing method and irrigation interval. From the results of the experiments conducted, the agronomic package for container grown yardlong bean can be summarised as

- Growth medium with soil, sand, coirpith, FYM in 1: 0.5: 0.5: 1 ratio by weight basis for a growbag having 9 kg potting media (3 kg soil, 1.5 kg sand, 1.5 kg coirpith and 3 kg FYM).
- Nutrient level and time of application (nutrient schedule) of 100 per cent RD of NPK as organic in split application (basal application of 20 g groundnut cake + 10 g bone meal + 70 g wood ash and top dressing with fermented groundnut cake (10 g L^{-1}) bag^{-1} @ 30 & 45 DAS).
- Trellis system of trailing with daily irrigation.

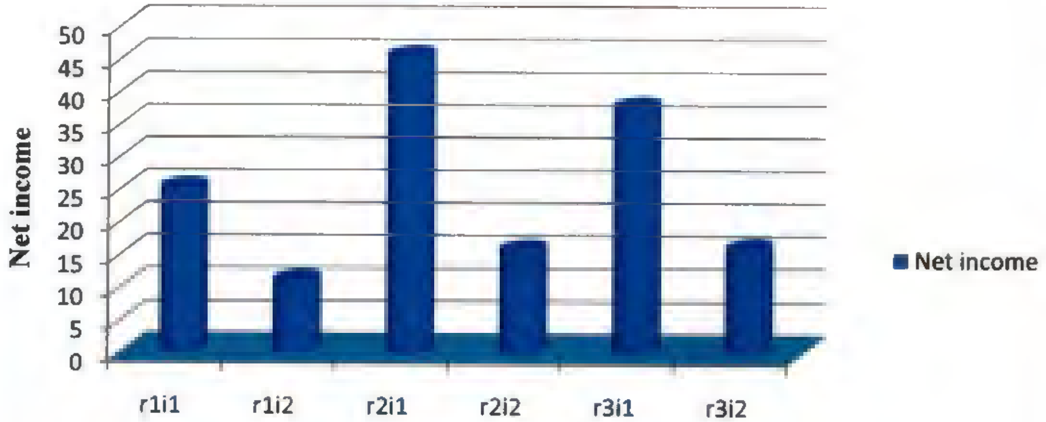


Fig. 34 Interaction effect of trailing method and irrigation interval on net income (₹ bag $^{-1}$)

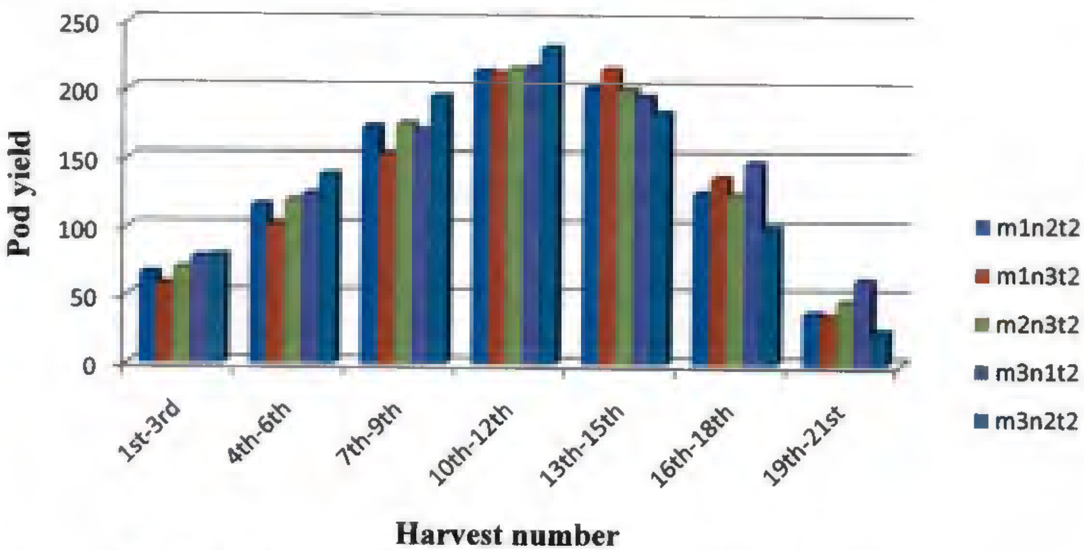


Fig. 35 Effect of growth media, nutrient levels and time of application on pod yield harvest^{-1}

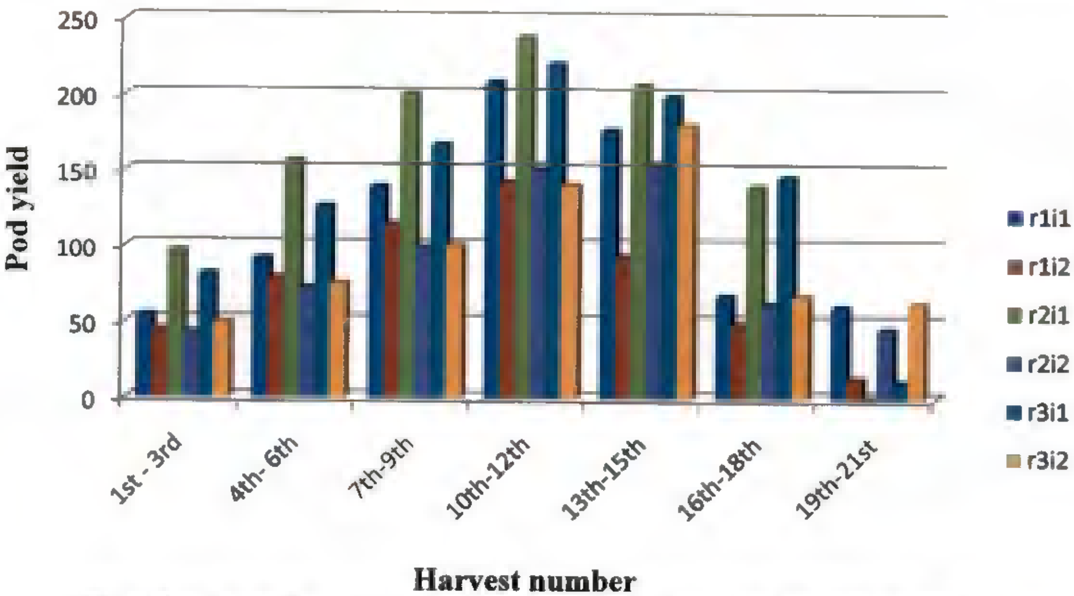


Fig. 36 Interaction effect of trailing method and irrigation on pod yield harvest^{-1}

Summary

6. SUMMARY

The investigation entitled "Agro techniques for container grown yardlong bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)" was undertaken at College of Agriculture, Vellayani during the period 2015-2017.

The primary objectives of the study were to identify an ideal growth medium; to standardise nutrient schedule, irrigation interval and trailing method so as to formulate an agronomic package for container grown yardlong bean. The study was conducted as two separate experiments in containers.

The first experiment on 'Growth media evaluation and nutrient studies in container grown yardlong bean' was conducted during the *rabi* season of 2016 at the Instructional Farm, College of Agriculture, Vellayani. The treatments consisted of three growth media {M_1: soil : sand : FYM (1:1:1), M_2 : soil : sand : coirpith : FYM (1: 0.75 : 0.25 : 1), M_3: soil: sand: coirpith: FYM (1: 0.5 : 0.5 : 1)}, three nutrient levels (N_1: 100% recommended dose (RD) of NPK, N_2: 150% RD of NPK, N_3: 200% RD of NPK) and two time of application (T_1: full NPK as basal and T_2: half N, full P & K as basal + half N as fermented groundnut cake at fortnightly interval up to 50 per cent flowering). The nutrient recommendation for yardlong bean is N: P_2O_5: K_2O @ 30: 30: 20 kg ha^{-1} as per the Package of Practices Recommendations Crops. The experiment was laid out in completely randomized design with three replications. The crop was raised in uniform sized growbags (39 cm x 26 cm) with 18 treatment combinations. The major nutrients N, P and K were applied by organic means as groundnut cake, bone meal and wood ash respectively as per the treatments.

The results of the experiment are summarized in this chapter.

- The growth medium, M_3 {soil: sand: coirpith: FYM in 1: 0.5: 0.5: } and M_2 {soil: sand: coirpith: FYM in 1:0.75:0.25:1} registered higher values for growth parameters viz., primary branches and functional leaves plant^{-1} at 30 &

45 DAS while different nutrient levels and time of application did not exert any influence on growth attributes.

- Among the interactions, m_2n_1, n_3t_1, m_2t_1 and $m_2n_3t_1$ recorded higher number of primary branches plant^{-1} at 30 DAS and m_3n_3, m_3t_1 recorded higher number of primary branches plant^{-1} at 45 DAS.
- M_3 recorded longer crop duration and was on par with M_2.
- Interaction of growth media and nutrient levels influenced duration of the crop where m_2n_2 recorded longer duration.
- Different growth media significantly influenced days for 50 per cent flowering where M_1 {soil: sand: FYM in 1:1:1} was on par with M_2 registered early flowering, while different nutrient levels had no influence on days for 50 per cent flowering.
- T_1 (full NPK as basal) recorded early flowering when compared to T_2 (half N, full P and K as basal + half N as fermented groundnut cake at fortnightly interval).
- m_2n_2, n_2t_1, m_2t_1 and $m_2n_2t_2$ recorded early flowering among the interactions.
- The number of pods plant^{-1} were higher in M_3 {soil: sand: coirpith: FYM in 1: 0.5: 0.5: 1}.
- Application of 100 per cent recommended dose of NPK (N_1) recorded higher number of pods plant^{-1} and was on par with 200 per cent recommended dose of NPK (N_3).
- T_2 recorded significantly superior number of pods plant^{-1}.
- Among the interactions, m_3n_2, n_2t_2, $m_3n_2t_2$ recorded higher number of pods plant^{-1}.
- M_3 {soil: sand: coirpith: FYM in 1: 0.5: 0.5: 1} registered significantly superior pod yield plant^{-1} while different nutrient levels had no influence on pod yield plant^{-1}.

- T_2 (half N, full P and K as basal + half N as fermented groundnut cake at fortnightly interval) recorded significantly superior pod yield plant^{-1} (899.57 g) when compared to T_1.
- Interaction of growth media and time of application influenced pod yield plant^{-1} where m_3t_2 recorded higher pod yield plant^{-1}.
- Among the high order interaction of main effects M, N and T, $m_3n_1t_2$ recorded significantly superior pod yield plant^{-1} (973.76 g).
- Total dry matter yield plant^{-1} was significantly influenced by different growth media where M_3 recorded higher value.
- T_2 recorded higher total dry matter yield plant^{-1} compared to T_1.
- m_3t_2 and $m_2n_2t_2$ registered higher total dry matter yield plant^{-1}.
- M_3 recorded more number of pickings when compared to other growth media.
- Nutrient levels had no influence on number of pickings however time of application exerted significant influence on it where T_2 registered more number of pickings.
- Among the interactions, m_3n_2, n_2t_2, m_3t_2 and $m_3n_2t_2$ recorded more number of pickings.
- M_3 registered significantly superior harvest index.
- Application of 100 per cent recommended dose of NPK (N_1) recorded higher harvest index.
- T_2 registered significantly superior harvest index compared to T_1.
- The two factor interactions m_3n_2, n_2t_2, m_3t_2 and three factor interaction $m_3n_1t_2$ recorded superior harvest index.
- Root weight was significantly influenced by different growth media where M_3 recorded higher root weight.
- Application of 200 per cent recommended dose of NPK (N_3) recorded superior root weight.

- Between the time of application, T_1 registered higher root weight compared to T_1.
- Among the interactions, m_3n_2, n_3t_1, m_3t_1 and $m_3n_3t_1$ recorded higher root weight.
- Application of 200 per cent recommended dose of NPK (N_3) recorded superior root volume over other nutrient levels while different growth media and time of application had no influence on it.
- M_3 registered superior root shoot ratio among the different growth media.
- Application of 200 per cent recommended dose of NPK (N_3) recorded superior root shoot ratio.
- T_1 recorded higher root shoot ratio compared to T_2.
- All two factor interactions influenced root shoot ratio where m_3n_3, n_3t_1 and m_2t_1 registered higher root shoot ratio.
- M x N x T interaction influenced root shoot ratio where $m_3n_3t_1$ superior root shoot ratio.
- M_3 registered significantly superior plant NPK content and uptake at final harvest.
- Different nutrient levels significantly influenced plant NPK content and uptake at final harvest, where application of 100 per cent recommended dose of NPK (N_1) recorded superior values.
- T_2 registered significantly superior plant N, K content and NPK uptake at final harvest.
- Interaction of growth media and nutrient level influenced plant NPK content and uptake at final harvest, where m_3n_1 recorded superior values.
- M x T interaction exerted influence on plant P content at final harvest, where m_3t_2 recorded higher value.
- $m_3n_1t_2$ registered superior plant NPK uptake at final harvest.

- The available N and K of the media were influenced by different growth media where M_1 {soil: sand: FYM in 1:1: 1} and M_2 recorded higher values.
- Among the interactions, n_3t_1, m_1t_2 and $m_2n_3t_1$ registered higher available N after the experiment.
- Application of 200 per cent recommended dose of NPK (N_3) recorded higher available NPK and organic carbon content after the experiment.
- The available N content was found to be higher in T_1 and T_2 and organic carbon content was found to be higher in T_2.
- The chemical characters of the best medium (M_3) were found to be pH – 7.13, EC - 1.3 d S m^{-1}, N - 0.085%, P - 0.042%, K - 0.018% and OC - 3.8 %.
- The growth medium (M_3) composed of soil: sand: coirpith: FYM in the ratio 1: 0.5: 0.5: 1 by weight recorded significantly superior net income and BCR.
- Nutrient levels significantly influenced economics of cultivation where application of 100 per cent recommended dose of NPK recorded higher net income and BCR.
- T_2 recorded significantly superior net income and BCR over T_1.
- m_3n_1, m_3t_2 and $m_3n_1t_2$ recorded higher net income and BCR.

The second experiment 'Studies on trailing pattern of yardlong bean under various irrigation frequency' was conducted during the summer season of 2017 at the Instructional Farm, Vellayani using the best growth media identified {soil: sand: coirpith: FYM (1: 0.5 : 0.5 : 1)} from the first experiment. The treatments included three trailing methods (R_1: pandal system, R_2: trellis system and R_3: trailing stand) and two irrigation frequencies (I_1: daily and I_2: when plant is at temporary wilting stage) replicated thrice adopting completely randomized design.

- Irrigation frequency had significant influence on growth attributes where daily irrigation (I_1) recorded superior values.

- Trailing the crop on trailing stand (R_3) recorded longer duration (105.9 days).
- Duration of the crop was influenced by irrigation frequency where irrigation on daily basis (I_1) recorded longer duration.
- Trailing the crop on trellis system (R_2) registered early flowering.
- Irrigation given when plant is at temporary wilting stage (I_2) recorded least days for 50 per cent flowering.
- The number of pods plant^{-1} was influenced by different trailing methods where trailing the crop on trellis system (R_2) recorded significantly superior number of pods (50.5).
- Daily irrigation (I_1) registered significantly superior number of pods over irrigation when plant is at temporary wilting stage (I_2).
- Interaction of trailing method and irrigation frequency profoundly influenced number of pods plant^{-1} where r_2i_1 (trellis system under daily irrigation) recorded higher number of pods.
- Higher pod yield plant^{-1} was recorded when the crop was trailed on trellis system (R_2) (832.02 g).
- Pod yield plant^{-1}was significantly superior on daily irrigation (I_1) (941.84 g) compared to irrigation when plant is at temporary wilting stage on.
- R x I interactions significantly influenced pod yield plant^{-1}, where trellis system under daily irrigation (r_2i_1) recorded superior pod yield.
- Total dry matter yield plant^{-1}and harvest index was found to be higher in trellis system (R_2).
- Daily irrigation recorded superior total dry matter yield plant^{-1} and harvest index over I_2 (irrigation when plant is at temporary wilting stage).
- Trailing the crop on trellis system under daily irrigation (r_2i_1) recorded superior total dry matter yield plant^{-1} and harvest index.
- Trailing the crop on trailing stand (R_3) recorded more number of pickings.

- The number of pickings was found to be more in daily irrigation (I_1) over irrigation when plant is at temporary wilting stage (I_2).
- Root shoot ratio was found to be higher in pandal system (R_1).
- The root parameters viz., root weight, root volume and root shoot ratio were higher on daily irrigation (I_1).
- The N and P uptake was found to be higher in trellis system (R_2) and K uptake was higher in both trellis system (R_2) and trailing stand (R_3).
- Higher NPK uptake and P content was observed on daily irrigation (I_1).
- Interaction of trellis system and daily irrigation (r_2i_1) registered higher N and K uptake.
- Trailing the crop on trailing stand along with daily irrigation (r_3i_1) recorded higher P uptake.
- The available P after the experiment was influenced by irrigation interval where daily irrigation (I_1) recorded higher value.
- Superior net income (₹ 30.65 bag^{-1}) and BCR (1.59) were recorded when the crop was trailed on trellis system (R_2).
- Irrigating the crop on a daily basis (I_1) recorded superior net income and BCR.
- Interaction of trailing method and irrigation interval influenced economics of cultivation where trailing the crop on trellis system under daily irrigation (r_2i_1) recorded superior net income (₹ 45.48 bag^{-1}) and BCR (2.36).

The agronomic package for container grown yardlong bean can be summarised as

- Growth media : soil, sand, coirpith, FYM in ratio 1: 0.5: 0.5: 1 by weight basis (3 kg soil, 1.5 kg sand, 1.5 kg coirpith and 3 kg FYM)
- Nutrient level and time of application : 100% recommended dose of NPK (basal application of 20 g groundnut cake + 10 g bone meal + 70 g wood ash and top dressing with fermented groundnut cake (10 g L^{-1}) bag^{-1} @ 30 & 45 DAS)

- Trailing method : Trellis system
- Irrigation interval : Daily basis

Future line of work

- Formulation of ready to use media for container grown vegetables.
- The response of yardlong bean to biofertilizers as source of nutrients to be studied.
- Performance of yardlong bean under other irrigation methods like wick irrigation to be explored.

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Abstract

AGRO TECHNIQUES FOR CONTAINER GROWN YARDLONG BEAN

(*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)

by

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ABSTRACT

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The study entitled "Agro techniques for container grown yardlong bean (*Vigna unguiculata* var.*sesquipedalis* (L.) Verdcourt)" was undertaken at College of Agriculture, Vellayani during 2015 - 17. The objectives of the study were to identify an ideal growth medium, to standardise nutrient schedule, irrigation interval and trailing method so as to formulate an agronomic package for container grown yardlong bean. The study was conducted as two separate experiments.

The first experiment on 'Growth media evaluation and nutrient studies in container grown yardlong bean' was conducted during the *rabi* season of 2016 at the Instructional Farm, College of Agriculture, Vellayani. The treatments consisted of three growth media {M_1: soil : sand : FYM (1 : 1 : 1), M_2 : soil : sand : coirpith : FYM (1 : 0. 75 : 0.25 : 1), M_3: soil: sand: coirpith: FYM (1: 0.5 : 0.5 : 1)}, three nutrient levels (N_1 : 100% recommended dose (RD) of NPK, N_2 : 150% RD of NPK, N_3 : 200% RD of NPK) and two time of application (T_1: full NPK as basal and T_2: half N, full P & K as basal + half N as fermented groundnut cake at fortnightly interval up to 50 per cent flowering). The recommended dose (RD) for yardlong bean is N: P_2O_5: K_2O @ 30: 30: 20 kg ha^{-1} as per the Package of Practices Recommendations Crops. The experiment was laid out in completely randomized design with three replications. The crop was raised in uniform sized growbags (39 cm

x 26 cm) with 18 treatment combinations. The major nutrients N, P and K were applied by organic means as groundnut cake, bone meal and wood ash respectively as per the treatments.

Results of the study indicated that among the growth media, M_3 registered significantly higher values for growth parameters *viz*., primary branches and functional leaves plant^{-1} and crop duration (104.33 days) and was on par with M_2. The major yield attribute, number of pods plant^{-1} (48.51) was significantly superior in M_3. Pod yield plant^{-1} (862.74 g) was superior for M_3. Total dry matter yield plant^{-1}, number of pickings, harvest index, root weight, root volume, plant NPK content and uptake were also found higher in M_3.

The different nutrient levels did not exert any significant influence on growth attributes. However, N_1 recorded the highest number of pods plant^{-1} (48.50) and harvest index (0.392). The plant NPK content and uptake were significantly superior in N_1. N_3 recorded higher root parameters viz., root weight, root volume and root shoot ratio.

Between the time of application, T_2 was found superior with respect to most of the yield attributes *viz*., number of pods plant^{-1} (50.5), pod yield plant^{-1} (899.74 g), total dry matter yield plant^{-1}, number of pickings and harvest index. T_1 recorded higher root parameters viz., root weight and root shoot ratio. The treatment combination $m_3n_1t_2$ registered the highest pod yield plant^{-1} (973.76 g). The individual effects (M_3, N_1 and T_2) and their combinations ($m_3n_1t_2$) recorded the highest net income (₹ 39.15 bag^{-1}) and benefit cost ratio (2.03).

The second experiment 'Studies on trailing pattern of yardlong bean under various irrigation frequency' was conducted during the summer season of 2017 at the Instructional Farm, Vellayani using the best growth media identified {soil: sand: coirpith: FYM (1: 0.5 : 0.5 : 1)} from the first experiment. The treatments included three trailing methods (R_1: pandal system, R_2: trellis system and R_3: trailing stand)

and two irrigation frequencies (I_1: daily and I_2: when plant is at temporary wilting stage) replicated thrice adopting completely randomized design.

Results of the study indicated that among the trailing methods, R_3 registered the longest crop duration (105.9 days). The major yield attributes *viz.*, number of pods plant^{-1} (50.49), pod yield plant^{-1} (832.03 g), total dry matter yield plant^{-1} and harvest index were significantly superior in R_2 which also registered the highest NPK uptake. R_1 and R_2 recorded higher root shoot ratio.

Between the irrigation frequencies, daily irrigation (I_1) registered significantly superior growth attributes like primary branches and functional leaves at 45 DAS. The major yield attributes *viz.*, number of pods plant^{-1} (50.49) and pod yield plant^{-1} (941.84 g) were significantly superior in daily irrigation (I_1). The same treatment also registered higher total dry matter yield plant^{-1}, more number of pickings, harvest index, root parameters and high plant NPK uptake.

Net income and benefit cost ratio were found to be higher with the trellis system (R_2) and daily irrigation (I_1). The treatment combination r_2i_1 recorded the highest net income (₹ 45.48 bag^{-1}) and benefit cost ratio (2.36).

From the results of the experiments conducted, the agronomic package for container grown yardlong bean can be summarised as

- Growth media : soil, sand, coirpith, FYM in ratio 1: 0.5: 0.5: 1 by weight basis (3 kg soil, 1.5 kg sand, 1.5 kg coirpith and 3 kg FYM)
- Nutrient level and time of application : 100% recommended dose of NPK (basal application of 20 g groundnut cake + 10 g bone meal + 70 g wood ash and top dressing with fermented groundnut cake (10 g L^{-1}) bag^{-1} @ 30 & 45 DAS)
- Trailing method : Trellis system
- Irrigation interval : Daily basis

സംഗ്രഹം

കണ്ടെയ്നറിൽ വളർത്തുന്ന വള്ളിപ്പയറിനു അനുയോജ്യമായ പരിപാലന രീതികൾ വികസിപ്പിക്കുന്നതിനായി ''അഗ്രോടെക്നിക്സ് ഫോർ കണ്ടെയ്നർ ഗ്രോൺ യാർഡ് ലോങ്ബീൻ'' എന്ന ഒരു പഠനം, രണ്ടായിരത്തി പതിനഞ്ചു-പതിനേഴ് കാലയളവിൽ വെള്ളായണി കാർഷിക കോളേജിൽ നടത്തുകയുണ്ടായി. അനുയോജ്യമായ വളർച്ചാമാധ്യമം കണ്ടെത്തുക, പോഷകമൂലക ക്രമം തയ്യാറാക്കുക, ജലസേചനത്തിനുള്ള ഇടവേളകൾ ക്രമീകരിക്കുക, അനുയോജ്യമായ പടർത്തൽ രീതികൾ രൂപപ്പെടുത്തുക എന്നിവ വഴി ഒരു അഗ്രോണമിക് പാക്കേജ് രൂപം നൽകുക എന്നതായിരുന്നു പഠനത്തിന്റെ ലക്ഷ്യങ്ങൾ.

ഈ ഗവേഷണ പദ്ധതിയ്ക്കായി നടത്തിയ രണ്ടു വ്യത്യസ്ത പരീക്ഷണത്തിന്റെ ഒന്നാം ഘട്ടം 'വളർച്ചാ മാധ്യമങ്ങളുടെ വിലയിരുത്തലും പോഷക മൂലക ക്രമം തയ്യാറാക്കലും' എന്നതായിരുന്നു. മണ്ണ്, മണൽ, ചകിരിച്ചോറ്, കാലിവളം എന്നിവ വ്യത്യസ്ത അനുപാതത്തിൽ ചേർത്ത മൂന്നു വളർച്ചാമാധ്യമങ്ങൾ, വളപ്രയോഗ ശുപാർശയുടെ 100 ശതമാനം, 150 ശതമാനം, 200 ശതമാനം എന്നീ മൂന്ന് പോഷക മൂലക അളവുകൾ, രണ്ടു വളപ്രയോഗ സമയ ക്രമങ്ങൾ (ശുപാർശ ചെയ്ത മുഴുവൻ പാക്യജനകം, ഭാവഹം, ക്ഷാരം എന്നിവ അടിവളമായി നല്കുന്ന രീതി; പകുതി പാക്യജനകം, മുഴുവൻ ഭാവഹം, ക്ഷാരം എന്നിവ അടിവളമായി നൽകുന്നത് + ബാക്കി പാക്യജനകം ചെടി 50 ശതമാനം പുഷ്പിച്ച ശേഷം പുളിപ്പിച്ച കടലപ്പിണ്ണാക്ക് ഉപയോഗിച്ച് 14 ദിവസത്തെ ഇടവേളയിൽ നൽകുന്നത്) എന്നിവ പഠന വിധേയമാക്കി.

ഒന്നാം ഘട്ട പരീക്ഷണത്തിന്റെ വിലയിരുത്തലുകൾ ഇവയാണ്. മണ്ണ്, മണൽ, ചകിരിച്ചോറ്, കാലിവളം എന്നിവ 1:0.5:0.5:1 എന്ന അനുപാതത്തിൽ ചേർത്ത വളർച്ചാ മാധ്യമം മെച്ചപ്പെട്ട സസ്യവളർച്ചയും വിളവും രേഖപ്പെടുത്തി. പോഷക മൂലക വളപ്രയോഗ ശുപാർശയുടെ 100 ശതമാനം രണ്ടു വേവ്വേറെ ക്രമത്തിൽ ശുപാർശ ചെയ്ത പകുതി പാക്യജനകം മുഴുവൻ ഭാവഹം, ക്ഷാരം അടിവളമായി നൽകുന്നത് + ബാക്കി പകുതി പാക്യജനകം ചെടി 50 ശതമാനം പുഷ്പിച്ച ശേഷം, പുളിപ്പിച്ച കടലപ്പിണ്ണാക്ക് ഉപയോഗിച്ച് 14 ദിവസത്തെ ഇടവേളകളിൽ നല്കുന്നതാണ് ഫലപ്രദമെന്നും കണ്ടെത്തി.

പഠനത്തിന്റെ രണ്ടാം ഘട്ടത്തിൽ ഒന്നാം ഘട്ട പഠനത്തിലെ മികച്ച വളർച്ചാ മാധ്യമം ഉപയോഗിച്ചു. മൂന്ന് വ്യത്യസ്ത പടർത്തൽ രീതികളും, രണ്ടു ജലസേചന ഇടവേളകളും പഠന വിധേയമാക്കി.

ഇതിൽ നിന്നും ട്രെയിലിംഗ് സ്റ്റാൻഡ് ഉപയോഗിച്ചുള്ള പടർത്തൽ രീതിയിൽ വിളവിന്റെ കാലദൈർഘ്യം കൂട്ടുന്നതായും ട്രെല്ലിസ് സിസ്റ്റം കൂടുതൽ വിളവു നൽകുന്നതായും കണ്ടെത്തി. വിവിധ ജലസേചന രീതികൾ പരീക്ഷച്ചതിൽ ദൈനംദിന ജലസേചനം വളർച്ചയും വിളവും മെച്ചപ്പെടുത്തുന്നതായി മനസ്സിലാക്കാൻ കഴിഞ്ഞു. ഒപ്പം, ഇവ മികച്ച അറ്റാദായവും വരവ്: ചെലവു അനുപാതവും രേഖപ്പെടുത്തി.

പഠനത്തിന്റെ മുഖ്യകണ്ടെത്തലുകൾ

മികച്ച വളർച്ചാ മാധ്യമം	:	1:0.5:0.5:1 എന്ന അനുപാതത്തിലുള്ള മണ്ണ്, മണൽ, ചകിരിച്ചോറ്, കാലിവള മിശ്രിതം.
പോഷക മൂലക ക്രമം	:	വളപ്രയോഗം ശുപാർശയുടെ 100 ശതമാനം (ബാഗൊന്നിന് 20 ഗ്രാം കടലപ്പിണ്ണാക്ക്, 10 ഗ്രാം എല്ലുപൊടി, 70 ഗ്രാം ചാരം എന്നിവ അടിവളമായും പുളിപ്പിച്ച കടലപ്പിണ്ണാക്ക് ബാഗ് ഒന്നിന് 10 ഗ്രാം/ലി. എന്ന തോതിൽ 30,45 ദിവസങ്ങൾ മേൽ വളമായും)
പടർത്തൽ രീതി	:	ട്രെല്ലിസ് സിസ്റ്റം
ജലസേചന രീതി	:	ദൈനംദിന ജലസേചനം

Appendices

APPENDIX

Appendix I

Weather data for the cropping period (Aug – Dec, 2016)

Period	Standard week	Temperature (^0C)		Rainfall (mm) weekly Total	Evaporation (mm) weekly total	Relative humidity (%)
		Max.	Min.			
2017	5	31.9	22	10	26.9	94.4
	6	31.9	20.7	0	30.9	94.1
	7	32.7	20.9	0	32.4	86.4
	8	33.3	22.7	65.7	34	88.9
	9	33.3	24.1	0	33.1	84.3
	10	32.8	24.6	59.1	29.1	89.6
	11	33.3	24.3	1.6	30.4	89.3
	12	33.3	24.3	0	32.2	89.3
	13	34	24.5	0	36.2	86
	14	34.2	25.8	0	36.5	90
	15	34.2	25.7	0	42.2	89
	16	33.8	26.2	0	35.9	89.3
	17	34.5	26.2	0	39.2	87.4
	18	34.4	25.7	20	40.8	88.3
	19	33.7	25.6	10.8	34.8	87.1
	20	34.1	25.8	77.3	27.7	90.3

Appendix II

Weather data for the cropping period (Jan – May, 2016)

Period	Standard week	Temperature (^0C)		Rainfall (mm) weekly Total	Evaporation (mm) weekly total	Relative humidity (%)
		Max.	Min.			
2017	5	31.9	22	10	26.9	94.4
	6	31.9	20.7	0	30.9	94.1
	7	32.7	20.9	0	32.4	86.4
	8	33.3	22.7	65.7	34	88.9
	9	33.3	24.1	0	33.1	84.3
	10	32.8	24.6	59.1	29.1	89.6
	11	33.3	24.3	1.6	30.4	89.3
	12	33.3	24.3	0	32.2	89.3
	13	34	24.5	0	36.2	86
	14	34.2	25.8	0	36.5	90
	15	34.2	25.7	0	42.2	89
	16	33.8	26.2	0	35.9	89.3
	17	34.5	26.2	0	39.2	87.4
	18	34.4	25.7	20	40.8	88.3
	19	33.7	25.6	10.8	34.8	87.1
	20	34.1	25.8	77.3	27.7	90.3

Appendix III

Effect of treatments on water requirement and water use efficiency of container grown yardlong bean (experiment II)

Treatments	Crop duration (days)	Crop yield (g)	Water requirement (L)	Water use efficiency (g L^{-1})
r_1i_1	103.77	751.52	103.77	7.24
r_1i_2	101.80	501.28	101.80	4.92
r_2i_1	104.13	1,079.15	104.13	10.36
r_2i_2	102.96	584.91	102.96	5.68
r_3i_1	105.99	994.87	105.99	9.39
r_3i_2	105.82	634.19	105.82	5.99

Appendix IV

Cost of inputs

Sl No.	Inputs	Cost (₹)
1	Growbag	15 bag^{-1}
2	Seed	3000 kg^{-1}
3	Coirpith	1 kg^{-1}
4	Sand	3 kg^{-1}
5	Farmyard manure	5 kg^{-1}
6	Groundnut cake	50 kg^{-1}
7	Bone meal	20 kg^{-1}
8	Wood ash	2 kg^{-1}
9	Lime	15 kg^{-1}
10	Neem cake	23 kg^{-1}
11	Trailing stand	150 $unit^{-1}$