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INFLUENCE OF LIGHT INTENSITY AND NUTRIENT SOURCE ON YIELD AND QUALITY OF IRUVELI (*Plectranthus vettiveroides*) K.C.Jacob, N.P. Singh and B.D.Sharma

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Influence of light intensity and nutrient source on yield and quality of Iruveli (*Plectranthus vettiveroides*) K.C.Jacob, N.P. Singh and B.D. Sharma"** is a bonafide record of research work done by me during the course of research and that it has not been previously formed the basis for the award to me any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that thesis entitled **"Influence of light intensity and nutrient source on yield and quality of Iruveli (*Plectranthus vettiveroides*) K.C.Jacob, N.P. Singh and B.D. Sharma"** is a bonafide record of research work done by Mr. Varun kumar A.V. under my guidance and supervision and that it has not formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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We, the undersigned members of the advisory committee of **Mr. Varun kumar A.V.** (2010-11-126), a candidate for the degree of **Master of Science in Agriculture**, with major field in **Agronomy**, agree that the thesis entitled **"Influence of light intensity and nutrient source on yield and quality of Iruveli (*Plectranthus vettiveroides*) K.C.Jacob, N.P. Singh and B.D. Sharma"** may be submitted by **Mr. Varun kumar A.V. (2010-11-126)**, in partial fulfillment of the requirement for the degree.

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Introduction

1. INTRODUCTION

India is considered as the botanical garden of the world, with its varied agro climatic conditions and topography and is a veritable emporium of medicinal plants. Two out of the eighteen biodiversity hot spots of the world are located in India, and this versatility in biodiversity perhaps helped us to be the largest producer of medicinal herbs in the world. These valuable resources have been extensively used in various systems of medicine like *Ayurveda, Sidha, Unani, Emchi* and so on. Ayurveda is the most ancient and widespread system of health care in the country, still practiced with the legacy inherited through generations over centuries. Products that relate to about 20,000 higher plants species are being marketed world over and about 120 chemical compounds of plant origin have been developed into modern pharmaceuticals. The world market of herbal products, including the herbal medicines and raw materials, is estimated to have an annual growth rate between 5 to 15 per cent. Total herbal health products market is estimated to be 62 billion US $ and is expected to grow to 5 trillion US $ by the year 2050.

Keralites have a tradition of using plant based medicine, eventhough their per capita incomes are rising and opportunities for standard of living similar to western style are increasing. Modern pharmacopoeia still contains at least 25 per cent drugs derived from plants and many other synthetic analogues built on prototype compounds isolated from plants. Hence, the demand for medicinal plants is increasing day by day in both developing as well as developed countries. Ayurvedic system of medicine uses about 900 species of medicinal plants. Ayurveda contributes Rs 3500 crores annually to the internal market. Health tourism is another area gaining momentum, where Ayurveda treatment is increasingly being linked to tourism.

According to World Health Organisation (WHO, 2009), about 80 per cent of the people living in developing nations rely on traditional medicines, mostly herbal drugs, for their primary health care and therapeutic needs. Their earnest reliance to these natural products is due to non narcotic property and its safety from adverse side effects compared to synthetic drugs. India has the presence of over 45,000 different plant species, out of which about 15,000- 20,000 plants have good medicinal properties. Over 8000 species of plants found in the different ecosystems are used for the preparation of medicines in the country.

After information technology, herbal technology is considered as India's biggest revenue earner (Chaudhri, 1996). The global trend of increased demand for medicinal plants for pharmaceuticals, phytochemicals, cosmetics and other product is an opportunity for Indian trade and commerce (Pushpangadan and Govindarajan, 2005).

Forests are the main source for medicinal plants and they are collected by the tribes and local communities. Increased demands for the raw drugs have led to the problem of unsustainable – over harvesting from the wild sources, which resulted in the loss of biodiversity and finally the extinction of certain important medicinal plants. The current practice of harvesting medicinal plants from the wild is unsustainable and consequently this will lead to the depletion of resource base. Conservative estimates suggest that over half a million of raw materials are harvested in India from the forest every year (Maiti and Geetha, 2005). Increasing population, rapid expansion of area under food and economic crops, deforestation, expansion of urban area and establishment of industries in the rural areas resulted in considerable depletion of our herbal wealth and many of the valuable medicinal plant species by the process of extinction. Medicinal plants demand domestication due to the natural unavailability from forests coupled with increased demand for quality crude drugs. The commercial production of medicinal plants fills this global demand in the market by providing green health alternatives and other eco-friendly products for both domestic and industrial uses (Bordeker, 2002). There has been a global realisation regarding the potential extinction of these plants and it becomes important to conserve the medicinal plants both *in situ* and *ex situ*.

Farmers in different states in India have a tradition of practicing mixed farming systems. The advantages of cultivating MAPs include the ease of their incorporation into existing cropping systems. Cultivation needs to be done on a business platform by a chain of small and micro-enterprise-based groups and individuals. In order to achieve economics of scale and the desired impact, it may be necessary to intensify production of specific crops within selected production areas and as a cluster of micro-enterprises. Cultivation of medicinal plants ensures the uniform supply of raw materials to the pharmaceutical industry, conservation of natural resources, supply of authentic material and at the same time it entails the manipulation of medicinal plants both genetically and agronomically.

The biosynthesis of secondary metabolites in medicinal plants is an adaptive mechanism and resynthesis of primary products and this process is favoured by agronomic management. The scope for cultivation of medicinal plants as monocrop is very limited due to non availability of land and low holding size. But there is ample scope for cultivation of these crops as intercrops in coconut and arecanut gardens. Medicinal plants when grown in intercropped situation interact with main crop and these interactions could be positive or negative or complex with the competition being mostly for light, moisture and nutrients. In medicinal plants, the quality and quantity are equally important. The environment and stage of maturity cause quality variations in these crops. The varied microclimate resulting in stress may improve the quality despite lower yields. Soil and atmospheric environments have significant influence on quality and quantity components of the yield as well as their interrelations. Hence, the ideal source and optimum source combinations of nutrients have to be identified for maximum yield and quality.

Plectranthus vettiveroides (K.C.Jacob), Coleus is an annual herb belonging to the family Lameaceae, which is mostly seen in tropical countries and are cultivated in gardens. It is a small profusely branched, succulent aromatic herb with quadrangular stems, branches and deep straw coloured aromatic roots. It is recommended for inter cropping in coconut gardens. The whole plant is used against skin diseases, bronchitis, chronic allergies, hyperdipsia, vitiated conditions of *pitta*, burning sensation, strangury, leprosy, skin diseases, leucoderma, fever, vomiting, diarrhoea and ulcers. It is also used as a stimulant, carminative and hair tonic. Shivananda *et al.* (2009) reported that *P. vettiveroides* is facing threat to their existence in the wild and cultivation has to be encouraged for making future needs. It is reported that 50 tonnes of *Plectranthus vettiveroides* is required annually for ayurvedic preparations (Skaria *et al.*, 2009).

Studies on the scientific management of this crop are very meagre. The optimum light intensity and ideal source of nutrients have to be identified for higher yield and quality. With due consideration of the above facts, the study entitled "Effect of light intensity and nutrient source on yield and quality of Iruveli (*Plectranthus vettiveroides*) (K.C.Jacob, N.P. Singh & B.D. Sharma)" was taken up with the following objectives.

1. To study the effect of light intensity and nutrient source on the yield and quality of Iruveli
2. To standardize the light intensity requirement and ideal nutrient source for higher yield and quality.

Review of Literature

2. REVIEW OF LITERATURE

According to Shrestha and Dhillions (2003), 60 per cent of the world population and 80 per cent of the population of developing countries rely on traditional medicine, mostly plant drugs, for their primary health care needs. Medicinal plants are essential natural resource which constitutes one of the potential sources of new products and bioactive compounds for drug development (Gangwar *et al.*, 2010). *Plectranthus vettiveroides* is widely used in more than 35 ayurvedic preparations including *Eladithailum, Blarishtam* etc and 50 tonnes of *P vettiveriodes* is required for the ayurvedic preparations of Kerala annually (Skaria *et al*, 2009). Shivananda *et al.* (2009) reported that *P. vettiveroides* is facing threat to its existence in the wild and cultivation has to be encouraged for meeting future needs.

1. LIGHT INTENSITY

1.1 Effect of light intensity on growth and yield

Light is one of the most important environmental factors affecting survival, growth, reproduction and distribution of medicinal plants. It affects photosynthesis and is related to the accumulation of organic matter and biomass. At light intensity of less than 45 per cent or below, leaf, stem, root, bud, flower and fruit growth were poorer than at higher light intensities in *Catheranthus roseus* (Reda, *et al.,* 1978). Plants react to changes that occur in the spectrum of electromagnetic radiation to which they are exposed through alterations in morphology and physiological functions that result in adaptation to different environmental conditions (Kasperbbauer and Hamilton, 1984).

In Ocimum (*Ocimum gratissimum* Linn.), Pillai (1990) observed that the effect of shade on plant height and spread was positive upto intermediate shade level whereas its effect on the number of branches, number of flowering shoots, length of inflorescence and leaf area was negative. The flowering and attainment of maturity were delayed progressively with increasing intensities of shade. Total herbage yield, highest values of oil content and oil yield were also recorded by the plants grown in open condition. Paul (1992) reported that in turmeric no significant difference was observed between cultivars at different shade levels, but all cultivars gave highest rhizome yield at 50 per cent shade. Dry matter production and harvest index were also more at 50 per cent and 75 per cent shade respectively.

According to Menon (1994) flower initiation in *Plumbago rosea* was comparatively earlier in the open condition as compared to shade. The plants under open were taller compared to those under shade. Plant spread was more in east- west direction in open while in shade north- south spread was more. A sudden increase in internodal length was noticed during January in the case of plants grown under shade. In the case of plants under open, a progressive increase in length was recorded upto March and declined during April. Den Dubbleden and Oosterbeek (1995) reported that to sustain higher photosynthetic capacity or survival, plants modify their morphology and biomass allocation at different light conditions. Asparagus performed well as an intercrop in the coconut plantation recording high root yield and high BCR (1.25), when compared to pure crop (Kurian, 1999).

In Kalmegh (*Andrographis paniculata*), plants grown under increasing light intensity were found with decreased chlorophyll content per unit leaf area. The total dry matter production of the plants grown under full light was also less, as compared to plants grown under 15 per cent light intensity (Kapur and Kapur, 1999). Menon (1999) studied the performance of *Plumbago indica* in open and under shade and noticed that the plant came up well under shade and can be successfully raised as an intercrop in coconut gardens, but therapeutic principles of the plant did not vary between pure crop and intercrop. Reddy and Biddappa (2000) reported that *Plectranthus vettiveroides* is well suited to growth under shaded conditions of coconut. The intercropping studies of medicinal and aromatic crops conducted in Kerala indicated that *P. vettiveroides* is well suited to grow under partially shaded conditions of coconut (Maheswarappa 1997, Skaria *et al.*, 2005).

Neerakkal *et al.* (2001) studied the leaf anatomy of medicinal species under different light regimes observed a significant decrease in leaf thickness for *Plumbago indica* grown under shade due to decrease in intercellular space and cell number in palisade layer. They further reported that in *P. indica* maximum photosynthesis was noticed only for a short period in open sunlight, whereas, peak photosynthesis under shade continued for 3-4 hours even at mid day.

According to Li *et al.* (2000) alterations are mediated by pigments, known as phytochromes, which have absorption peaks in the red and blue/ultraviolet regions of the electromagnetic spectrum. Coloured shade netting not only exhibit special optical properties that allow the control of light, but also have the advantage of influencing the microclimate to which the plant is exposed to (Oren Shamir *et al.*, 2001). Gangadharan (2003) reported that lower shade level promoted higher rhizome yields in Kacholam, while increased shading intensity lead to increase in qualitative contents in rhizomes. Promotion of open conditions during the initial stages of growth followed by imposition of shade during the rhizome development phase, resulted in production of more quantity of officinal part with increased quality.

In safed musli (*Chlorophytum borivilianum*), rate of plantlet survival was 87 per cent and 90 per cent under open field and shade net conditions, respectively. Plantlets grown *ex vitro* under net and field conditions produced tuberose roots which could be grown in the next season as a secondary propagule (Dave *et al.,* 2003). Coloured shade netting offer physical protection against excessive radiation, insect pests and environmental changes (Shahak *et al.*, 2006). Joy *et al.* (2004) found that *Curculigo orchioides* plants yielded high dry matter production at 25 per cent shade and the uptake of nutrients was also higher under shaded condition. Palanikumar and Jessykutty (2007) reported that mild shade intensity of 25 per cent is ideal for maximum fresh and dry herbage yield in different types of mint *(Mentha arvensis)* .

1.2 Effect of light intensity on yield

In *Cephaelis ipecacaunha*, Kurian and Shankar (2007) mentioned that planting in open fields gave higher content of alkaloids but lesser root yield. The light can be modulated during growing in order to get desirable morphologic characteristics and to maximize the production of active principles in *Ocimum gratissimum* (Martins, *et al.*, 2008). Light intensity affected the rate of colour transition, anthocyanin and chlorophyll concentrations, and plant growth in *Solenostemon scutellarioides* (Nguyen *et al,* 2009). Asiaticoside, madecassoside and nutritional contents in the leaves of three accessions grown under the black shade cloth at 0, 50 and 80 per cent shading had shown influence in *Centella asiatica*.(Kanlayanarat *et al,* 2009).

Hou JunLing *et al.* (2010) reported that *Glycyrrhiza uralensis* could endure an environment with low light intensity and suitable light control will increase the secondary metabolite contents within agroforestry systems. Light period exerts the most important effect on altering the growth and essential oil production of Japanese mint (Malayeri *et al.*, 2010). The changes in pigment concentration and chloroplast structure showed a chromatic adaptation of *Oscimum gratissimum* to the variation of light intensity and quality. This can improve photosynthetic performance under different luminosity conditions (Martins *et al.*, 2010). Radusiene *et al.* (2011) reported that the increase in light intensity from 803.4 to 1618.6 μmol m^{-2} s^{-1} determine the continuous increase in content of bioactive compounds in St John's wart. According to Li *et al.* (2011), shading increased the plant height, laminar area per plant, and chlorophyll content in *Pinella ped-tisecta*.

Ghasemzadeh (2011) reported that phenolic acids and flavonoids are absolutely light dependent and their biosynthetic rate is related to light intensity in *Zingiber officinale.* At high light intensity, leaf area and petiole length were smaller than at low light intensity in accessions of *Centella asiatica* (Srithongkul *et al.*, 2011). According to Ndhala *et al.* (2012), 50 per cent light intensity achieved the healthy seedlings and bulb sizes compared to 75 and 100 per cent light in *Eucomis autumnalis*. Cruz *et al.* (2012) reported that the microscopy of *Kalancho brasiliensis* stems evidenced the deposition of anthocyanins in the adjacent tissue to the epidermis and cortex, which increased with light intensity in *Kalancho* sp.

2. SOURCE OF NUTRIENTS

2.1 Organic source

2.1.1 Effect of Farm Yard Manure (FYM)

Analyzing growth and yield performance of *Piper longum* during initial 1 1/2 years in coconut garden, Sheela (1996) reported that 20 t/ ha of organic manure is optimum for growth. According to Sadanandan *et al.* (1998) improvement in soil physical properties and availability of N, P, K and micronutrients were obtained by the application of organic manure, Farm Yard Manure (FYM), neem cake, leaf compost and vermicompost. Organic manures have been reported to improve the soil physical, chemical and biological properties and also conserved and improved the moisture holding capacity of the soil and resulted in enhanced productivity and quality of *Kaempferia galanga*, in which combined application of FYM and vermicompost recorded the highest number of tillers, number of leaves and leaf area index at all stages of growth (Maheswarappa *et al.*, 1999). Addition of any form of organics has been found to improve the soil health, buffering capacity, water retention capacity, chelation, release of micronutrients, microbiological process, *etc.*,(Saravana Pandian *et al.*, 2005). Highest rhizome yield was being recorded at application of FYM at 20 t ha^{-1}in arrow root (*Maranta arundinaceae*) (Vidyadharan and Swadija, 2000).

In scented geranium (*Pelargonium graveolens*) application of FYM 30 t ha^{-1} resulted in the highest leaf: stem ratio, highest fresh herbage yield and higher oil content (Bhaskar *et al.*, 2001). Rao (2001) reported that in *Cymbopogon martinii* (Roxb.) application of FYM @ 15 t ha^{-1} per year increased the total biomass yield by 10.7 per cent and total essential oil yield by 10.3 per cent. The number of fresh and dry tuber yield and steroidal sapogenin content of Safed musli (*Chlorophytum borivilianum*) were significantly increased due to application of FYM at 10t/ha and vermicompost at 5 t/ha. However no significant difference in the yield was noticed due to FYM and vermicompost application alone (Patrude *et al.*, 2002). Krishnamurthi *et al.* (2002) stated that application of coir pith compost recorded higher fresh rhizome yield in turmeric over the unamended control.

Joy *et al.* (2002) reported that in *Alpinia galanga* application of FYM (20 t ha^{-1}) recorded the highest number of clumps per plot, highest plant height, number of suckers per clump, number of leaves per sucker, fresh rhizome yield and oil yield. A field experiment conducted on Safed musli with four levels of FYM (0, 15, 30 and 45 t ha^{-1}) at Rajasthan revealed that application of FYM @ 30 t per ha significantly increased the root yield and was on par with the application of FYM @ 45 t per ha. In an experiment conducted at National Research Centre on Medicinal and Aromatic Plants on Safed musli crop with five levels of FYM (0, 5, 10, 15 and 20 t ha^{-1}), the maximum fresh and dry root yields were obtained with 15 t FYM ha^{-1}which was on par with 10 and 20 t FYM ha^{-1} (CIMAP, 2003). Krishnamurthy *et al.* (2002) obtained 22 per cent increase in yield of turmeric mainly due to application of 10t of FYM /ha over the unamended control.

Application of 20t of FYM increased the herbage yield in Brahmi (*Bacopa monnieri*) by 18.4 per cent over the control (Rao *et al.*, 2003). Chandra *et al.* (2003) reported that application of 20 t FYM ha^{-1} resulted in the highest mean root length and mean number of roots per clump, whereas application of 15 t FYM ha^{-1} resulted in the highest mean weight of roots per clump and mean fresh root yield. Increasing levels of manure significantly increased the mean number of tubers, length of tubers, fresh weight per plant, dry weight per plant and yield per hectare of Safed musli when applied with 20 t FYM per ha followed by 10 t and no FYM (Ingle *et al.*, 2004; Sharma, 1996 and PDKV, 2000). Wankhade *et al*. (2004) observed that application of 20 t FYM per ha significantly increased the fresh yield of Safed musli and dry root than all other treatments. Annamalai *et al*. (2004) reported that in *Phyllanthus amarus* the maximum shoot length, root length, branches per plant, leaves per branch, fruits per branch, fresh weight and dry weight were obtained with 1.5 t FYM ha^{-1} treatment.

Harinkhede *et al.* (2005) reported that application of 40 t FYM ha^{-1} is recommended to get maximum and sustainable dry root yield of Safed musli. According to Joy *et al*. (2005) the optimum level of FYM for the growth of black musli is 30t of FYM ha^{-1} and substitution of 25 per cent of FYM with inorganic fertilizers was ideal for realizing highest rhizome yield of good quality. According to Tiwari (2006) FYM at 10 t ha^{-1} resulted in higher yields of fresh fasciculated roots in safed musli (*Chlorophytum borivilianum*). Rao *et al.* (2006) observed that application of FYM at the rate of 20 t ha^{-1} and commercial formulations of micro nutrients and biofertilizers in ambrette (*Abelmoschus moschatus*) significantly increased the plant height, yield attributing characters, pod and seed yields. An increase of 141.3 per cent of pod yield and 308.7 per cent of seed yield were observed with the application of FYM at 20 t ha^{-1}.

Ganorkar *et al*. (2006) found that the highest values of nutrient uptake and tuber yield in safed musli were observed for FYM application at the rate of 20 t ha^{-1} and nitrogen at the rate of 75 kg N ha^{-1} when applied alone or in combination. Application of 22.5 t ha^{-1} of FYM provided higher oil yield as compared to 15.0 t ha^{-1} of FYM in *Curcuma aromatica* Salisb (Gopichand *et al.*, 2006). According to Shirole, *et al.*, (2006) the dry matter of Brahmi per plant was significantly improved with the application of 10 t FYM ha^{-1}, resulting in significant increases in fresh and dry yield. Hossain and Ishimine (2007) reported that vegetative growth parameters (number of leaves per plant, plant height, number of tillers per plant, leaf biomass) and yield of turmeric increased with the FYM application than control.

According to Sanwal *et al.* (2007) significantly higher rhizome yield was recorded with the application of FYM at 18t ha^{-1} which was on par with 10t ha^{-1} of poultry manure. Application of these organic sources resulted in 16-30 per cent higher rhizome yield over control and also improved the quality parameters in turmeric. In *Coleus forskohlii* carbohydrate content of 10.28 per cent and fibre content of 13.30 per cent was recorded in roots upon treatment with FYM at 5 t ha^{-1} + vermicompost at 2.5 t ha^{-1} (Nema *et al.*, 2008). Dadheesh and Lekhchand (2008) reported that in *Plantago ovata*, incorporation of 5 t ha^{-1} of FYM significantly increased the plant height and dry matter accumulation and protein content. In *Phyllanthus fraternus*, combined application of compost + FYM +VAM was found most suitable for obtaining maximum growth parameters, biomass and harvest index after four months of planting (Sher and Kasera, 2008). According to Datta *et al.* (2009) in sweet flag (*Acorus calamus*), plant height, number of leaves, rhizome length, rhizome diameter and yield increased with increase in dose of FYM up to 50 t ha^{-1}. Maximum fresh and dry rhizome yield was recorded with 50 t ha^{-1} FYM supplemented with 100 ppm GA_3, followed by application of 50 t ha^{-1} FYM.

Manhas and Gill (2010) reported that application of FYM increased the growth, dry matter accumulation, yield and quality of turmeric. Upadhyaya *et al.* (2010) conducted a study for comparison of total phenol and flavanoid content in *Adhatoda vasica* grown using different organic manures and revealed that the total phenol content was higher in samples collected from plants applied with cowdung followed by compost and vermicompost. Total flavanoid content recorded highest in samples collected from cowdung followed by vermicompost and compost. Sudhakar *et al.* (2010) reported that the treatment combination consisting of organic manures, biofertilizers, FYM, vermicompost and neem cake recorded maximum plant height, maximum number of tuberous roots per plant and maximum fresh weight of tuberous roots in *Coleus forskohlii*.

2.1.2 Effect of Vermicompost

According to Edward and Burrows *et al.* (1988) vermicomposting is a non-thermophilic biodegradation of organic material through interaction between the earth worms and microorganism resulting in the production of vermicompost. Application of organic manure in the form of vermicompost in soil recorded the highest value for all the available nutrients as it consists of large amount of humic substances (Masciandro *et al.,* 1997). Maheswarappa *et al.* (1999) reported that in arrow root, microbial population and dehydrogenase activity was higher under FYM and vermicompost treatments compared to composted coirpith treatments. Organic carbon and pH of the soil increased to a greater extent under FYM and vermicompost treated plots than with composted coirpith.

Saha *et al.* (2006) reported that organic fertilizers in the form of vermicompost and vermiwash was effective and comparable to the inorganic fertilizers in increasing gel moisture, gel ash and aloin content in *Aloe vera*. Hansen *et al.* (2007) found that worm casting was rich in nutrients and readily available to plants. Utilization of enriched coirpith vermicompost as a substrate for FYM in the preparation of potting mixture enhanced the sprouting percentage (100%) and modulated the rhizosphere for promoting the activity of bioinoculants on five medicinal plants Long pepper (*Piper longum*), Koduveli (*Plumbago rosea*), Asparagus (*Asparagus racemosus*), Chittadalodakaom (*Adhatoda beddomi*) and Munja (Premna nervosa) (Anilkumar *et al.*, 2007).

Vermicompost application in an improved German chamomile variety 'Goval' improved plant height, early flowering, flower dry weight, anthodia height and diameter significantly. Fifteen percent vemicompost with an irrigation level of two weeks was found to be the best treatment to produce the flower yield in Goval cultivars of German chamomile in organic system (Azizi *et al.*, 2008). According to Chiluvuru *et al.* (2009) growth and yield of *Vigna radiata* and *Centella asiatica* were found to be increased with application of different concentrations of vermicompost over the control and the plant response was maximum at 20 per cent amendment of vermicompost to soil. Ghosh *et al.*, (2009) reported that the highest plant height, number of leaves, number of primary branches , number of secondary branches, root weight and plant weight were obtained with 50 per cent vemicompost + 50 per cent urea in Ashwagandha at 110 days after planting.

According to Mandal *et al.* (2008) higher productivity, extractive value, oil content and antioxidant quality of oils were recorded when mixture of inorganic fertilizers and organic manures like vermicompost were applied in Patchouli. Maximum plant height, primary branches per plant and secondary branches per plant were recorded in the treatment combination of 50 per cent recommended dose of fertilizers + 50 per cent vermicompost in coriander (Bodamwad *el al.*, 2009). Venkatesan *et al.*, (2010) reported that cuttings planted in vermicompost along with *Azospirillum* dipping significantly increased the rooting parameters like rooting percentage, number of roots per cutting and root length and shoot parameters like number of sprouts per cutting, length of sprout, number of leaves per cutting and leaf area in *Gymnema sylvestre*. According to Darzi *et al.* (2012), highest essential oil content in seed and carvone content in essential oil and the minimum dillapiole content were obtained after applying 4 ton ha^{-1} vermicompost in dill (*Anethum graveolens*).

2.2 Bio fertilizers

Bio fertilizers have emerged as an important component of integrated soil fertility management practices which would be feasible and viable to sustain agriculture as a commercial and profitable proposition ensuring yield of crops without deterioration in the quality of the produce and make soil living and dynamic (Ali *et al.*, 2009). According to Karlidag *et al.* (2007), among different groups of biofertilizers, nitrogen fixing and phosphorus solubilising bacteria may be considered to be important since they improve plant nutrition by increasing N and P uptake by plants, and they play a significant role as plant growth promoting rhizobacteria (PGPR) in the biofertilization of crops.

The PGPR strains may promote growth either by fixation of atmospheric nitrogen or by solubilization of minerals such as phosphorus (Karthikeyan *et al.*, 2007; 2008) they can also promote growth through production of plant growth regulators (Klopper & Schroth, 1978; Karthikeyan *et al.*, 2007). Boby and Bhagyraj (2003) reported that wilt caused by

Fusarium chlamydosporum a serious soil borne disease in *Coleus froskholi* could be controlled effectively with the inoculation of *Trichoderma viride*. Karthikeyan *et al.* (2008) reported that the occurrence of *Azospirillum, Azotobacter* and *Pseudomonas* in the rhizosphere of medicinal plants such as *Catheranthus roseus*, *Coleus forskholi*, *Ocmium sanctum* and *Aloe vera* has been documented earlier.

2.2.1 Azospirillum

Azospirillum is a free-living, gram negative, associative nitrogen fixing, plant growth promoting bacterium capable of affecting growth and yield of numerous plant species, many of which have agronomic and ecological significance. Its Nitrogen fixing, NO reductase and phytohormone producing activities stimulate better root growth and establishment. It produces plant growth hormones like giberlines, cytokinins and auxins like IAA. The growth promotion capacity lies in its ability to produce various phytohormones that improve root growth, absorption of water and minerals that eventually yield larger and in many cases more productive plants (Dobbelaere *et al.*, 2001).

Chezhiyan *et al.* (2003) reported that treatment of poultry manure, azospirillum and phosphate solublising bacteria recorded more plant height, leaf area index, dry matter production, herbage yield per ha and the quality parameters such as lignans, phyllanthin and hypophyllanthin at its maximum in *Phyllanthus amarus*. Azospirillum fixes about 20-25 kg/ha of nitrogen under ideal conditions and thereby effecting a reduction of 25 per cent in the quantity of nitrogenous fertilizers (KAU, 2007). Badran and Safwat (2004) found that nitrogen fixing bacteria such as Azotobacter and Azospirillum increased growth and yield in fennel. Abdou *et al.*, (2004) reported that application Azospirillum in the field increased per ha yield and the quality parameters in fennel.

According to Mahfouz and Sharaf (2007) an increase in the growth and yield of medicinal plants were observed with the application of nitrogen fixing bacteria such as Azotobacter and Azospirillum. Kalyanasundaram *et al.* (2008) reported that Azotobacter and Azospirillum could cause increased growth and yield in sweet flag. Application of biofertilizers like Azotobacter and Azospirillum could cause increased growth and yield in davana (Swaminathan *et al.*, 2008; Kumar *et al.*, 2009). Growth and yield were found to be increasing with the application of Azospirillum alone in the field than control in fennel (Azzaz *et al.*, 2009).

2.2.2 Arbuscular Micorrhizal Fungi (AMF)

Use of biofertilizers is an alternative value added sustainable technology for modern agriculture. Microbial fertilizers are biologically active products containing one or more specific microorganisms like bacteria, BGA (Cyanobacteria) or fungi. These organisms are capable of nitrogen fixation, P solublisation or phosphatic mobilization. Michorrhiza literally means fungus roots. An Arbuscular micorrhizal fungus (AMF) is an obligate symbiont in nature requiring a suitable host plant for its growth. Plants with AM association are capable of mobilizing more of the available nutrients from soil by extending to several centimetres from root surface. AM association will enable the host plant to absorb more P by greater exploration of soil, resulting in better access to soil pool of available P. Symbiotic associations between mycorrhizal fungi and plant roots are widespread in nature and can provide a range of benefits to the host plant. Of the several mycorrhizal symbiosis, arbuscular mycorrhizas are the most abundant.

Harold (1980) reported that mycorrhizal plants translocate higher amount of photosynthates from shoot and root than non mycorrhizal plants, without altering the leaf area and the AM fungi derive their carbon requirement from the host plants. According to Bagyaraj and Manjunath, (1980) the shoot and root weight was increased in finger millet by inoculation of AM fungi *Glomus fasciculatum* in an unsterile soil which is lower in available phosphorus.

Hirrel and Gerdemann (1980) reported that the inoculation of *Glomus fasciculatum* increased the growth of onion. Allen *et al.* (1981) reported that mycorrhizal infection by *Glomus fasciculatum* increased the chlorophyll concentration in *Coleus aromaticus*. According to Thangaraju *et al.* (1986), AMF inoculation induced maximum plant height and biomass of shoot in maize and soybean. Direct benefits are usually related to the enhancement of phosphate uptake by the plant and in some soils enhanced uptake of zinc, copper and ammonium are also important (Stribley, 1987).

Bolan (1991) reported that AMF enhances the plant growth as a result of the improved phosphate nutrition of the host plant and has been confirmed by the use of isotropic traces. The inoculation of AMF and other beneficial soil microorganisms significantly increased the biomass of different medicinal plants [Sena and Das (1998), Kothari et al. (1999)]. Inoculation with arbuscular-mycorrhizal fungi improved the phosphorous uptake in *Coleus aromaticus* (Earanna *et al.* 2001). Earanna et al., (2001) reported that *Catharanthus roseus* showed a positive response to *Glomus mosseae* and *Glomus aggregatum* inoculation in respect to per cent colonization and spore count. Plants grown in soil inoculated with *Glomus fasciculatum* showed increased chlorophyll content and phytochemical constituents (Selvaraj, 1989; Selvaraj and Chellappan, 2006). Rathore *et al* (2007) reported that inoculation of AMF resulted in the maximum plant height, collar diameter, total dry weight and quality index in *Santalum album* seedlings.

Krishna *et al.* (2008) reported that germination percentage, root and shoot length and vigour index of *Andrographis paniculata, Withania somnifera* and *Ocimum tenuiflorum*, after 21 days of planting was maximum with the combined application of biofertilizers like Azospirillum and phosphorus solubilizing bacteria. In Kalmegh (*Andrographis paniculata*) application of 15 t FYM, NPK (15:25:25) and 1 kg Azospirillum ha^{-1} resulted in maximum nutrient content in leaf tissues, high herbage yield and andrographolide content (Hemalatha *et al.*, 2008). Rani *et al.* (2008) reported that conjunctive use of 50 per cent N (20 kg N ha^{-1}) with organic manures like FYM at 2.5 tonnes ha^{-1}, castor cake at 0.25 tonnes ha^{-1} and biofertilizers had resulted in the highest fresh tuber yield (121.91 tonnes ha-^{1}) and dry tuber yield (21.59 q ha^{-1}) at harvest and soil nutrient status (available N, P, K, S and Fe) at all the growth stages studied.

Vegetative growth and biomass production in *Clitoria ternatia* revealed that Azospirillum, Azotobacter and their combined biofertilizers have increased the germination rate of seeds and overall plant growth respectively. Seedling Quality Index (SQI) of the *Azospirillum*, *Azotobacter* and combined biofertilizers treated seedlings were 0.46, 0.44 and 0.46, respectively while for the control, it was 0.34 only (Ramkumar *et al.*, 2009). According to Gajbhiye and Deshmukh, (2009) 5 t FYM, 4 kg *Azotobacter* and 4 kg PSB ha^{-1} resulted significantly increased root length, root thickness, fresh weight of root, dry root yield and seed yield in Aswagandha.

Satyendra and Singh (2010) reported that application of blue green algae as biofertilizer at 50 gms BGA kg^{-1} soil in Aswagandha increased the catalase and peroxidase activity and there was an increase in chlorophyll and ascorbic acid content at 200g BGA kg^{-1} soil. Nihad and Jessykutty (2010) reported that the use of neem cake and FYM in the ratio 1:4 along with the microbial inoculants as basal dose has a long term effect on the nutrient supplying capacity of the soil thus reducing the cost of production of organic cultivation and enhancing the benefit cost ratio of the farmers. According to Ravikumar, *et al.* (2010) application of FYM+ recommended dose of NPK+neem cake+*Azotobacter+Azospirillum* recorded significantly higher plant height, number of leaves, dry weight of leaves, stem, aerial part, total dry weight, fresh and dry weight of tuberous roots per plant and per hectare yield in *Coleus forskohlli.*

2.3 Integrated Nutrient Management (FYM + NPK)

Integrated supply of nutrient to plants through planned combinations of organic and inorganic sources is becoming an increasingly important aspect of environmentally sound agriculture. According to Ayisha (1997) growth and yield characteristics of *Piper longum* increased with the application of 20 t ha^{-1} organic manure and 30:30:60 NPK kg ha^{-1}.Gill *et al.*, (1999) reported that application of organic manures along with inorganic fertilizers not only improves the physical status of the soil, but also increases the organic status of the soil. This results in rapid multiplication of beneficial soil microbes promoting the availability and uptake of nutrients by the plants, favouring an increase in yield. In kacholam, the essential oil and oleoresin contents were significantly higher in treatments with FYM (20 t ha^{-1}) and NPK (50:50:50 kg ha^{-1}), followed by FYM and vermicompost treatments (Maheswarappa *et al.*, 2000b).Maheswarappa *et al.* (2000) observed that the combination of organic manure with chemical fertilizer resulted in better growth of the crop as reflected in more number of leaves, tillers, higher leaf area duration and yield components in kacholam.

According to Yadav *et al.* (2003), it was found that application of N through urea (25%) and through FYM (75%) significantly increased the number of tillers per plant, plant height and dry matter accumulation at all the growth stages, as well as number of spikes per plant, grains per spike, and grain and straw yields at harvest in *Plantago ovata*. Ramamoorthy *et al.* (2003), reported that application of FYM in combination with a fertilizer level of

60:25:40 kg NPK/ha and a spacing of 45×30 cm can be recommended for enhanced herbage, pod and seed yields, and germination percentage in Senna (*Cassia angustifolia*).

According to Joy *et al.,* (2005) application of 22.5 t FYM, 10:8:5 Kg N, P_2O_5 and K_2O ha^{-1} is ideal for highest yield of quality rhizome in *Curculigo orchioides.* It was also evident from both the point of view of quantity and quality that FYM application is inevitable for the crop and an integrated application of FYM and fertilizer is preferable for quality crude drug production in *Curculigo orchioides*. Puttanna *et al.* (2005) reported that yield could be improved by supplementing 25-50 kg N, 60 kg P, 60 kg K with 10 t FYM/ha, without changes in the total alkaloid content in the roots in *Withania somnifera.* Kavitha, (2006) reported that combined application of 5 t cocopeat/ha + 12.5 t FYM/ha + 40:30:30 kg NPK/ha resulted in the lowest number of days to 50 per cent flowering and highest number of flowers per plant, leaf area, leaf area index, crop growth rate, and root weight in *Mucuna pruriens.*

According to Puttanna *et al.*, (2006) application of either 100 kg N, 60 kg P_2O_5 and 60 kg K_2O per year or 50 kg N, 30 kg P_2O_5 and 30 kg K_2O along with 10 t FYM per ha per year can be applied to obtain the maximum herb and saponin yields of *Centella asiatica.* Kavitha and Vadivel (2006) reported that the integrated nutrient combination involving organic form of manures (Cocopeat 5 t/ha+Farmyard manure 12.5 t/ha) and inorganic fertilizers (NPK 40:30:30 kg/ha) showed a greater degree of positive influence on the seed yield and yield attributing characters viz., number of flowers, number of pods, single pod dry weight, seed weight pod^{-1} , dry matter production and seed yield in *Mucuna puriens.* Shivanna *et al.* (2009) reported that application of FYM at 10t ha^{-1} along with NPK @ 100:50:50 kg ha^{-1} recorded the maximum plant height, number of branches, number of leaves and spread per plant in *Solanum nigrum.* In *Plantago ovata,* incorporation of 5t ha^{-1} of FYM significantly increased the plant height and dry matter accumulation at 45 days after sowing, 75 days after sowing and at harvest (Dadheesh and Lekhchand, 2008).

According to Dwivedi *et al.* (2008), the best N source treatment was 25 per cent N by urea+75 per cent N by FYM (total 30 kg N/ha), which recorded significantly the highest seed yield up to 14.43 q ha^{-1} in *Plantago ovata*. Singh *et al.* (2008), reported that the maximum fruit yield, size (length and breadth), weight, volume, pulp stone ratio, total soluble solids, ascorbic acid, total sugars, minimum acidity and total phenol were recorded with the application of 50 per cent NPK+50 kg FYM +5 kg bio-pressmud in Amla (*Emblica officinalis*).

According to Vennila and Jayanthi (2008), application of recommended dose of fertilizers (40:60:50 kg NPK ha^{-1}+FYM 10 t ha^{-1}) resulted in the highest tuber yield of *Coleus forskohlii.* Goel *et al.* (2011), reported that the combined use of 25 mg N/kg soil and FYM @ 12.5 t/ha produced significantly taller plants (47.7 cm) in Ashwagandha. Kumar *et al.* (2011) observed that use of 75 per cent recommended dose of fertilizers (RDF) through fertilizers and 25 per cent recommended dose of fertilizers through FYM resulted in higher dry matter production, nutrient composition and uptake of the nutrients (N, P_2O_5 and K_2O) in *Phyllanthus amarus.*

Rao *et al.* (2010), revealed that dry spike yields significantly increased due to integrated management of FYM and fertilizers in thippali. Application of 40 t/ha FYM and 125: 50: 160 Kg N, P_2O_5 and K_2O per ha gave significantly higher spike yield and increased piperine yield. The higher total dry matter with 40 t/ha FYM was positively correlated with higher plant height, more number of branches and maximum plant spread. The growth, yield and quality attributes were also significantly higher with this combination. Application of 5t of FYM + N_{60} P_{40} K_{20} and N_{90} P_{60} K_{30} treatments in *Eclipta prostrata* recorded superiority over other treatments in plant height, no. of branches, leaves per plant and maximum alkaloid yield (Kalita *et al.*, 2010).

Kumar *et al.* (2010) reported that, conjunctive supply of 75 per cent nutrients through fertilizers and 25 per cent through FYM, registered maximum plant height, number of branches, number of compound leaves, fresh and dry herbage yield and total alkaloid yield in *Phyllanthus amarus*. Application of 5t of FYM along with inorganic fertilizers in *Eclipta prostrata*, proved superior over other treatments, in plant height, number of branches, leaves per plant and maximum alkaloid yield (Kalita *et al.*, 2010).

Application of 275:112.5:172.5 Kg N, P_2O_5 and K_2O as fertilizers and FYM @ 20 t/ha produced maximum height, higher number of leaves and branches and thereby yield in Stevia (Nevase *et al.,* 2011). Rao *et al.* (2011) reported that 50 percent of NPK and 10 tonnes of farm yard manure per hectare was found to be better for maximum yield of forskolin in *Coleus forskohlli.* According to Singisala *et al.* (2012) root biomass as well as forskolin contents were higher by 3-folds when 50 per cent NPK with 10 tonnes of farm yard manure were supplied to the plants.

2.4 Combined application of organic manure and bio fertilizers

Amrithalingam (1988) reported the growth enhancement in chilli with the application of organics along with Azospirillum and AMF. Hemavathi (1997) revealed the growth increase in Chrysanthemum with the application of Azospirillum and AMF. According to Bagyaraj (1991) apart from organic manures, bio fertilizers like Azospirillum and AMF contribute to the improved crop production through eco friendly nutrient supply. Higher microbial population and the better availability of nutrients with the combined application of organic manures and microbial inoculants attributed to the production of higher dry root yield in *Plumbago rosea* (Gupta *et al.,* 2003).

Krishnan (2003) reported that incorporation of vermi-compost at the rate of 6.26 t $ha^{-1}yr^{-1}$ and combined application of bio inoculants *viz Azospirillum,* fluorescent pseudomonas and AMF was found favourable for enhancing total fresh and dry spike yield and total alkaloid production in long pepper. Combined application of coir pith compost at N Eq to 10t ha^{-1} of FYM along with Azospirillum and PSB each at 1kg ha^{-1} was found to be better for higher nutrient uptake, herbage yield and bacoside content in Brahmi (Latha and Radhakrishnan, 2010). Manjunatha *et al.* (2009) revealed that combined application of biofertilizers viz Azospirillum and AMF, was found to be more effective for higher herbage yield and essential oil content over their sole application in *Pogostemon cablin.* Pratibha *et al.* (2010) reported an increase in dry leaf yield by the application of organic manures along with *Azospirillum* in Senna.

Annamalai *et al.* (2004) reported that the highest number of compound branches per plant and seed yield per plant was obtained with application of FYM 12 t ha^{-1}, Azospirillum

(6.5 kg ha^{-1}) and phosphobacteria (2.5 kg ha^{-1}). Plant growth has been enhanced with the combined application of organic manures and Azospirillum and AMF in fenugreek (Srinivasa, 2004). Application of the combination of organic manure along with microbial inoculants could render higher yield in green ginger (Sreekala, 2004). Shivanna (2009) revealed that the combination of organic manures (farmyard manure and poulty manure) and biofertilizers (Azospirillum and AMF) produced high herb yield and enhanced andrographolide content in Kalmegh. According to Gajbjiye and Deshmukh (2009) combined application of organics and biofertilizers produced more fresh and dry root yield and better quality of roots in terms of length and thickness in Ashwagandha.

Materials and Methods

3. MATERIALS AND METHODS

The study entitled effect of light intensity and nutrient source on the yield and quality of Iruveli (*Plectranthus vettiveroides*) was carried out in Kerala Agricultural University during the year 2011-2012.The details of the materials and methods adopted for the study are described in this chapter.

3. 1. GENERAL DETAILS:

3.1.1 Location

The area is situated at 10°31'N and 76°13'E longitude and at an altitude of 40.3 m above mean sea level.

3.1.2 Soil

The soil of the experimental site is sandy loam in texture (order: Ultisols). The physio-chemical properties of the soil are given in Table 2.

3.1.3 Weather and climate

The experimental site represents the typical agro climatic features of the midlands of the state. It experiences a warm humid tropical climate. The weather data recorded during the cropping period (August 2011- February 2012) are given in Appendix I and graphically represented in Fig 3.1 and Fig 3.2.

3.1.4 Field operations

The experimental site was ploughed, stubbles removed, levelled and laid out as per lay out plan treatments.

3.1.5 Planting

Planting was done on 28.08.2011 by using top shoot cuttings. Cuttings were planted in beds of size 3.2 x 2 m^2 with a spacing of 30 x 30 cm.

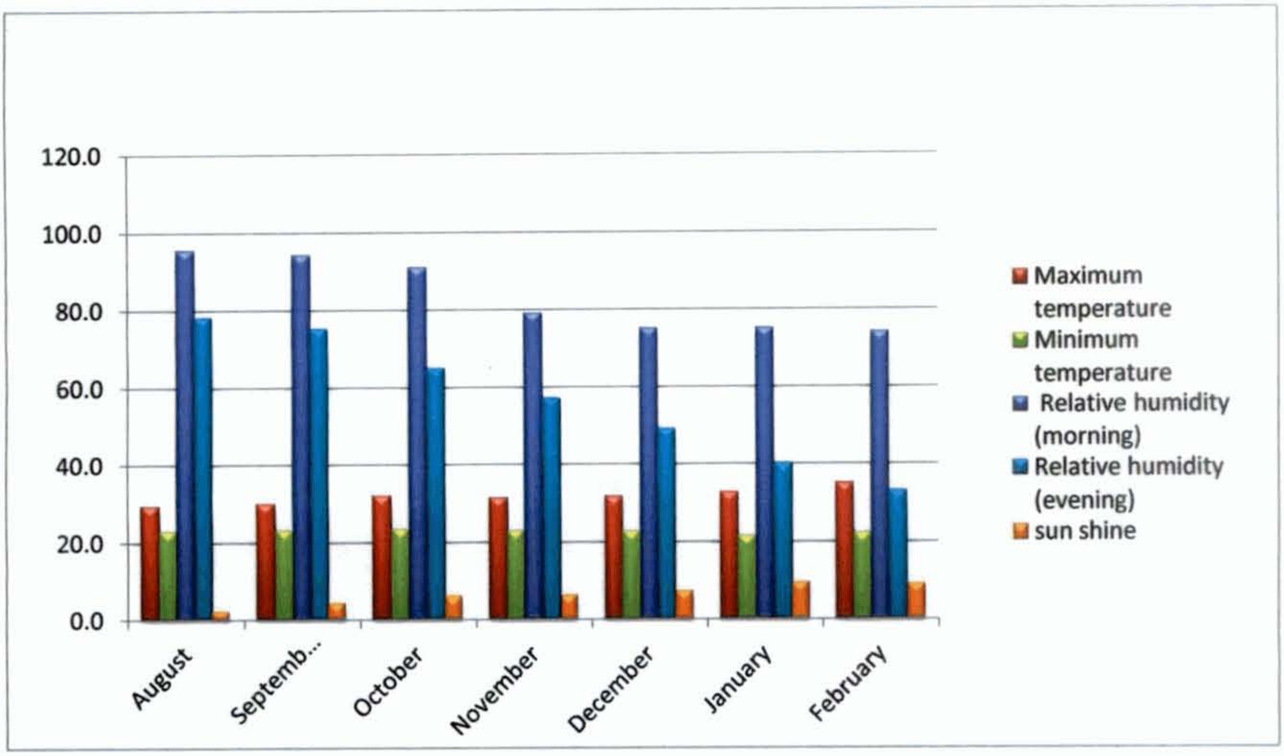

Fig 3.1 Weather data during the crop period (Aug 2011- Feb 2012) at Vellanikkara

Fig 3.2 Sun shine hours during the crop period (Aug 2011- Feb 2012) at Vellanikkara

3.1.6 Shade Net

The light intensity was regulated by providing artificial shade nets. Shade levels were created using shade nets of varying meshes. Shade nets of 50 and 25 per cent were provided in the present study to create light intensity levels of 50 and 75 per cent.

3.1.7 Manures and fertilizers

Organic manures *viz* FarmYard Manure (FYM) and biovermi and biofertilizers viz Azospirillum and AMF were applied along with N, P and K. Biovermi is an enriched product of vermicompost with *Trichoderma viridae* and *Pseudomonas fluorescence*, developed at Department of Soil Science & Agricultural Chemistry, College of Horticulture, Vellanikkara. The strains of Azospirillum and AMF developed at College of Agriculture, Vellayani were used as biofertilizers. Inorganic sources of nutrients were urea, rock phosphate and muriate of potash for N,P and K. Bio fertilizers were applied along with organic manure.

3.2 EXPERIMENT DETAILS

Experiment was designed as split plot in RBD with three replications. Levels of light intensity were allotted to main plots and nutrient sources to the sub plots. Three light intensities *viz* open, 50 per cent light intensity and 75 per cent light intensity were imposed. Adequate shade was provided using shade nets of appropriate grades. The required shade was provided by erecting *pandal* at a height of 2 m using bamboo poles and shade nets of desired mesh size was spread over it.

The biofertilizers were applied @ 1kg/ha along with organic manures. Phosphorus fertilizer was applied as basal and N and K fertilizers in two split doses, half basal and half two months after planting. Random sampling technique was adopted to select sample plants for recording various morphological and yield characters and for chemical analysis. Five plants were selected at random from each plot for observation and labelled. Five plants from each plot were uprooted and bulked together to get a representative sample for chemical analysis.

$M_1T_5R_1$	$M_1T_1R_1$	$M_1T_2R_1$	$M_1T_3R_1$	$M_1T_4R_1$	$M_1T_6R_1$
$M_1T_3R_2$	$M_1T_1R_2$	$M_1T_5R_2$	$M_1T_4R_2$	$M_1T_6R_2$	$M_1R_2T_2$
$M_1T_5R_3$	$M_1T_6R_3$	$M_1T_2R_3$	$M_1T_1R_3$	$M_1T_4R_3$	$M_1T_3R_3$
$M_2T_1R_1$	$M_2T_3R_1$	$M_2T_4R_1$	$M_2T_5R_1$	$M_2T_2R_1$	$M_2T_6R_1$
$M_2T_2R_2$	$M_2T_3R_2$	$M_2T_4R_2$	$M_2T_1R_2$	$M_2T_6R_2$	$M_2T_5R_2$
$M_2T_6R_3$	$M_2T_1R_3$	$M_2T_2R_3$	$M_2T_5R_3$	$M_2T_3R_3$	$M_2T_4R_3$
$M_3T_5R_1$	$M_3T_2R_1$	$M_3T_6R_1$	$M_3T_1R_1$	$M_3T_3R_1$	$M_3T_4R_1$
$M_3T_3R_2$	$M_3T_4R_2$	$M_3T_2R_2$	$M_3T_1R_2$	$M_3T_5R_2$	$M_3T_6R_2$
$M_3T_4R_3$	$M_3T_6R_3$	$M_3T_1R_3$	$M_3T_2R_3$	$M_3T_5R_3$	$M_3T_3R_3$

M- main plot **T- sub plot** **R- replication**

Fig 3.3 Layout of the field experiment

Design : Split plot design

Replication: 3

Plot size : 3.2 x 2 m^2

Main plots	**Sub plots (quantity per plot)**
M_1 – open M_2 – 50 % light intensity M_3 – 25% light intensity	T_1 –FYM @ 10t/ha T_2 - FYM@ 10t/ha + Azospirillum +AMF T_3 – Biovermi*@ N eq of 10 t/ha FYM T_4 - Biovermi*@ N eq of 10 t/ha FYM + Azospirillum +AMF T_5 – FYM @ 5t/ha + 30:15:30 NPK kg /ha T_6 – Control

* Biovermi : Vermicompost enriched with *Pseudomonas* and *Trichoderma* developed at Department of SS and AC , College of Horticulture, Vellanikkara.



Plate 1: Field lay out

Biometric observations:

Height of the plant

Number of leaves

Number of branches

Root: shoot ratio

Biomass production

Dry matter production

Herbage yield

Nutrient analysis:

NPK content of the herbage

Nutrient uptake by the crop

Soil analysis (before and after the experiment)

pH

EC

Organic carbon

Available NPK

Quality analysis:

Essential oil content of the herb

Observations of the growth characters were recorded at the second and fourth month after planting and at the time of harvest.

3.2.1 Biometric observations

Five plants from each plot were selected randomly and tagged. Biometric observations from these plants were taken at second and fourth month after planting and at the time of harvest.

3.2.1.1. Plant height

The plant height in cm was recorded from the base of the plant to the tip of the top most leaf during observation.

3.2.1.2. Number of leaves

Number of leaves per selected plants was counted.

3.2.1.3. Number of branches

Total number of branches of each plant was counted.

3.2.1.4. Root: Shoot ratio

The whole plant was separated into root and shoot and dried at 105° C in oven for 48 hours. The dry weight of root and shoot were taken and expressed as ratio.

3.2.1.5. Biomass production

The whole plant was uprooted and the weight was taken.

3.2.1.6. Dry matter production

Five plants were selected randomly from each plot, oven dried at 105° C and dry weight was recorded. The average weight was expressed as dry matter production

3.2.1.7. Herbage yield

The whole plant was uprooted and the biomass production in kg ha $^{-1}$ was calculated as herbage yield (kg ha^{-1}).

3.2.2. Nutrient analysis

3.2.2.1. NPK content of the herbage

Nutrient content of the experimental plant was estimated by selecting five plants at random from each treatment. Whole plant was subjected to chemical analysis. The plant parts were cleaned, chopped into small pieces and dried in hot air oven @ 70-80°C. They are powdered well and analysed for major nutrients. The methods used for the analysis of major nutrients in sample plants are given in Table 3.1

Table 3.1. Methods used for nutrient analysis of plant samples

Sl no	Nutrients	Digestion process	Method of extraction	Reference
01	Nitrogen	H_2SO_4 digestion	Distillation and titration	Jackson (1973)
02	Phosphorus	9:4 HNO_3 -$HClO_4$ diacid digestion	Vanado Molybdate yellow colour method using Spectrophotometer	Jackson (1973)
03	Potassium	9:4 HNO_3 -$HClO_4$ diacid digestion	Direct reading using flame photometer	Jackson (1973)

3.2.2.2. Nutrient uptake by the crop

Uptake of major nutrients by sample plants were calculated by multiplying the dry matter and total content of each of the major nutrients in each replication of the treatment and expressed in kg ha^{-1}.

3.2.2.3. Soil analysis (before and after the experiment)

Assessment of the status of major nutrients in soil before and after the experiment was carried out at the analytical laboratories of Dept of Agronomy, Soil science and Agricultural chemistry. Details of the methods used for chemical analysis are indicated in the Table 3.2.

Table 3.2 Methods used for chemical analysis of soil samples

Sl no	Nutrient	Method	Reference
01	pH	pH meter	Jackson (1973)
02	EC	Electrical conductivity bridge	Jackson (1973)
03	Available Nitrogen	Alkaline permanganate method	Subbiah and Asija (1956)
04	Available Phosphorus	Bray- 1 extractant Ascorbic acid reductant - spectrophotometry	Bray and Kurtz (1945)
05	Available Potassium	Neutral normal ammonium acetate extract using flame photometry	Jackson (1973)
06	Organic Carbon	Chromic acid wet digestion method	Walkely and Black (1934)

3.2.3. Quality analysis:

Essential oil content of the herb

Essential oil content was estimated by hydro distillation, adopting Clevenger trap method as per AOAC (1980) and expressed in per cent. Essential oil yield of the crop was computed by multiplying the oil content with yield.

Table 3.3.Physico-chemical properties of the soil prior to experiment

A. Mechanical composition		
Particulars	**Value**	**Method used**
Sand (%)	67.10	Robinson international pipette method (Piper, 1942)
Silt (%)	18.78	
Clay (%)	11.27	
B .Chemical properties		
Particulars	**Quantity**	**Method used**
pH (1:2.5)	5.97	pH meter (Jackson, 1973)
EC (dS m^{-1})	0.012	Electrical conductivity bridge (Jackson, 1973)
Organic C (%)	1.75	Walkley and Black method (Jackson, 1958)
Available N (kg ha^{-1})	204.88	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P (kg ha^{-1})	19.59	Bray- 1 extractant Ascorbic acid reductant – spectrophotometry Bray and Kurtz (1945)
Available K (kg ha^{-1})	127.30	Neutral normal ammonium acetate extractant flame photometry (Jackson, 1958)

Table 3.4 .Details of the experiment

1	Date of planting	27.08.2011
2	Total number of plots (beds)	54
3	Bed size	3.2 X 2 m^2
4	Spacing	30 x 30 cm
5	Total number of plants per bed	60

Results

4. RESULTS

The present study was conducted at the Department of Agronomy, College of Horticulture, Vellanikkara to evaluate the effect of levels of light intensities and various nutrient sources on the yield and quality of Iruveli (*Plectranthus vettiveroides*). The results of this study are presented in this chapter.

4.1 BIOMETRIC CHARACTERS

4.1.1 Plant height

Plant height at different light intensities and sources of nutrients are presented in the Table 4.1 and 4.2.The data on plant height revealed that light intensity had profound influence on height of the plants at 30 and 60 days after planting. The level M_3 of light intensity was found to be better for taller plants during the growth period. The plants grown under M_3 light intensity (75 per cent) level had the tallest plants (30.35cm) at 30 and 60 days (32:13cm) after planting.

Table 4.1 Effect of light intensity and nutrient source on plant height at 30 DAP

Nutrient source	Light intensity			Mean
	M_1 (cm)	M_2(cm)	M_3(cm)	
T_1	29.53	24.53	31.46	28.51
T_2	26.60	24.66	30.33	27.20
T_3	25.53	21.13	34.06	26.91
T_4	25.66	22.26	29.26	25.73
T_5	28.46	20.46	34.24	27.72
T_6	23.66	22.86	22.73	23.08
Mean	26.57	22.65	30.35	
CD (0.05) for light intensity (M)				1.10
CD (0.05) for nutrient source (T)				1.31
CD (0.05) for M × T				NS

Significant difference was also noticed in the height of plants due to variation in the source of nutrients. The plants were found to be taller (28.51 cm) when (T_1) FarmYard Manure (FYM) alone was applied at 30 days after planting (DAP). Maximum plant height (30.64 cm) at 60 days after planting was found when it was applied with FYM +Azospirllum +AMF (T_2) and was on par (30.55 cm) with treatment of FYM alone. The plants were shorter

(23.08 cm) at 30 days after planting and at 60 days after planting (27.64 cm) when the nutrients were not applied (T_6).

Table 4.2 Effect of light intensity and nutrient source on plant height at 60 DAP

Nutrient source	Light intensity			Mean
	M_1 (cm)	M_2(cm)	M_3(cm)	
T_1	30.20	29.06	32.40	30.55
T_2	29.66	29.93	32.33	30.64
T_3	27.60	25.66	34.46	29.24
T_4	29.86	26.86	31.86	29.53
T_5	30.06	24.36	34.80	29.74
T_6	26.46	29.53	26.93	27.64
Mean	28.97	27.56	32.13	
CD (0.05) for light intensity (M)				1.05
CD (0.05) for nutrient source (T)				1.25
CD (0.05) for M × T				NS

4.1.2 Number of leaves

Influence of different light intensity levels and sources of nutrients on the number of leaves at 30 and 60 days after planting is presented in Table 4.3 and 4.4. The number of leaves of experimental plants was taken at 30 and 60 days after planting and an increase in the leaf number was noticed during the growing period. The data showed that light intensities had influenced the leaf production at 30 and 60 days after planting. Open condition (M_1) was found to be better for leaf production followed by M_3 (75 per cent) light intensity at 30 and 60 days after planting.

Table: 4.3 Effect of light intensity and nutrient source on number of leaves at 30 DAP

Nutrient source	Light intensity			Mean
	M_1	M_2	M_3	
T_1	81.26	37.33	47.53	55.37
T_2	55.60	44.73	50.33	50.22
T_3	47.80	38.33	43.26	43.13
T_4	72.83	41.40	57.46	57.23
T_5	87.86	30.73	55.53	58.04
T_6	42.20	38.33	51.86	44.13
Mean	64.59	38.47	51.00	
CD (0.05) for light intensity (M)				2.16
CD (0.05) for nutrient source (T)				2.57
CD (0.05) for M × T				NS

Higher number of leaves was produced by plants treated with FYM and 30:15:30 kg/ha of NPK (T_5) which was on par with the application of Biovermi+Azospirillum +AMF (T_4) at 30 DAP and 60 DAP. The highest number of leaves (58.04) was observed when treated with (T_5) at 30 DAP which was on par with T_4 and T_1. Lowest number of leaves (43.13) was found when applied with Biovermi alone at 30 DAP . Combined application of Biovermi, Azospirillum and AMF was found to be better for higher leaf production (85.01) at 60 DAP. The number of leaves (73.42) was found to be the lowest when no nutrients were applied (T_6). Maximum leaf production was noticed under open condition with T_5 followed with T_1.

Table: 4.4 Effect of light intensity and nutrient source on number of leaves at 60 DAP

Nutrient source	Light intensity			Mean
	M_1	M_2	M_3	
T_1	103.13	63.86	76.13	81.04
T_2	88.13	84.80	74.80	82.57
T_3	83.80	56.73	83.06	74.53
T_4	100.8	69.73	84.46	85.01
T_5	108.8	43.33	81.20	77.80
T_6	71.20	63.26	85.80	73.42
Mean	92.66	63.62	80.91	
CD (0.05) for light intensity (M)				**3.13**
CD (0.05) for nutrient source (T)				**3.72**
CD (0.05) for M × T				**S**

4.1.3 Number of branches

Light intensity influenced the development of branches significantly at 30 and 60 days after planting. Among the various light intensity levels used in the experiment, M_1 (open) was found to be giving maximum branches during the growth period. At 30 days after planting the number of branches under open condition was 6.35 and the least was (4.08) noticed in M_2. The highest number of branches (6.8) was observed under open condition which was on par with M_3 (6.36) and the least number of branches (4.65) was noticed at 50 per cent light intensity level (M_2) at 60 days after planting.

Table: 4.5 Effect of light intensity and nutrient source on number of branches at 30 DAP

Nutrient source	Light intensity			Mean
	M_1	M_2	M_3	
T_1	7.06	4.13	3.86	5.02
T_2	5.93	4.66	4.73	5.11
T_3	6.73	3.93	4.00	4.88
T_4	6.73	3.93	3.80	4.82
T_5	7.60	3.80	5.20	5.53
T_6	4.06	4.06	4.46	4.20
Mean	6.35	4.08	4.34	
CD (0.05) for light intensity (M)				**0.73**
CD (0.05) for nutrient source (T)				**0.86**
CD (0.05) for M × T				**NS**

Significant variation was observed in the number of branches with different source of nutrients. The plants were found to be producing the highest number of branches (5.53) when applied with a combination of FYM and inorganic fertilizers at the rate of 30:15:30 kg NPK ha^{-1} (T_5) which was on par (5.11) with the treatment of FYM+Azospirillum+AMF (T_2) at 30 days after planting. The branch production was lowest (4.20) when no nutrients were applied (T_6) at 30 DAP.

Table: 4.6 Effect of light intensity and nutrient source on number of branches at 60 DAP

Nutrient source	Light intensity			Mean
	M_1	M_2	M_3	
T_1	6.80	4.53	6.40	5.91
T_2	5.93	5.53	6.66	6.04
T_3	7.00	4.80	6.06	5.95
T_4	8.80	4.13	6.57	6.50
T_5	7.86	3.93	6.60	6.13
T_6	4.40	5.00	5.86	5.08
Mean	6.80	4.65	6.36	
CD (0.05) for light intensity (M)				**0.88**
CD (0.05) for nutrient source (T)				**1.05**
CD (0.05) for M × T				**NS**

Plate 2: Crop performance under open condition

At 60 days after planting the plants produced maximum number of branches (6.50) when applied with Biovermi+Azospirillum +AMF (T_4) which was on par (6.13) with combined application of FYM and inorganic fertilizers at the rate of 30:15:30 kg NPK ha^{-1} (T_5). Least number of branches (5.08) were noticed when no nutrients were applied (T_6) at 60 DAP.

4.1.4 Root: shoot ratio

Root: shoot ratio of the plants are presented in the Table 4.7. Randomly selected five plants from each plot were uprooted. The root and shoot weights were recorded seperately after drying in oven and expressed as ratio. Levels of light intensity and the various nutrient sources had affected the root: shoot ratio of the plants.

It was observed that plants exhibited variation in the root: shoot ratio at various light intensity levels. Open condition (M_1) proved to be the best for maximum (1.45) root: shoot ratio in the field and was on par with 75 per cent light intensity (M_3), while the least root: shoot ratio of (1.28) was given by 50 per cent light intensity (M_2).

Root: shoot ratio showed significant variation with source of nutrients used in the field. Application of Biovermi+ Azospirillum+ AMF (T_4) showed maximum root: shoot ratio of 1.67 and was on par (1.50) with FYM alone (T_1). Lowest root: shoot ratio (1.20) was observed in the plot which was treated with a combination of FYM and inorganic fertilizers at the rate of 30:15:30 kg NPK/ha (T_5).

Table: 4.7 Effect of light intensity and nutrient source on root: shoot ratio of Iruveli

Nutrient source	Light intensity			Mean
	M_1	M_2	M_3	
T_1	1.52	1.40	1.58	1.50
T_2	1.44	0.88	1.39	1.24
T_3	1.46	1.04	1.25	1.25
T_4	1.44	1.79	1.78	1.67
T_5	1.22	1.23	1.16	1.20
T_6	1.65	1.36	1.46	1.49
Mean	1.45	1.28	1.44	
CD (0.05) for light intensity (M)				0.51
CD (0.05) for nutrient source (T)				0.60
CD (0.05) for M × T				NS

4.1.5 Biomass production

It was observed that the experimental plants shown significant variation in the biomass production under levels of light intensities. 75 per cent light intensity (M_3) had profound influence on the biomass production of the experimental plants. The highest biomass production of 130.30 g plant^{-1} was noticed in 75 per cent light intensity level (M_3). Open condition (M_1) recorded the lowest biomass of 59.10 g plant^{-1}.

Table: 4.8 Effect of light intensity and nutrient source on biomass production of Iruveli

Nutrient source	Light intensity			Mean
	M_1(g plant^{-1})	M_2(g plant^{-1})	M_3(g plant^{-1})	
T_1	53.04	105.52	87.12	81.89
T_2	50.62	140.9	126.33	105.95
T_3	73.00	88.67	122.61	94.76
T_4	38.10	126.06	193.31	119.15
T_5	64.49	88.52	120.16	91.05
T_6	75.35	90.49	132.29	99.37
Mean	59.10	106.69	130.30	
CD (0.05) for light intensity (M)				**4.54**
CD (0.05) for nutrient source (T)				**5.41**
CD (0.05) for M × T				**NS**

Biomass production of plants showed significant variation with variation in sources of nutrients. Maximum biomass (119.15 g plant^{-1}) was produced by the plants when applied with Biovermi+Azospirillum + AMF alone (T_4). Application of FYM (T_1) alone could render least biomass production (81.89 g plant^{-1}).

Dry matter production

Experimental plants showed significant variation in dry matter production when grown under different light intensities. Dry matter production was the highest (15.97 g plant^{-1}) when the plants were grown under 75 per cent light intensity (M_3) condition which was on par with 50 per cent light intensity (M_2) compared to open (M_1). Lowest dry matter production (11.96g plant $^{-1}$) was noticed in plants grown under open condition (M_1).

Table: 4.9 Effect of light intensity and nutrient source on dry matter production of Iruveli

Nutrient source	Light intensity			Mean
	M_1(g plant^{-1})	M_2(g plant^{-1})	M_3(g plant^{-1})	
T_1	14.12	14.80	10.76	13.22
T_2	11.54	15.20	13.78	13.50
T_3	12.86	11.92	18.32	14.36
T_4	20.16	19.42	19.78	19.78
T_5	13.10	15.93	13.19	14.07
T_6	18.66	18.34	20.04	19.01
Mean	11.96	15.93	15.97	
CD (0.05) for light intensity (M)				**1.94**
CD (0.05) for nutrient source (T)				**2.31**
CD (0.05) for M × T				**NS**

Dry matter production of plants showed significant variation with variation in sources of nutrients. Maximum dry matter (19.78 g plant^{-1}) was produced by the plants when applied with Biovermi+Azospirillum+AMF (T_4). Application of FYM (T_1) alone could render the least dry matter production (13.22 g plant^{-1}).

4.1.5 Yield

Result of the study exhibited that yield had significant variation under open and light intensity conditions. The 75 per cent light condition (M_3) was found to be better during the growth period. The maximum yield of 3042 kg ha^{-1} was obtained under 75 per cent light intensity condition. The lowest yield of 1388 kg ha^{-1} was found in the plots with open condition (M_1).

Significant variation was also observed in yield when various sources of nutrients were applied. Among the treatments maximum herbage yield (2908.32 kg ha^{-1}) was obtained in experimental plants when treated with Biovermi +Azospirillum + AMF (T_4) which were on par with T_3. Herbage yield was comparatively lower (1616.01 kg ha^{-1}) when no nutrients were applied (T_6).

Table: 4.8 Effect of light intensity and nutrient source on yield of Iruveli

Nutrient source	Light intensity			Mean
	M_1 (kg ha^{-1})	M_2(kg ha^{-1})	M_3(kg ha^{-1})	
T_1	474	1899	4629	2334
T_2	1092	2374	2492	1986
T_3	2255	2018	1899	2057
T_4	2581	2255	3888	2908
T_5	1210	1779	2255	1748
T_6	717	1044	3086	1616
Mean	1388	1895	3042	
CD (0.05) for light intensity (M)				29.2
CD (0.05) for nutrient source (T)				34.7
CD (0.05) for M × T				NS

4.2 PLANT NUTRIENT STATUS

Data pertaining to the result of chemical analysis of plant samples are given below.

4.2.1 Nitrogen

It was observed that the experimental plants had shown significant variation in nitrogen per cent under light intensity and open conditions. 75 per cent light intensity (M_3) had profound influence on the nitrogen per cent of the experimental plants. The higher nitrogen content of 2.78 per cent was noticed in 75 per cent light intensity level (M_3) and open condition (M_1). 50 per cent light intensity (M_2) recorded the lowest nitrogen content of 2.46 per cent.

Table: 4.10 Effect of light intensity and nutrient source on nitrogen content of Iruveli

Nutrient source	Light intensity			Mean
	M_1 (%)	M_2(%)	M_3(%)	
T_1	2.80	2.19	2.80	2.59
T_2	2.80	2.29	2.76	2.61
T_3	2.80	2.62	2.81	2.74
T_4	2.78	2.70	2.72	2.73
T_5	2.76	2.50	2.80	2.68
T_6	2.74	2.50	2.80	2.68
Mean	2.78	2.46	2.78	
CD (0.05) for light intensity (M)				0.27
CD (0.05) for nutrient source (T)				0.32
CD (0.05) for M × T				NS

Variation in the source of nutrients had significant variation in the per cent nitrogen content of plant samples. Application of Biovermi alone (T_3) yielded maximum nitrogen content of 2.74 per cent and was on par with T_4, T_5 and T_6. The lowest nitrogen content of 2.59 per cent was observed when the plants were treated with FYM (T_1) alone.

4.2.2 Phosphorus

Significant variation was observed in phosphorus content among the experimental plants with variation in the light intensity level. Open (M_1) condition provided the best result. Maximum phosphorus content (0.64%) was observed under open condition. 75 per cent light (M_3) was found to be showing the lowest value of phosphorus content of the plants.

Different sources of nutrients had shown significant variation in the phosphorus content of experimental plants. Control plot (T_6) had given the maximum content of phosphorus in the plant (0.59) which was on par with T_2 and T_6. The lowest phosphorus content of 0.46 per cent was noticed in plants applied with Biovermi alone.

Table: 4.11 Effect of light intensity and nutrient source on phosphorus content of Iruveli

Nutrient source	Light intensity			Mean
	M_1(%)	M_2(%)	M_3(%)	
T_1	0.68	0.52	0.50	0.57
T_2	0.68	0.39	0.35	0.47
T_3	0.67	0.19	0.51	0.46
T_4	0.42	0.47	0.69	0.53
T_5	0.54	0.47	0.52	0.51
T_6	0.82	0.36	0.59	0.59
Mean	0.64	0.40	0.52	
CD (0.05) for light intensity (M)				0.47
CD (0.05) for nutrient source (T)				0.67
CD (0.05) for M × T				NS

4.2.3 Potassium

Data on potassium content of the plant revealed that light intensity had profound influence on the potassium content of the experimental plants. Among the various light intensity levels provided, 75 per cent light intensity (M_3) was found to be giving maximum value for per cent of potassium in the plant. Maximum potassium content (2.09%) was observed in plants grown under 75 per cent light intensity (M_3). Open condition (M_1) proved to be least effective regarding the potassium content of the experimental plants. Plant analysis showed the lowest value of 1.13 per cent potassium under open condition (M_1).

With respect to the per cent of potassium content in plants, application of various sources of nutrients in the field had showed significant variations. The highest content of potassium was given by plants when they were applied with a combination of FYM and inorganic fertilizers at 30:15:30 kg ha^{-1} (T_5). Highest potassium content was 1.76 per cent in T_5 was on par with potassium content with application of FYM (T_1) alone (1.71%). Experimental plants when applied with a combination of Biovermi, Azospirillum and AMF (T_4) were found to be giving the lowest potassium content of plants. Lowest potassium content of 1.44 per cent was observed for the treatment T_4.

Table: 4.12 Effect of light intensity and nutrient source on potassium content of Iruveli

Nutrient source	Light intensity			Mean
	M_1(%)	M_2(%)	M_3(%)	
T_1	1.47	1.38	2.27	1.71
T_2	0.96	1.85	2.22	1.68
T_3	1.11	1.72	1.73	1.52
T_4	0.80	1.58	1.94	1.44
T_5	1.32	1.94	2.13	1.76
T_6	1.13	1.58	2.27	1.66
Mean	1.13	1.67	2.09	
CD (0.05) for light intensity (M)				**0.63**
CD (0.05) for nutrient source (T)				**0.75**
CD (0.05) for M × T				**NS**

4.2.4. Nutrient uptake

Nutrient uptake was calculated after the harvest of the crop. The product of the dry matter yield and the nutrient content was calculated to obtain the uptake by the plant. The data regarding the nutrient uptake is given in the table.

Plate 3: Crop performance under 50% light intensity

4.2.4.1 Nitrogen uptake

Plant analysis data revealed that light intensity had influenced the nitrogen uptake by the experimental plants in the field. Among the various light intensity levels provided, 75 per cent light (M_3) had favoured the nitrogen uptake considerably. Maximum nitrogen uptake (416.4 kg ha $^{-1}$) was shown by the plants maintained under 75 per cent light intensity level (M_3)and was on par with M_1. Plants maintained under 50 percent light intensity level (M_2) showed the least uptake of nitrogen. Lowest nitrogen uptake was 370.71 kg ha $^{-1}$.

Table: 4.13 Effect of light intensity and nutrient source on nitrogen uptake of Iruveli

Nutrient source	Light intensity			Mean
	M_1(kg ha $^{-1}$)	M_2(kg ha $^{-1}$)	M_3(kg ha $^{-1}$)	
T_1	370.6	301.6	282.4	318.2
T_2	302.9	334.3	354.7	330.6
T_3	337.5	292.1	484.0	371.2
T_4	526.5	491.6	505.6	507.9
T_5	338.0	383.2	346.1	355.8
T_6	479.3	421.1	525.7	475.4
Mean	392.5	370.7	416.4	
CD (0.05) for light intensity (M)				**9.8**
CD (0.05) for nutrient source (T)				**11.6**
CD (0.05) for M × T				**NS**

Significant difference was noticed in the nitrogen uptake of the plant when treated with various nutrient sources. Among the various treatments, experimental plants applied with Biovermi+ Azospirillum +AMF (T_4) showed maximum nitrogen uptake. The highest nitrogen uptake noticed was 507.95 kg ha $^{-1}$. Experimental plots when treated with FYM (T_1) alone showed the lowest nitrogen uptake of 318.26 kg ha $^{-1}$.

4.2.4.2 Phosphorus uptake

Analysis of data showed that various light intensity levels provided in the field had influenced the plant phosphorus uptake significantly. Among the various light intensity levels provided open condition (M_1) was found to be better for the maximum phosphorus uptake by the plants. The maximum plant phosphorus uptake was observed with the plants maintained under open condition was 95.27 kg ha $^{-1}$. Lowest phosphorus uptake was showed by the plants grown under 75 per cent light intensity level (M_3). The least plant phosphorus uptake observed with the plants under 75 per cent light intensity level was 60.54 kg ha $^{-1}$.

Table: 4.14 Effect of light intensity and nutrient source on phosphorus uptake of Iruveli

Nutrient source	Light intensity			Mean
	M_1(kg ha $^{-1}$)	M_2(kg ha $^{-1}$)	M_3(kg ha $^{-1}$)	
T_1	96.65	74.25	53.25	74.71
T_2	75.07	85.66	49.09	69.94
T_3	82.09	51.77	30.54	54.80
T_4	131.26	146.66	85.07	121.00
T_5	66.68	76.00	56.59	66.42
T_6	119.88	107.84	88.71	105.47
Mean	95.27	90.36	60.54	
CD (0.05) for light intensity (M)				**6.64**
CD (0.05) for nutrient source (T)				**7.90**
CD (0.05) for M × T				**NS**

With the variation in sources of nutrients significant variation was observed in the phosphorus uptake of the plant. Among the various sources of nutrients, application of the combination of Biovermi, Azospirillum and AMF (T_4) had profound influence on the phosphorus uptake by the crop. Maximum phosphorus uptake of 121.00 kg ha $^{-1}$ was observed with combined application of Biovermi, Azospirillum and AMF. The lowest phosphorus uptake of 54.80 kg ha $^{-1}$ was observed when the plants were applied with biovermi (T_3) alone.

4.2.4.3 Potassium uptake

Potassium uptake by the plants was influenced by the variations in the light levels provided. Among the different light levels given, 75 per cent light intensity level (M_3) influenced the plants for maximum potassium uptake. Maximum potassium uptake noticed was 315.90 kg ha $^{-1}$ which was maintained under 75 percent light intensity level. The lowest potassium uptake value of 151.06 kg ha $^{-1}$ was given by plants maintained under open condition (M_1).

Potassium uptake data showed significant variation with different sources of nutrients used in the experimental field. Maximum potassium uptake was shown by the experimental plants applied with a combination of Biovermi, Azospirillum and AMF (T_4). The highest potassium uptake value was 255.05 kg ha $^{-1}$ which was on par with T_5. The lowest potassium uptake was shown by plants applied with FYM (T_1) alone which was 215.22 kg ha^{-1}.

Table: 4.15 Effect of light intensity and nutrient source on potassium uptake of Iruveli.

Nutrient source	Light intensity			Mean
	M_1(kg ha $^{-1}$)	M_2 (kg ha $^{-1}$)	M_3(kg ha $^{-1}$)	
T_1	203.99	196.13	245.55	215.22
T_2	107.18	267.33	285.11	219.87
T_3	134.28	188.29	343.37	221.98
T_4	156.79	258.42	349.94	255.05
T_5	179.34	295.94	258.80	254.69
T_6	124.82	219.66	412.64	252.37
Mean	151.06	237.62	315.90	
CD (0.05) for light intensity (M)				9.44
CD (0.05) for nutrient source (T)				11.23
CD (0.05) for M × T				NS

4.3 SOIL NUTRIENT STATUS

Data pertaining to the result of chemical analysis of the soil samples from the experimental field are given below.

4.3.1 Available NPK

At the time of crop harvest the per plot soil samples were taken. The samples drawn were dried, sieved and undergone chemical analysis for available Nitrogen, available Phosphorus, available Potassium and Organic Carbon. The result of the analysed data is provided here.

4.3.1.1 Available Nitrogen

The data showed that light intensity had profound influence on the available nitrogen content of soil in the experimental plots. The 75 per cent light intensity level (M_3) produced the best result. Maximum amount of available nitrogen in soil observed was 195.37 kg ha^{-1}. Lowest amount of available nitrogen (174.49 kg ha^{-1}) was found in the experimental plots maintained under 50 per cent light intensity level (M_2).

Significant difference was also noticed in the amount of available nitrogen with variation in the source of nutrients used for the experiment. Among the various nutrient sources used, application of FYM (T_1) alone gave the maximum available nitrogen content of 250.43 kg ha^{-1}. The least value of available nitrogen was estimated from the analysed samples treated without any nutrients (T_6). The lowest value of available nitrogen was 145.82 kg ha^{-1} in T_6.

Table: 4.16 Effect of light intensity and nutrient source on nitrogen content of soil

Nutrient source	Light intensity			Mean
	M_1(kg ha^{-1})	M_2(kg ha^{-1})	M_3(kg ha^{-1})	
T_1	245.30	248.09	257.84	250.43
T_2	210.45	186.76	225.78	207.69
T_3	158.88	143.55	164.46	155.69
T_4	172.82	153.31	186.76	170.99
T_5	202.09	167.24	178.39	182.52
T_6	131.01	147.73	158.88	145.82
Mean	186.75	174.49	195.37	
CD (0.05) for light intensity (M)				2.91
CD (0.05) for nutrient source (T)				3.47
CD (0.05) for M × T				NS

4.3.1.2 Available Phosphorus

Variation in the light intensity levels had significant influence on the available phosphorus level of soil samples from experimental plots. Among the various light intensity levels, 75 per cent light intensity level (M_3) was found to be giving better results. Maximum amount of available phosphorus was found in the soil samples taken from 75 percent light intensity levels. Highest amount of available phosphorus found in the experimental soil sample was 28.15 kg ha^{-1}. Open condition (M_1) was to be showing the least amount of available phosphorus in the soil samples. Lowest amount of available phosphorus was 22.57 kg ha^{-1}.

Difference in the sources of nutrients had significant variation among the available phosphorus content of soil samples analysed. Highest amount of available phosphorus was noticed from the field samples treated with Biovermi, Azospirillum and AMF (T_4). 30.06 kg ha^{-1} was the highest amount of available phosphorus obtained from the experimental field. Application of FYM (T_1) alone had the lowest amount of available phosphorus in the experimental field and 23.44 kg ha^{-1} of soil P was noticed in T_1 of the experiment.

Table: 4.17 Effect of light intensity and nutrient source on phosphorus content of soil

Nutrient source	Light intensity			Mean
	M_1(kg ha^{-1})	M_2(kg ha^{-1})	M_3(kg ha^{-1})	
T_1	21.27	25.12	23.93	23.44
T_2	18.93	28.64	27.98	25.18
T_3	28.24	24.00	31.23	27.82
T_4	30.97	30.06	29.15	30.06
T_5	15.14	27.69	30.68	24.50
T_6	20.91	26.77	25.94	24.54
Mean	22.57	27.05	28.15	
CD (0.05) for light intensity (M)				**1.32**
CD (0.05) for nutrient source (T)				**1.57**
CD (0.05) for M × T				**NS**

4.3.1.3 Available Potassium

Data showed that light intensity had significant influence on the available potassium in soil samples analysed from experimental plots. Maximum available potassium content of soil was found in M_3 with 224.86 kg ha^{-1} of soil potassium. Soil samples collected from the experimental plots maintained under 75 per cent light intensity level (M_3) gave the highest available potassium during chemical analysis. Lowest available potassium level observed in the experiment was 166.60 kg ha^{-1}. Experimental plots maintained under open condition (M_1) showed the lowest available potassium content in soil samples.

Table: 4.17 Effect of light intensity and nutrient source on potassium content of soil

Nutrient source	Light intensity			Mean
	M_1(kg ha^{-1})	M_2(kg ha^{-1})	M_3(kg ha^{-1})	
T_1	127.42	176.21	176.83	160.15
T_2	118.09	162.27	113.36	131.24
T_3	173.97	186.58	279.97	213.50
T_4	226.73	112.62	294.05	211.13
T_5	121.37	330.77	275.06	242.40
T_6	232.03	282.42	209.93	241.46
Mean	166.60	208.47	224.86	
CD (0.05) for light intensity (M)				**1.81**
CD (0.05) for nutrient source (T)				**2.15**
CD (0.05) for M × T				**NS**

Difference in the sources of nutrients had showed significant variation among the available potassium content of soil samples analysed. Highest amount of available potassium

Plate 4: Crop performance under 75% light intensity

was noticed in the soil samples collected from the experimental plots treated with combination of FYM and inorganic fertilizers at the rate of 30:15: 30 kg ha^{-1} of N P and K (T_5). 242.40 kg ha^{-1} was the highest amount of available potassium obtained from the experimental field. Application of the combination of FYM, Azospirillum and AMF (T_2) had the lowest amount of available potassium in the experimental field. Lowest amount of 131.24 kg ha^{-1} kg/ha was noticed in T_2.

4.3.1.3 Organic carbon

Various light intensity levels had significant influence on the organic carbon content of soil samples tested. Among the various light intensity levels studied, open condition (M_1) showed maximum organic carbon content in the soil samples and the experimental plots maintained under 75 percent light intensity level (M_3) provided the least amount, which were 1.77 and 1.71 per cent respectively.

Table: 4.18 Effect of light intensity and nutrient source on organic carbon content of soil

Nutrient source	**Light intensity**			**Mean**
	M_1 (%)	**M_2 (%)**	**M_3 (%)**	
T_1	2.03	1.52	1.65	1.73
T_2	1.66	1.88	1.82	1.79
T_3	1.53	1.91	2.00	1.81
T_4	1.89	1.85	1.53	1.76
T_5	1.71	1.71	1.51	1.64
T_6	1.81	1.49	1.79	1.69
Mean	1.77	1.73	1.71	
CD (0.05) for light intensity (M)				**0.08**
CD (0.05) for nutrient source (T)				**0.10**
CD (0.05) for M × T				**S**

Application of various sources of nutrients in the experimental field showed significant variation on the organic carbon content of the soil sample. Among the various nutrient sources used, application of biovermi (T_3) alone gave the maximum organic carbon content in the analysed soil samples. The highest amount of organic carbon content noticed in the soil sample was 1.81 per cent. No application of fertilizers (T_6) in the experimental field yielded the lowest amount of organic carbon content of 1.69 per cent. Application of FYM alone under open condition recorded the highest organic carbon content followed by the treatment combination of Biovermi alone under 75 per cent light intensity.

4.3.1.4. pH and Electrical conductivity of soil

Table: 4.19 Effect of various nutrient sources on the pH of soil.

Nutrient source	Light intensity								
	M_1			M_2			M_3		
Sub plots	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
T_1	6.00	5.99	5.99	6.00	5.99	5.98	5.98	5.97	5.92
T_2	5.99	6.02	6.02	5.99	5.98	5.99	6.00	5.99	6.01
T_3	6.00	6.00	5.99	6.00	5.99	5.98	5.98	5.98	5.98
T_4	6.01	6.01	6.00	6.00	5.98	5.98	5.98	5.99	5.99
T_5	6.01	6.00	6.01	5.98	5.98	5.99	5.99	6.02	6.02
T_6	5.98	5.94	5.98	5.97	5.98	5.97	5.98	5.98	5.98

The application of various nutrient sources did not produced considerable variation in pH of the soil. The pH of the soil ranged between 5.92 to 6.01 after application of the different sources of nutrients at the end of the experiment which is favourable for crop growth and nutrient uptake. The electrical conductivity of soil also did not show considerable changes with variations in the source of nutrients.

Table: 4.20 Effect of various nutrient sources on the EC of soil.

Nutrient source	Light intensity								
	$M_1(dSm^{-1})$			$M_2(dSm^{-1})$			$M_3(dSm^{-1})$		
Sub plots	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
T_1	0.021	0.020	0.019	0.021	0.021	0.020	0.021	0.019	0.020
T_2	0.022	0.019	0.020	0.020	0.020	0.018	0.019	0.020	0.020
T_3	0.023	0.021	0.022	0.021	0.021	0.021	0.021	0.021	0.021
T_4	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.022	0.022
T_5	0.022	0.021	0.021	0.022	0.022	0.022	0.021	0.022	0.022
T_6	0.012	0.012	0.013	0.013	0.012	0.012	0.012	0.013	0.013

4.4 QUALITY ANALYSIS

4.4.1 Essential oil content of the herb

The data showed that light intensity had profound influence on the essential oil content of the herb from the experimental plots. Open condition (0% light intensity level) (M_1) produced better result. Maximum amount of essential oil content observed was 1.77 per cent under open condition. Lowest amount of essential oil (1.71 %) was found in the experimental plots maintained under 75 per cent light intensity level (M_3) and was on par with open condition.

Significant difference was also noticed in the essential oil content of the herb with variation in the source of nutrients used for the experiment. Among the various nutrient sources used, application of Biovermi alone (T_3) gave the maximum essential oil content of 1.81per cent which was on par with T_4. The least value of essential oil was obtained from the plots treated with FYM and 30:15:30 kg ha^{-1} of NPK (T_5). The lowest essential oil content obtained was 1.64 per cent in T_5 which was on par with control (T_6).

Table: 4.21 Effect of light intensity and nutrient source on the essential oil content in Iruveli

Nutrient source	Light intensity			Mean
	M_1 (%)	M_2 (%)	M_3 (%)	
T_1	2.03	1.52	1.65	1.73
T_2	1.66	1.88	1.82	1.79
T_3	1.53	1.91	2.00	1.81
T_4	1.89	1.85	1.53	1.76
T_5	1.71	1.71	1.51	1.64
T_6	1.81	1.49	1.79	1.69
Mean	1.77	1.73	1.71	
CD (0.05) for light intensity (M)				0.08
CD (0.05) for nutrient source (T)				0.10
CD (0.05) for M × T				S

4.4.2 Essential oil yield of the herb

It was observed that the experimental plants shown significant variation in the oil yield under light intensity and open conditions. 75 per cent light intensity (M_3) had profound influence on the oil yield of the experimental plants. The highest oil yield production of 106.04 kg ha^{-1} was noticed in 75 per cent light intensity level (M_3) which was on par with open condition (M_1). 50 per cent light intensity level (M_2) recorded the lowest oil yield of 37.82 kg ha^{-1}.

Table: 4.21 Effect of light intensity and nutrient source on the essential oil yield in *Iruveli*

Nutrient source	Light intensity			Mean
	M_1(kg ha^{-1})	M_2(kg ha^{-1})	M_3(kg ha^{-1})	
T_1	22.15	52.22	162.23	78.86
T_2	55.86	47.48	79.92	61.08
T_3	90.21	40.35	75.97	68.84
T_4	105.15	45.10	151.94	100.73
T_5	68.05	20.89	104.46	64.46
T_6	23.86	20.89	61.72	35.49
Mean	60.88	37.82	106.04	
CD (0.05) for light intensity (M)				**5.87**
CD (0.05) for nutrient source (T)				**6.98**
CD (0.05) for M × T				**NS**

Oil yield of plants showed significant variation with variation in sources of nutrients. Maximum oil yield (100.73 kg ha^{-1}) was produced by the plants when treated with combination Biovermi, Azospirillum and AMF (T_4). Application of no nutrients (T_6) could render least oil yield (kg ha^{-1}).

Discussion

5. DISCUSSION

A field experiment was conducted at Department of Agronomy, College of Horticulture, Vellanikkara to evaluate the effect of different levels of light intensities and different sources of nutrients on yield and quality of Iruveli (*Plectranthus vettiveroides*). The results obtained from the experiment presented in the last chapter are discussed in this chapter.

5.1 Effect of light intensity on yield of Iruveli

Iruveli (*Plectranthus vettiveroides*) is an annual herb and whole plant is used against skin diseases, bronchitis and chronic allergies. The growth and yield traits of a plant though genetically controlled, can be modified by altering the environmental condition. Soil and atmospheric condition have significant influence on quantity and quality as well as their inter relations in medicinal plants. Hence the optimum light intensity has to be identified for higher yield and quality.

The experiment was conducted during August 2010 - January of 2011. The light intensity was regulated by providing artificial shade nets of desired meshes. The plant height was maximum when 75 per cent light intensity was provided. Though the plants attained maximum height at 75 per cent light intensity, the number of leaves were higher under open condition. The number of branches did not produce significant variation under open situation and at 75 percent light intensity. Among the environmental factors, light is an important factor influencing plant growth and development. Different plants had different response to the light intensity alteration and the resulting growth and development (Ali *et al.*, 2010). Herbage yield being economically important in Iruveli, the number of leaves as well as the number of branches are directly related to yield of the plant. The data on root shoot ratio of plants under different levels of light intensities revealed that open condition and 75 per cent light intensity were on par. Higher root shoot ratio with open and 75 per cent light intensity signified that proportionally more photosynthates are allocated to root tissue under full sunlight and at 75 per cent light. Higher root shoot ratio under full sunlight compared to shade was reported in *Sida cordifolia* . According to Devkota and Jha (2010) less shaded plants tended to concentrate the dry weight in roots in relation to more shaded plants. The root shoot ratio of Iruveli plant was affected by the light intensity and it was highest in full light. On the

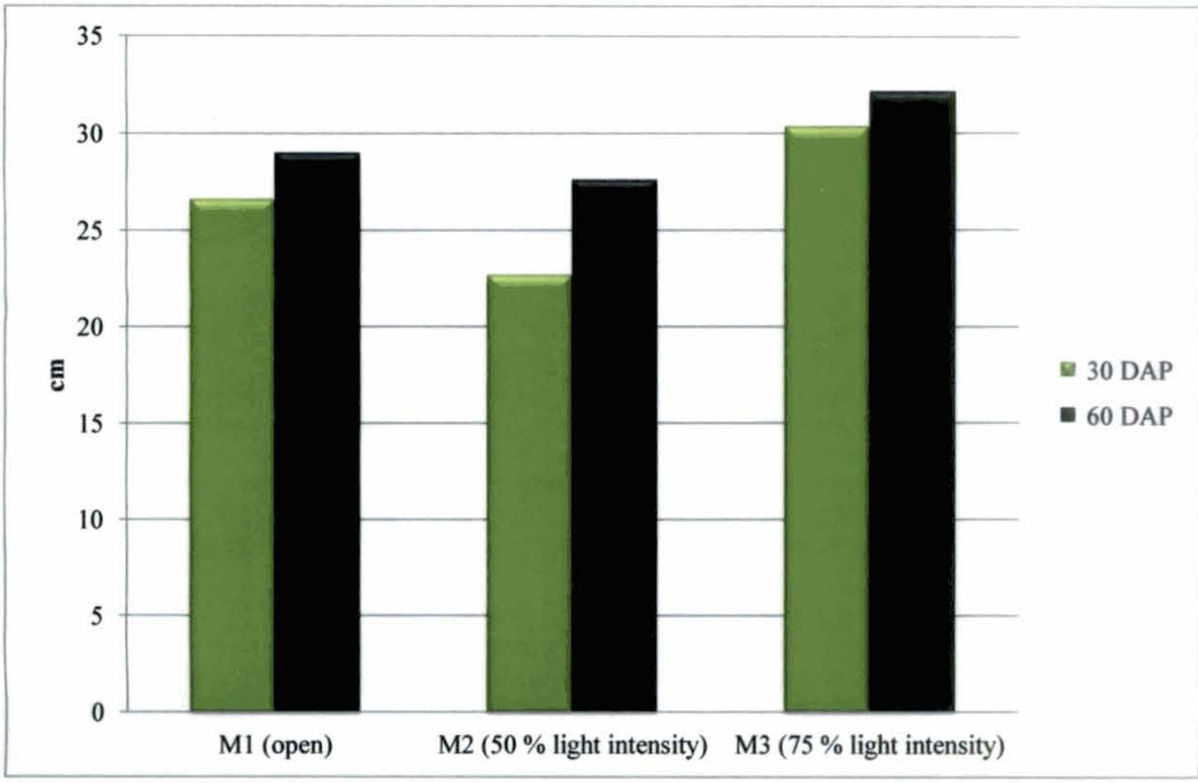

Fig 5.1. Effect of light intensity on height of Iruveli

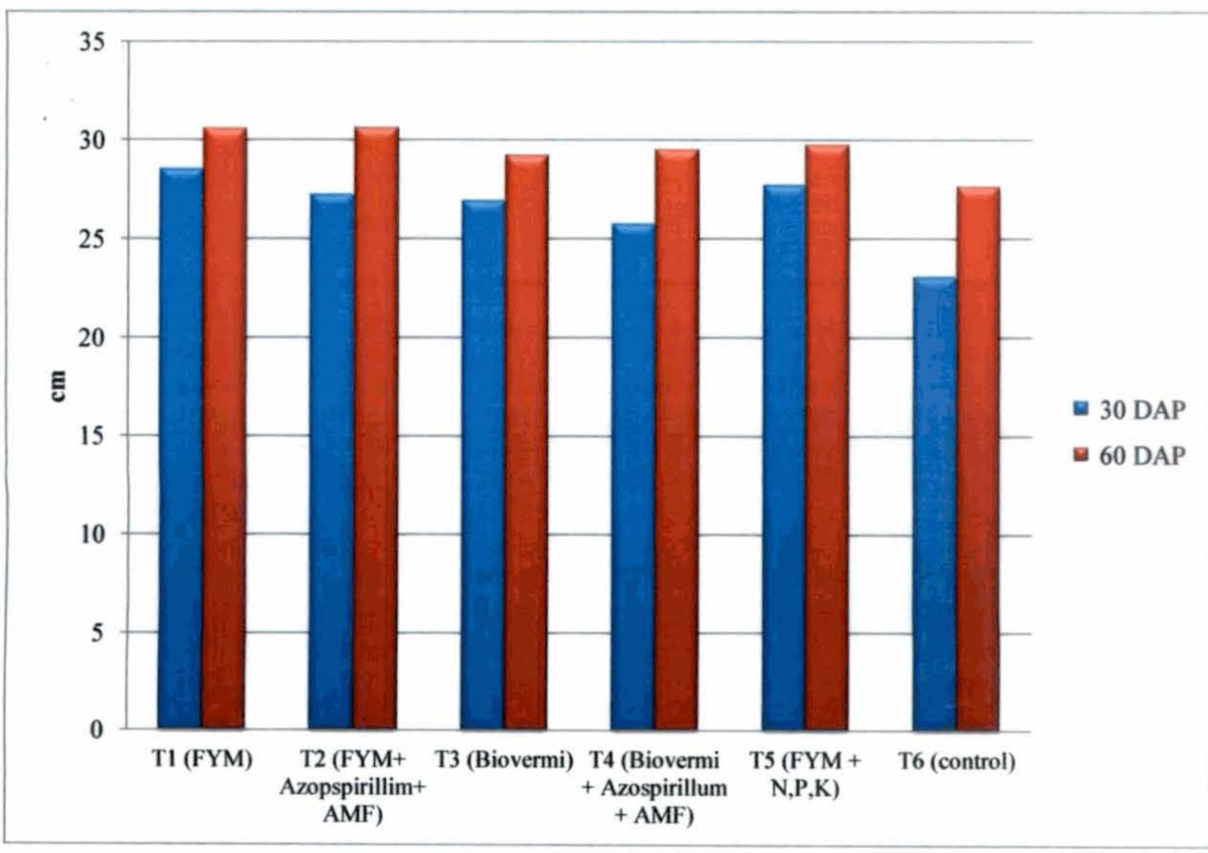

Fig 5.2. Effect of nutrient source on height of Iruveli

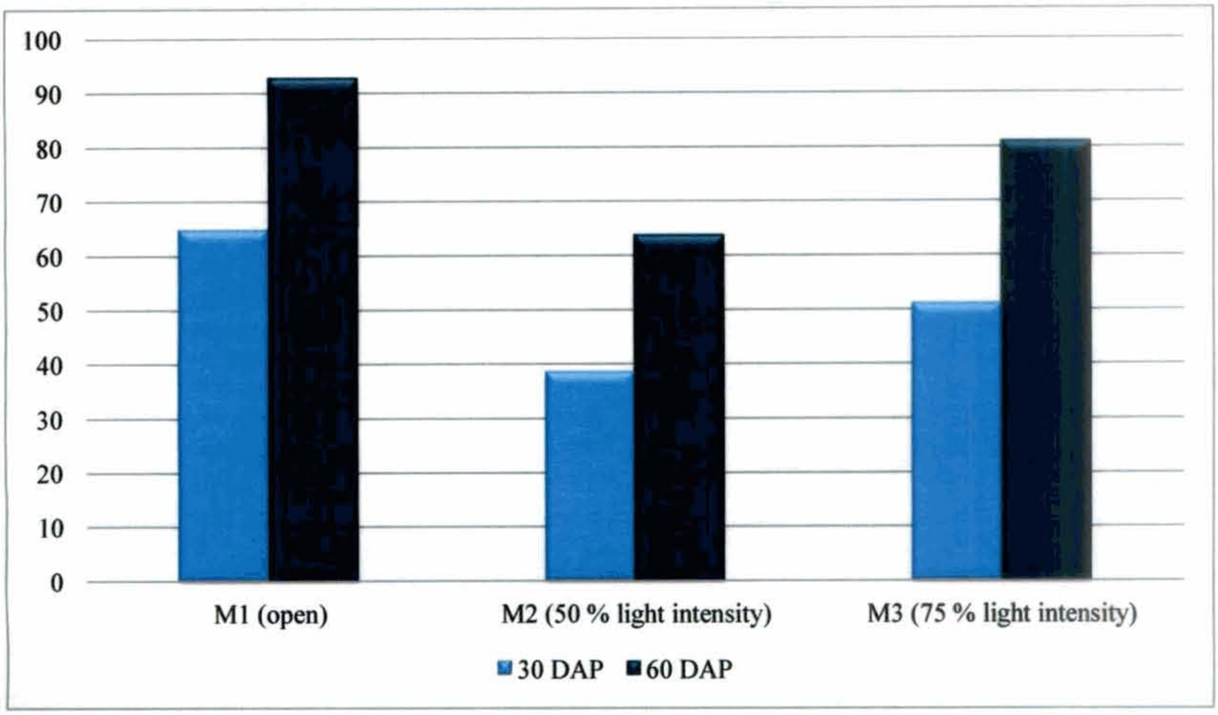

Fig 5.3. Effect of light intensity on number of leaves of Iruveli

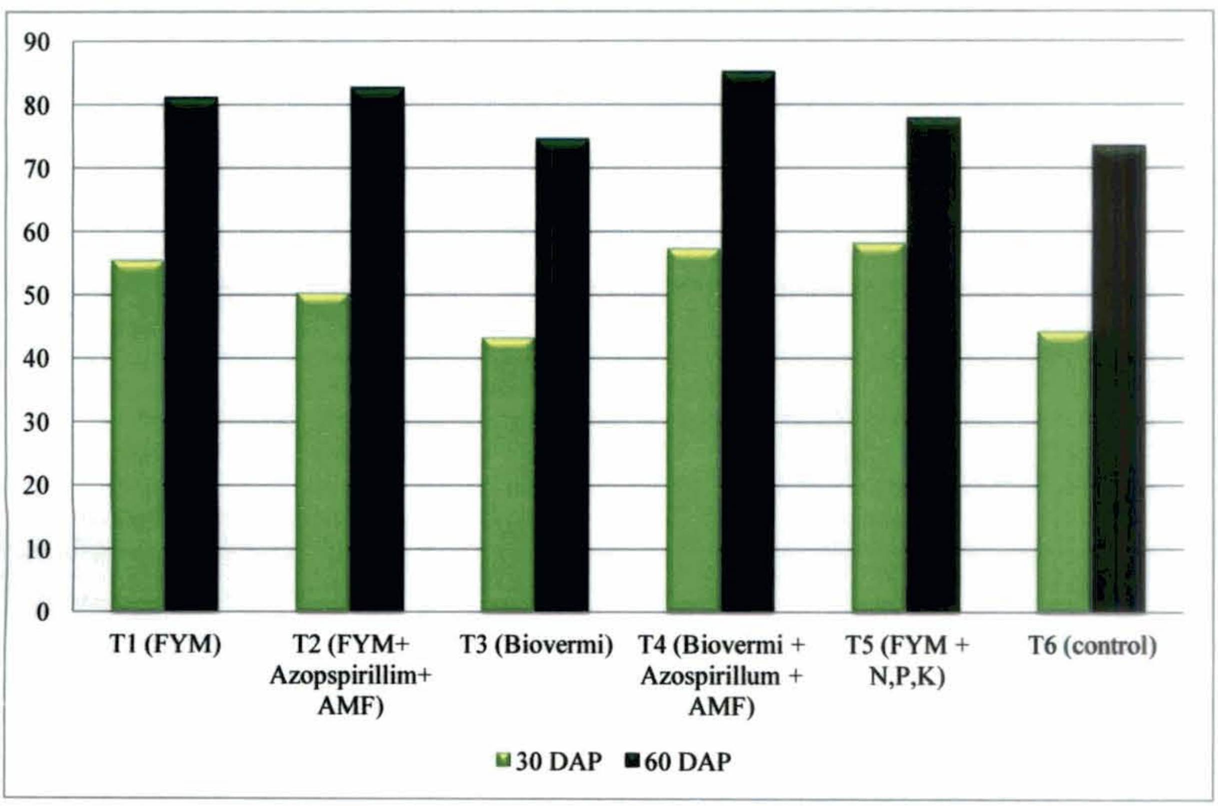

Fig 5.4. Effect of nutrient source on number of leaves of Iruveli

contrary, higher R:S ratio with increasing shade was reported in *Adathoda beddomei* by Neerakal *et al.* (2009). Under full sunlight the rate of photosynthesis will be higher due to higher quantity of sun light received and higher photosynthates produced may be proportionally allocated from sink to roots. Hence higher root: shoot ratio was obtained under higher light intensities (open and 75 % light intensity) compared to the 50 per cent light intensity.

The biomass production of Iruveli was maximum when light intensity was regulated by 25 per cent. Biomass production is the direct indicator of yield in the case of Iruveli. Under open situation, the biomass production was more compared to 50 per cent light intensity. According to Devkota and Jha (2010) light intensity affects photosynthesis which in turn is related to the accumulation of biomass and to sustain higher photosynthetic capacity, plants modify their morphology and biomass allocation at different light intensities. Thought the number of leaves was higher under open compared to 75 per cent light intensity, the leaves were smaller in size under open condition. The bigger size of leaves under 75 per cent light intensity resulted in higher biomass which was also reflected in dry matter production. The dry matter production also followed the same trend as that of biomass production in Iruveli. Similar results of increased fresh and dry herbage yield under mild shade intensity of 25 per cent was noticed in *Mentha arvensis* (Palanikumar and Jessykutty, 2007). It was reported that to utilise the available photosynthetic photon flux density efficiently, the plants maximise the production of photosynthetic tissues by redistributing the dry matter (Regnier *et al*, 1988). The herbage yield did not produce significant variation between open and 75 per cent light intensity and it was lower when the light intensity was reduced from 75 to 50 per cent. The photosyntate production may be lower under intense shade due to insufficiency of sunlight and that may be the reason for low bio mass and dry matter production under 50 per cent light intensity. The higher number of leaves and number of branches under open and 75 per cent light intensity had contributed directly to increased herbage of the plant which is the economic yield in Iruveli.

In Kerala the scope for cultivation of medicinal plants as monocrop is very much limited due to low holding size and non availability of land. But a lot of potential and scope exists for cultivation of medicinal plants as inter crop in coconut and rubber plantations. CPCRI studies showed that properly planted coconut gardens permit a multiple cropping system having combination of annual crops such as medicinal plants. The coconut tree in the

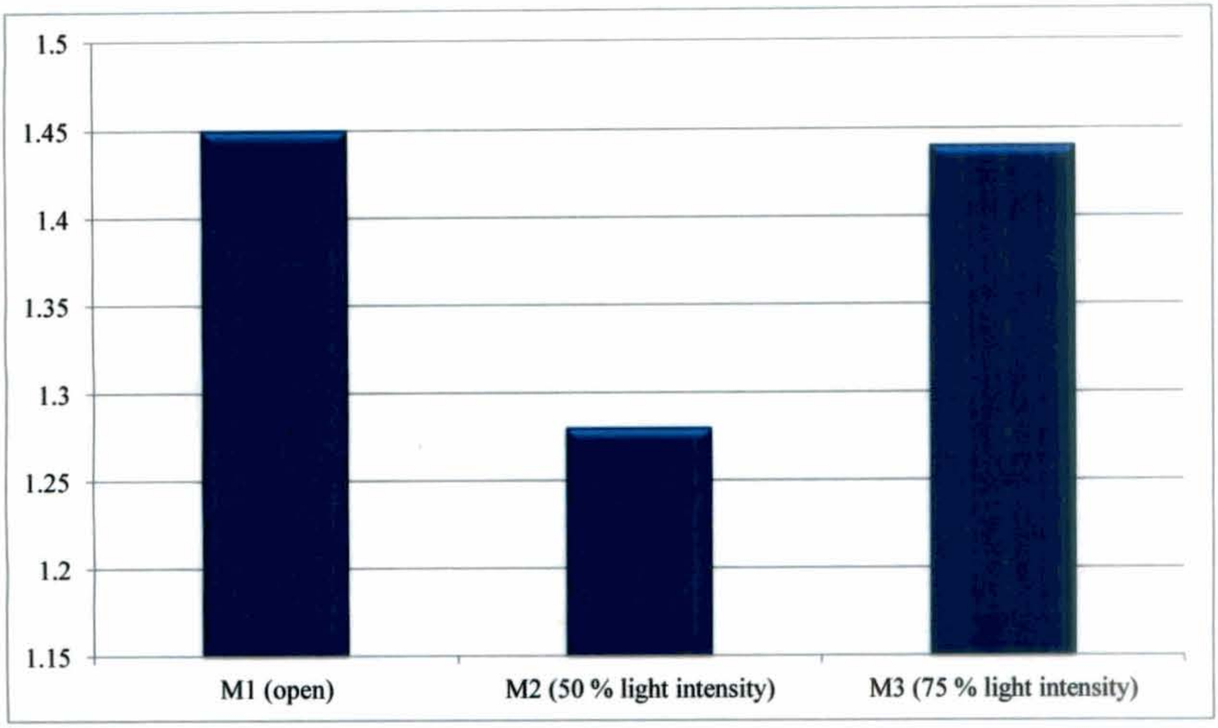

Fig 5.5. Effect of light intensity on root-shoot ratio of Iruveli

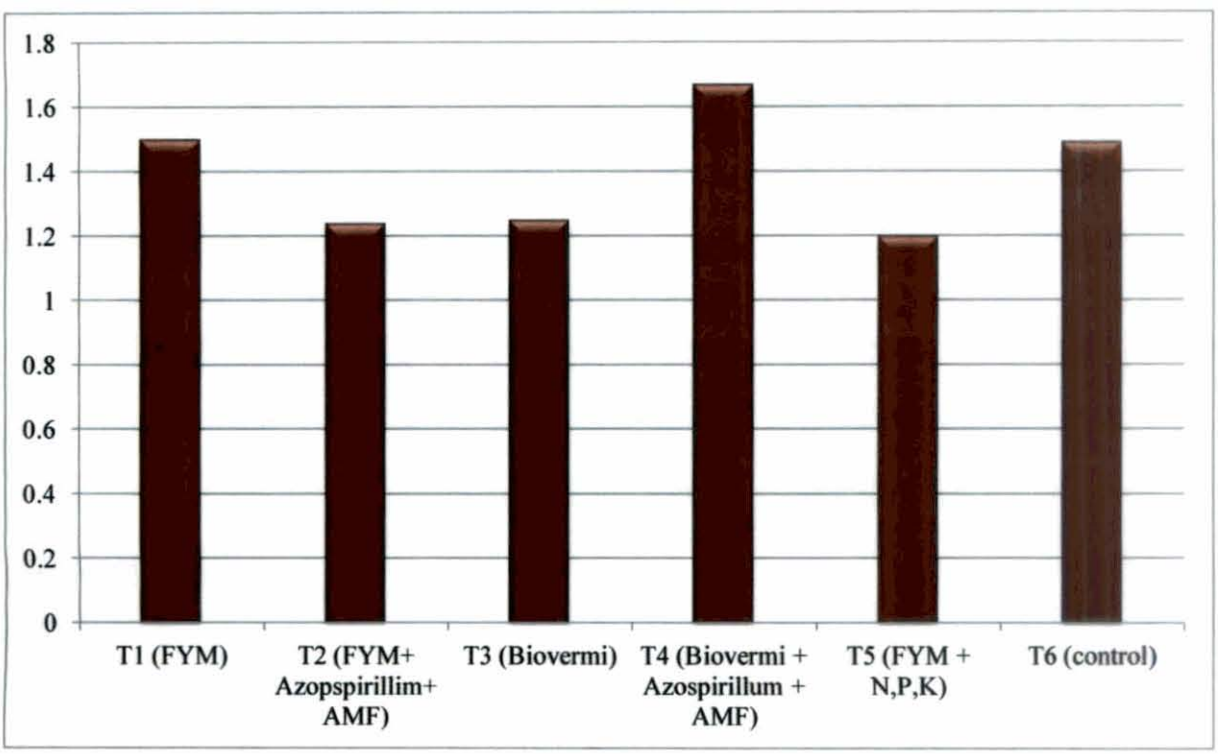

Fig 5.6. Effect of nutrient source on root-shoot ratio of Iruveli

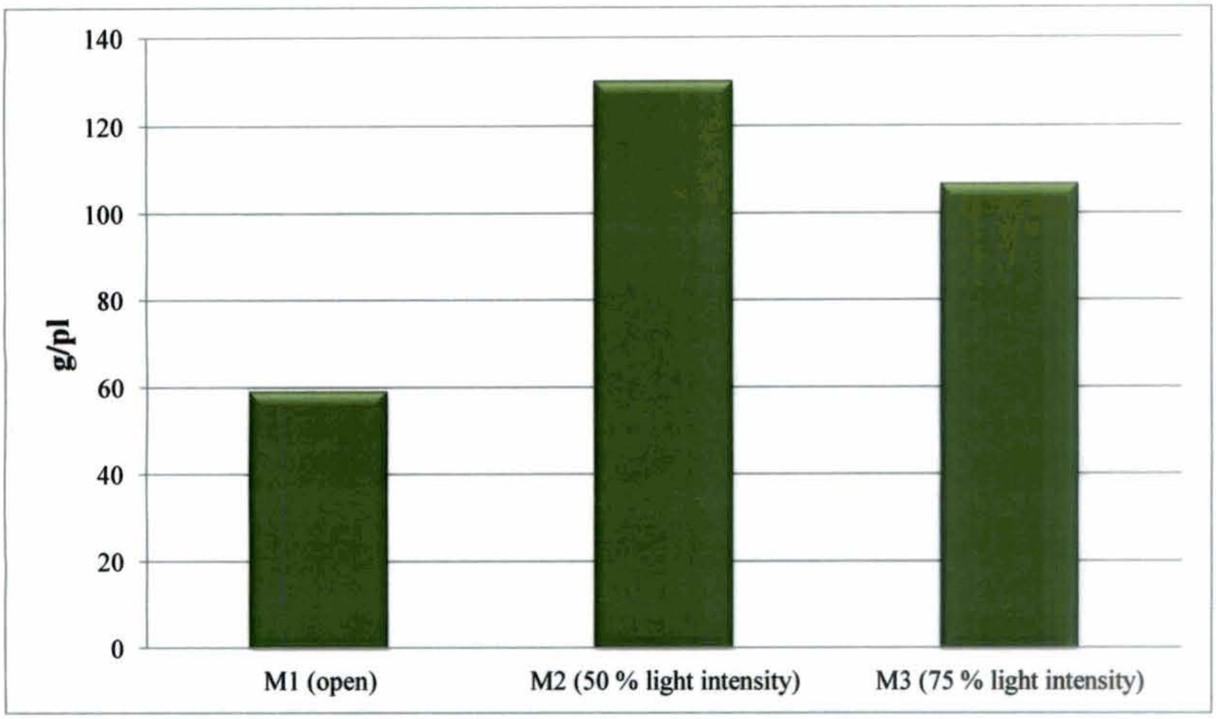

Fig 5.7. Effect of light intensity on biomass production of Iruveli

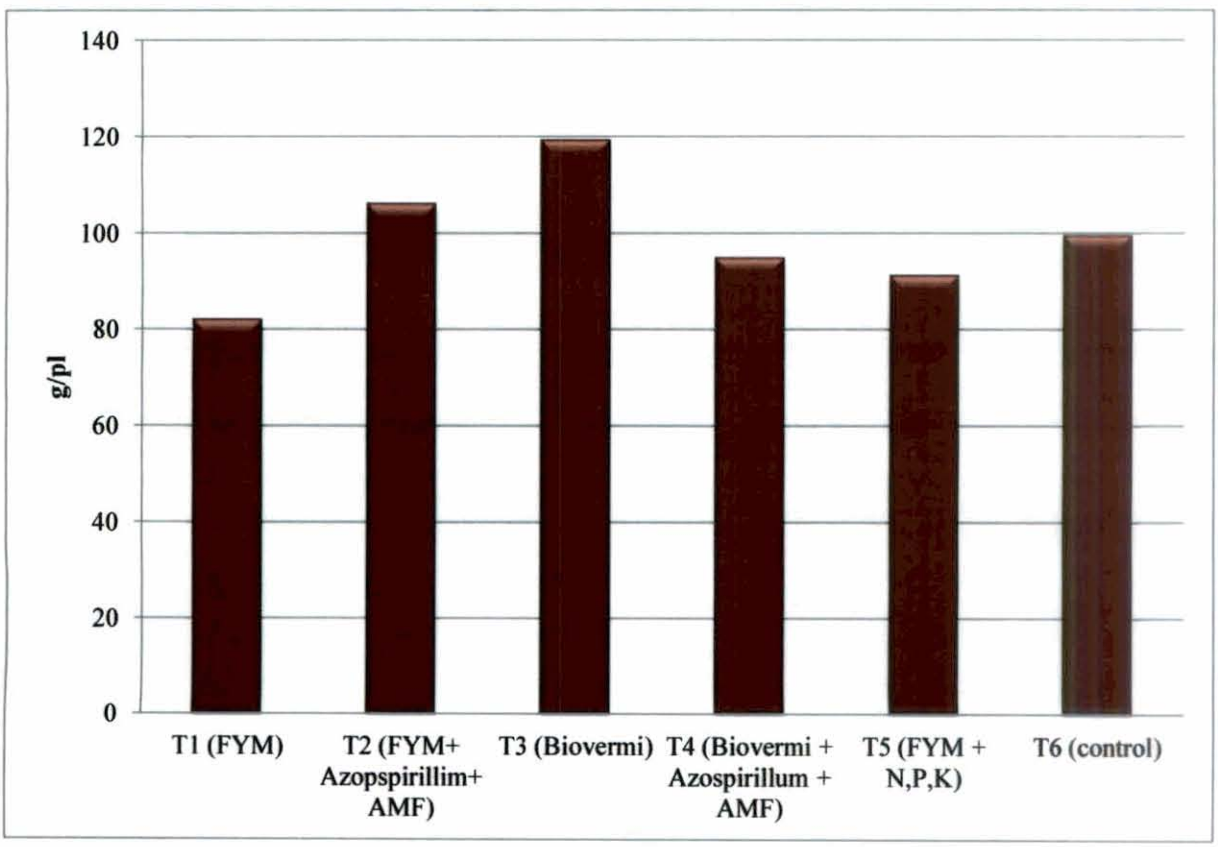

Fig 5.8. Effect of nutrient source on biomass production of Iruveli

age group of above 25 years and more provide mild shade of 25 per cent and Iruveli can be efficiently fitted as inter crop in such coconut plantations.

The inter cropping studies of medicinal and aromatic crops conducted in Kerala indicated that *P vettiveroides* is well suited to grow under partially shaded conditions of coconut (Maheshwarappa, 1997; Reddy and Biddappa, 2000 and Skaria *et al.*, 2005). The results of this study are in conformity with the findings of Maheshwarappa, 1997 and Skaria *et al.*, 2005. The increased herbage yield under mild shade of 25 per cent and no variation in essential oil content between levels of light intensity can be considered as adaptations which can be utilised efficiently under inter cropping situation.

5.2 Effect of light on essential oil content of Iruveli

The levels of light intensity had no profound influence on essential oil content of the plant. The light is known to regulate the biosynthesis of both primary and secondary metabolites (Ali *et al,* 2010). The studies showed that changes in light intensity were able to change the production of secondary metabolites in herbs (Graham, 1998). According to Briskin *et al*. (2001) and Kurata *et al.* (1997) light intensity produced changes in plant morphology and physiological characteristics and affected the medicinal component in herbs. The essential oil content of Iruveli was maximum under 100 and 75 per cent light intensities. The quantity of the medicinal plants is at the expense of quality and *vice versa*. Under 75 per cent light intensity the biomass production as well as dry matter accumulation were higher compared to other levels of light intensities. Hence the higher herbage yield resulted in higher dry matter accumulation and this will in turn result in the partitioning of higher dry matter for quality development. Thus the higher herbage yield might have resulted in increased essential oil content of Iruveli under open and 75 per cent light intensity. Higher quantity/ yield will pave way for higher quality if the conditions for secondary metabolic production are favourable. In this experiment higher biomass produced under high light intensity is utilized for the development of essential oil resulting in higher essential oil content. Maheswarappa *et al.* (2000) reported increased essential oil and oleoresin contents in kacholam and starch and crude protein yield in arrow root under coconut. Gunathilake *et al.* (2002) observed increased piperine content of pepper and essential oil content of kacholam under coconut. Channabasappa *et al.* (2007) observed increased essential oil content in citronella, lemon grass and palmarosa and alkaloid content in kalmegh under shade of trees. The higher essential oil yield was mainly due to higher herb yield of Iruveli. Due to higher herb yield and dry matter production significantly higher essential oil yield was obtained under 75 per cent light intensity.

5.3 Effect of light intensity on nutrient content of plant and soil

The nitrogen and phosphorus content of the plant had higher values under open and 75 per cent light intensity. The higher content of these nutrients might have utilised efficiently for more vegetative growth and biomass production. It is evidenced from the increased growth characters and herbage yield of Iruveli under mild shade and open situation compared to intense shade. Under higher light intensity, the photosynthetic activity will be more and hence more photosynthates will be produced as evidenced from the higher biomass and dry matter production. Higher biomass warrants higher quantity of nutrients for growth which were absorbed by the plant under higher light intensity. This is also evident by higher nutrient content and uptake by the plants (N, P and K). The increased N uptake under open and 75 per cent light intensity clearly indicated the efficient utilisation of absorbed N for maximum vegetative growth and herbage yield. The P and K uptake were also higher under increased levels of light intensity. Under increased light intensity the metabolic activity of the plant will be higher and this may result in increased absorption of nutrients from the soil and higher uptake was noticed due to the absorption. The higher essential oil yield was mainly due to higher herb yield of holy basil. These results are in line with the reports of Singh and Ramesh (2002) and Anwar *et al.* (2005) in sweet basil (*Oscimum basilicum*). The available nutrient contents of the soil revealed that the nutrients available for absorption by the plant was significantly higher under 75 per cent light intensity followed by open condition. The availability of nutrients in the soil in significant quantities might have resulted in higher absorption and utilisation by the plant as reflected by the higher uptake by the plant under higher light intensity.

5.4 Effect of source of nutrients on the growth and yield of Iruveli

The effect of different sources of nutrients on morphological characters and herbage yield are discussed in this chapter. Five levels of organic sources in combination with bio fertilizers and one level of integrated nutrient management of FYM with inorganic fertilizers

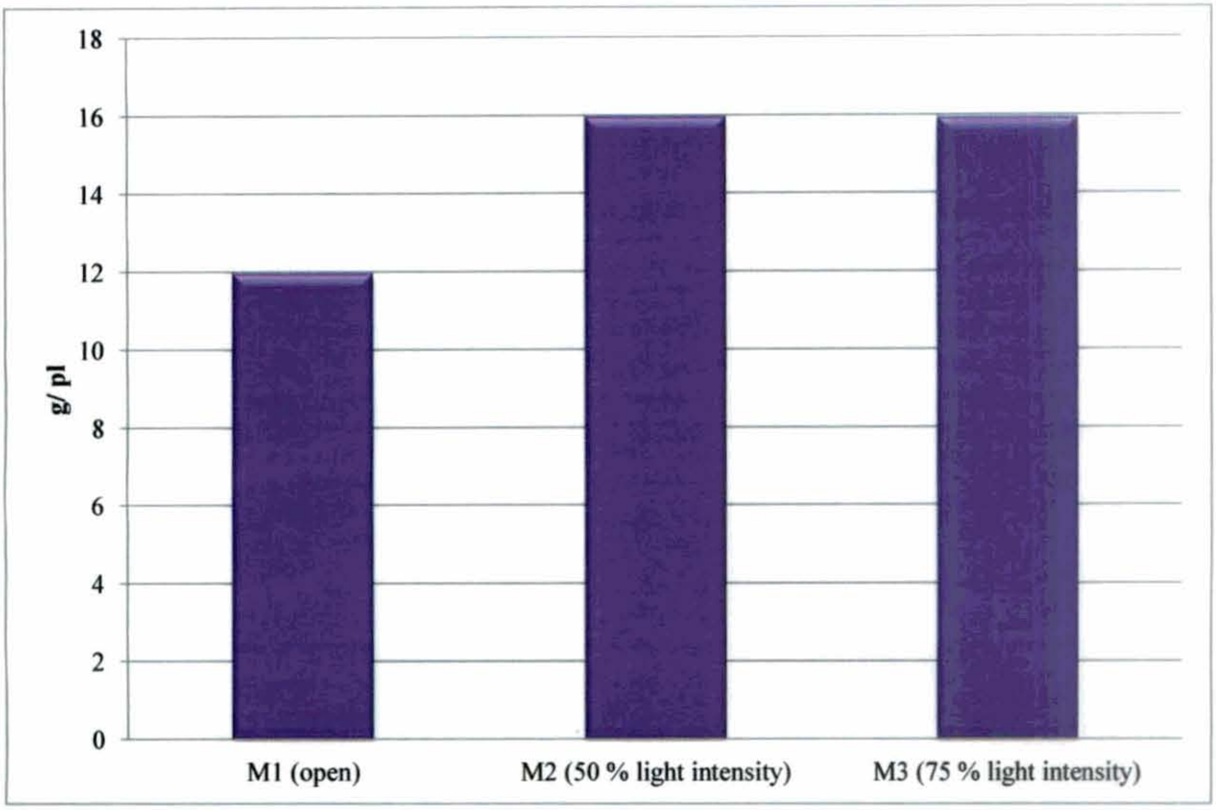

Fig 5.9. Effect of light intensity on dry matter production of Iruveli

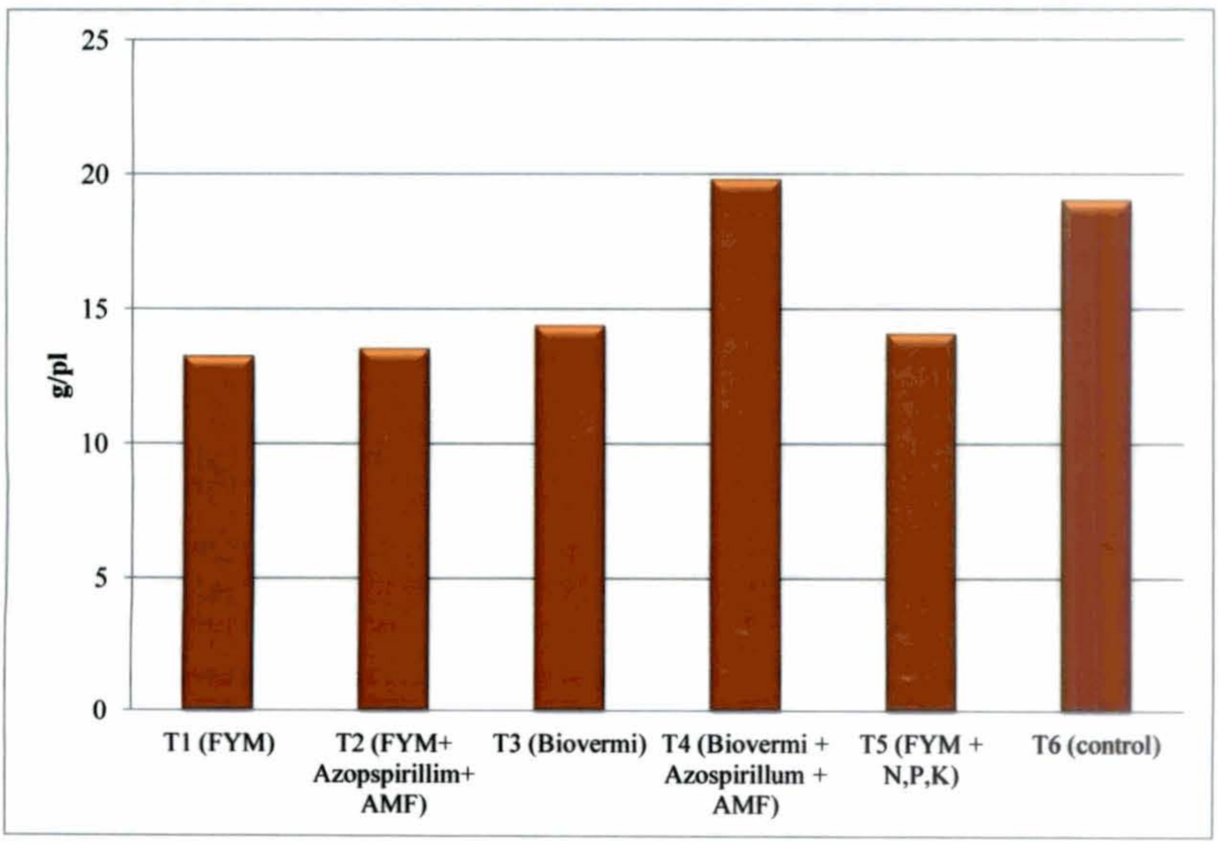

Fig 5.10: Effect of nutrient source on Dry matter production of Iruveli

were used for the study. In general, the medicinal plants responded well to organic source of nutrients compared to inorganics in terms of yield and quality. Though yield was found to be better under inorganics, the yield and quality were found to be better under organics (Menon, 1996).

In this study the variation in the source of nutrients significantly influenced the growth of Iruveli. The plants were taller with higher number of leaves and branches in the treatment applied with FYM and inorganic fertilizers in the initial stage *ie* 30 days after planting. The availability of nutrients in the readily available form from inorganic fertilizers have resulted in higher absorption of nutrients and increased growth initially. Gradually, the growth was found to be better in the plots applied with organics and biofertilizers. The height, number of leaves and number of branches were higher with plants treated with organics either FYM or Biovermi with biofertilizers at 60 DAP. The highest number of leaves as well as number of branches were noticed when Biovermi was applied in combination with Azospirillum and AMF. This result is in conformity with the findings of Latha *et al.* 2009. Biovermi is a product of vermicompost enriched with *Pseudomonas* and *Trichoderma.* In addition to the effect of nutrient availability and supply, the enrichment with *Pseudomonas* and *Trichoderma* influenced the growth through pest and disease resistance and hormonal vigour.

The higher root: shoot ratio was noticed with plants applied with Biovermi and biofertilizers followed by FYM alone. Application of organic manures might have increased the porosity and aeration of soil resulting in higher root weight. In addition, the effects of biofertilizers have envisaged better root and overall growth of plant. Azospirillum in addition to fixing atmospheric nitrogen is also known to produce growth promoting substances like IAA, GA and kinetin (Okon and Labandera, 1994). This will enhance the mineral and water uptake and dry matter accumulation (Sarig *et al.*, 1988). AMF in association with plant roots has been shown to associate with an increase in cytokinin and chlorophyll content in plants (Allen *et al.*, 1980). The treatment involving Biovermi, Azospirillum and AMF (T_4) was found to have the higher biomass as well as dry matter production. The higher dry matter accumulation can be attributed to taller plants, more number of branches and leaves and higher R:S ratio. The synergistic effect as a result of two microbial cultures contributed to higher availability and uptake of nutrients. The combined application of organics with biofertilizers have provided increased and steady availability and utilization of nutrients throughout the growing phase which may result in enhanced carbohydrate synthesis and effective translocation of photosynthates to the sink. This is evident from higher herbage

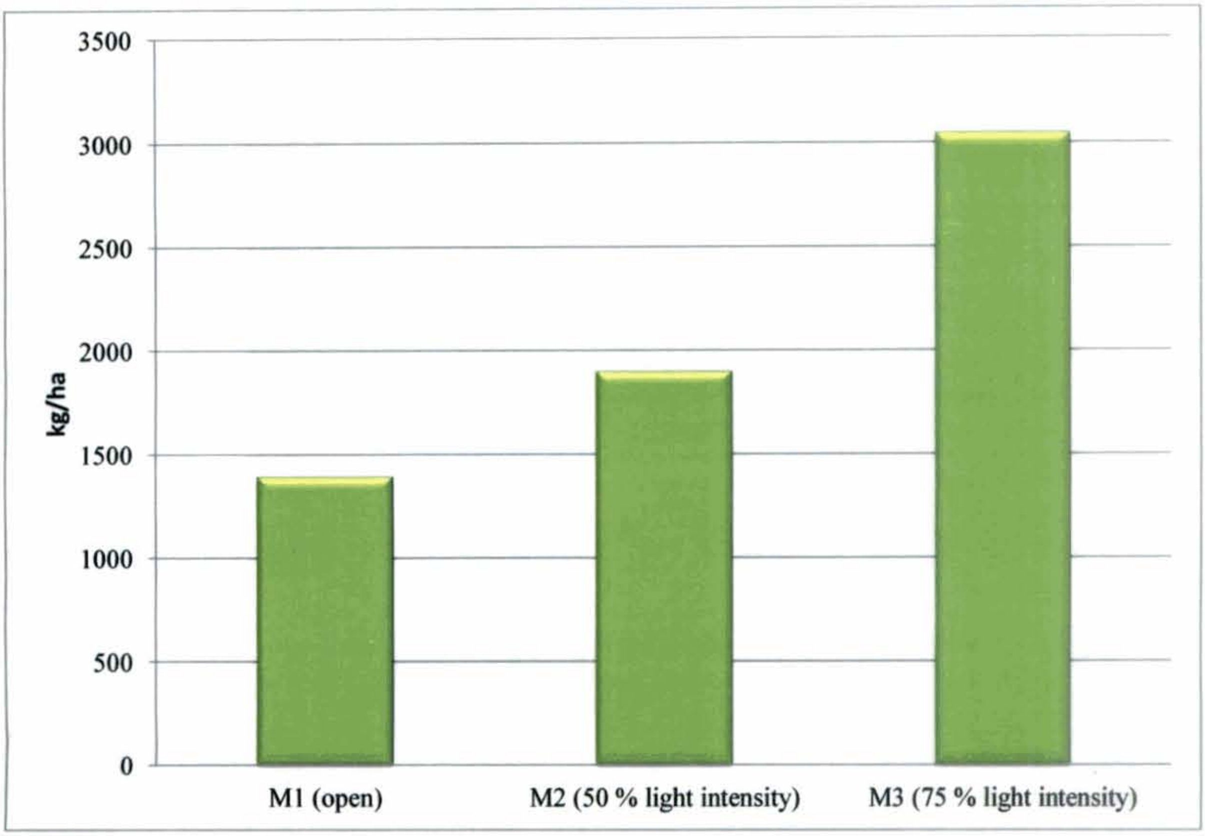

Fig 5.11. Effect of light intensity on yield of Iruveli

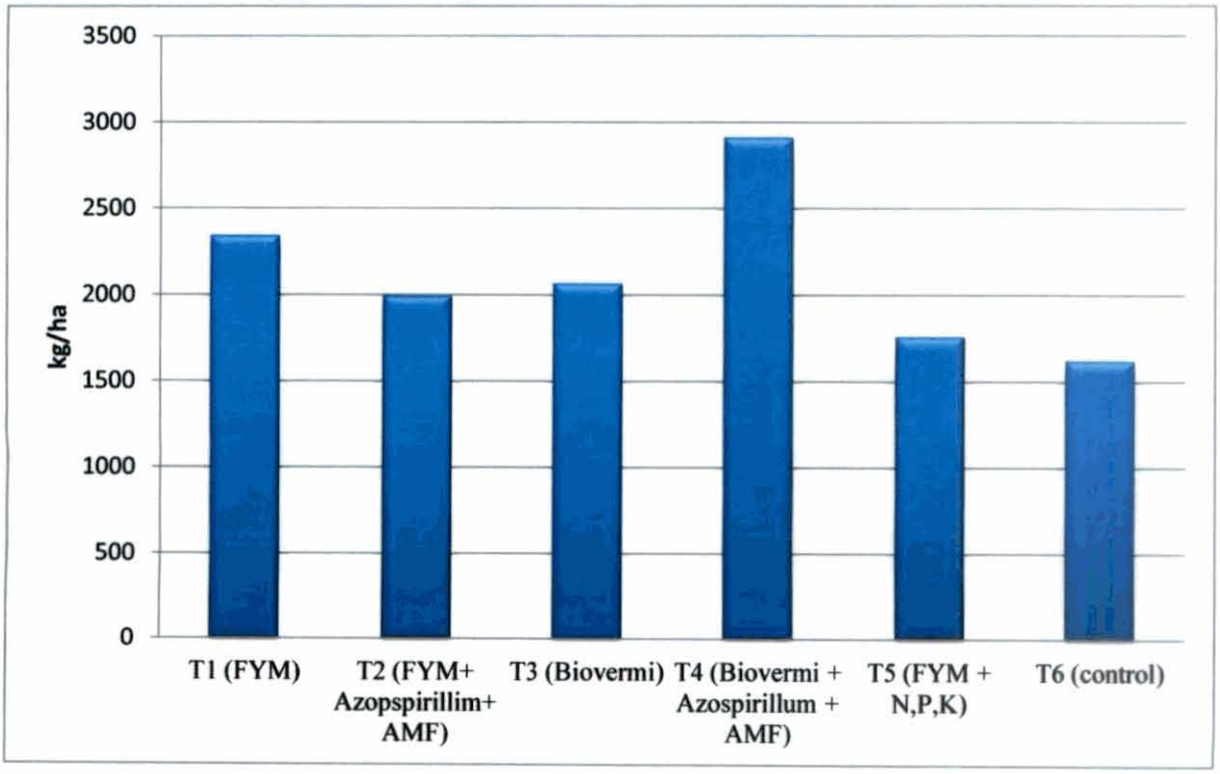

Fig 5.12. Effect of nutrient source on yield of Iruveli

yield in the treatment of Biovermi + Azospirillum + AMF. Higher herbage yield in this treatment can be attributed to better growth and dry matter accumulation in the crop due to improved nutrient supply and efficiency. Due to consistent and steady supply of nutrients to plants under the treatment with Biovermi +Azospirillum +AMF, the nutrient base and population of Azospirillum and AMF have increased which converted complex nutrients into simple and easily available form. This facilitates quick and easy absorption of nutrients by plants through efficient root system evidenced by higher R: S ratio in the plants. The plants registered lower yield in the treatment where no nutrients were applied due to low fertility status of the soil. The increased yield in medicinal plants due to the combined application of organics with biofertilzers was reported by several workers. (Latha *et al*, 2009; Gajbhiye and Deshmukh, 2010; Shivana *et al*, 2010).

5.5 Effect of nutrient source on quality

Nutritional environment regulates the biosynthesis of secondary metabolites. The nutritional condition for biomass yield and quality are different in medicinal plants. The quality of Iruveli was measured in terms of essential oil content. The essential oil content was maximum in plants provided with Biovermi alone while the herbage yield was lower in these plants. In medicinal plants the biomass yield and quality are inversely related and morphological growth expression is at the expense of quality (Menon, 1994). The synthesised photosynthates and dry matter accumulated in the plants treated with Biovermi alone might have utilised for the biosynthesis of essential oil and that may be the reason for yield reduction compared to the treatment Biovermi +Azospirillum +AMF in which the herbage yield was maximum. With respect to oil yield, which is a product of essential oil content and dry matter content, the plants having the treatment of Biovermi+ Azospirillum + AMF recorded the highest. According to Menon (1996) the yield of Njavara was linked to macronutrients and quality to micronutrients. So the balanced supply of macro and micro nutrients is found to be essential for higher yield and quality. The slow and steady availability of both macro and micronutrients in balanced proportion may be the reason for higher yield and quality in plants treated with organics and biofertilizers. These results are similar to that of Singh and Ramesh (2002), Ajimoddin *et al.* (2005) and Anwar *et al.* (2005).

An equilibrium between yield and quality is needed in medicinal plants for optimum yield with quality. The data on essential oil yield with respect to source of nutrients revealed

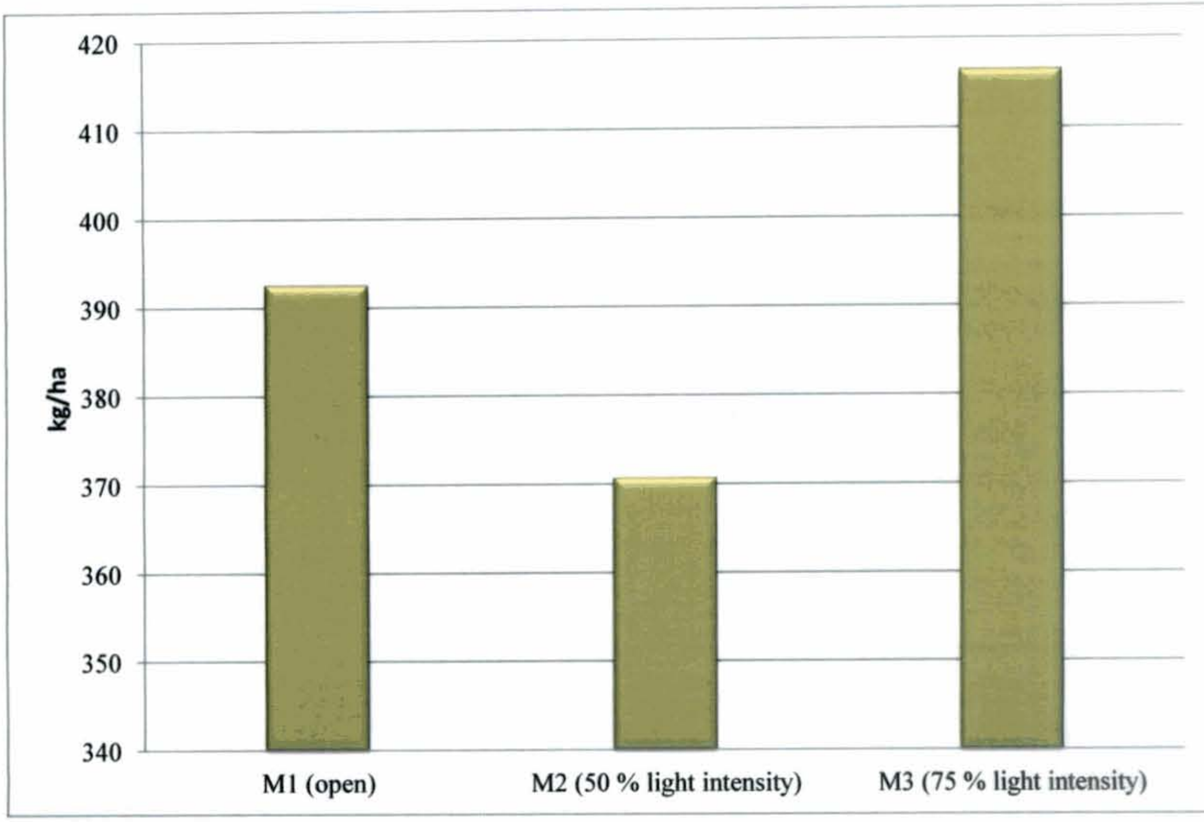

Fig 5.13. Effect of light intensity on nitrogen uptake of Iruveli

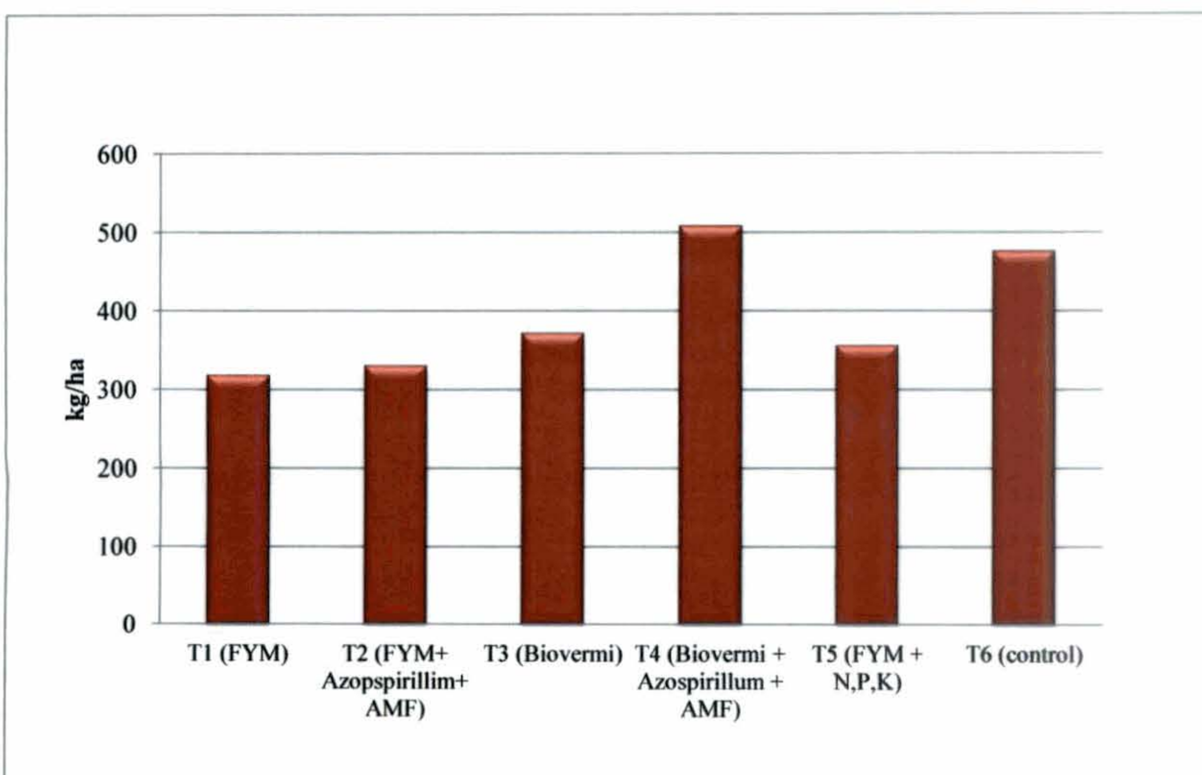

Fig 5.14. Effect of nutrient source on nitrogen uptake of Iruveli

that the combined application of Biovermi, Azospirillum and AMF was a better choice for higher yield and essential oil content. The integrated effect of organics and biofertilizers had improved the nutritional environment for higher availability and absorption of macro and micro nutrients which might have resulted in higher herbage yield and relatively higher essential oil content at the expense of herbage yield. The essential oil content was lower in the treatment of inorganics and control. In these treatments the plants might have failed to synthesise the metabolites effectively and also to utilise the metabolites for the biosynthesis of secondary metabolite production.

5.6 Effect of source of nutrients on the nutrient uptake by plants

AMF is known to improve the uptake of macro and micro nutrients, after plant growth and facilitate synergistic interactions with beneficial rhizosphere microorganisms. The plants applied with Biovermi, Azospirillum and AMF recorded the highest N, P and K uptake. The increased availability, absorption and utilisation of nutrients by the plants were confirmed by the higher herbage yield and nutrient uptake by plants in this treatment. Increased soil fertility and availability of nutrients has promoted better root growth and development enabling plants to absorb more nutrients. The improvement in growth crop has increased nutrient uptake. The contribution of N to nutrient pool by fixing atmospheric nitrogen by Azospirillum and the principal way by which AMF benefits plant growth through the uptake of P by plant roots have been very well established (Bolan, 1991). The higher uptake of K from the soil would be due to the beneficial effect of Biovermi on the release of K from the non exchangable fractions to the available pool (Dosani *et al.*, 1999). Thus, the increased uptake of N, P and K from soil resulted in the increased herbage yield in plants treated with Biovermi+ Azospirillum+AMF.

Menon (1994) reported that the stable pathway of yield formation under organic resources is due to the balanced nutrition. Organic sources had also registered higher nutrient use efficiency over fertilizers (Menon, 1994) and they contain all nutrients in balanced proportion. Fertilizer materials being limited elemental sources, they are capable of making up the deficiency of specific nutrients. The lower yield in plants treated with FYM and inorganics may be due to the availability of specific nutrients alone. Due to the combination of organics with biofertilizers the plants treated with Biovermi + Azospirillum + AMF availed balanced supply of nutrients from soil pool with increased uptake of nutrients. The balanced

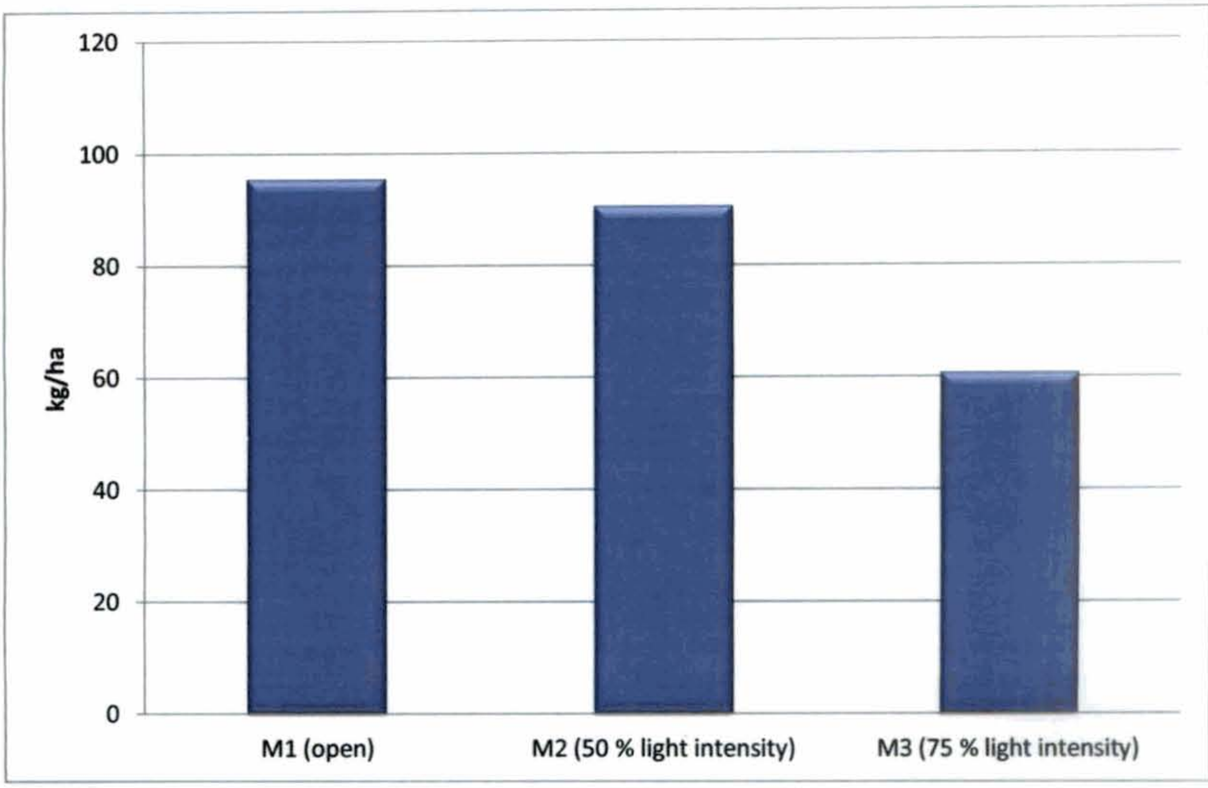

Fig 5.15. Effect of light intensity on phosphorus uptake of Iruveli

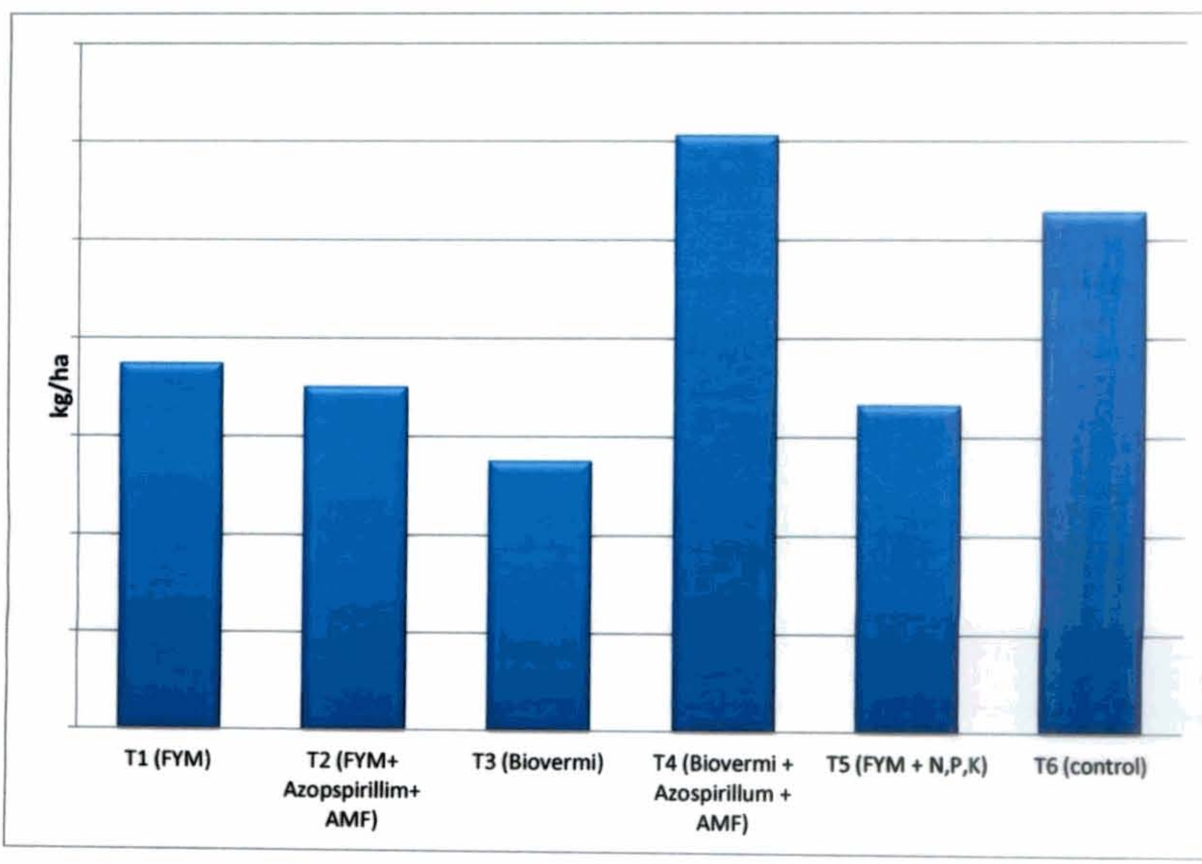

Fig 5.16. Effect of nutrient source on phosphorus uptake of Iruveli

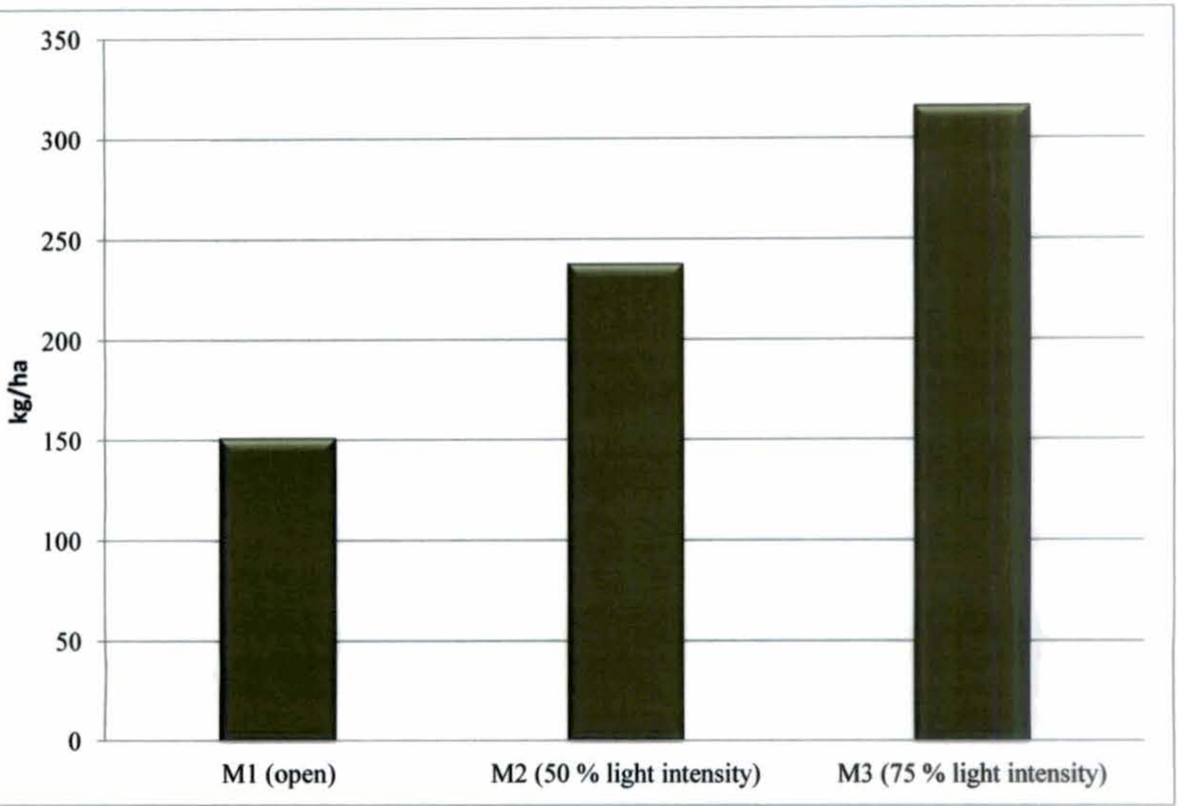

Fig 5.17. Effect of light intensity on Potassium uptake of Iruveli

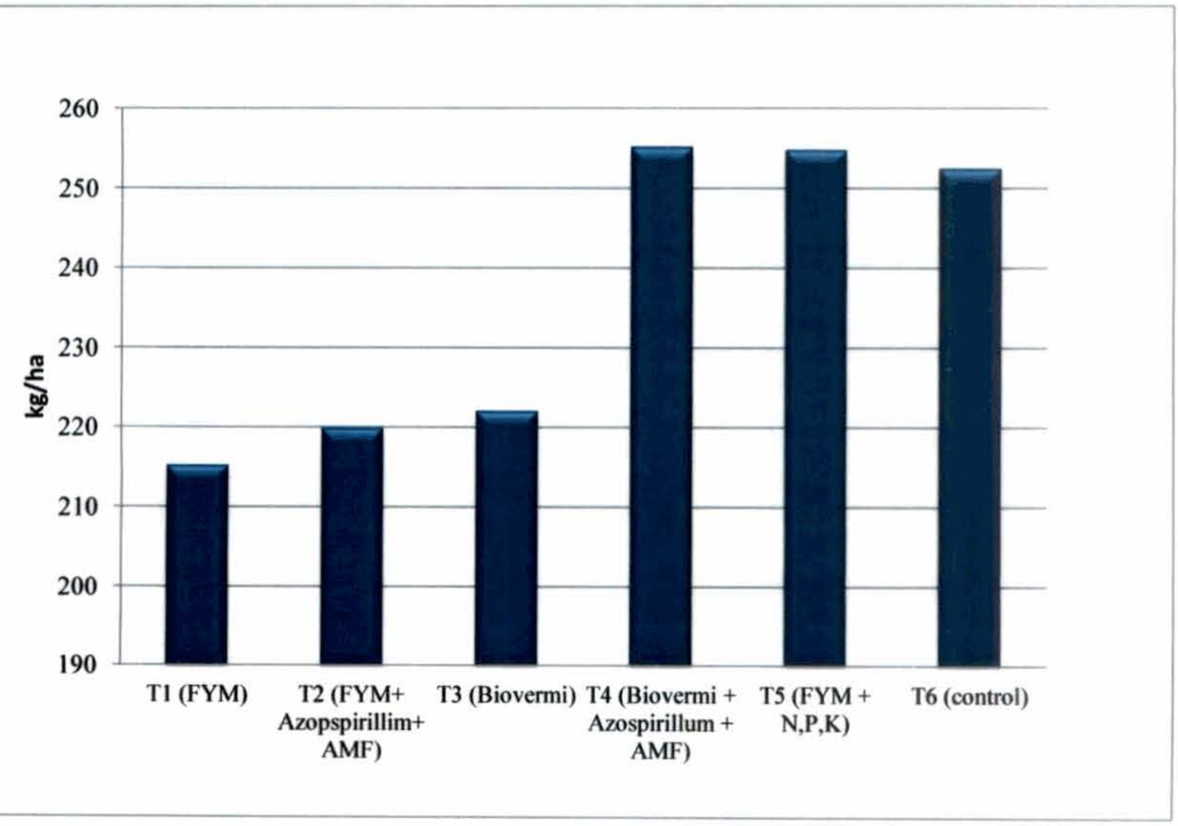

Fig 5.18. Effect of nutrient source on potassium uptake of Iruveli

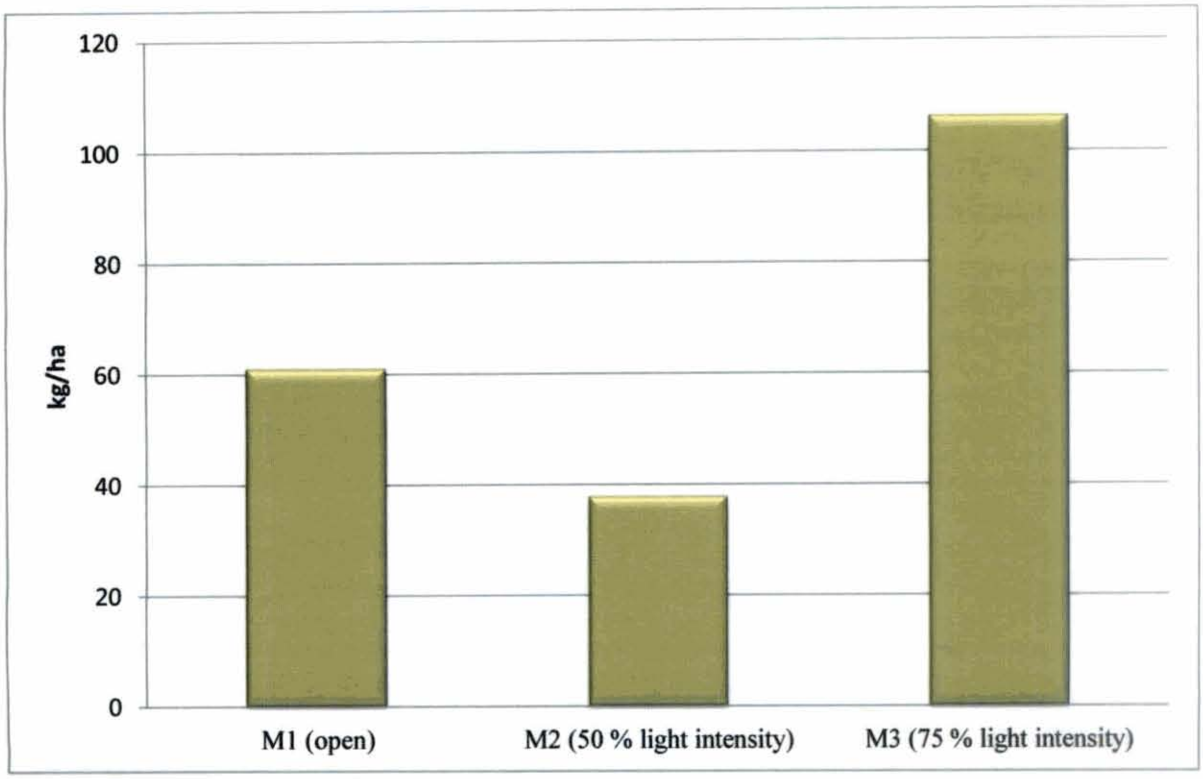

Fig 5.19. Effect of light intensity on oil yield of Iruveli

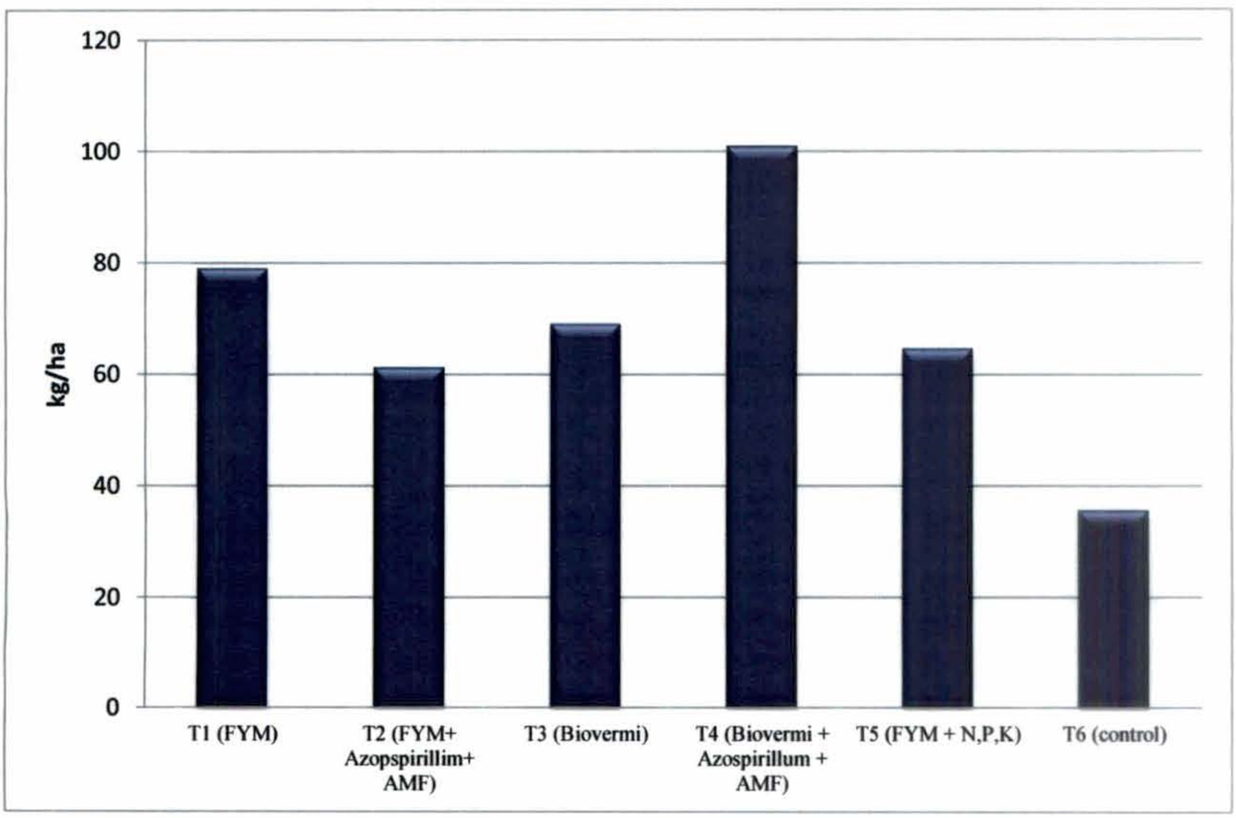

Fig 5.20. Effect of nutrient source on oil yield of Iruveli

and steady uptake of nutrients in this treatment resulted in higher herbage and oil yield. Higher uptake is also found to be related to higher concentration of nutrients in the crop and also higher biomass production by the crop.

5.7 Effect of nutrient source on soil nutrient content

The organic carbon content of the soil was the highest in the plants that received Biovermi alone which was on par with the plants that had treated with Biovermi + Azospirillum + AMF. The application of organic manure had added organic matter to the soil which is evidenced by increased organic carbon content of soil. This increased organic matter also helped to provide a favourable environment for the availability of the nutrients and which in turn resulted in the increased absorption of nutrients by the plants. The P and K content were also relatively high in plants with combination of Biovermi +Azospirillum+ AMF. The relatively high fertility status of soil in this treatment may also be due to the activity of two bio fertilizer agents in association with Biovermi. The application of Biovermi with biofertilizers contributed increased fertility of soil even after crop growth phase. The presence of the above minerals in the soil even after the harvest of the crop helps to maintain the soil fertility of the soil. This suggested that the combination of Biovermi+ Azospirillum+ AMF also found to be beneficial for the succeeding crop also. In a cropping system situation, the companion crops are also benefitted by the increased fertility of the soil due to the application of organics and bio fertilizers. As Iruveli is suitable for intercropped situation, the intercrops will also be benefited by high nutrient status of soil as increased nutrient status was noticed in the soil even after harvest of the crop due to the combined application of organics and biofertilizers.

The increased herbage yield and essential oil yield obtained when plants grown under 75 per cent light intensity using shade nets revealed that Iruveli is a shade tolerant plant and optimum light intensity is 75 per cent. This result is an indication that the crop can be effectively grown under coconut garden in the age group of above 25 years. In Kerala there is high potential for inter cropping due to limited scope of mono cropping. Iruveli can be fitted very well in such inter cropping situation. The increased demand of Iruveli in ayurvedic preparations warrants its cultivation and can be cultivated in large scale as inter crops in perennial crops having light intensity of 75 per cent.

Medicinal plants responded very well to organics. The results of this experiment also revealed that combined application of Biovermi with Azospirillum and AMF produced highest herbage yield and quality. Balanced and slow availability of macro and micro nutrients might have been the reason for higher herbage yield and a balance is also maintained between quality and quantity in this treatment due to which the herbage yield is effectively utilised for secondary metabolite production *ie,* essential oil. Hence higher herbage yield and essential oil was noticed with combined application of Biovermi with Azospirilllum and AMF. The hormonal vigour of Biovermi, Azospirillum and AMF had also favourably influenced the herbage yield and secondary metabolite production.

From the results of this experiment it is evident that 75 per cent light intensity and combined application of Biovermi, Azospirillum and AMF was found to be the best for higher herbage yield and essential oil content in Iruveli.

Summary

6. SUMMARY

A field experiment was conducted during 2011-2012 at College of Horticulture, Vellanikkara to study the effect of light intensity and nutrient source on the yield and quality of Iruveli (*Plectranthus vettiveroides*). The objective of the experiment was to study the effect of light intensity and nutrient source on the yield and quality of *Plectranthus vettiveroides* and to standardize the nutrient source and optimum light intensity requirement of Iruveli for maximum yield and quality performance.

The experiment was laid out in split plot in randomized block design with three replications. Different levels of light intensity were allotted to main plots and nutrient sources to sub plots. Variations in the light intensity were provided using shade nets of different shade levels, *viz* 0, 25 and 50 per cent. The sub plot treatment comprised of organics, biofertilizers and integrated nutrient management with nutrient sources *viz* Farm yard manure (FYM), Biovermi (an enriched product of Vermicompost with *Trichoderma viridae* and *Pseudomonas flourescence*), Azospirillum, AMF and inorganic fertilizers *viz* urea, rock phosphate and muriate of potash for N, P and K respectively. Top shoot cuttings were planted with a spacing of 30 X 30 cm and the crop duration was six months.

Biometric observations, plant nutrient status, soil nutrient status and quality analysis were studied during the experiment. Five plants from each plot were randomly selected, tagged and the biometric observations were recorded at 30 and 60 days after planting and at harvest. Plant height, number of leaves and branches of these plants were recorded at 30 and 60 DAP while the root: shoot ratio, biomass and dry matter production were studied at the time of harvest. Herbage yield was estimated on per plot basis after harvesting the entire crop from each plot and the yield per ha was estimated.

To estimate the nutrient status of the crop, the tagged plants were uprooted, dried powdered and subjected to chemical analysis. Nitrogen, phosphorus and potassium content were estimated from these samples. Nutrient uptake was calculated from data on the nutrient content and dry matter production. Soil samples were collected and analysed before and after the experiment to study the nutrient status of the soil. Using the hydro distillation technique with Clevenger apparatus the quality content of the crop was determined. Analyses of variance were performed on all data collected using the statistical package, 'MSTAT'

Biometric observations

Light intensity had profound influence on the biometric characteristics of the crop. 75 per cent light intensity level had the tallest plants (30.35cm) at 30 and 60 days (32.13cm) after planting. Regarding the number of leaves, open condition (M_1) was found to be better followed by M_3 (75 per cent light intensity) at 30 and 60 days after planting. Light intensity variation influenced the root: shoot ratio also. Open condition (M_1) proved to be the best for maximum (1.45) root: shoot ratio in the field and was on par with 75 per cent light intensity (M_3), while the least root: shoot ratio of 1.28 was given by 50 per cent light intensity (M_2). 75 per cent light intensity (M_3) recorded the maximum biomass production (110.69 g plant^{-1}) of the experimental plants and the lowest biomass production of 59.10 g plant^{-1} was recorded under open condition (M_1). Dry matter production was highest (15.97 g plant^{-1}) when grown under 75 per cent light intensity (M_3) and was on par with 50 per cent light intensity (M_2) compared to open (M_1). Lowest dry matter production (11.96g plant $^{-1}$) was noticed in plants grown under open condition (M_1).

Significant difference was noticed in height of plants due to variation in the source of nutrients. Taller plants (28.51 cm) were observed when (T_1) Farmyard manure (FYM) alone was applied at 30 days after planting (DAP). Maximum plant height (30.64 cm) at 60 days after planting was found when it was applied with FYM +Azospirllum +AMF (T_2) and was on par (30.55 cm) with the treatment of FYM alone. The plants were shorter (23.08 cm) at 30 and 60 days after planting (27.64 cm) when the nutrients were not applied (T_6). Combined application of Biovermi, Azospirillum and AMF was found to be better for higher leaf production (85.01) at 60 DAP. Regarding the root : shoot ratio, application of Biovermi+ Azospirillum+ AMF (T_4) showed a maximum of 1.67 and was on par (1.50) with FYM alone (T_1). Lowest root: shoot ratio (1.20) was observed in the plot which was treated with a combination of FYM and inorganic fertilizers at the rate of 30:15:30 kg NPK/ha (T_5). Maximum biomass (119.15 g plant^{-1}) was produced by the plants when applied with Biovermi+Azospirillum+AMF (T_4) and the application of FYM (T_1) alone showed the least biomass production (81.89 g plant^{-1}). Maximum dry matter (19.78 g plant^{-1}) was produced by the plants applied with Biovermi+Azospirillum+AMF (T_4) and the application of FYM (T_1) alone could render the least dry matter (13.22 g plant^{-1}).

Nutrient analysis

Chemical analysis data revealed that higher nitrogen content of 2.78 per cent was noticed under 75 per cent light intensity level (M_3) and open condition (M_1). 50 per cent light intensity (M_2) recorded the lowest nitrogen content of 2.46 per cent. Open condition resulted in maximum phosphorus content (0.64%) while 75 per cent light intensity (M_3) showed the lowest value. Maximum potassium content (2.09%) was observed in plants grown under 75 per cent light intensity (M_3).

Maximum nitrogen uptake (416.45 kg ha $^{-1}$) was shown by the plants maintained under 75 per cent light intensity level (M_3) and was on par with open condition (M_1) and the least nitrogen uptake of 370.71 kg ha $^{-1}$was showed by the plants grown under 50 per cent light intensity (M_2). Under open condition phosphorus uptake was maximum (95.27 kg ha $^{-1}$). Lowest phosphorus uptake of 60.54 kg ha $^{-1}$was recorded by the plants grown under 75 percent light intensity level (M_3). Among the different light intensity levels, 75 percent light intensity (M_3) recorded maximum potassium uptake of 315.90 kg ha $^{-1}$. Open condition (M_1) had the lowest potassium uptake of 151.06 kg ha $^{-1}$.

Among various nutrient sources tried, application of Biovermi alone (T_3) yielded maximum nitrogen content of 2.74 per cent and the lowest nitrogen content of 2.59 per cent was observed when treated with FYM (T_1) alone. Different sources of nutrients had shown significant variation in the phosphorus content and the plant applied with no organics (T_6) recorded the maximum content of phosphorus in the plant (0.59) and the lowest phosphorus content of 0.46 per cent was noticed in plants applied with Biovermi alone. With respect to potassium content in plants, the highest content was given by plants applied with a combination of FYM and inorganic fertilizers @ 30:15:30 kg ha^{-1} (T_5). Highest potassium content of 1.76 per cent was in T_5 and on par with application of FYM (T_1) alone (1.71%). Combined application of Biovermi, Azospirillum and AMF (T_4) recorded the lowest potassium content (1.44%) in plants.

The highest nitrogen, phosphorus and potassium uptake of 507.95 kg ha $^{-1}$, 121.00 kg ha $^{-1}$ and 255.05 kg ha $^{-1}$ respectively were noticed in the plants applied with combination of Biovermi+ Azospirillum +AMF (T_4). Experimental plots when treated with FYM (T_1) alone showed the lowest nitrogen (318.26 kg ha $^{-1}$) and potassium uptake (215.22 kg ha^{-1}) while lowest phosphorus uptake of 54.80 kg ha $^{-1}$ was noticed with application of biovermi (T_3) alone

Soil analysis

Soil sample analysis was conducted before and after the experiment. Maximum amount of available nitrogen (195.37 kg ha^{-1}) was recorded under 75 percent light intensity level (M_3) and the lowest (174.49 kg ha^{-1}) were found in 50 per cent light intensity level (M_2). At 75 percent light intensity highest amount of available phosphorus (28.15 kg ha^{-1}) was found while the open condition (M_1) showed the least amount (22.57 kg ha^{-1}). Plots maintained under 75 per cent light intensity level (M_3) gave the highest available potassium (224.86 kg ha^{-1}) and the lowest available potassium content (166.60 kg ha^{-1}) was under open condition (M_1). Open condition (M_1) showed maximum organic carbon content (1.77 %) in the soil samples while the experimental plots maintained under 75 percent light intensity level (M_3) provided the least (1.71 %).

Significant difference was also noticed in the amount of available nitrogen, available phosphorus, available potassium and organic carbon content with variation in the source of nutrients. Application of FYM (T_1) alone gave the maximum available nitrogen content (250.43 kg ha^{-1}) and the least (145.82 kg ha^{-1}) from the control plots (T_6). Combined application of Biovermi, Azospirillum and AMF (T_4) noticed the highest amount of available phosphorus (30.06 kg ha^{-1}) and the lowest (23.44 kg ha^{-1}) was with application of FYM (T_1) alone. With the integrated nutrient application of FYM and inorganic fertilizers at the rate of 30:15: 30 kg ha^{-1} of N P and K (T_5) highest amount of available potassium (242.40 kg ha^{-1}) was obtained and the lowest amount of 131.24 kg ha^{-1} kg ha^{-1} was noticed in the combination of FYM, Azospirillum and AMF (T_2). Application of biovermi (T_3) alone gave the maximum organic carbon content (1.81%) in the analysed soil samples and the least (1.69%) in the control plot (T_6).

Quality analysis

Open condition (M_1) produced maximum amount of essential oil content of 1.77 per cent whereas the lowest amount of essential oil (1.71 %) was found in the experimental plots maintained under 75 per cent light intensity level (M_3). It was observed that the experimental plants have shown significant variation in the oil yield under various light intensity levels. 75 per cent light intensity (M_3) had the highest oil yield production of 106.04 kg ha^{-1} and the lowest oil yield of 37.82 kg ha^{-1} was recorded under 50 per cent light intensity level (M_2).

Significant difference was also noticed in the essential oil content of the herb with variation in the source of nutrients used, application of Biovermi alone (T_3) gave the maximum essential oil content of 1.81per cent and the least value of 1.64 per cent was obtained from the plots treated with FYM and 30:15:30 kg ha^{-1} of NPK (T_5). Combined application of Biovermi, Azospirillum and AMF (T_4) registered the maximum essential oil yield of 100.73 kg ha^{-1} and the least yield of 35.49 kg ha^{-1} was recorded from the control plot (T_6).

Conclusion

From the study, it can be concluded that 75 per cent light intensity and crop nutrition involving Biovermi, Azospirillum and AMF resulted in highest herbage yield and essential oil content in *Plectranthus vettiveroides.*

References

REFERENCES

Abdou, M.A.H., Sayed, A.A., Badran, F.S., and Deen, R.M.S. 2004. Effect of planting density and chemical and biofertilization on vegetative growth, yield and chemical composition of fennel (*Foeniculum vulgare* Miller): I - Effect of planting density and some chemical (Nofatrein) and biochemical (Biogen) fertilizers. *Ann. Agric. Sci. Moshtohor.* 42(4): 1907-1922.

Abbott, L. K. and Robson, A. D. 1982. The role of vesicular-arbuscular mycorrhizal fungi and selection of fungi for inoculation. *Aust. J. Agric. Res.*, 33: 389-408.

Ajimoddin, I., Vasundhara, M., Radhakrishna, D., Biradar, S.L: and Rao, G.G.E. 2005. Integrated nutrient management studies in sweet basil (*Ocimum basilicum* L.) *Indian Perfumer*, 49: 95-101.

Allen, M.F., Moore, T.S., and Christensen, M. 1980. Phytohormone changes in *Buteloua gracilis* infected by Vesicular arbuscular mycorrhizae. *Can. J. Bot.* 58: 371-374.

Allen, M. F., Smith, W. K., Moore, T. S. and Christensen, M. 1981. Comparative water relations and photosynthesis of mycorrhizal and non-mycorrhizal *Bouteloua gracilis. Newphytol.* 88: 683-643.

Ali, A., Ali, I., and Mustafa, U. A. 2009. Microbial inoculants: Panaceae for the sustainable production of medicinal and aromatic plants. *Ann. Agri. Bio. Res.* 14 (1): 67-73.

Ali Ghasemzadeh, Hawa Z. E., Jaafar, Asmah Rahmat, Puteri Edaroyati, Megat Wahab, and Mohd Ridzwan Abd Halim. 2010. Effect of Different Light Intensities on Total Phenolics and Flavonoids Synthesis and Anti-oxidant Activities in Young Ginger Varieties (*Zingiber officinale* Roscoe) . *Int. J. Mol. Sci.* (11): 3885-3897.

Ammon, H. P. and Kemper, F. H. 1982. Ayurveda: 3000 years of Indian traditional medicine. *Med. Welt*. 33:148-153.

Amirthalingam, S. 1988. Studies on the effect of *Azospirillum*, nitrogen and NAA on growth and yield of chilli. *South Indian Hortic.*, 36: 218.

Annamalai, A., Lakshmi, P.T.V., Lalithakumari, D., and Murugesan, K. 2004. Optimization of biofertilizers on growth, biomass, and seed yield of *Phyllanthus amarus* (Bhumyamalaki) in sandy loam soil. *J. Med. Arom. Pl. Sci.,* 26(4): 717-720.

Anilkumar, A.S., Nair, K.H., and Sherief, A.K. 2007. Utilization of enriched coir pith-vermicompost in organic mediculture. *Pl. Arch.*, 7(2): 617-620.

Anwar, M., D. D. Patra, S. Chand, Kumar Alpesh, A. A. Naqvi, and S. P. S. Khanuja. 2005. Effect of Organic Manures and Inorganic Fertilizer on Growth, Herb and Oil Yield, Nutrient Accumulation, and Oil Quality of French Basil. In :*Abstract:Communications in Soil Science and Plant Analysis*. Central Institute of Medicinal and Aromatic plants, Lucknow. p.36: 1737–1746.

A.O.A.C. [Association of Official Analytical Chemists] 1975. *Official and Tentative Methods of Analysis*, (12^{th} Ed.) Association of Official Analytical Chemists, Washington, D.C. 1094p.

Ayisha, T. P. 1997. Yield and quality of *Piper longum* L. under differential spacing and manorial regimes in coconut gardens. M Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 88p.

Azizi, M., Rezwanccee, F., Khayat, M. H., Lackzian, A., and Neamati, H. 2008. The effect of different levels of vermicompost and irrigation on morphological practices and essential oil content of German chamomile (*Matricaria recutita*) C.V Goral. *Iranian J. Med. Arom. Pl. Sci.,* 24(1): 82-93.

Azzaz, N.A., Hassan, E.A., and Hamad, E.H. 2009. The chemical constituent and vegetative and yielding characteristics of fennel plants treated with organic and bio-fertilizer instead of mineral fertilizer. *Aust. J. Basic and Appl. Sci.,* 3(2): 579-587.

Badran, F.S. and Safwat, M.S. 2004. Response of fennel plants to organic manure and bio-fertilizers in replacement of chemical fertilization. *Egyptian J. Agric. Res.*, 82(2): 247-256.

Bagyaraj, D. J. 2007. Arbuscular mycorrhizal fungi and their role in Horticulture. In: Keshavchandran (Ed.), *Recent trends in horticultural biotechnology*. pp: 53-58.

Bagyaraj, D. J. and Manjunath, A. 1980. Response of crop plants to VA-mycorrhizal inoculation in an unsterile, *Indian Soil. New Phytol.,* 85: 33-36.

Bagyaraj, D. J. 1991. Ecology of vesicular arbuscular mycorrhizae, In: Hand book of Applied Mycology. Soil and Plant, Marcel Dekker, Inc., New York (USA). 1: 3-4.

Bagyaraj, D. J. and Varma, A. 1995. Interactions between arbuscular mycorrhizal fungi and plants: their importance in sustainable agriculture in arid and semiarid tropics. *Adv. Microbial Ecol.,* 14: 119-142.

Bhaskar, S., Kumar, T.V., Shivananda, T.N., Arun, M.N., Janardhan, G., and Ramachandra, C. 2001. Effect of FYM, nitrogen levels and its method of application on scented geranium (*Pelargonium graveolens*). *J. Med. Arom. Pl. Sci.*, 23(3): 388-391.

Bilalis, D. and Karamanos, A. 2010. Organic maize growth and mycorrhizal root colonization response to tillage and organic fertilization . *J. Sustain. Agric.*, pp. 836-849.

Boby, V. U. and Bagyaraj, D.J. 2003. Biological control of root-rot of *Coleus forskohli* Briq. using microbial inoculants. *World j. Microbiol. Biotechnol.,* 19: 175-180.

Bodamwad, S.G., Rajeswar, S.R., Katkar, P.B., Kudumulwar, R.R., and Dange, M.B. 2009. Effect of organic and inorganic manures on growth, flowering and seed yield of coriander. *PKV Res. J.*, 33(1): 11-13.

Bolan, N. S. 1991. A critical review on the role of mycorrhizal fungi in the uptake of phosphorus by plants. *Plant and Soil.* 134: 189-207.

Bordeker, G. 2002. Medicinal Plants: Towards Sustainability & Security; IDRC Medicinal Plants Global Network Sponsored Discussion Paper for WOCMAP III, Chiang Mai, Thailand.

Borkowska, B. 2002. Growth and photosynthetic activity of micropropagated strawberry plants inoculated with endomycorrhizal fungi (AMF) and growing under drought stress. *Acta Physiol. Plant.*, 24: 365–370.

Bray, R. H., and Kurtz, L. T. 1945. Determination of total, organic, and available forms of phosphorus in soils. *Soil Sci.*, 59:39-45.

Briskin, D.P. and Gawienowski, M.C. 2001. Differential effects of light and nitrogen on production of hypericins and leaf glands in *Hypericum perforatum*. *Plant Physiol.*, 39, 1075–1081.

Brown, C. S., Schuerger, A. C. and Sager, J. C. 1995. Growth and photomorphogenesis of pepper plants under red light emitting diodes with supplemental blue or far-red lighting. *J. Am. Soc. of Hort. Sci.,* 120: 808- 813.

Cakmakci, R., Donmez, M. F. and Erdogan, U. 2007. The effect of Plant growth promoting rhizobacteria on barley seedling growth, some soil properties and bacterial counts. *Tur. J. Agric. For.*, 31: 189–199.

Channabasappa, K. S., Praveena kumar, and S. L. Madiwalar. 2007. Influence of Arecanut on Economic Yield and Quality Parameters of Medicinal Plants. *Karnataka J. Agric. Sci., 20 (4) : (880-882).*

Chandra, R., Kumar, D., Aishwath, O. P. and Jha, B. K. 2003. Response of *Chlorophytum borivilianum* to organic manure. *J. Trop. Med. Plants.,* 4 (2): 261-264.

Chaudhri, R.D. 1996. Herbal Drugs Industry (1st Ed.). Eastern Publisher, New Delhi, 498p.

Chezhiyan, N., Saraswathy, S. and Vasumathi, R. 2003. Studies on organic manures, biofertilizers and plant density on growth, yield and alkaloid content of bhumyamalaki (*Phyllanthus amarus* Schum. and Thonn.). *S. Indian Hort.,* 51 (1/6): 96-101.

Chiluvuru, N., Tartte, V., Kalla, C.M., and Komalapathi, R. 2009. Plant bioassay for assessing the effects of vermicompost on growth and yield of *Vigna radiata* and *Centella asiatica*, two important medicinal plants. *J. Dev. Sustain. Agric.*, 4(2): 160-164.

Chouhan, G. G. and Joshi A. 2002. Response of Safed musli (*Chlorophytum borivilinum*). In: *Extended summaries 2nd International Agronomy Congress, vol.1,* Nov. 26-30, New Delhi, pp. 505-506.

CIMAP [Central Institute of Medicinal and Aromatic plants] . 2003. *Annual Report for 2003.* Central Institute of Medicinal and Aromatic plants, Lucknow. pp. 7-8.

Cremeneac, L. and Boclaci, T. 2011. The study of the viermicompost influence on the harvest and on the quality of forage cultures. *Zootehnie si Biotehnologii*, 44 (2): 192-195.

Cruz, B. P., Chedier, L. M., Peixoto, P. H. P., Fabri, R. L. and Pimenta, D. S. 2012. Effects of light intensity on the distribution of anthocyanins in *Kalanchoe brasiliènsis* Camb. and *Kalanchoe pinnata* (Lamk.) Pers. *Academia Brasileira de Ciencias*. 84 (1): 211-218.

Dadheesh, R. C and Lekhchand. 2008. Effect of sowing dates, fertility levels and farmyard manure on growth and yield of isabgol (*Plantago ovata* Forsk.). *J. Med. Arom. Plant Sci.* 30(4): 356-358.

Darzi, M. T., Hadi, M. H. S. and Rejali, F. 2012. Effects of the application of vermicompost and nitrogen fixing bacteria on quantity and quality of the essential oil in dill (*Anethum graveolens*). *J. Med. Pl. Res.*, 6 (21): 3793-3799.

Datta, S.N., Dey, A.N., and Maithra, S. 2009. Effect of FYM and GA_3 on growth and yield of sweet flag (*Acorus calamus* L.) under terai zone of west Bengal. *J. Hort. Sci.*, 4(1): 59-62.

Dave, A., Bilochi, G. and Purihit, S.D. 2003. Scaling up production and field performance of micro propagated medicinal herb Safed musli (*Colophytum orivillianum*). *Invitro Cellular and Dev Biol.*, 39(4): 419-425.

Den Dubbleden, K. and Oosterbeek, M. J. 1995. The availability of external support affects allocation and morphology in herbaceous climbing plants. *Functional Ecol.*, 9: 628-634.

Devkota, A. and Jha, P. K. 2010. Effect of different light levels on the growth traits and yield of *Centella asiatica*. *Middle East J. Sci. Res.*, 5(4): 226-230.

Dobbelaere, S., Croonenborghs, A., Thys, D., Ptacek, J., Vanderleyden, P., Dutto, C., Labandera-Gonzalez, J., Caballero-Mellado, J. F., Aguirre, Y., Kapulnik, S., Brener, S., Burdman, D., Kadouri, S., Sarig, and Okon, Y. 2001. Responses of agronomically important crops to inoculation with *Azospirillum, Aust. J. Plant Physiol.*, 28: 871-879.

Dosani, A.A.K., Talashikar, S., Mehta, V.B. 1999. Effect of poultry manure applied in combination with fertilizers on the yield, quality and nutrient uptake of ground nut. *J. Indian Soc. Soil. Sci.*, 47: 188-189.

Dwivedi, R. S. P., Dwivedi, S. N., Namdeo, K. N., Pathak. S. and Mittoliya, V. K. 2008. Effect of row spacings and nitrogen sources on growth, yield and quality of isabgol (*Plantago ovata* Forsk.) varieties. *Crop Res.*, 36 (1): 349-353.

Earanna, N., Mallikarjuniah, R. R., Bagyaraj, D. J. and Suresh, C. K. 2001. Response of *Coleus aromaticus* to *Glomus fasciculatum* and other beneficial soil microflora. *J. Spices and Arom. Crops.*, 10(2): 141-143.

Edwards, C.A., Burrows, I., Fletcher, K. E., and Jones, B. A. 1988. The use of earthworms for composting farm wastes. *In*: J.K.R. Gasser (ed). *Composting of agricultural and other wastes.* Elsevier Applied Science Publishers, London. pp 229-242.

Esitken, A., Ercisli, S., Karlidag, H. and Sahin, F. 2005. Potential use of plant growth promoting rhizobacteria (PGPR) in organic apricot production. In: *Proceedings of the International scientific conference of environmentally friendly fruit growing*, Tartu-Estonia, September 7–9, 2005. pp. 90–97.

Gajbhiye, R.P. and Deshmukh, S.B. 2009. Root production and seed yield of ashwagandha as influenced by organic manures and biofertilizers. *J. Med. Arom. Pl. Sci.,* 32(4): 358-361.

Gemma, J. N., Koske, R. E., Roberts, E. M., Jackson. N. and De Antonis, K. 1997. Mycorrhizal fungi improve drought resistance in creeping bentgrass. *J. Turfrass. Sci.,* 73: 15-29.

Ganorkar, S.R., Barabde, N.P., Futane, N.W., Pote, S.R., and Wankhade, S.G. 2006. Nutrient uptake by safed musli (*Chlorophytum borivilianum*) as influenced by different levels of FYM and nitrogen. *J. Soils Crops.*, 16(2): 379-383.

Ganesan, V. and Mahadevan, A. 1994. Effect of mycorrhizal inoculation of cassava, elephant foot yarn and taro. *J. Root Crops.,* 20(1): 1-14.

Gangadharan, H. 2003. Soil plant shade interaction in the productivity of Kacholam (Kaempferia galangal L.) MSc. (Ag.) thesis, KAU, Thrissur, 113p.

Gangwar, K., Deepali, K. and Gangwar, R. S. 2010. Ethnomedicinal plant diversity in Kumaun Himalaya of Uttarakhand, India. *Nat. Sci.,* 8(5): 66-78.

Ghasemzadeh, A. and Ghasemzadeh, N. 2011. Effects of shading on synthesis and accumulation of polyphenolic compounds in ginger (*Zingiber officinale* Roscoe) varieties. *J. Med. Pl. Res.*, 5(11): 2435-2441.

Ghosh, D.K., Bandopadhyay, A., and Samantha, G. 2009. Studies on the influence of organic substitution of nitrogenous fertilizers on growth and yield of ashwagandha (*Withania somnifera*) grown as intercrop in coconut plantation. *J. Crop Weed.*, 5(2): 1449-180.

Gill, B. S., Randhawa, R. S., Randhawa, G. S. and Singh, J. 1999. Response of turmeric (*Curcuma longa* L.) to nitrogen in relation to application of farmyard manure and straw mulch. *J. Spices and Arom. Crops.*, 8(2): 211-214.

Goel, V., Duhan, B. S., Madan, V. K., Dev Raj, and Ramprakash. 2011. Effect of nitrogen and FYM on yield, growth parameters and quality of Ashwagandha (*Withania somnifera*). *Ann. Agri. Bio. Res.* 16(2): 101-106.

Gopichand, Singh, R. D., Meena, R. L., Singh, M. K., Kaul, V. K., Brij Lal, Acharya, R. and Prasad, R. 2006. Effect of manure and plant spacing on crop growth, yield and oil-quality of *Curcuma aromatica* Salisb. in mid hill of western Himalaya. *Ind. Crops and Products.* 24 (2): 105-112.

Govinda Rao, Y. S., Suresh, C. K., Suresh, N. S., Mallikarjunaiah, R. R. and Bagyaraj, D. J. 1989. Vesicular arbuscular mycorhizae fungi in medicinal plants. *Indian J. Phythopath.*, 42: 476-478.

Gracy, L. S. and Bagyaraj, D. J. 2005. Influence of different AM fungi on growth, nutrition and forskolin content of *Coleus forskohlii. Mycol. Res.*, 109: 795-798.

Graham, T.L. 1998. Flavonoid and flavonol glycoside metabolism in Arabidopsis. *Plant Physiol. Biochem.*, 36, 135–144.

Gunathilake, H. M., Senaratne, D. M., and Abeygunawardena, V. 2002. Role of Non-Timber Forest Products in the Economy of Peripheral Communities of Knuckles National Wilderness Area of Sri Lanka: A Farming Systems Approach. *Econ Botany.*, (3) 47.

Gupta, R. P., Sharma, V. P., Singh, D. K. and Srivastava, K. J., 2003, Effect of organic manures and inorganic fertilizers on growth, yield and quality of *Plumbago rosea. News Lett Nation. Hortic. Res. and Dev. Found.,* 19(2): 7-11.

Hansen, S., Maehlum, J.E., and Bakken, L.R. 2007. NO and CH fluxes in soil influenced by fertilization and tractor traffic. *Soil Biol.*, 25: 621-630.

Harinkhede, D. K., Tripathi, R. K., and Khare, A. K. 2005. Effect of organic and inorganic sources of nutrients on growth and root yield of *Safed Musli* (*Chlorophytum borivillianum* L.). *Vaniki Sandesh.* 29 (4): 24-26.

Harley, J. L. and Harley, E. L. 1987. A check list of mycorrhiza in the British flora. *New Phytol.*, 105(2), Acad. Press London.

Harold, A. 1980. Regulation of photosynthesis by sink activity. *New Phytol.,* 86: 131-144.

Heijden, V., Klironomos, J. N., Ursic, M., Moutoglis, P., Streitwolf-Engel, R., Boller, T., Wiemken, A. and Sanders, I. R. 1998. Mycorrhizal fungal diversity determines plant biodiversity, ecosystem variability and productivity. *Nature.*, 396: 69-72.

Hemalatha, P., Suresh, I., Saraswathi, T., and Vadivel, E. 2008. Studies on nutrient content, herbage yield and alkaloid content of kalmegh under integrated nutrient management system. *Adv. Pl. Sci.*, 21(2): 447-451.

Hemavathi, M. 1997. Effect of organic manures in growth and productivity of chrysanthemum, cv Local yellow. MSc. (Agri.) Thesis submitted to University of Agriculture Sciences, Bangalore, pp. 95.

Hirrel, M. C. and Gerdemann, J. W. 1980. Improved growth of onion and bell pepper in saline soils by two vesicular arbuscular mycorrhizal fungi. *Soil Sci. Soc. Am. J.,* 44: 654-655.

Hossain, A and Ishimine, Y. 2007. Effects of Farmyard manure on growth and yield of turmeric (*Curcuma longa* L.) cultivated in dark-red soil, red soil and gray soil in Okinawa, Japan. *Plant pro. Sci.,* 10(1): 146-150.

Hou JunLing, Li WeiDong, Zheng QiaoYun, Wang WenQuan, Xiao Bin and Xing Dan. 2010. Effect of low light intensity on growth and accumulation of secondary metabolites in roots of *Glycyrrhiza uralensis* Fisch. *Biochemical Systematics and Ecology.* 38(2) pp. 160-168.

Ingle, V. G., Wankhade, S. G., Jadhao, B. J. and Men, M. U. 2004. Effect of manure and fertilizer levels of yield of Safed musli. *Agric. Sci. Digest.*, 24 (4): 311-312.

Jackson, M. L., 1973, *Soil Chemical Analysis*, Prentice Hall of India Pvt. Ltd., New Delhi, pp. 498-499.

Joy, P.P., Thomas, J., Mathew, S., and Skaria, B.P. 2002. Effect of spacing and manuring on growth, yield and nutrient content of *Alpinia galanga* (L.) wild. *J. Spices Arom. Crops.*, 11(1): 22-25.

Joy, P. P., Savithri, K. E., Mathew, S., Thomas, J. and Kurien, K. 2005. Effect of sole and combined application of FYM and fertiliser on growth, yield and quality of black musli (*Curculigo orchioides*). *J. Med. and Arom. Pl. Sci.,* 27(3): 454-461.

Joy, P. P., Savithri, K. E., Mathew, S. and Skaria B.P. 2004. Effect of shade and spacing on growth, yield and quality of black musli (*Curculigo orchioides*). *J. Med. and Arom. Pl. Sci.,* 27(3): 454-461.

Kalita, S., Singh, P.L., and Singh, B. 2010. Effect of spacing and inorganic and organic nutrient application on performance of bhringaraj (*Eclipta prostrata*) in foothills of Arunachal Pradesh. *Indian J. Agron.*, 55(3): 240-243.

Kalyanasundaram, B., Kumar, T.S., Kumar, S., Swaminathan, V. 2008. Effect of N,.P, K with biofertilizers and vermicompost on growth and physiological characteristics of sweet flag (*Acorus calamus* L.). *Adv. Plant Sci.*, 21(1): 323-326.

Kanlayanarat, S., Sritongkul, J., Srilaong, V., Uthairatanakij, A., and Chalermglin, P. 2009. Effect of light intensity on chemical composition of Asiatic pennywort (*Centella asiatica* L. Urban). *Acta Horticulturae.*, No. 837 pp. 87-93.

Kapoor, A. and Mukerji, K. G. 1990. A strategy for selection and application of VAM fungi, In: Jalali, B. and Chand, H. (eds.), *Current Trends in Mycorrhizal Research.* Haryana Agricultural University, Hissar, pp. 139-140.

Kapur, P. And Kapur, P. 1999. Chlorophyll as an indicator of light intensity in *Andrgraphis panculata*. *Indian J. Plant Physiol.*, 4(1): 15-19.

Karlidag, H. A., Esitken, M., Turan, F. and Sahin. 2007. Effects of root inoculation of plant growth promoting rhizobacteria (PGPR) on yield, growth and nutrient element contents of apple. *Scientia Horticulturae.*, 114: 16–20.

Karthikeyan, B., C. A. Jaleel, R. Gopi and Deiveekasundaram, M. 2007. Alterations in seedling vigour and antioxidant enzyme activities in *Catharanthus roseus* under seed priming with native diazotrophs. J. Zhejiang Uni. Sci. B. 8(7): 453–457.

Karthikeyan, B., Jaleel, C. A., Lakshmannan, G. and Deiveekasundaram, M. 2008. Studies on the microbial biodiversity of some commercially important medicinal plants. Colloids and Surfaces B: *Biointerfaces.*, 62: 143–145.

Kasperbauer, M. J. 1987. Far-red light reflection from green leaves and effects on phytochrome-mediated assimilate partitioning under field conditions. *Pl. Physiol.*, 8: 350-354.

Kasperbauer, M. J. and Hamilton, J. L. 1984. Chloroplast structure and starch grain accumulation in leaves that received different red and far-red levels during development. *Pl. Physiol.*, 74: 967-970.

Kasperbauer, M. J. and Peaslee, D. E. 1973. Morphology and photosynthetic efficiency of tobacco leaves that received endof- day red or far red light during development. *Pl. Physiol.*, 52: 440-442.

KAU [Kerala Agricultural University]. 2007. *Package of Practices Recommendations: Crops* (12th Ed.). Kerala Agricultural University, Thrissur, 334p.

Kavitha, C. and Vadivel, E. 2006. Effect of organic manures and inorganic fertilizers on yield and yield attributing characters of *Mucuna pruriens*. *J. Med. and Arom. Pl. Sci.*, 28 (1): 18-22.

Kavitha, C. and Vadivel, E. 2006. Effect of organic manures and inorganic fertilizers on growth characters of *Mucuna pruriens* (L.). *Plant Archives* 6 (1): 197-200.

Kavitha, C. and Vadivel, E. 2008. Effect of organic manures and inorganic fertilizers on dry matter production and L-DOPA content of *Mucuna pruriens* (L.) DC. - a leguminous medicinal plant. *Legume Res.*, 31 (1): 44-47.

Kevinvessey, J. 2003. Plant growth promoting rhizobacteria as biofertilizers. *Plant and Soil* 255: 571–586.

Kim, S. J., Hahn, E. J., Heo, J. and Paek, K. Y. 2004. Effects of LEDs on net photosynthetic rate, growth and leaf stomata of chrysanthemum plantlets in vitro. *Scientia Horticulturae*. 101: 143-151.

Klopper, J. W. and Schroth, M. N. 1978. *Plant Growth Promoting Rhizobacteria on Radishes*, p. 879, Angers (Ed.), Gibert-Clarey, Tours

Kothari, S. K., Singh, S., Singh, V. B. and Kumar, S. 1999. Response of bergamot mint (*Mentha citrata*) to vesicular arbuscular mycorrhizal fungi and phosphorus supply. *J. Med. and Arom. Pl. Sci.*, 21: 990-995.

Krishnan, B. 2003. Rhizosphere modulation for higher productivity of long pepper (*Piper longum* L.). M Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur. 83p.

Krishna, A., Patil, C.R., Raghavendra, S.M., and Jakati, M.D. 2008. Effect of biofertilizers on seed germination and seedling quality of medicinal plants. *Karnataka J. Agric. Sci.*, 21(4): 588-590.

Krishnamurthi, V. V., Manikasundaram, P., Tamilmani, D., Vaiyapuri, K and Ganamurthy, P. 2002. Role of digested coir pith, Zinc and Iron on the yield of turmeric. In: *Proceedings of National Seminar on Emerging Trends in Horticulture:* 29-31 January 2002; Annamalai University, Tamil Nadu, pp.141-143

Kumar, T. S., Swaminathan, V., Kumar, S. 2009. Influence of nitrogen, phosphorus and biofertilizers on growth, yield and essential oil constituents in ratoon crop of Davana (*Artemisia pallens* Wall.). *Electronic J. Environ. Agric. Food Chem.*, 8(2): 86-95.

Kumar, A. R., Raju, B., Umesh, K., Smitha, G. R. and Sreeramu, B. S. 2010. Integrated nutrient management in growth, yield and economics of Bhumyamalaki (*Phyllanthus amarus*) an antijaundice plant. *J. Med. Arom. Plant Sci.,* 1(2): 456-567.

Kumar, R. A., Raju, B., Umesha, K., Smitha, G. R. and Sreeramu, B. S. 2011. Integrated nutrient management on dry matter distribution, nutrient uptake, plant and soil nutrient content of Bhumyamalaki var. Niharika (*Phyllanthus amarus*). *J. Med. Arom. Plant Sci.*, 33 (3): 342-348.

Kurata, H., Matsumura, S. and Furusaki, S. 1997. Light irradiation causes physiological and metabolic changes for purine alkaloid production by a *Coffeaa arabica* cell suspension culture. *Plant Sci.,* 123, 197–203.

Kuriean, A. 1999. Final report of the ICAR Adhoc Project, Evaluation and selection of Medicinal plants suitable for a Coconut based Farming System, Kerala Agricultural University, Vellanikkara, Thrissur.

Kurian, A and Shankar, M.A. 2007. Medicinal plants- Horticulture Science Series- 2. New Delhi Publishing Agency, New Delhi, 351 p.

Latha, A., Radhakrishnan, V. V. and Mini, S. 2009. Effect of organic manures and biofertilisers on nutrient uptake, yield and quality of *Plumbago rosea* grown as intercrop with coconut. *J. Plantn. Crops.*, 37(2): 157-159.

Latha, A and Radhakrishna, V. V. 2010. Effect of organic manures and biofertilizers on nutrient uptake, herbage yield and bacoside content of *Bacopa monnieri.* In: Proceedings of 22nd Kerala Science Congress, January 28-3-2010. KFRI, Peechi. Pp. 67-69

Lee, D.W., Oberbauer, S.F., Krishnapilay, B., Mansor, M., Mohamad, H. and Yap, S.K. 1997. Effects of irradiance and spectral quality on seedling development of two Southeast Asian Hopea species. *Oecologia.,* 110: 1-9.

Li, S., Rajapakse, N. C., Young, R. E. and Oi, R. 2000. Growth responses of chrysanthemum and bell pepper transplants to photoselective plastic films. *Scientia Horticulturae*, 84: 215- 225.

Li Wei Sheng, Wang WenQuan, Qin ShuYing, Wang JiYong and Wu ZengZhi. 2011. Effects of shading on growth, yield and photosynthesis physiological characteristics of *Pinellia peda-tisecta* Schott.; *Progress in Modern Biomedicine*, Harbin, 11 (24): 4811-4815.

Macedo, A. F., Lage, C. L., Esquibel, M. A., Souza, M. M., Silva, K. L., Niero, R. and Cechinel-Filho, V. 2004. Preliminary phytochemical and pharmacological studies on plantlets of *Alternanthera brasiliana* cultured under different spectral quality of lights. *Acta Farmaceutica Bonaerense*, 23: 515-519.

Maheswarappa, H. P. 1997. Agronomic investigations on kacholam (*Kaempferia galanga* L.) and arrow root (*Maranta arundinaceae*) grown as intercrops in coconut garden. Ph.D thesis, University of Agricultural Sciences, Bangalore, 210p.

Maheswarappa, H. P., Nanjappa, H.V., and Hedge, M.R. 1999. Influence of organic manures on yield of arrow root, soil physico chemical and biological properties when grown as intercrop in coconut garden. *Ann. Agric. Res.,* 20(3): 318-323.

Maheswarappa, H. P., Nanjappa, H. V., Hedge, M. R and Biddappa, C. C. 2000. Nutrient content and uptake by galangal (*Kaempferia galanga* L.) as influenced by agronomic practices as intercrop in coconut (*Cocos nucifera* L.) garden. *J. Spices Arom.Crops.*, 9: 65-68.

Mahfouz, S. A. and Sharaf Eldin, M. A. 2007. Effect of mineral vs. biofertilizer on growth, yield, and essential oil content of fennel (*Foeniculum vulgare* Mill). *Int. Agrophisics.* 21(4): 361-366.

Maiti S. and K. A. Geetha, 2005. Commercialization of medicinal plants *viz-a-viz* their conservation strategies. . In: N. Sasidharan, P. Vijayakumaran Nair, M. P. Sujatha, K. R. S. Krishnana. J. K. Sharama, R. Prakash Kumar and Kamalakshan Kokkal (eds.) *Medicinal Plants of Kerala: Conservation & Beneficiation – compendium of seventeenth Kerala Science Congress.* Kerala State Council for Science, Technology and Environment, Thiruvananthapuram. 1- 3.

Malayeri, S. H., Hikosaka, S. and Goto, E. 2010. Effects of light period and light intensity on essential oil composition of Japanese mint grown in a closed production system. *Environ. Control in Biol.,* 48 (3): 141-149.

Mandal, P., Misra, T.K., Das, A.P., and Singh, I.D. 2008. Production ability of medicinal herbs under agroforestry system and effect of organic manures. *Indian J. Pl. Physiol.,* 13(2): 177-184.

Manhas, S. S and Gill, B. S. 2010. Effect of planting materials, mulch levels and farmyard manure on growth, yield and quality of Turmeric. *Indian J. Agrl. Sci.,* 80(6): 27-29.

Manjunatha, R., Farooq, A. A., Vasundhara, M. and Srinivasappa, K. N. 2009. Effect of biofertilizers on growth, yield and essential oil content in patechouli (*Pogostemon cablin Pellet.*). *Indian Perfumer* 46(2):97-104

Martins, J. R., Alvarenga, A. A., Castro, E. M., Pinto, J. E. and Silva, A. P. 2008. Vegetative development and essential oil content in plants of *Ocimum gratissimum* L. under colored nets. *Revista Brasileira de Plantas Medicinais.* 10 (4) :102-107.

Martins, J. R., Alvarenga, A. A., Castro, E. M., Silva, A. P., and Alves, E. 2010. Pigments content and Alfavaca-cravo chloroplast structure cultivate under coloured nets. *Ciência Rural.* 40 (1): 64-69.

Menon, J. S. 1994. Influrnce of methods of planting and shade on growth, yield and plumbagin content of Chethikoduveli (*Plumbago rosea* Linn.). M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, 84p.

Menon, J. S. 1999. Analysis of growth, flowering and quality in 'Koduveli', *Plumbago sp.* Ph. D. Thesis, Kerala Agricultural University, Thrissur, 122p.

Menon, M. V. 1996. Effect of different inputs on productivity and quality relaations in Njavara. Ph. D. Thesis, Kerala Agricultural University, Thrissur, 134p.

Ndhlala, A. R., Mulaudzi, R. B., Kulkarni, M. G and Staden, J. 2012. Effect of environmental factors on seedling growth, bulb development and pharmacological properties of medicinal *Eucomis autumnalis*. *S. Afr. J. Bot.*, 79: 1-8.

Nema, J., Shrivastava, A., Thakur., and Agraval, V.K. 2008. Effect of organic manures, biofertilizers and inorganic fertilizers on productivity, biochemical parameters and active ingredients of *Coleus forskohlii*. *Pl. Arch.*, 8(1): 321-323.

Neerakkal, I., Vinod, T., Meenakkumari, T., Vijayakumar, K. R and Sethuraj, M. R. 2001. Leaf anatomy of five medicinal species grown under low light regimes. *Phytomorphology.*, 51(2): 185-189.

Neerakal, R., Rajagopal, and Vijayakumar, K.R. 2009. Influence of inanimate shade on growth of rooted *Adalodakam* (*Adhatoda beddomei* C.B. Clarke) cuttings. *J.Tropical Agric.*, 43 (1-2): 91-93.

Nevase, P. V., Bafna, A. M. and Shinde, K. A. 2011. Effect of N, P, K and FYM on growth and TSS of stevia. *Crop Res.*, 42 (1/2/3): 131-135.

Nguyen, P. and Cin, V. dal, 2009. The role of light on foliage colour development in coleus (*Solenostemon scutellarioides* (L.) Codd). *Pl. Phys. and Biochem.*, 47(10): 934- 945.

Nihad, K. and Jessykutty, P. C. 2010. Long term effect of organic manures and microbial inoculants on nutrient uptake and yield of *Plumbago rosea* when grown as an intercrop in coconut garden. *J. Med. and Arom. Pl. Sci.,* 32 (3): 257-261.

Nowak, J. 2004. Effects of arbuscular mycorrhizal fungi and organic fertilization on growth, lowering, nutrient uptake, photosynthesis transpiration of geranium. *Symbiosis.,* 37: 259-266.

Okon, Y. and Labandera, G. 1994. Agronomic application of Azospirillum: An evaluation of 20 years world wide field inoculation. *Soil Bio. Biochem.,* 26: 1591-1601.

Oren-Shamir, M., Gussakovsky, E. E., Spiegel, E., Nissim-Levi, A., Ratner, K., Giller, Y.E. and Shahak, Y. 2001. Coloured shade nets can improve the yield and quality of green decorative branches of *Pittosporum variegatum. J. Hort. Sci. and Biotech.*, 76: 353-361.

Palanikumar, M. and Jessykutty, P.C. 2007. Influence of different shade levels on herbage yield and oil content of mint (*Mentha spp.*). *Crop Res.,* 33(1,2 & 3): 229-232

Paul, S. 1992. Evaluation of Turmeric cultivars for shade tolerance. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 73p.

Patrude, J. J., Wankhade, S. G., Khode, P. P. Chatol, P.U., Des, D. D and Bhuyar, S. A. 2002. Effect of organic manures and plant population on yield of Safeed musli (*Chlorophytum basivilianum*) *Agric. Sci. Digest.,* 22 (1): 51-52.

Rao, B.R.R., Rajput, D.K., Sastry, K.P., Kothari, S.K., Singh, C.P., and Bhattacharya, A.K. 2006. Nutrient and intercropping studies in ambrette (*Abelmoschus moschatus*). *J. Med. Arom. Pl. Sci.,* 28(3): 372-376.

Rao, S. N., Rao, S. G., Bhargavi, B. and Reddy, K. J. 2011. Effect of NPK and farm yard manure on the accumulation of forskolin, an anti-obesity diterpenoid molecule in *Coleus forskohlii. Curr. Trends in Biotechnol. and Pharmacy.*, 5 (3): 1346-1352.

Rao,G. G. E., Reddy, G.S.K., Vasundhara, M., Nuthan, D., Reddy, M., Ganier, P.C. and Jagadeesha, N. 2010. Integrated nurtrient management (INM) in long pepper (*Piper longum* L.). *Asian J. Hort.*, 5(2): 359-363.

Rao, P. E. V. S., Puttanna, K., Rao, R. S. G. and Chandravamshi, P. 2003. Response of Bacopa monnieri to inorganic sources of nutrients. In: National Seminar on New Perspectives in Spices, Medicinal and Aromatic plants; 27-29. Nov. 2003; Calicut, Kerala, India, pp. 160- 168.

Rathore, S. D., Kamble, B. M., Phalke, D. H., Pavar, V. P. 2007. Advances in Plant Science. *J Maharashtra Agri. Univ.,* 23:1. 174-175.

Ravikumar, M., Venkatesha, J., Gangadharappa, P. M., Prabhuling, G. and Munikrishnappa, P. M. 2010. Effect of nitrogen fixing bacteria in combination with organic manures and chemical fertilizers on growth and yield of coleus. *J. Ecobiol.,* 27 (3/4): 349-358.

Read, D. J. 2000. Mycorrhiza-the state of the art. In: Varma, A. and Hock, B. (eds) *Mycorrhiza: structure, function, molecular biology, and biotechnology.* Springer-Verlag Berlin Heidelberg, Germany, pp 3–34.

Radusiene, J., Stanius, .Z., Cirak, C.and Odabas, M. S. 2011. Quantitative effects of temperature and light intensity on accumulation of bioactive compounds in St. John's worth. *Acta Horticulturae., 925.* pp. 135-140.

Rajasekharan S, V. George, P. G. Latha and G. M. Nair, 2005. Medicinal plants of Kerala – Past, present and future prospects. In: N. Sasidharan, P. Vijayakumaran Nair, M. P. Sujatha, K. R. S. Krishnana. J. K. Sharama, R. Prakash Kumar and Kamalakshan Kokkal (eds.) *Medicinal Plants of Kerala: Conservation & Beneficiation – compendium of seventeenth Kerala Science Congress.* Kerala State Council for Science, Technology and Environment, Thiruvananthapuram. 11-22.

Ramamoorthy, K., Krishnaveni, K. and Aruna, N. 2003. Effect of manure, fertilizer andspacing on herbage and seed yield in senna (*Cassia angustifolia* Vahl.). *Plant Archives.,* 3 (2): 287-290.

Ramkumar, G., Chandrasekarenthiran, S., Kirupaa, S., Benjamin, A.K., and Anandapandian, K.T.K. 2009. Effect of diazotrophs in increasing vegetative growth of medicinal plants, *Clitoria ternaceae*. J. Ecoobiology., 25(3): 275-281.

Rani, K. S., Devi, M. U., Patnaik, M. C. and Kumar, M. R. 2008. Integrated nutrient management on medicinal coleus and soil nutrient status. *Crop Res.,* 36 (1): 341-348.

Rao, B.R.R. 2001. Biomass and essential oil yields of rainfed palmarosa (*Cymbopogon martinii* (Roxb.) Wats. Var.*motia* Burk. Supplied with different levels of organic manure and fertilizer nitrogen in semi arid tropical climate. *Ind. Crops Products.,* 14(3):171-178.

Rao, B.R.R., Rajput, D.K., Sastry, K.P., Kothari, S.K., Singh, C.P., and Bhattacharya, A.K. 2006. Nutrient and intercropping studies in ambrette (*Abelmoschus moschatus*). *J. Med. Arom. Pl. Sci.,* 28(3): 372-376.

Rao, S. N., Rao, S. G., Bhargavi, B. and Reddy, K. J. 2011. Effect of NPK and farm yard manure on the accumulation of forskolin, an anti-obesity diterpenoid molecule in *Coleus forskohlii*. *Curr. Trends in Biotechnol. and Pharmacy*., 5 (3): 1346-1352.

Rao,G. G. E., Reddy, G.S.K., Vasundhara, M., Nuthan, D., Reddy, M., Ganier, P.C. and Jagadeesha, N. 2010. Integrated nurtrient management (INM) in long pepper (*Piper longum* L.). *Asian J. Hort*., 5(2): 359-363.

Rao, P. E. V. S., Puttanna, K., Rao, R. S. G. and Chandravamshi, P. 2003. Response of Bacopa monnieri to inorganic sources of nutrients. In: National Seminar on New Perspectives in Spices, Medicinal and Aromatic plants; 27-29. Nov. 2003; Calicut, Kerala, India, pp. 160- 168.

Rathore, S. D., Kamble, B. M., Phalke, D. H., Pavar, V. P. 2007. Advances in Plant Science. *J Maharashtra Agri. Univ.,* 23:1. 174-175.

Ravikumar, M., Venkatesha, J., Gangadharappa, P. M., Prabhuling, G. and Munikrishnappa, P. M. 2010. Effect of nitrogen fixing bacteria in combination with organic manures and chemical fertilizers on growth and yield of coleus. *J. Ecobiol.,* 27 (3/4): 349-358.

Read, D. J. 2000. Mycorrhiza-the state of the art. In: Varma, A. and Hock, B. (eds) *Mycorrhiza: structure, function, molecular biology, and biotechnology*. Springer-Verlag Berlin Heidelberg, Germany, pp 3–34.

Reda, F., El-Gamasi, A., El-Gendi, S. and Abdel-Zaher, M. H. 1978. Effect of light intensity on growth, development and alkaloids production of *Catharanthus roseus* G. Don. 147 (3): 228-238.

Reddy, D. V. and Biddappa C.C. 2000.Coconut based cropping / farming systems in India. *J. Plant. Crops.,* 281(1):1-18.

Regnier, A. P., Levi, J. D., Vance, I. and Smith, A.D. 1988. Microbes and oil recovery. *Int Bioresour J.,* 1: 336.

Rodriguez, H. and Fraga, R. 1999. Phosphate solubilizing bacteria and their role in plant growth promotion. *Bacteriol. Adv.,* 17: 319–339.

Sadanandan, A. K., Srinivasan, V., Hamza, S., Sajna, A. M., and Rukina, M. R. 1998. Effect of organic fertilizers on soil quality, productivity and quality of black pepper and cardamom, Indian Institute of Spices Research, pp. 450

Saha, R., Palit, S., Ghosh, B. C. and Mittra, B. N. 2006. Performance of *Aloe vera* as influenced by organic and inorganic sources of fertilizer supplied through fertigation. *Acta Horticulturae.,* 676: 171-175.

Saleh, A. L. and Garni, M. 2006. Influence of malathion and mancozab on mycorrhizal colonization and growth of *Zea mays* and *Vicia faba. Agric. Sci. Digest.,* 22 (1): 51-52.

Sanwal, S. K., Laxminarayana, R. K., Yadav, N., Rai, N., Yadav, D. S and Bhuyan, M. 2007. Effect of organic manures on soil fertility, growth, physiology, yield and quality of turmeric. *Indian J. Hort.*, 64(4): 105-111.

Saravana Pandian, P., Subramanian, S., Paramasivam, P. and Kumaraswamy, K. 2005. Organic farming in sustaining soil health. *Rev. Agric. Res.*, 26(2): 141-147.

Sarig , S., Balan, A. and Okon, Y. 1988. Improvement of the water status and yield of field grown sorghum (*Sorgghum bicolor*) by inoculation with *Azospirilllum brasilense. J. Agric. Sci.*, 110:271-277.

Satyendra, K.S. and Singh, P. 2010. Effect of blue green algae as biofertilizer on yield and composition of asgandh plants. *Trends Biosci.*, 3(1): 74-75.

Schubler, A., Schwarzott, D. and Walker, C. 2001. A new fungal phylum, the Glomeromycota: phylogeny and evolution. *Mycol. Res.*, 105: 1413-1421.

Schuerger, A. C., Brown, C. S. and Stryjewski, E. C. 1997. Anatomic features of pepper plants (*Capsicum annum* L.) grown under red light-emitting diodes supplemented with blue or far-red light. *Annals of Botany.*, 79: 273-282.

Selvaraj, T. 1989. Studies on *Vesicular arbucular* mycorrhizae of some crop and medicinal plants, Ph.D. Thesis, Bharathidasan University, Tiruchirapalli, Tamil Nadu, India, p. 12.

Selvaraj, T. and Chellappan, P. 2006. Arbuscular mycorrhizae: A diverse personality. *J. Cent. Europ. Agric.*, 7: 349-358.

Sena, M. K. and Das, P. K. 1998. Influence of microbial inoculants on quality of turmeric. *Indian J. Cocoa, Arecanut and Spices.* 21: 31-33.

Shahak, Y., Gussakovsky, E. E., Gal, E. and Ganelevin, R. 2006. Colornets: crop protection and light-quality manipulation in one technology. *Acta Hort.*, 659: 143-151.

Sharma, 1996. Effect of FYM on yield variability of Safed musli grown under varying plant population. *Paper Presented at the AICRP Workshop*, Udaipur, p. 129.

Sheela, N. 1996. Response of *Piper longum* L. in coconut gardens to differential spacing and manorial regimes. M Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 69p.

Sher, S.K. and Kesara, M.P.K. 2008. Cultivation practices of *Phyllanthus fraternus*- an important medicinal plant of the Indian arid zone. *Haryana Agric. Univ. J. Res.*, 38(1/2): 37-40.

Shirole, M. S., Jadhav, A. S., Mahatale, P. V., Shinde, R. H. and Mahatale, Y. V. 2006. Effect of organic manure and spacings on growth and yield of Brahmi. *Ann. of Plant Physiol.*, 19 (2): 264-265.

Shivananda, T. N., Mamatha, B. and Ganeshamurthy, A. N. 2009. Problems and prospects in cultivation of *Plectranthus vettiveroides* (K. C. Jacob, N. P. Singh & B. D. Sharma). *Biomed.,* 2(2): 146-154.

Shivanna, J., Ravi, C., and Sreeramu, B.S. 2007. Influence of spacing, nitrogen, phosphorus and potassium on growth, herbage yield and nutrient uptake in makoi (*Solanum nigrum* L.).*Environ. Ecol.* 25s (1): 71-75.

Shivanna, M.B., Ramesh, G. and Santaram, A. 2009. Influence of organic fertilizers on the growth and yield of kalmegh (*Andrographis paniculata*). *J. Med. Arom. Plant Sci.,* 32(3): 251-256.

Shivanna, M. B., Ramesh, G. and Ram, A. S. 2010. Influnce of organics and biofertilizers on the growth and yield of Kalmegh (*Andrographis paniculata).* J. Med. Arom. Plant Sci. 32(3): 251-256.

Shrestha, P. M. and Dhillions, S. S. 2003. Medicinal plant diversity and use in the highlands of Dolakha district, *Nepal. J. Ethnopharmacol.,* 86: 81-96.

Shrestha, Y. H., Ishll, T. and Kadoya, K. 1995. Effect of VAM fungi on the growth, photosynthesis, transpiration and the distribution of photosynthates of bearing Satsuma mandarin tress. *J. Jpn. Soc. Hort. Sci.,* 64: 517-525.

Singh, A., Yadav, A. L., Yadav, D. K. and Misra, S. K. 2008. Effect of integrated nutrient management of yield and quality of aonla (*Emblica officinalis* Gaertn.) cv. NA-10. *Pl. Archives.,* 8 (1): 473-474.

Singh, S., Sharma, S., and Ramesh, S. 2002. Herbage, oil yield and oil quality of [Patchouli (*Pogostemon cablin*](Blanco) Benth.] influenced by irrigation, organic mulch and nitrogen in semi- arid tropical climate. Central Institute of Medicinal and Aromatic Plants, Bangalore

Singisala, N. R., Rao, S. G. and Reddy, K. J. 2012. Influence of NPK and farm yard manure on root biomass and forskoline content in *Coleus forskohlii. Adv. in Pl. Sci.,* 25(1): 247-250.

Skaria, B. P., Mathew, G., Joy, P. P and Mathew, S. 2005. Coconut interspace – an ideal habitat for medicinal plants. *Indian Coconut J.*, 36(4): 12-18

Skaria, B. P., Miniraj, N., Mathew, S. and Josep, A. 2009. Oushadhasasyakrshikku Oru Vazhikatti (A primer on Medicinal Plant cultivation) Malayalam. Kerala Agricultural University, Vellanikkara. 270p.

Sreekala, G. S. 2004. Effect of organic manure and microbial inoculants on growth, yield and quality in ginger. Ph.D. thesis, Kerala Agricultural University, Thrissur, pp. 195.

Srinivasa, H. S. 2004. Influence of organics on physiology and quality in fenugreek (*Trigonella foenum-graceum*). MSc thesis, UAS, Dharwad, pp. 118.

Srithongkul, J., Kanlayanarat, S., Srilaong, V., Uthairatanakij, A. and Chalermglin, P. 2011. Effects of light intensity on growth and accumulation of triterpenoids in three accessions of Asiatic pennywort (*Centella asiatica* (L.) Urb.). *J. Food, Agri. & Environ.*, 9(1): 360-363.

Stribley, D. P. 1987. Mineral nutrition. In: Safir, G. R. (ed.) *Ecophysiology of VA-Mycorrhizal Plant.*, C.R.C. Press, Boca Raton, F1. pp. 59-70.

Stuefer, J. F. and Huber, H. 1998. Differential effects of light quantity and spectral light quality on growth, morphology and development of two stoloniferous *Potentilla* species. *Oecologia,* 117: 1-8.

Sturz, A. V. and Nowak, J. 2000. Endophytic communities of rhizobacteria and the strategies required to create yield enhancing associations with crops. *Appl. Soil Ecol.,* 15: 183–190.

Subbiah, B. V., and Asija, G. L. A. 1956. A raid procedure for the estimation of available nitrogen in soils. *Curr. Sci.*, 25:259-260.

Sudhakar, H.A., Mangesh, S., Shirayogappa, G., Prabhuling, G., and Babu, P. 2010. Standardization of organic farming practices for coleus (*Coleus forskohlii*). *Biomed.*, 5(2): 98-103.

Sudhakar, P., Chattopadhyay, G. N., Gangwar, S. K. and Ghosh, J. K. 2000. Effect of foliar application of *Azotobacter*, *Azospirillum* and *Beijerinckia* on leaf yield and quality of mulberry (*Morus alba*), *J. Agric. Sci.*, 134: 227–234.

Swaminathan, V., Kumar, T. S., Sadasakthi, A., Balasubramanian, R. 2008. Effect of nitrogen and phosphorus along with biofertilizers on growth, yield and physiological characteristics of Davana (*Artemisia pallens* Wall.). *Adv. Plant Sci.*, 21(2): 693-695.

Thangaraju, M., Rajamanickam, R. and Kandasamy, D. 1986. Response of maize and soyabean to the inoculation of different isolates of VA-mycorrhizal fungi [abstract]. In: *Abstracts, National Seminar on Microbial Ecology:* Jan., 1986, at Tamil Nadu Agricultural University, Coimbatore, *India,* pp. 24.

Tholkappian, P., Sivasaravanan, A. and Sundaram, M. D. 2000. Effect of phosphorous levels on the mycorrhizal colonization, growth, yield and nutrient uptake of Cassava (*Manihot esculenta* Crantz) in alluvial soils of coastal Tamil Nadu. *Mycorrhiza News* 11: 15-17.

Tiwari, P. N. 2006. Effect of organic manures and plant spacing on yield and quality of safed musli (*Chlorophytum borivilianum*). *Crop Res.*, 32 (3): 551-553.

Upadhyaya, S., Khativora, E., saikia, L.R. 2010. Comparison of total phenol and flavanoid content in *Adhatoda vasica* Nees. grown using different organic manure. *J. Pharmacy Res.*, 3(10): 2408-2409.

Venkatesan, S., Sudhagar, R. and Shakila, A. 2010. Effect of potting media and *Azospirillum* on the rooting of *Gymnema sylvestre* cuttings. *Asian J. Hort.*, 5 (2): 260-262.

Vennila, C. and Jayanthi, C. 2008. Nutrient use pattern and available nutrient balance as influenced by sources of nutrients in medicinal Coleus. *J. Fmg. Syst. Res. & Dev.*, 14 (1): 73-77.

Vidyadharan, V. and Swadija, O.K. 2000. Effect of varying levels of farmyard manure, nitrogen and potassium on the yield of arrow root under partial shade. *J. Root Crops*. 26(2): 84-86.

Walkley, A., and Black, I. 1934. An examination of the Degjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil. Sci.*, 37: 29-38.

Wankhade, S. G., Ganorkar, S. R. and Hadole, S. S. 2004. Effect of FYM and nitrogen on yield, quality and uptake of nutrients by Safed musli (*Chlorophytum borivilianum)*. *Res. J.*, 28(1): 105-107.

WHO [World Health Organisation]. 2009. World health statistics. World Health Organization, Geneva. 72 p.

Yadav, R. D., Keshwa, G. L. and Yadav, S. S. 2003. Effect of integrated use of FYM, urea and sulphur on growth and yield of isabgol (*Plantago ovata*). *J. Med. and Arom. Pl. Sci.,* 25 (3): 668-671.

Appendix

APPENDIX-I

Weekly mean rainfall(mm), surface air temperature(^{0}C), Relative humidity(%) and unshine hours(hr/week) at COH, Vellanikkara from June 2011 to May 2012(Latitude10^{0}31'N, ongitude 76^{0}13' and Altitude 40.29MSL)

Ionths 7/08/2011 o 0/02/2012	Weeks	Surface air temperature (^{0}C)		Relative Humidity (%)		Wind speed (Km/hr)	Sunshine Hours (hr/day)	Rainfall (mm/week)
		Maximum	Minimum	Morning	Evening			
	36	30.00	23.10	95	79	2.0	2.7	131.90
	37	28.90	22.80	96	79	2.3	2.4	174.80
	38	30.20	23.40	94	71	2.0	4.6	34.20
	39	31.60	23.10	91	63	2.5	9.1	0.50
	40	32.30	23.30	91	58	2.80	9.5	0.00
	41	32.40	23.40	92	62	2.30	6.2	5.90
	42	32.30	23.70	92	69	1.90	5.1	94.30
	43	31.70	23.30	89	71	5.00	5.0	87.40
	44	30.70	23.30	90	69	2.90	2.8	192.80
	45	31.70	22.00	84	54	3.20	7.3	34.20
	46	32.40	22.00	80	48	4.70	9.3	0.00
	47	30.70	23.90	63	54	9.20	6.8	3.50
	48	31.50	23.80	87	64	3.40	3.8	11.90
	49	32.10	22.80	82	51	4.40	8.5	0.00
	50	32.50	23.90	73	46	8.00	8.9	0.00
	51	31.00	23.50	62	44	9.80	6.1	0.00
	52	31.70	20.10	81	50	4.40	6.4	2.40

Months 27/08/2011 to 20/02/2012	Weeks	Surface air temperature (^0C)		Relative Humidity (%)		Wind speed (Km/hr)	Sunshine Hours (hr/day)	Rainfall (mm/week)
		Maximum	Minimum	Morning	Evening			
	01	32.10	21.60	84	44	5.80	8.50	0.00
	02	33.30	22.60	81	44	5.50	9.50	0.00
	03	32.00	20.20	71	31	6.00	9.10	1.00
	04	32.60	20.80	67	34	7.80	9.90	1.00
	05	32.50	22.30	66	39	8.80	9.20	1.00
	06	34.70	23.00	78	41	4.90	8.60	1.00
	07	35.10	22.50	83	38	4.50	8.80	1.00
	08	35.90	21.00	74	22	4.80	9.20	1.00

INFLUENCE OF LIGHT INTENSITY AND NUTRIENT SOURCE ON YIELD AND QUALITY OF IRUVELI (*Plectranthus vettiveroides*) K.C.Jacob, N.P. Singh and B.D.Sharma

By

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ABSTRACT OF THE THESIS

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ABSTRACT

The study on "Influence of light intensity and nutrient source on yield and quality of Iruveli (*Plectranthus vettiveroides*)" was conducted during 2011-2012 at College of Horticulture, Vellanikkara. Iruveli (*Plectranthus vettiveroides*), is an aromatic annual herb with an escalating demand in the pharmaceutical industry worldwide due to its notified curative property against skin diseases, bronchitis, ulcers, heart attacks, chronic allergies *etc.* The objectives of the experiment were to study the effect of light intensity and nutrient source on yield and quality of *Plectranthus vettiveroides* and to standardize the nutrient source and optimum light intensity requirement of Iruveli for maximum yield and quality.

The experiment, which was laid out as split plot in randomized block design with three replications consisted of different levels of light intensity and nutrient sources. Top shoot cuttings were planted at a spacing of 30 X 30 cm. Shade nets with mesh size, *viz* 25 and 50 per cent were used to regulate 75 and 50 per cent light intensity respectively. The sub plot treatments comprised of various source of nutrients *viz.* FarmYard Manure (FYM) and Biovermi (an enriched product of vermicompost with *Trichoderma viridae* and *Pseudomonas flourescence*) alone and in combination with Azospirillum and AMF and inorganic fertilizers. Inorganic sources of nutrients were urea, rock phosphate and muriate of potash for N, P and K..

Light intensity had profound influence on the biometric characteristics of the crop. Light intensity level of 75 per cent had the tallest plants while open condition was found to be better, regarding the number of leaves, at 30 and 60 days after planting. Light intensity variation also influenced the root: shoot ratio and open condition proved to be the best for maximum root: shoot ratio. Maximum biomass and dry matter production was noticed in plants grown under 75 per cent light intensity. Significant difference was also noticed in the biometric characters of the plants with variation in the source of nutrients. Maximum plant height was found when it was applied with FYM +Azospirllum +AMF while combined application of Biovermi, Azospirillum and AMF was found to be better for higher leaf production, root: shoot ratio, bio mass and dry matter production.

The data on nutrient contents of the plants revealed that higher nitrogen and potassium content were noticed under 75 per cent light intensity level while open condition

resulted in maximum phosphorus content. Maximum nitrogen and potassium uptake were shown by the plants maintained under 75 per cent light intensity level while phosphorus uptake was maximum with open condition. Application of Biovermi alone yielded maximum nitrogen content and the plant applied with no organics recorded the maximum content of phosphorus. Highest potassium content was in plants applied with a combination of FYM and inorganic fertilizers @ 30:15:30 kg ha^{-1}. The highest nitrogen, phosphorus and potassium uptake were noticed in the plants applied with combination of Biovermi+ Azospirillum +AMF.

Maximum amount of available nitrogen, phosphorus and potassium of the soil were noticed under 75 percent light intensity level while open condition showed maximum organic carbon content. Application of FYM alone gave the maximum available nitrogen content and the combined application of Biovermi, Azospirillum and AMF recorded the highest amount of available phosphorus. Highest amount of available potassium was observed with integrated nutrient application of FYM and inorganic fertilizers at the rate of 30:15: 30 kg ha^{-1} of NP and K and the application of Biovermi alone gave the maximum organic carbon content.

Plants showed significant variation in the oil yield under varying light intensity levels. Open condition produced maximum essential oil content but oil yield was maximum at 75 per cent light intensity. Significant difference was also noticed in the essential oil content of the herb with variation in the source of nutrients used: Application of Biovermi alone recorded the maximum essential oil content and the maximum essential oil yield was noticed with the combined application of Biovermi, Azospirillum and AMF .

From the results of the experiment, it can be concluded that 75 per cent light intensity and combined application of Biovermi with Azospirillum and AMF were found to be the best management practice for maximum herbage yield and essential oil content in *Plectranthus vettiveroides.*