STANDARDIZATION OF GOOD AGRICULTURAL PRACTICES (GAP) IN KACHOLAM (*Kaempferia galanga* L.) FOR YIELD AND QUALITY

By

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(2009-12-107)

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VELLANIKKARA, THRISSUR - 680656
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THESIS

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DEPARTMENT OF PLANTATION CROPS AND SPICES

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DECLARATION

I, hereby declare that this thesis entitled **"Standardization of good agricultural practices (GAP) in kacholam (*Kaempferia galanga* L.) for yield and quality"** is a bonafide record of research done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Certified that this thesis, entitled **"Standardization of good agricultural practices (GAP) in kacholam (*Kaempferia galanga* L.) for yield and quality"** is a record of research work done independently by **Miss Chandana. R** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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ABBREVIATIONS

AMF	: Arbuscular Mycorrhizal Fungi
CFU	: Colony Forming Units
EFYM	: Enriched Farm Yard Manure
GAP	: Good Agricultural Practices
MAP	: Months After Planting
MAS	: Months After Storage
PET	: Poly Ethylene Terephthalate
PSB	: Phosphorus Solubilizing Bacteria
RDF	: Recommended Dose of Fertilizers
RDN	: Recommended Dose of Nitrogen
VAM	: Vesicular Arbuscular Mycorrhiza

Introduction

1. INTRODUCTION

The state of Kerala is witnessing an unprecedented growth in the use of herbal medicines. About 70 per cent of the raw drugs used in the preparation of Ayurvedic medicines in the state are collected from the forest and non- forest areas. The rest is obtained through cultivation and through import from other states. Supply base of raw drugs from the wild is being eroded due to unscrupulous collection practices, necessitating promotion of cultivation of medicinal plants.

Kaempferia galanga L., a Zingiberaceous medicinal species, is a glabrous perennial aromatic herb and is a reputed remedy for respiratory ailments like cough, bronchitis and asthma. The drug is aromatic, acrid and bitter and alleviates skin diseases and digestive disorders (Aiyer and Kolammal, 1964). The officinal part of the plant is the rhizome which enters into the compositions of major Ayurvedic formulations like Valiyarasnadikashayam, Asanaeladi tailam, and Dashamularishtam (Sivarajan and Balachandran, 1997). Kacholam figures prominently among the medicinal species, identified for commercial cultivation in Kerala, being ideal for the coconut based cropping system of our state. Consequent to its demand by the perfumery and Ayurvedic user industries, the species has attained the status of a cash crop in the homesteads of Kerala. The annual requirement of the raw drug, is around 100 tonnes. Currently, crude drug of kacholam fetches an attractive market price of Rs. 250 per kg. Sustenance of a reasonably attractive market price over the years has made its cultivation a feasible proposition.

Safety and quality of herbal medicines have become increasingly important to the public. In recent years, good agricultural practices have been recognized as an important tool for ensuring safety and quality of a variety of agricultural commodities. Quality control of crude drugs which are the raw material for herbal medicines is more demanding than that for food products. Hence adoption of good agricultural practices in medicinal plants in presently

being prioritized to ensure that the raw materials maintain standards of highest purity and quality and that the Ayurvedic medicines prepared out of them meet the strongest demands of the consumer. Good agricultural practices or GAP as they are popularly known as, are a set of guidelines which provides guidance to the producers, for reducing raw material contamination to the lowest level. GAP guidelines are intended to produce the raw materials with care, keeping microbial and heavy metal contamination load to the minimum, without irrational compromise on yield and net returns per unit area. They mainly apply to the growing and primary processing of medicinal plants traded and utilized in the country.

Though an ideal candidate for commercial cultivation in Kerala, systematic attempts to standardize better crop husbandry practices in the crop, giving emphasis to organic resource management, are lacking. Since its entire requirement by the perfumery and drug industries is met through cultivation, adoption of GAP in a crop like kacholam assumes great relevance. Though not as serious in ginger, incidence of bacterial wilt has been reported from a few kacholam growing tracts of Kerala, which has to be tackled without irrational use of pesticides.

Post harvest handling practices in kacholam are generally confined to slicing rhizomes into circular pieces and sun drying. Dried rhizomes are stored under unhygienic conditions wherein microbial contamination and quality deterioration are likely to result. Hence refinement in post harvest handling practices in kacholam, requires priority to minimize quality deterioration and storage space.

In this context, the present study entitled "Standardization of good agricultural practices (GAP) in kacholam (*Kaempferia galanga* L.) for yield and quality" was taken up at the Dept. of Plantation Crops and Spices with the following objectives leading to the formulation of good agricultural practices in the crop.

1. To standardize organic nutrient resource management in the crop, through investigations on growth, yield and quality attributes.
2. To assess the comparative effect of organic and inorganic nutrient sources with respect to enriching soil nutrient status and microbial population.
3. To identify the best drying method for producing crude drug of kacholam based on the content of quality constituents.
4. To standardize storage techniques in kacholam ensuring quality of crude drug.

Review of Literature

2. **REVIEW OF LITERATURE**

Interest in traditional medicines has increased substantially and global and national markets for medicinal herbs have grown rapidly. Medicinal plants collected from the wild or procured through cultivation, often fail to meet stringent standards intended for quality raw drugs which may have unsafe consequences. Hence World Health Organization has recommended the adoption of good agricultural practices for the growing and primary processing of medicinal plants with an objective to encourage and support sustainable cultivation of medicinal species. The proposed study was thus taken up for standardizing good agricultural practices in kacholam, a versatile medicinal plant of high demand in the perfumery and Ayurvedic user industries, for yield and quality. Commercial cultivation of this medicinal species is prevalent in various tracts of Kerala, but a systematic investigation on organic resource management and postharvest handling, important components of good agricultural practices, are lacking in this crop. Perusal of past literature in the experimental crop on the above aspects revealed only scanty information. Hence in this chapter, an attempt has been made to review the important past literature pertaining to the topic of study, in other medicinal and aromatic plants and zingiberaceous species like ginger and turmeric besides kacholam. The review of literature is presented under the following heads:

2.1. GOOD AGRICULTURAL PRACTICES FOR MEDICINAL AND AROMATIC PLANTS

As suggested by Mathe and Franz (1999), GAP is meant to provide defined and reproducible production conditions for medicinal and aromatic plant producers.

Guidelines on good agricultural practices propose a voluntary process control system to ensure the healthiness of the primary product. Adoption of GAP by producers enable purchasers of these primary products to reduce sampling costs and other verifications of non certified products, leaving a disposition to pay higher prices for such goods (Demarco *et al*., 1999).

World Health Organization recommends the development of globally applicable guidelines to provide safety and quality of medicinal plant materials through formation of codes for good agricultural practices and good collection practices in medicinal plants to ensure safety and quality at the first and most important stage of production of herbal medicines (WHO guidelines, 2003).

A good agricultural practice in the context of medicinal plants is a cultivation programme designed to ensure optimal yield in terms of both quality and quantity of any crop intended for health purposes wherein the grower should identify the best possible environment, where the plant can express its full potential in terms of both quality and quantity during its entire growth period (germination, growth and maturity). The seeds chosen for cultivation purposes must be physically free from pests, diseases, foreign and inert matter and must have originated from recent harvests.

Use of organic manure is preferred for growing medicinal plants. However, mineral nutrition through inorganic source may be opted in inevitable cases. Use of compost, vermi-compost, poultry manure, green leafy manure is desirable. Similarly, use of microbial fertilizers for distinct purposes like nitrogen fixing or for phosphate solubilizing is desirable. Comprehensive preventive and control measures enumerated in the agronomic protocol should be used for disease, insect and pest management to minimize loss of the final crop and its quality. In general, crop protection plans should be limited to the use of bio-control agents and bio-pesticides.

The harvesting season should be determined and followed on the basis of qualitative parameters set for the end product of the constituents rather than the total vegetative yield. The drying procedure and the temperature employed for this purpose should be in conformity with the quality needs of the farm produce. The selection of packaging material should be based on the quality requirements and possible length of storage before consumption. It should be clean, dry and undamaged. The storage area should be a dry place protected from insects, rodents and other factors that may be detrimental to the quality of the product (National Medicinal Plant Board, 2010).

2.2. MEDICINAL AND AROMATIC PLANTS AS INTERCROPS IN COCONUT GARDEN

The state of Kerala which is a major consumer of medicinal plants and ayurvedic pharmacies constitute the major user industry of medicinal species. Hence, augmenting the supply of medicinal plants from the wild by cultivating them has become necessary due to the increase in demand (Suneetha and Chandrakanth, 2003). In a state like Kerala, cultivating medicinal plants as intercrops in coconut gardens ensure their sustained supply and give remunerative returns.

Nair *et al.* (1991) observed that yield of *Plumbago*, *Rauvolfia*, *Catharanthus* and Kacholam, when grown under natural shade of coconut, were on par with the yield obtained under open condition. High yield of patchouli was obtained when the plant was grown under 50 per cent shade (Radhakrishnan *et al.*, 1991).

Growth and rhizome yield of *Kaempferia galanga* were higher (6.1 t ha^{-1}) as compared with a fresh rhizome yield of (4.8 t ha^{-1}), when grown as intercrop, than when grown as a pure crop. Also, the essential oil and oleoresin contents were higher in rhizomes of intercropped plants (Maheshwarappa *et al.*, 1998).

Gunathilake *et al*. (2000) who conducted a study to assess the feasibility of growing medicinal plants in coconut fields of West zone of Sri Lanka, reported that yield and chemical quality of medicinal plants like *Piper longum, Kaempferia galanga* and *Plumbago indica* grown in coconut garden, recorded higher yield and chemical quality than that in open.

Ghosh *et al*. (2007) reported that among the various medicinal plants intercropped in coconut garden in West Bengal, tulsi recorded the greatest plant height (138 cm), number of leaves (12507) and number of branches (60) whereas arrowroot registered the highest fresh yield (45 kg/9 m^2). The presence of intercrops increased the nut yield of coconut by 14.16 per cent and profitability of the cropping system.

Ramesh and Shivanna (2010) observed that in *Andrographis paniculata*, growth parameters such as plant height, number of leaves, number of branches, plant spread, leaf area and yield parameters such as fresh weight of leaves, fresh weight per plant, fresh and dry weight per plot, herb yield and uptake of major nutrients such as N, P, K were maximum in plants intercropped in more than twenty five year old coconut garden.

2.3. KACHOLAM- A MEDICINAL PLANT FOR COCONUT BASED CROPPING SYSTEM

Kaempferia galanga L (known as 'Chandramula' in Hindi and 'Kacholam' in Malayalam) belongs to the family Zingiberaceae. Kirtikar and Basu (1935) have described the plant as a stemless herb with fibrous aromatic rootstalk and horizontally spreading leaves, laying flat on the ground with the inflorescence, a scape, arising directly from the rhizome. Rhizomes are used as expectorants, stimulatory, carminative medicines and diuretics. The herb yields volatile oil which is used for flavouring. The officinal part of the plant is the rhizome which enters into the composition of major Ayurvedic formulations like

Valiyarasnadikashayam, Asanaeladi tailam and Dasamularishtam (Sivarajan and Balachandran, 1997). Volatile oil of the dried rhizomes of *Kaempferia galanga* obtained by water distillation contain the major chemical constituents like ethyl-p cinnamate (31.77 %), methyl cinnamate (23.23 %), carvone (11.13 %), eucalyptol (9.59 %) and pentadecane (6.41 %) (Tewtrakul *et al.*, 2005). Indrayan *et al.* (2007) reported that the crop is cultivated mainly in India, China, Malayasia and Indonesia. 'Kasthuri' and 'Rajani' are the two varieties which differ in their chemical composition and morphology. The essential oil from their rhizomes has remarkably different refractive indices, specific gravities, saponification and iodine values.

Seedlessness contributes to absence of sexual reproduction in the crop and occurrence of minimum natural variability which is a major constraint in the genetic improvement of the crop (Rekha, 1993). Gangadharan and Menon (2003) reported that fresh and dry rhizome yield in kacholam were significantly higher in locations with 50 per cent shade intensity. They also observed that in kacholam, levels of shade did not affect vegetative growth significantly.

2.4. EFFECT OF ORGANIC NUTRIENTS ON GROWTH, YIELD AND QUALITY

Soil organic matter is recognized as a fundamental indicator of soil quality and sustainability, making the soil a living and dynamic system. Soil structure, porosity, water holding capacity and soil drainage are some of the physical properties influenced by the action of soil organic matter. It helps in improving the various chemical properties of the soil like cation exchange capacity and soil buffering action (Narayanaswami and Arora, 2002). Organic nutrient management is the best approach for effective utilization of resources as well as to produce crops with less expenditure (Deivasigamani and Thanunathan, 2011). In India, farmyard manure provides a significant source of organic matter. Compost is prepared from diverse types of plant materials and household wastes.Vermicomposting utilizing earthworms is an eco-biotechnological process that

transforms energy rich and complex organic substances into stabilized humus like product. Increased productivity of crops, in response to vermicompost amendments, have been attributed to better availability of mineral nutrients as well as their rich microbial population (Parthasarathy *et al* .,2008). The organic manures besides containing nitrogen have other macro and micro nutrients. Since literature on the effect of organic manures on growth, yield and quality attributes are scanty in kacholam, studies conducted in other medicinal and aromatic plants and zingiberaceous crops are also reviewed in this chapter.

2.4.1. **Effect of FYM on Growth Attributes**

Chaves *et al.* (2002) reported that in *Ocimum gratissimum* L., application of organic manure at 8 and 12 kg m^{-2} through fertigation resulted in maximum leaf production.

A study conducted by Kanimozhy (2004) on productivity and quality of *Coleus forskohlii* revealed that treatment combination of FYM + panchagavya (3 %) recorded a fresh and dry weight of 91 g and 15.2 g per plant in main crop and 70.7 and 11.10 g per plant in ratoon crop with a total alkaloid content of 2 .17 per cent and 2.15 per cent in main crop and ratoon crop respectively.

Trials conducted by Shivanna *et al.* (2007) in *Solanum nigrum* revealed that application of FYM at 10 t ha^{-1} along with NPK @ 100:50:50 kg ha^{-1}, with a spacing of 60 x 45 cm, recorded the maximum plant height (93.60 cm), number of branches (45.33), number of leaves (412) and spread (7222.60 cm^2) per plant.

In *Coleus forskohlii*, a carbohydrate content of 10.28 per cent and fibre content of 13.30 per cent were recorded in roots, upon treatment with FYM at 5 t ha^{-1} + vermicompost at 2.5 t ha^{-1} (Nema *et al.*, 2008).

In *Plantago ovata*, incorporation of 5 t 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 (Lekhchand and Dadheesh, 2008).

In *Phyllanthus fraternus*, an important medicinal plant of Indian arid zone, combination of compost + FYM +VAM was found most suitable for obtaining maximum growth parameters, biomass and harvest index after four months of starting the experiments (Sher and Kasera, 2008).

Kumar *et al.* (2010) reported that in *Phyllanthus amarus,* 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 besides obtaining maximum net returns and highest benefit cost ratio.

Padmapriya *et al.* (2010) conducted a study on the effect of organic amendments and bio-stimulants in *Gymnema sylvestre* and found that the treatment combination of FYM (25 t ha^{-1}) along with recommended dose of fertilizer (90:45:35 kg ha^{-1} of NPK ha^{-1}) and foliar spraying of panchagavya and manchurian mushroom extract, each at 3 per cent and humic acid at 0.3 per cent, recorded the highest plant height (227.53, 286.47, 300.1 and 334.54 cm respectively), number of laterals (40.0, 52.0, 58.0 and 62.0 respectively) and number of leaves (62.0, 70.0, 82.0 and 95.0 respectively) at 180, 240, 300 and 360 days after transplanting.

Application of 5 t of FYM along with inorganic fertilizers in *Eclipta prostrata,* proved superior over other treatments, in plant height, no. of branches, leaves per plant and maximum alkaloid yield (Kalitha *et al.*, 2010).

Jayasree and Anuja (2010) reported that in sweet basil (*Ocimum basilicum* L.), application of FYM 25 t ha^{-1} + *Azospirillum* + Phosphobacteria +

Panchagavya 3 per cent as foliar spray, recorded highest plant height, number of branches and fresh weight of the herb per plant.

2.4.2. **Effect of FYM on Yield and Quality Attributes**

Maheswarappa *et al*. (2000a) found that N content and dry matter in kacholam were significantly higher in plants treated with FYM, vermicompost as well as FYM (20t ha^{-1}) and inorganic fertilizers (50:50:50 kg ha^{-1}), compared with composted coirpith and inorganic fertilizers applied singly.

Maheshwari *et al*. (2000) reported that in Ashwagandha cultivar 'JA 20', use of 2.5 t FYM along with 12.5 kg N_2 and 25 kg P_2O_5, recorded 23.7 per cent higher root yield and was highly remunerative, fetching maximum net returns of Rs. 29390 ha^{-1} with a B:C ratio of 5.

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).

Vidyadharan and Swadija (2000) observed that in arrowroot (*Maranta arundinaceae*), rhizome yield increased with increasing levels of FYM, the highest yield (13.95 t ha^{-1}) being recorded at 20 t ha^{-1}.

Maheswarappa *et al*. (1999) observed that in arrowroot (*Maranta arundinaceae* L.) intercropped with coconut, the treatment combination of FYM along with inorganic fertilizers, recorded the highest dry matter of 65.12 g per plant and 125.69 g per plant at 120 and 240 days after planting and at harvest (167.93 g per plant). The contents of chlorophyll a and b were significantly higher in FYM + inorganic fertilizers as well as inorganic fertilizer alone (2.1 and 2.113 mg g^{-1} fresh leaf respectively).

Rao (2001) reported that in *Cymbopogon martinii* (Roxb.) Wats. var. motia Burk., application of FYM at 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.

In scented geranium (*Pelargonium graveolens,*), application of FYM 30 t ha^{-1} resulted in the highest leaf:stem ratio (2.03), highest fresh herbage yield (95.5 t ha^{-1}) along with higher oil content (Bhaskar *et al.*, 2001).

Joy *et al.* (2002) found that in *Alpinia galanga*, FYM (20 t ha^{-1}) recorded the highest number of clumps per plot (19.17), highest plant height (90.18 cm), number of suckers per clump (57.10), number of leaves per sucker (10.23), fresh rhizome yield (45.14 t ha^{-1}) and oil yield (94.80 l ha^{-1}). Fresh rhizome yield was highest (60.69 t ha^{-1}) at 30 x 20 cm spacing with FYM application. In *Curculigo orchioides*, application of FYM 40 t ha^{-1} resulted in significant improvement in number, length and thickness of tuber and dry recovery (Kothari and Singh, 2003).

Sharma *et al.* (2003), who conducted a study to find out the differential response of turmeric to inorganic fertilizers, revealed that, continuous application of chemical fertilizers reduced turmeric yield in the subsequent years, whereas addition of FYM or vermicompost enhanced yield of turmeric by 7- 10 % over the preceeding years.

In turmeric, the highest dry yield (7.75 t ha^{-1}) and curcumin content were noticed with neem cake + FYM + recommended dose of fertilizers, followed by FYM + recommended dose of chemical fertilizers (Rao *et al.*,2005) .

Joy *et al.* (2005) reported that the optimum level of FYM for the growth of black musli is 30 t 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.

Ganorkar *et al.* (2006) reported that the highest values for nutrient uptake and tuber yield in safed musli were observed with FYM application (20 t ha^{-1}) and nitrogen (75 kg N_2 ha^{-1}), when applied alone or in combination.

Application of FYM at the rate of 20 t ha^{-1} and commercial formulations of micronutrients and biofertilizers in ambrette (*Abelmoschus moschatus*) significantly increased plant height, yield attributing characters and pod and seed yields. An increase of 141.3 per cent of pod yield and 308.7 per cent of seed yield was observed with the application of FYM at 20 t ha^{-1} (Rao *et al.*, 2006).

Trials conducted by Singh *et al.* (2006) revealed that in *Curcuma aromatica,* application of 22.5 t of FYM ha^{-1} provided higher oil yield (234.4 kg ha^{-1}). Interaction between plant spacing and FYM at a level of 22.5 t ha^{-1} showed high crop growth rate.

Pandey and Singh (2007) reported that in brahmi (*Bacopa monneri*), use of 75 kg N_2 along with 5 t FYM ha^{-1} resulted in maximum NPK uptake, higher mean crop growth rate, maximum number of leaves, branches, plant spread and yield which was significantly higher than all other treatments.

Harshavardhan *et al.* (2007) reported that in lemon balm (*Melissa officinalis* L.) application of 50 per cent inorganic fertilizers and 50 per cent enriched FYM (6 t ha^{-1}) resulted in increased oil yield of 47.27 kg ha^{-1}. The treatment with 100 per cent enriched FYM recorded higher content of nerol (28.23 %), geraniol (39.86 %) and geranyl acetate (8.67 %).

Sanwal *et al.* (2007) reported that in turmeric, application of FYM at the rate of 18 t ha^{-1} resulted in significantly higher rhizome yield. Also, application of various organic sources resulted in 16-103 % higher rhizome yield over control and improved the quality parameters.

Dwivedi *et al.* (2008) reported that the best nitrogen source for growth and yield of isabgol was 25 per cent N_2 by urea and 75 per cent by FYM, which recorded significantly higher seed yield of 14.43 q ha^{-1} , seed mucilage of 36.16%, swelling factor of 11.27ccg^{-1} and net returns upto Rs. 53610 ha^{-1}.

In senna, application of FYM increased leaf, pod and leaf equivalent yields by 39.9, 25.4, 35.9 per cent respectively, over the control treatments. The mean yield of four seasons showed that there was an increase of 176.72 and 139 per cent in leaf, pod and leaf equivalent yields. Sennoside content also showed 67 per cent increase with FYM application (Pratibha *et al.*, 2008).

Gayathri and Anburani (2008) reported that in kacholam, the number of rhizomes per plant (19), fresh weight of rhizomes (76.66 g plant-^{1}), dry weight of rhizomes (75.16 g plant^{-1}), yield of rhizomes (1455.77 g plant^{-1}) and essential oil content (2.12 %) were highest in the treatment combination of FYM at 30 t ha^{-1} along with the recommended dose of inorganic fertilizers at 50:50:50 kg NPK ha^{-1} and with foliar application of vermiwash (1:5) dilution.

Rani *et al.* (2008) revealed that in medicinal coleus, conjuctive use of 50 per cent N_2 (20 kg N_2 ha^{-1}) with organic manures (FYM, 2.5 t ha^{-1} + castor cake, 0.25 t ha^{-1}) and biofertilizers resulted in highest fresh tuber yield (121.91 t ha^{-1}) and dry tuber yield (21.59 q ha^{-1}), at harvest.

Kavitha and Vadivel (2008) found that in *Mucuna*, the highest dry matter production of 156.94 g plant^{-1} and highest amount of L-DOPA (7.43%) were recorded in an integrated nutrient combination involving organic form of manures (cocopeat, 5 t ha^{-1} + FYM, 12.5t ha^{-1}) and inorganic fertilizers, @ 40:30:30 kg NPK ha^{-1}.

For integrated nutrient management in *Andrographis paniculata*, application of FYM at 15 t ha^{-1}, NPK at 75:75:50 kg ha^{-1} and Panchagavya at 3

per cent foliar spray recorded the highest growth parameters, nutrient uptake, yield and andrographolide content followed by FYM at 15 t ha^{-1} along with panchagavya at 3 per cent foliar spray (Sanjutha *et al.*, 2008).

Sehgal and Thakur (2008) reported that organic manures like enriched compost improved the performance and production efficiency of medicinal herbs like *Ocimum basilicum* and *Tagetes minuta*, when intercropped with trees.

Datta *et al.* (2009) reported that in sweet flag (*Acorus calamus*), plant height, number of leaves, rhizome length, rhizome diameter and yield increased with increase in dose of FYM upto 50 t ha^{-1}. Maximum fresh (3013.23 kg ha^{-1}) and dry rhizome yield (1389.15 kg ha^{-1}) were recorded with 50 t ha^{-1} FYM supplemented with 100 ppm GA_3, followed by application of 50 t FYM ha^{-1}.

Shaikh *et al.* (2010) reported that, in ginger, application of recommended dose of fertilizers + 25 t FYM ha^{-1} favorably influenced the yield and uptake of nutrients followed by the application of 50 per cent N through recommended fertilizer dose + 50 per cent N through poultry manure.

Sudhakar *et al.* (2010) observed that in *Coleus forskohlii*, 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.

Taie *et al.* (2010) found that in sweet basil (*Ocimum basilicum*), application of 50 per cent compost and 50 per cent sand along with biofertilizers, resulted in the enhancement of fresh and dry weights, total phenolics, total flavonoids and pigment contents, as compared with compost alone.

Nihad and Jessykutty (2010) conducted a study to find out the long term effect of organic manures and microbial inoculants on nutrient uptake and yield of

Plumbago rosea. They reported that the treatment supplying 50 per cent recommended dose of nitrogen through FYM and neemcake along with microbial inoculant mixture (AMF, *Azospirillum* and Phosphobacter) recorded the highest fresh (86.33 g plant^{-1}) and dry root yield (33.03 g plant^{-1}) per plant. It had also a long term effect on the nutrient supplying capacity of soil.

Upadhyaya *et al*. (2010) conducted a study for comparison of total phenol and flavonoid content in *Adhatoda vasica* grown using different organic manures. It was observed that the total phenol content was higher in samples collected from cowdung followed by FYM, compost and vermicompost. Total flavonoid content recorded highest values in samples collected from cowdung followed by vermicompost, FYM and compost.

Deivasigamani and Thanunathan (2011) reported that in glory lily, application of enriched FYM at the rate of 750 kg ha^{-1} recorded significantly higher yield attributes viz., number of pods per plant (20.36), number of seeds per pod (44.34), test weight (2.31g), seed yield (686 kg ha^{-1}) and tuber yield (2148 kg ha^{-1}).

2.5. EFFECT OF VERMICOMPOST ON GROWTH, YIELD AND QUALITY

Vermicompost is a granular aggregate of enzymatically digested organic matter containing nutrients in easily available form. It enhances and improves aeration, water holding capacity and drainage capacity of the soil. It is rich in macro and micro nutrients, vitamins, growth hormones and immobilized microflora. Vermicompost application facilitates easy availability of essential plant nutrients. It is an ideal organic manure and has a versatile role to play in the scenario of organic farming and integrated nutrient management (Das, 2009).

2.5.1. **Effect of Vermicompost on Growth Attributes**

Vadiraj and Potty (1998) reported that among the cultivars of turmeric, Armoor and Suroma, responded positively to vermicompost application with plant height varying from 18.3 to 26.6 cm in control plots and from 28.9 to 33.9 cm in treated plots and registered an yield increase of 6.7 per cent in BSR-1 and 25.5 per cent in Armoor.

Butola and Badola (2006) conducted a study to determine a suitable growing media for vegetative propagation of Himalayan endangered medicinal plants like *Angelica glauca* and *Heracleum candicans*. It was observed that, sandy loam soil and vermicompost mixture was appropriate for higher rooting and plant survival. The treatments comprising of sand, sandy loam, FYM, vermicompost and forest humus mixture proved suitable for higher growth and biomass in *Angelica glauca*.

Anilkumar *et al.* (2007) conducted a study to find out the efficacy of enriched coir pith-vermicompost on five promising medicinal plants, long pepper (*Piper longum*), koduveli (*Plumbago rosea*), asparagus (*Asparagus racemosus*), Chittadalodakaom (*Adhatoda beddomi*) and munja (*Premna nervosa*). The study revealed that utilization of enriched coirpith- vermicompost as a substitute for FYM in the preparation of potting mixture was encouraging and it enhanced the sprouting percentage (100%) and modulated the rhizosphere for promoting the activity of bioinoculants.

In a study to evaluate the effect of organic manure and nitrogen fertilizers on growth and nutrient uptake of brahmi (*Bacopa monnieri*), Singh *et al.* (2007) observed that use of 7 kg N in combination with 5 t ha^{-1} FYM, resulted in higher crop growth rate and maximum NPK uptake.

Azizi *et al.* (2008) reported that application of 15 per cent vermicompost with an irrigation regime of 4 mm per 2 weeks, in an improved German chamomile variety 'Goral', resulted in maximum plant height (64.82 cm), flower dry weight (7.84 g per plot) and flowering time (35.5 days).

Ghosh *et al.* (2009) conducted a study to find out the influence of organic substitutions of nitrogenous fertilizers on growth and yield of ashwagandha. He reported that the highest plant height (129.48 cm), number of leaves (158), number of primary branches (4.6), number of secondary branches (16.1), root weight (87.6 g per plant) and plant weight (296.4 g), 110 days after planting were obtained with 50 per cent vermicompost and 50 per cent urea. Application of organic manures also decreased bulk density and particle density of soil and increased pore space and water holding capacity.

In a study for assessing the effects of vermicompost on growth and yield of *Vigna radiata* and *Centella asiatica*, Chiluvuru *et al.* (2009) found that there was a significant increase in growth and related parameters with different concentrations of vermicompost over the control and that plant response was maximum at 20 per cent amendment of vermicompost to soil.

Bodamwad *et al.* (2009) observed that in coriander the maximum plant height (49.88 cm), primary branches per plant (6.44) and secondary branches per plant (15.37) were recorded in the treatment combination of 50 per cent recommended dose of fertilizer + 50 per cent vermicompost. Also, minimum days required for 50 per cent flowering (39.01) and number of days required for seed set to harvesting (37.73) were recorded with the same treatment.

2.5.2. **Effect of Vermicompost on Yield and Quality Attributes**

A study conducted by Sharma *et al.* (2003) to find out the differential response of turmeric to organic and inorganic fertilizers, revealed that application

of 50 per cent RDF (175: 60: 125 kg NPK ha^{-1}) + vermicompost 10 t ha^{-1}) recorded the highest yield, improved soil porosity, reduced bulk density and increased organic carbon content.

Joy *et al.* (2005) reported that in *Curculigo orchioides*, application of poultry manure at 2.7 t ha^{-1} without mulch was best for optimum yield, quality and soil health which produced 407 kg ha^{-1} of dry rhizome with 59.11 per cent starch, 3.04 per cent crude fibre, 11.89 per cent crude protein, 1.71 per cent crude fat and 11.32 ppm curculigoside.

Anwar *et al.* (2005) observed that in French basil, a better performance with respect to growth, herb yield, dry matter and oil yield was observed with vermicompost at the rate of 5 t ha^{-1} along with chemical fertilizers containing NPK at the rate of 50:25:25 kg ha^{-1}. Content of principal constituents of basil oil (methyl chavicol and linalool) was also higher in the same treatment. Content of organic carbon, available nitrogen and phosphorus were high in soils after the experiment that received organic manure alone or organic manure in combination with inorganic fertilizers.

Suchindra and Anburani (2008), who conducted a study to optimize levels of N and K fertilizers along with foliar application of biostimulants for increasing turmeric yield and yield parameters in the cultivar Erode Local, revealed that, application of vermicompost at the rate of 5 t ha^{-1} + 100 per cent recommended doses of fertilizers (25:60:60 kg NPK ha^{-1}), along with humic acid at the rate of 0.2 per cent, exhibited significant increase in fresh rhizome yield per plant (567.12 g $plant^{-1}$), number, length and weight of mother, primary and secondary rhizomes per plant.

Anilkumar *et al.* (2009) reported that in long pepper, the integrated nutrient management system involving incorporation of vermicompost at the rate 6.25 t ha^{-1} $year^{-1}$, addition of NPK at the rate of 30:30:60 $kg^{-1}ha^{-1}$ and combined

application of bioinoculants viz., *Azospirillum* + *Pseudomonas flourescens* + Arbuscular Mycorrhizal Fungi, was favourable for enhancing both fresh and dry spike yield and total alkaloid content.

Mandal *et al*. (2009) reported that in patchouli, higher productivity, extractive value, oil content and antioxidant quality of oils were observed when a mixture of inorganic fertilizers and organic manures like vermicompost were applied. Analysis of cost benefit ratio indicated that in patchouli, integrated nutrient management practices resulted in maximum returns.

In *Curcuma aromatica,* application of vermicompost at the rate of 25 t ha^{-1} and neem cake at the rate of 6 t ha^{-1} recorded the maximum rhizome spread, root thickness, root spread, root length, root weight and number of fingers. Vermicompost at the rate of 25 t ha^{-1} recorded the maximum fresh rhizome yield of kasthuri turmeric. At final harvest, the treatment recorded a fresh yield of 364.95g per plant and 396.33g per plant during first and second crop respectively (Nirmalatha *et al*., 2010).

2.6. EFFECT OF BIOFERTILIZERS ON GROWTH, YIELD AND QUALITY OF MEDICINAL AND AROMATIC PLANTS AND ZINGIBERACEOUS SPICES

Biofertilizers have emerged as 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 rendering soil, living and dynamic (Ali *et al.*, 2009). These are microbial inoculants which are carrier based preparations containing beneficial micro organisms in a viable state intended for seed or soil application and designed to improve soil fertility. They aid plant growth by increasing the number and biological activity of desired micro organisms in the root environment. They accelerate microbial processes to

augment the availability of nutrients in a form which can easily be assimilated by plants (Rao, 1993).

2.6.1. **Effect on Growth Attributes**

Annamalai *et al.* (2004) found that in *Phyllanthus amarus*, the maximum shoot length (94.97 ± 2.05 cm), root length (21.62 ± 0.42 cm), branches per plant (63.72 ± 0.50), leaves per branch (46.50 ± 0.28), fruits per branch (26 ± 0.40), fresh weight (42.27 ± 0.13 g) and dry weight (12.01 ± 0.08g) were obtained with 1.5 t ha^{-1} FYM and the highest number of compound branches per plant (22.5 ± 0.91) and seed yield per plant (0.40 ± 0.20 g) were obtained with FYM 12 t ha^{-1}, *Azospirillum* (2.5 kg ha^{-1}) and phosphobacteria (2.5 kg ha^{-1}).

Poinkar *et al.* (2006) reported that in ginger plant height, number of leaves, size and surface area of leaves, girth of pseudostem and number of tillers per plant were significantly higher with a combination of NPK (120:60:60 kg ha^{-1}) followed by FYM (10 t ha^{-1}) + *Azotobacter* + Phosphorus solubilizing bacteria (250 g per 10 kg seed).

Choudhary (2007) reported that in tuberose, application of biofertilizers like *Azotobacter*, PSB and VAM in combination with N at the rate of 100 kg ha^{-1} and P at the rate of 50 kg ha^{-1}, proved effective in increasing plant height, number of leaves per plant, number of bulbs per plant and advanced the sprouting of bulbs.

Krishna *et al.* (2008) who conducted a study to determine the effect of biofertilizers on seed germination and seedling quality of medicinal plants like *Andrographis paniculata*, *Withania somnifera* and *Ocimum tenuiflorum*, reported that combined application of biofertilizers like *Azospirillum*, Phosphorus Solubilizing Bacteria and *Azotobacter* resulted in higher germination percentage, root and shoot length and vigour index.

Padmapriya and Chezhiyan (2009) reported that in turmeric, under partially shaded conditions, plants receiving the treatment combination, 100 per cent inorganic fertilizer + 50 per cent FYM (15 t ha^{-1}) + coir pith compost (10 t ha^{-1}) + *Azospirillum* (10 kg ha^{-1}) + phosphobacteria (10 kg ha^{-1}) + 3 per cent panchagavya, exhibited cent per cent sprouting, increased height of plant (90.52 cm), number of leaves (19.70) and leaf area (723.51 cm^2) at 180 DAP as compared to absolute control, in open conditions.

Ramkumar *et al*. (2009) conducted a study with nitrogen fixing bacteria viz. *Azospirillum sp*. and *Azotobacter sp*., to analyse the effect of bioinoculants on vegetative growth and biomass production of the medicinal plant *Clitoria ternatia*. The study revealed that *Azospirillum, Azotobacter* and their combinations increased the germination rate of seeds to 54.5, 36.4 and 63.6 per cent and plant overall growth by 34.3, 31.1 and 38.2 per cent respectively. Seedling Quality Index (SQI) of the *Azospirillum*, *Azotobacter* and combined biofertilizer treated seedlings were 0.46, 0.44 and 0.46, respectively, while for the control, it was only 0.34.

Roy and Hore (2009) observed that in turmeric, application of *Azospirillum* and AMF along with NPK (75 per cent) through inorganic fertilizers, proved superior to other treatments, by recording maximum plant height, number of tillers, number of leaves and weight per clump followed by NPK (75 %) through inorganic fertilizers along with *Azotobacter* and AMF, as compared to inorganic NPK alone.

Jayasree and Anuja (2010) observed that in sweet basil (*Ocimum basilicum* L.), application of FYM at the rate of 25 t ha^{-1} along with *Azospirillum*, Phosphobacteria and Panchagavya 3 per cent as foliar spray recorded the highest plant height and number of branches

2.6.2. **Effect on Yield and Quality Attributes**

In patchouli (*Pogostemon cablin*) application of 75 per cent N and P and 100 per cent K of the recommended dose of fertilizers (150:50:50 NPK kg ha^{-1}) + *Azotobacter* + *Azospirillum* + VAM recorded significantly superior values for plant height (80.14 cm), number of leaves (357.75 cm), number of branches (22.04), leaf area (4075.66 cm^2), fresh herbage yield (10.73 t ha^{-1}) and essential oil yield (71.74 l ha^{-1}) (Manjunatha *et al*., 2002).

Chezhian *et al*. (2003) observed that in *Phyllanthus amarus* the highest number of branches per plant, number of leaves per plant, plant spread, specific leaf area, fresh weight per plant, leaf dry weight per plant and root dry weight per plant were produced by treatments with poultry manure along with *Azospirillum* and phosphate solubilizing bacteria at 45 x 10 cm spacing, and that plant height, leaf area index, dry matter production, herbage yield per hectare and contents of lignans, phyllanthin and hypophyllanthin were highest in *P.amarus* treated with poultry manure, *Azospirillum* and PSB, at 15 x 10 cm spacing.

Mohan *et al*. (2004) reported that in turmeric cv. DK Local, inoculation of *Azospirillum* in combination with inorganic fertilizers, profoundly increased growth, yield and quality over the control.

Dharana *et al*. (2006) reported that in *Coleus forskohlii*, application of Consortia 1 consisting of *Azotobacter chroococcum*, *Azospirillum brasiliense*, *Pseudomonas striata* and *Trichoderma harzianum* resulted in better establishment of cuttings (93.33 %), maximum tuber length (13.52 cm), number of tubers (16.8), maximum forskohlin content (0.403 %) and yield (26.07 mg $plant^{-1}$).

In *Centella asiatica*, a study conducted to determine the effect of inorganic and organic sources of nutrients on yield and nutrition revealed that FYM 10 t +

50:30:30 kg NPK through inorganic fertilizers, per year, can be applied to obtain the maximum herb and saponin yield (Puttanna *et al*., 2006).

Das *et al*. (2007) conducted a study to evaluate the effect of biofertilizer application on the biomass yield of *Stevia rebaudiana*, consisting of various treatments like FYM, phosphate solubilizing bacteria, *Azospirillum* and Vesicular Arbuscular Mycorrhiza (VAM). The study revealed that fresh and dry yield increased upto six months with different treatments and highest yields were obtained when a mixture of biofertilizers were applied.

Velmurugan *et al*. (2007) reported that in the turmeric cv. BSR-2, combined application of FYM along with *Azospirillum*, phosphobacteria and VAM recorded maximum values for yield attributes such as number of mother rhizomes per plant (3.98), number of primary rhizomes per plant (1.319) and number of secondary rhizomes per plant (2.13). The same treatment was found superior in terms of length of mother rhizomes (5.32 cm), primary rhizomes (10.90 cm) and secondary rhizomes (1.44 cm) as well.

Velmurugan *et al*. (2007) reported that in turmeric cv. BSR-2, application of FYM + *Azospirillum* + PSB + VAM recorded the highest curing percentage and cured rhizome yield (21.26 % and 7080 kg ha^{-1} respectively) as well as the highest content of curcumin (4.577 %), oleoresin (9.477 %) and essential oil (3.817 %). The lowest cured rhizome yield was obtained with the application of 50 per cent of the N, P and K through inorganic fertilizers.

Kalyanasundaram *et al*. (2008) reported that in sweet flag (*Acorus calamus*), inoculation of *Azospirillum* at 2 kg ha^{-1} along with 75 kg N_2 and 50 kg P ha^{-1} improved plant height, number of leaves, number of clumps, fresh and dry weight of herbage, fresh and dry weight of roots, leaf area, leaf area index, dry matter production and crop growth rate.

Hemalatha *et al*. (2008) observed that in kalmegh (*Andrographis paniculata*), application of 15 t FYM, NPK (15:25:25) through inorganic fertilizers and *Azospirillum*1 kg ha^{-1} resulted in maximum nutrient content in leaf tissues, high herbage yield and andrographolide content.

Dash *et al*. (2008) reported that in ginger, the highest fresh rhizome yield (18.70 q ha^{-1}), lower rhizome rot (11%) and content of quality constituents (5.82 % oleoresin) was obtained with the recommended dose of inorganic fertilizers, combined with *Azospirillum sp*. (10 kg ha^{-1}) and FYM (10 t ha^{-1})

Govindan *et al*. (2009) reported that in ginger, treatment of *Azospirillum* with 100 per cent inorganic fertilizer nitrogen, was superior to all other treatments in terms of maximum root length, number of fingers as well as yield and starch content at harvest. Inoculation of *Azospirillum* also resulted in increased protein content of rhizomes, at all the levels of fertilizer nitrogen.

In davana (*Artemisia pallens*), application of nitrogen and phosphorus at the rate of 93.75 kg ha^{-1} along with *Azospirillum*, gave the highest plant height (66.05 cm), number of laterals (19.46), fresh and dry weight of shoot (30.84 and 6.79 g per plant), dry matter production (5586.74 kg ha^{-1}), fresh herbage yield (19.35 t ha^{-1}), and essential oil content (27.54 kg ha^{-1}) (Kumar *et al*., 2009).

Gajbhiye and Deshmukh (2010) observed that in ashwagandha the treatment combination of 5 t ha^{-1} FYM along with *Azotobacter* and PSB (4 kg ha^{-1}) resulted in significant increase in root length(18.29 cm), root thickness (12.25 cm), fresh weight of root, dry root yield (9.40 q ha^{-1}) and seed yield (5.23 q ha^{-1}) compared to other treatments.

Neerja and Korla (2010) reported that in ginger, the highest rhizome yield of (11.59 t ha^{-1}) was recorded with *Azospirillum* alone, in comparison to organic fertilizers although the differences were not significant. Maximum dry matter

(17.7 %), oil (2 %) and oleoresin (6.98 %) was recorded with the application of *Azospirillum* + phosphorus + wood ash.

Satyendra and Singh (2010) reported that in aswagandha, application of blue green algae as biofertilizer at the rate of 50 g BGA kg^{-1} soil increased the catalase and peroxidase activity and there was an increase in chlorophyll and ascorbic acid content at 200g BGA kg^{-1} soil.

Taie *et al.* (2010) emphasized the importance of bioorganic fertilizers for enhancement of the antioxidant activity of phenolics, flavonoids and essential oils of basil plants, grown with 50 per cent and 75 per cent compost, in the presence of biofertilizers.

2.7. EFFECT OF ORGANIC MANURES ON NUTRIENT UPTAKE AND AVAILABILITY

In kacholam, nitrogen content was significantly higher with FYM, vermicompost and combination of FYM and inorganic fertilizers, compared to composted coir pith and inorganic fertilizers alone. P and K contents were significantly higher in completely organic treatments and FYM combined with inorganic fertilizers and with inorganic fertilizers alone. The higher nutrient content in these treatments could probably be attributed to better availability of nutrients. This was reflected in better growth of the crop and ultimately higher fresh rhizome yield (Maheswarapppa *et al.*, 2000a).

In *Coleus aromaticus*, higher N and P contents were observed in plants treated with *Glomus fasciculatum* and *Pseudomonas fluorescens* as well as combination of all micro organisms like *Glomus fasciculatum, Pseudomonas fluorescens, Trichodrema harzianum*, *Bacillus coagulans* and *Azotobacter chroococcum* (Earanna *et al.*, 2001).

A study conducted by Sreekala and Jayachandran (2006) to assess the effect of organic manures and microbial inoculants on nutrient uptake, yield and soil nutrient status in ginger crop revealed that FYM + neemcake + AMF + *Trichoderma* and FYM + AMF produced significantly higher yield and also enhanced the uptake of N, P and K, yield and fertility status of soil after each year of experimentation, compared to control.

Shivanna *et al*. (2007) reported that in *Solanum nigrum* L. the treatment combination of NPK (100:50:50 kg ha^{-1}) and FYM (10 t ha^{-1}) recorded the maximum nitrogen (293.5 kg ha^{-1}) and phosphorus uptake (27.79 kg ha^{-1}).

Velmurugan *et al*. (2007) reported that in ginger, application of FYM + *Azospirillum* + phosphobacteria + VAM recorded the highest nitrogen content (0.87 %), phosphorus content (0.21 %), nitrogen uptake (291.74 kg ha^{-1}) and phosphorus uptake (70.42 kg ha^{-1}), while application of digested coir pith compost + *Azospirillum* + phosphobacteria + VAM exhibited greater potassium content (0.90 %) and potassium uptake (285.05 kg ha^{-1}).

According to Garg (2007) in seed spice fennel, application of *Azotobacter* and PSB alone or in combination with inorganic fertilizers indicated a remarkable increase in the availability of phosphorus (28.44 kg ha^{-1}) after the harvest. Available potassium was maximum with the application of PSB + inorganic fertilizers.

Vennila and Jayanthi (2008) observed that in medicinal coleus (*Coleus forskohlii*), application of recommended dose of fertilizers 40:60:50 kg NPK ha^{-1} and FYM 10 t ha^{-1}, along with poultry manure, registered the highest nutrient uptake.

In stevia, combined application of biofertilizers like *Azospirillum*, VAM and phosphorus solubilizing bacteria, recorded the highest nutrient uptake with

32.28 mg per kg for nitrogen, 12.23 mg per kg for phosphorus and 90.79 mg per kg for potassium (Das *et al*., 2008).

In *Mentha longifolia*, the estimated uptake of N, P and K by shoot tissues was significantly higher in the treatments where plants were inoculated with *Azotobacter chroococcum* (35 kg ha^{-1}). The status of available N, P and K was relatively lower in the rhizosphere soils of bioinoculant treated fields than in the non inoculated soil. Depletion in the available nutrients in rhizosphere soils inoculated with bioinoculants might be attributed to the increased uptake of those mineral elements by bioinoculant treated plants (Mir *et al*., 2009).

According to Kalitha *et al*. (2010), in *Eclipta prostrata,* integration of FYM with N, P and K (60: 40: 20) resulted in highest NPK uptake followed by application of FYM (10 t ha^{-1}) alone.

In *Andrographis paniculata*, the uptake of nitrogen (34.64 kg ha^{-1}), phosphorus (5.03 kg ha^{-1}) and potassium (96.08 kg ha^{-1}) was maximum with the application of 7.5 t ha^{-1} FYM + 1.33 t ha^{-1} poultry manure + *Azospirillum* + VAM. Application of FYM and poultry manure has been shown to provide the environment suitable for root growth and increase absorptive root surface. Higher nitrogen uptake could be due to the enhanced mineralization of nitrogen from applied organic manures (Shivanna *et al*., 2010).

Treatment combination of FYM at the rate of 10 t ha^{-1}, FYM (25% RDN) and neem cake (25% RDN) of Package of Practices Recommendation of KAU along with microbial inoculants, recorded the highest nutrient uptake of 285.6 kg N_2 ha^{-1}, 16.1 kg P ha^{-1} and 197.97 kg K ha^{-1} in *Plumbago rosea*. The beneficial effect of AMF and P solubilisers can be attributed as the reason for the enhanced P uptake in microbial inoculant supplied plants (Nihad and Jessykutty, 2010).

According to Shivanna *et al*. (2010), in *Andrographis paniculata*, NPK content in soil after plant harvest was considerably higher in those treated with either the organics alone or their combination with biofertilizers. Nitrogen content was significantly higher in soil treated with organics in combination with *Azospirillum* (214 kg ha^{-1}) and phosphorus content increased significantly in soil treated with combination of organics and VAM (67 kg ha^{-1}). The content also increased significantly in FYM + *Azospirillum* + VAM treatments individually and also in most combinations of organics and biofertilizers.

Kalitha *et al*. (2010) reported that application of FYM either alone or in combination with NPK resulted in higher available nitrogen (66.9 kg ha^{-1}), phosphorus (16.7 kg ha^{-1}) and K (56.8 kg ha^{-1}) content over inorganic fertilizers. FYM either alone or in combination with fertilizer produced the highest soil organic carbon content in comparison to inorganic fertilizer treatments.

In glory lily, application of enriched FYM at the rate of 750 kg ha^{-1} + 75 per cent nitrogen at the rate of 90 kg ha^{-1} recorded higher uptake of nutrients to the extent of 115.4, 34.16 and 105.4 kg of N, P_2O_5 and K_2O ha^{-1} (Deivasigamani and Thanunathan, 2011).

2.8. EFFECT OF *Kalanchoe pinnata* ON PLANT GROWTH, YIELD, UPTAKE OF NUTRIENTS AND SOIL NUTRIENT ENRICHMENT

Kalanchoe pinnata is a highly drought resistant, succulent herb which grows on fallow land. The plant has the potential of minimizing the use of inorganic fertilizers by 50 per cent to 60 per cent without affecting the yield.

Trials conducted at the Dept. of Plantation Crops and Spices, College of Horticulture, Vellanikkara, revealed that incorporation of *Kalanchoe pinnata* in turmeric plots increased the rhizome yield by about 4 kg per sq.m. The nitrogen

and potassium content in the soil increased by 26.65 kg ha^{-1} and 56 kg ha^{-1} respectively. But no significant increase was noticed in the phosphorus content.

As revealed by the trials conducted at Birsa Agricultural University, Ranchi, incorporation of the herb 'Patharkuchi'(*Kalanchoe pinnata*), increased the grain yield of rice from 8 to 13 g per plot. Similar increase was also noticed in straw yield. Herb incorporation increased the organic carbon and total nitrogen content of soil by more than 10 per cent. Availability of plant nutrients in soil was positively influenced by the incorporation of herb.

In onion variety, Agrifound Dark Red, incorporation of *Kalanchoe pinnata* helped to maintain plant stand till harvest, improved plant height, gave better bulb development, increased roots and root volume, bulb diameter, bulb size index, weight of 20 bulbs and thereby yield. The herb when used could reduce the NPK through fertilizer by 50 per cent and gave higher yield over 100 per cent NPK by about 13.14 per cent. The above observations were made in a trial conducted to assess the beneficial effect of herb at Regional Research Station, Sinnar.

Incorporation of kalanchoe in red laterite soil resulted in slight increase in organic carbon (7 %) and phosphate and potash content (13.09). The clay content of the treated soil increased by about 9 per cent and sand decreased by 14 per cent. The treatment gradually converted sand into clay at a rate of about 10 per cent per year.

2.9. EFFECT OF ORGANIC MANURE, BIOFERTILIZERS AND MULCHES ON SOIL MICROBIAL POPULATION

Microbial population present in the soil play an important role in various chemical transformations in soils, thus influencing the availability of major nutrients like nitrogen, phosphorus, potassium and sulphur to plants. Nitrogen fixing bacteria and phosphate solubilizers can be utilized to partially augment the

supply of major nutrients. Elad *et al*. (1980) reported that the fertility of soil not only depends on its chemical composition but also on the qualitative and quantitative nature of microorganisms inhabiting it. The microorganisms inhabiting the soil can be classified into bacteria, actinomycetes, fungi, algae and protozoa.

Maheswarappa *et al*. (1999) reported that in arrowroot, microbial population and dehydrogenase activity were higher under FYM and vermicompost treatments as compared to composted coir pith treatments. Organic carbon and pH of the soil increased to a greater extent in FYM and vermicompost treated plots than with composted coirpith.

A study conducted by Karthikeyan *et al*. (2008) on rhizosphere microbial diversity of some commercially important medicinal plants revealed that the highest bacterial populations of 23.33 $x10^6$ g^{-1} was recorded in *Ocimum sanctum* followed by *Catharanthus roseus* (20.46 x 10^6 g^{-1}), *Aloe vera* (18.44 x 10^6 g^{-1}) and *Coleus forskohlii* (16.64 x 10^6 g^{-1}). The fungal population was 19.44 x 10^4 g^{-1} in *C. roseus*, 18.66 x 10^4 g^{-1} in *O. sanctum*, 16.44 x 10^4 g^{-1} in *A. vera* and 14.22 x 10^5 g^{-1} in *O. sanctum*, 10.44 x 10^5 g^{-1} in *C.roseus*, 8.44 x 10^5 g^{-1} in *A. vera* and 6.22 x 10^5 g^{-1} in *C. forskohlii*.

In a study conducted in *Andrographis paniculata,* the population of *Azospirillum* cells was maximum (66.7 x 10^4 cfu g^{-1}) in FYM (7.5 t ha^{-1}) + poultry manure (1.33 t ha^{-1}) + *Azospirillum* + VAM followed by FYM + *Azospirillum* + VAM (62.69 x 10^4 cfu g^{-1}) in comparison to control where the cell count was only 21.54 x 10^4 cfu g^{-1} (Shivanna *et al*., 2010).

According to Nihad and Jessykutty (2010), the treatments applied with microbial inoculants consisting of AMF, *Glomus sp*., *Azospirillum* and Phosphobacteria, recorded the maximum population of bacteria (216 x 10^7 cfu g^{-1}), fungi (6 x 10^5 cfu g^{-1}) and actinomycetes (3 x 10^5 cfu g^{-1}).

Trials conducted at BCKV, Kalyani revealed that incorporation of the herb increased the microbial biomass by about 2.2 times compared to untreated soil due to the accumulation of more organic matter content in soil. The fungal, bacterial and actinomycete count also had increased in treated as against the untreated soil.

2.10. BIOCONTROL AGENTS IN INTEGRATED NUTRIENT AND DISEASE MANAGEMENT OF MEDICINAL PLANTS AND SPICES

Biocontrol of plant pathogens is considered as a potential control strategy in recent years because chemical control results in accumulation of harmful chemical residues which may lead to serious ecological problems. Fungi belonging to the genus *Trichoderma* are the most promising biocontrol agents against a range of plant pathogens under a variety of environmental conditions (Chet, 1987). Another important group of biocontrol agents is the *Pseudomonas fluorescens*. Even though *Pseudomonas fluorescens* is considered as a PGPR, it can suppress a wide range of pathogens including *Fusarium*, *Rhizoctonia* and *Pythium* (Nautiyal, 1997).

2.10.1. **Effect of *Pseudomonas fluorescens***

Jaleel *et al.* (2007) observed that in *Catharanthus roseus,* treatment with *Pseudomonas fluorescens* enhanced the growth parameters under drought stress, increased the ajmalicine content and partially ameliorated the drought induced growth inhibition, by increasing the fresh and dry weights significantly.

Jaleel *et al.* (2009) reported that application of *Pseudomonas fluorescens* in *Catharanthus roseus* resulted in significant enhancement in the production of individual alkaloids like ajmalicine, catharanthine, serpentine and vindoline when compared to untreated plants.

2.10.2. **Effect of *Trichoderma sp.***

Vijayan and Thomas (2002) observed that for the integrated management of rhizome rot of small cardamom, *Trichoderma harzianum* multiplied in coffee husk media at the rate of 1 kg plant^{-1} either alone or in combination with akomin (0.3%) to be promising as an effective antagonist.

For controlling root rot in *Coleus forskohlii,* inoculation of the plants with *Trichoderma viride* and *Glomus mosssea* gave the best result with a disease severity index of 33.28 per cent compared to uninoculated plants (Boby and Bagyaraj, 2003).

Trials conducted by Sagar *et al.* (2007) on the management of rhizome rot of ginger by bioagents showed that *Trichoderma harzianum* inhibited the mycelial growth to the maximum by 78.51 and 76.29 per cent which was on par with *Trichoderma virens* (77.03%).

Khalko and Choudhary (2008) in an experiment for the biological control of rhizome rot disease of turmeric caused by *Pythium,* reported that combination of seed treatments with both *Trichoderma viride* and *Pseudomonas fluorescens,* along with FYM, showed 63.65 per cent disease reduction. Soil application of *Trichoderma* and *Pseudomonas* along with FYM also gave good results in terms of percentage reduction in rot.

2.11. POST HARVEST HANDLING OF MEDICINAL / AROMATIC PLANTS

Post harvest processing of medicinal plants is highly essential for commercial exploitation as well as for retaining the medicinal value of the raw drugs. It helps to provide raw materials with the desired quality and strength conforming to the physicochemical parameters and concentration of active

ingredients. Improper post harvest handling practices mostly results in poor quality of raw materials which are used in medicinal preparations (Sujatha, 2002).

2.11.1. **Drying**

Drying is one of the most critical and fundamental unit operations in the post harvest processing of medicinal plants. Quality of drug and its marketability are significantly influenced by the drying regime (Mahapatra and Nguyen, 2007). It is the most common and fundamental method for post harvest preservation of medicinal plants. Generally, drying at a temperature of 50º C was found to be optimum, since quality reduction due to discolouration occurs at higher temperature (Muller and Heindl, 2006).

2.11.1.1**. *Effect of different drying methods on quality attributes***

Salaby *et al*. (1988) reported that samples of mint (*Mentha arvensis* L.) dried in oven at 60º C reduced the essential oil content of the samples by 89.5-91 per cent, whereas air drying at 27-30º had no effect on the essential oil content, which remained at 1.71-2.76 per cent.

In various aromatic plants, with the drying temperature varying between 40 and 100º C, the volatile oil contents decreased with increasing temperature accompanied by changes in the oil composition. Compositions of marjoram (*Marjorana hortensis*) and basil (*Ocimum basilicum*) changed significantly at 80º C, and in sage (*Salvia officinalis*), savory (*Satureja hortensis*) and tarragon (*Artemisia dracunculus*) oil composition changed at 50-60º while essential oils of thyme and rosemary did not change significantly, with changes in drying temperature (Deans and Svoboda, 1992).

Trials conducted by Dambrauskine *et al*. (2003) on the effect of drying methods on raw material quality of aromatic plants revealed that it takes longest

time to dry naturally, and the various grasses dry out in 3-7 days. With a convection drier, drying took 24 hours, while drying by active ventilation took 2-4 days. The quality of raw materials changed the least, when aromatic plants dried naturally. Convection drying slightly reduced the amount of essential oils in oreganum and contact reduced the amount of essential oils in sage.

Omidbaigi *et al.* (2004) reported that essential oil from the flowers of German chamomile dried by three different methods of drying viz., sun drying, shade drying and oven drying at 40º C recorded the highest essential oil percentage of 1.9 in shade dried compared to sun drying (0.4 %) and oven drying (0.9 %). But the drying methods had no effect on the number of chemical components present in the essential oil.

Mehta *et al.* (2005) did comparative evaluation of different drying methods like sun drying, solar drying, shade drying and tray drying at 60º C for liquorice (*Glycyrrhiza glabra*). He reported that tray drying recorded the shortest time of 36 hours followed by solar drying (52 hours), sun drying (64 hours) and shade drying (76 hours). Glycyrrhizin content of the product dried under shade was 9.81 per cent, tray drier, 8.76 per cent, solar drier, 8.36 per cent and on sun drying, 8 per cent.

Asekun *et al.* (2007) conducted an experiment to characterize essential oils from *Helichrysum odoratissimum* using different drying methods which yielded 0.28, 0.46, 0.33 and 0.36 per cent oil from fresh, air dried, sun dried and oven dried aerial parts of the plant, respectively. The fresh leaf oil is characterized by a high content of oxygenated monoterpenes with P-menthone, pulegone and 1,8 cineole, as major constituents. Generally, yield and chemical profile of *H. odoratissimum* were affected by the drying methods.

In herbs of lemon balm (*Melissa officinalis*), fresh herbs had the highest essential oil content followed by shade dried, oven dried and sun dried herbs

respectively. Drying methods had no effect on the number of chemical components of the essential oil (Khalid *et al*., 2008).

Calvo-Irabien *et al*. (2009) who conducted a study to determine the effect of postharvest drying on the composition of Mexican oregano (*Lippia graveolens*) essential oil, revealed that different drying treatments including drying in shade, sun and oven at 20 and 40º C had no effect on either the qualitative or quantitative composition of the oil.

Padmapriya *et al*. (2009) conducted a study on the optimization of post harvest techniques in *Tinospora cordifolia*, which revealed that drying of 2.5 cm stem bits in sun took the lowest time of 36 hours for drying, while in mechanical drier, drying at 60 degree Celsius, recorded the minimum drying time. The highest tinosporine content of 0.045 per cent was observed in mechanical drying at 40º C compared to sun drying, which recorded 0.33 per cent tinosporine content.

Young *et al*. (2010) reported that the quantity of essential oil is high if extracted from fresh herbs followed by frozen herbs, shade dried herbs and hot wind dried herbs.

In *Juniperus phoenica*, drying of leaves in sun and berries in oven was most suitable for obtaining higher essential oil yield, but for higher percentage of some special components such as alpha pinene and delta 3 carvone, shade drying was most suitable (Ennajar *et al*., 2010).

Sharma and Verma (2010) reported that in *Sechium edule* (chayote) dehydration at 55 and 65º C yielded better quality product as assessed from the time of drying, colour changes, reconstitution and sensory acceptability.

Verma *et al.* (2010) who conducted a study to investigate the influence of drying by comparing essential oil from fresh, shade dried and sun dried flowering twigs of *Artemissia capillaris* revealed that essential oil content was highest in fresh herb (0.63 %) compared to dry materials (0.37 %). The study suggested that the biomass of *A.capillaris* should be distilled fresh for better oil yield and quality.

2.12. STORAGE OF CRUDE DRUG

Medicinal plants must be stored under specified conditions in order to avoid contamination and deterioration. Proper packaging and storage are important to maintain the quality that increases the demand for herbal materials in the international market. Improper storage leads to fungal contamination and insect damage.

2.12.1. **Effect of Different Packaging Materials on Storage**

Misra (2009) reported that medicinal and aromatic plants are mostly perishable and utmost care should be taken during the post harvest processing for improving the quality and efficacy of active ingredients.

Salaby *et al.* (1988) reported that essential oil content of air dried samples of *Mentha arvensis* L. stored in paper bags, polyethylene bags and synthetic jute bags stored for 12 months did not show any variation in the content of essential oil throughout the storage period.

Paakkonen *et al.* (1990) who conducted a study on drying, packaging and storage effects on quality of basil, marjoram and wild marjoram reported that odour and taste of freeze dried basil and freeze dried and air dried marjorams were sensitive to storage conditions. Intensity of odour and taste of dried herbs could be maintained for 2 years at 23º C in air tight packaging.

Baritaux *et al.* (1992) observed that in *Ocimum basilicum* L. after storing for a period of three, six and seven months, the total losses in the essential oil were observed to be 19 per cent, 62 per cent and 66 per cent respectively.

Salaby *et al.* (1995) observed that in *Melissa officinalis* L., essential oils extracted from dried aerial parts stored in glass or aluminium bottles for one year at ± 4 or ± 27º C influenced the proportional content of some constituents. Storage markedly increased the concentration of geranial + geraniol (18.08 % to 48.68 - 54.73%) and decreased the concentrations of beta-caryophyllene, caryophyllene oxide and citronellol.

In *Mentha piperita,* long term storage of shade dried drops in polythene bags for one year, resulted in oil with slightly low menthone but higher menthol content (Singh *et al.*, 2008).

Padmapriya *et al.* (2009) reported that in *Tinospora cordifolia* dried stem bits packed in polyethylene lined gunny bag retained the highest alkaloid content of 0.042 per cent as compared to storage under ambient conditions.

2.12.2. **Microbial Contamination in Storage**

Medicinal plants may be associated with a broad variety of microbial contaminants, which are represented by bacteria, fungi and viruses. This microbiological background depends on several environmental factors and exerts an important effect on the overall quality of herbal products and preparations (Kniefe *et al.*, 2002).

Roy and Chourasia (1989) reported that on examining the various samples of medicinal plants like *Cyperus rotundus*, *Gmelina arborea*, *Hygrophilia spinosa*, *Mesua ferrea* and *Solanum nigrum*, the common microflora under

storage were *Alternaria, Aspergillus, Curvularia, Fusarium, Pencillium* and *Rhizopus.*

Roy and Kumari (1991) after examining commercial seed samples of medicinal plants like *Hydnocarpus laurifolia, Blepharis edulis, Piper betle, Acacia concinna* and *Cassia fistula* reported that *Aspergillus* and *Pencillium sp*. were the predominant microflora responsible for contamination with mycotoxin.

Malmsten *et al*. (1991) observed that in aromatic herbs like dill, basil, marjoram, and wild marjoram, the total aerobic count ranged from 10^4 to 10^7 g per dried material. Microbes and aerobic spore formers, especially *Bacillus cerus* were detected in most of the samples. Microbes survive air drying better than freeze drying. The lethal effect of storage time was most clearly shown when the herbs were packed in oxygen containing packages.

Khan *et al*. (2006) reported that usually plant parts of medicinal plants are stored under unhygienic condition which exposes them to a wide variety of biological and chemical contaminants. Contamination of medicinal herbs with mycelium and spores of *Alternaria sp., Fusarium oxysporum, Pencillium sp., Botrytis cinerea* and *Aspergillus niger* were reported.

Gupta *et al.* (2008) observed that contamination of medicinal herbs with aflatoxins after harvesting can be minimized by controlling the water activity and storage temperature, as *Aspergilllus flavus* did not grow in any of the samples of medicinal herbs with water activity above 0.81 and when stored below 10 ± 2º. Contamination of medicinal herbs with aflatoxins can be minimized by controlling water activity and storage temperature.

A study for the detection of fungal contamination of raw materials of some herbal drugs conducted by Singh *et al*. (2008) revealed that maximum isolates

were recorded from *Asparagus racemosus* (228) followed by *Glycirrhiza glabra* (221) whereas minimum were from *Terminalia chebula* (71).

Materials and Methods

3. **MATERIALS AND METHODS**

The present investigations on "Standardization of good agricultural practices (GAP) in kacholam (*Kaempferia galanga* L.) for yield and quality", was carried out at the Dept. of Plantation Crops and Spices, College of Horticulture, Vellanikkara, during June 2010-January 2011.

The details regarding the experimental materials used and methodology adopted for conducting various aspects of the study are presented in this chapter.

3.1. SITE, CLIMATE AND SOIL

The area is located at 10º 32' N latitude 76º 10' E longitude and at an altitude of 22.25 m above mean sea level. The area has a tropical monsoon climate with more than 80 per cent of the rainfall distributed through South-West and North-East monsoon showers.

3.2. CROP HISTORY OF THE FIELD

The experimental site is the adult coconut garden (20 years old) in the Gokhale block of Dept. of Plantation Crops and Spices, College of Horticulture, Vellanikkara, planted at a spacing of 7.5 x 7.5 m spacing. Intercropping with turmeric was done in the previous year.

3.3. EXPERIMENTAL MATERIAL

The kacholam, 'Kasthuri', variety released from the Dept. of Plantation Crops and Spices, College of Horticulture, Vellanikkara, with a reported dry rhizome yield of 2.52 t ha^{-1} and a driage of 32.78 per cent was used for the study. The essential oil and oleoresin contents are 1.6 per cent and 3.2 per cent respectively.

3.4. EXPERIMENTAL DETAILS

The whole programme was carried out as two experiments, as detailed below:

3.5. **EXPERIMENT I: Influence of organic nutrients, biofertilizers and mulches on yield and quality of kacholam**

Germination, plant growth and vigour, yield parameters and content of quality constituents of kacholam, as influenced by organic and inorganic nutrients, biofertilizers, green manure crops and mulches, were studied in this experiment.

3.5.1. **Design and Lay Out**

Design- RBD

Number of treatments- 11

Number of replications- 3

Plot size- Raised beds of 3 x 1 m^2

Width of interchannel- 50 cm

Spacing- 20 x 20 cm

Depth of planting- 10 cm

Seed rhizome size- 5 g

Seed rate-240 g per bed

Number of plants per plot- 48

3.5.2. **Land Preparation**

The land was thoroughly ploughed and beds of suitable size (3x1 m^2) were formed with an interspace of 50 cm between beds (Plate 1).

Plate.1.General view of the experimental field of *Kaempferia galanga* L. in coconut garden

3.5.3. **Treatments**

T_1- Farmyard manure (30 t ha^{-1})

T_2- Farmyard manure (30 t ha^{-1}) + Consortium of biofertilizers- KAU (Micro organisms providing N, P and K nutrition) @ 2.5 kg ha^{-1}

T_3- Farmyard manure (30 t ha^{-1}) + *Kalanchoe pinnata* (250 g sq m^{-1})

T_4- Farmyard manure (30 t ha^{-1}) + Consortium of biofertilizers- KAU (Micro organisms providing N, P and K nutrition) @ 2.5 kg ha^{-1} + *Kalanchoe pinnata* (250 g sq m^{-1})

T_5- Farmyard manure (30 t ha^{-1}) + Consortium of biofertilizers- KAU (Micro organisms providing N, P and K nutrition) @ 2.5 kg ha^{-1} + *Kalanchoe pinnata* (250 g sq m^{-1}) + mulching with *Chromolaena odorata* (1kg sq m^{-1})

T_6- Vermicompost (N equivalent of FYM 30 t ha^{-1}) – 37.5 t ha^{-1}

T_7-Vermicompost (N equivalent of FYM 30 t ha^{-1}) -37.5 t ha^{-1} + Consortium of biofertilizers- KAU (Micro organisms providing N, P and K nutrition) @ 2.5 kg ha^{-1}

T_8- Vermicompost (N equivalent of FYM 30 t ha^{-1}) – 37.5 t ha^{-1} + *Kalanchoe pinnata* (250 g sq m^{-1})

T_9- Vermicompost (N equivalent of FYM 30 t ha^{-1}) -37.5 t ha^{-1} + Consortium of biofertilizers- KAU (Micro organisms providing N, P and K nutrition) @ 2.5 kg ha^{-1} + *Kalanchoe pinnata* (250 g sq m^{-1})

T_{10}- Vermicompost (N equivalent of FYM 30 t ha^{-1}) -37.5 t ha^{-1} + Consortium of biofertilizers- KAU (Micro organisms providing N, P and K nutrition) @ 2.5 kg ha^{-1} + *Kalanchoe pinnata* (250 g sq m^{-1}) + mulching with *Chromolaena odorata* (1kg sq m^{-1})

T_{11}- Control (Package of Practices Recommendations of KAU for kacholam, FYM- 20 t ha^{-1}, N: P_2O_5:K_2O at the rate of 50:50:50 kg ha^{-1})

3.5.4. **Manures, Fertilizers and Mulches**

Farmyard manure, vermicompost and biofertilizers which are used as organic sources of nitrogen were applied in two equal split doses, basally and 45 days after planting. Factumphos and MOP were used as inorganic sources of nitrogen. Standardized formulation of Consortium of biofertilizers was procured from Dept. of Microbiology, College of Agriculture, Vellayani, Kerala Agricultural University which consists of microorganisms providing N, P and K nutrition. Vermicompost was procured from ABARD vermicompost unit, CoH, Vellanikkara. *Kalanchoe pinnata*, which is a green manure plant was incorporated to the beds at the time of planting. The beds were mulched with *Chromolaena odorata*, immediately after sowing, in the respective treatments. Seed rhizomes were treated with a suspension of *Pseudomonas fluorescens* at a concentration of 20 per cent and planted on raised beds. *Trichoderma* multiplied in cowdung-neemcake mixture was applied uniformly in all treatments @ 2.5 kg ha^{-1}, basally. Other field operations were conducted as per package of practices Recommendations of KAU. The crop was harvested seven months after planting

3.6. OBSERVATIONS

Random sampling technique was adopted to select sample plants for recording various morphological and yield characters and for conducting various chemical analyses. Seven plants were selected at random from each plot and were labelled.

3.6.1. **Crop Growth and Yield Characters**

Monthly observations on various morphological characters were recorded from the sample plants in each plot and the average was worked out.

3.6.1.1. ***Germination percentage***

Total number of plants germinated per plot was counted and expressed as percentage.

$$\text{Germination Percentage} = \frac{\text{No. of seed rhizomes germinated}}{\text{Total number of seed rhizomes}} \times 100$$

3.6.1.2. ***Earliness in germination***

Number of days taken for germination of rhizomes in each treatment was counted upto five weeks after planting, at weekly intervals.

3.6.1.3. ***Number of leaves per plant***

Total number of leaves produced per plant was recorded at monthly intervals from sample plants in each plot and the average was worked out.

3.6.1.4. ***Foliage spread***

Spread of the plant was measured using a scale in two radial directions viz. N-S and E-W from sample plants in each plot and the mean was calculated.

3.6.1.5. ***Fresh rhizome yield per plant***

Sample plants were harvested separately from each treatment in each replication. Rhizome yield of individual plant was recorded.

3.6.1.6. ***Fresh rhizome yield per plot (kg plot^{-1})***

Total fresh rhizome yield per plot was recorded and expressed on per hectare basis, for each treatment.

3.6.1.7. ***Driage***

Dry weight of rhizomes per plot was calculated on initial weight basis and expressed in percentage.

3.6.1.8. ***Dry rhizome yield per plot (kg plot^{-1})***

Dry rhizome yield per plot was calculated based on fresh rhizome yield and driage and expressed on per hectare basis for each treatment.

3.6.1.9. ***Essential oil***

Essential oil content in the dried rhizomes in each treatment was estimated by hydro distillation, adopting Clevenger trap method as per AOAC (1980) and expressed in percentage.

3.6.1.10. ***Oleoresin***

The oleoresin content in the dried rhizomes was estimated, in each treatment employing the solvent extraction by Soxhlet apparatus as suggested by AOAC (1980) and expressed in percentage.

3.6.1.11. ***Percentage of bacterial wilt incidence***

Number of plants affected with bacterial wilt was noted, in treatment plots and expressed as percentage. Need based drenching of plants with *Pseudomonas fluorescens* was done.

3.6.1.12. ***Incidence of other pests and diseases***

Incidence of other pests and diseases in the experimental plots if any, was noted and expressed as percentage.

3.6.2. **Assessment of Soil Nutrients**

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 and Radio Tracer Laboratory. Details of the methods used for chemical analyses are indicated in Table 3.1.

Table 3.1. Methods employed for soil analyses

Sl. No.	Nutrient (kg ha^{-1})	Methods Followed	Reference
1.	Organic Carbon (%)	Chromic acid wet digestion method	Walkely & Black (1934)

2.	Available N	Alkaline permanganate method	Subbiah & Asija (1956)
3.	Available P	Bray-1 Extractant Ascorbic acid reductant-spectrophotometry	Bray & Kurtz (1945)
4.	Available K	Neutral normal ammonium acetate extract using flame photometer	Jackson (1973)

3.6.3. **Plant Uptake of Major Nutrients**

Nutrient content of experimental plants was estimated by selecting five plants at random from each treatment. Leaves and rhizomes were subjected to chemical analyses. Leaves were collected from sample plants at active rhizome formation stage. Rhizomes were collected after harvest of the crop. The plant parts were cleaned, chopped into small pieces and dried in hot air oven at 70-80 ° C, powdered well and analysed for major nutrients. The methods used for the analysis of major nutrients in leaves and rhizomes of sample plants are given in Table 3.2.

Table 3.2. Method employed for the analyses of plant samples

Sl. No.	Nutrient	Digestion procedure	Methods of Extraction	References
1.	N	H_2SO_4 digestion	Distillation and titration	Jackson (1973)
2.	P	9:4 HNO_3-$HClO_4$ diacid digestion	Vanado molybdate yellow colour method using spectrophotometer	Jackson (1973)
3.	K	9:4 HNO_3-$HClO_4$ diacid digestion	Direct reading using flame photometer	Jackson (1973)

3.6.3.1. ***Plant uptake of major nutrients***

Uptake of major nutrients by sample plants was 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 per hectare.

3.6.4. **Microbial Population in the Soil**

Enumeration of the microorganisms in the soil was carried out during pre-planting, active growth stage and after harvest, at the Dept. of Agricultural Microbiology, by Serial Dilution Plate Technique (Johnson and Curl, 1972), using different media as detailed in Table 3.3

Table 3.3. Media used for enumeration of soil micro organisms

Sl. No.	Microbes	Dilution for plating	Medium	Reference
1.	Bacteria	10^{-6}	Nutrient Agar	Rao, 1986
2.	Fungus	10^{-3}	Martin's Rose Bengal Agar	Martin, 1950
3.	Actinomycetes	10^{-5}	Kenknight & Munaier's medium	Rao, 1986

Quantitative estimation of total microbial population

Ten grams of soil sample was added to 90 ml sterile distilled water in 250 ml conical flasks and shaken for 30 minutes in an orbital shaker (This gives 10^{-2} dilution). 1 ml of this solution of 10^{-2} dilution was then transferred to a test tube containing 9 ml sterile distilled water to obtain 10^{-3} dilution. Likewise, solutions of 10^{-4}, 10^{-5} and 10^{-6} dilution were prepared from this, by serial dilution.

3.6.4.1. ***Estimation of fungal population***

One ml of 10^{-3} dilution was pipetted into a sterile petridish using a micro pipette. Twenty ml of melted and cooled Martins Rose Bengal Streptomycin agar medium (selective medium for fungi) was poured into the petridish and was swirled (pour plate method).

Three petridishes were kept as replicates for each sample. These were then incubated at room temperature for 3 days. The fungal colonies developed at the end of three days were counted and expressed as CFU g^{-1} of suspension.

3.6.4.2. ***Estimation of bacterial population***

Bacterial population was estimated using 10^{-6} dilution. The method employed for the estimation of fungal population was followed for estimation of bacterial population as well. The dishes were incubated for 48 hours at room temperature. The bacterial colonies developed were counted and expressed as CFU g^{-1} of suspension.

3.6.4.3. ***Estimation of actinomycete population***

The population of actinomycetes was estimated using 10^{-5} dilution of the sample, using Kenknights agar medium (selective medium for actinomycetes). The same method employed for estimation of fungal population was followed here as well. The dishes were incubated at room temperature for a week and the actinomycete colonies were counted and expressed as CFU g^{-1} of suspension.

3.7. EXPERIMENT II- Refinement in post harvest handling techniques in kacholam

Harvested rhizomes from all treatments were pooled together and samples were taken from the pooled weight by quartering method to get composite sample. Rhizomes were sliced into thin circular pieces and subjected to drying treatments as indicated below:

The experiment was laid out in a Completely Randomised Design (CRD) with three replications of 250g each, for all the treatments (Plate 2).

3.7.1. **Treatments**

T_1- Sun Drying

Two hundred and fifty grams of sample was dried under sun with five replications till a constant weight for two consecutive days was recorded. Temperature during drying ranged between 28-34º C.

T_2- Shade Drying

Samples were dried in open condition inside a room, till they attained a constant weight for two consecutive days. Temperature within the room ranged between 21-31º C. Two hundred and fifty grams of sample in five replications was used for the study.

T_3- Mechanical Drying

A cabinet drier was used for drying. Temperature was maintained at 50ºC.

3.8. OBSERVATIONS

Observations on physical and chemical characteristics of the dried samples were noted.

3.8.1. **Recovery Percentage**

Recovery of dried samples was calculated on initial weight basis as suggested by Srivastava and Tandon (1968) and expressed in percentage.

$$\text{Recovery percentage} = \frac{\text{Final weight}}{\text{Initial weight}} \times 100$$

(i)

(ii)

(iii)

Plate 2. Methods of drying of crude drug samples

i) Mechanical drying ii) Shade drying iii) Sun drying

3.8.2. **Qualitative Analysis**

Estimation of essential oil and oleoresin contents in the different dried samples of various treatments were carried out as indicated below:

3.8.2.1. ***Essential oil***

Essential oil content in the composite sample obtained through various drying treatments was analysed as detailed in 3.6.1.9.

3.8.2.2. ***Oleoresin***

Oleoresin content in the composite sample obtained through various drying treatments was analysed as explained in 3.6.1.10

3.9. STORAGE OF DRIED SAMPLES

Samples from the drying method rated as best, based on the content of qualitative constituents, was pooled together and used for the storage study, employing the following treatments (Plate 3).

The experiment was conducted in a Completely Randomised Design with three replications of 250 g sample for each treatment.

3.9.1. **Treatments**

T_1- Dried samples stored in open (control)

T_2- Dried rhizomes stored in gunny bags

T_3- Dried rhizomes stored in gunny bags with neem leaves

T_4- Dried rhizomes stored in 250 gauge polyethylene bags

T_5- Dried rhizomes stored in Polyethyleneterephthalate (PET) bottles

(i)

(ii)

(iii)

(iv)

(v)

Plate 3. Methods of storage of crude drug samples

i) Open storage
ii) Storage in polyethyleneterephthalate (PET) bottles
iii) Storage in polyethylene covers
iv) Storage in gunny bag
v) Storage in gunny bags with neem leaves

3.10. OBSERVATIONS

Observations were recorded at bimonthly intervals for a period of six months.

3.10.1. **Percentage Loss in Weight**

The loss of weight of various stored samples were noted at bimonthly intervals and expressed as percentage of the initial weight.

3.10.2. **Residual Moisture Content**

Ten grams from each of the stored samples were kept in an oven and dried at 70 ± 2° C. Difference in the weight of the sample before and after drying was noted.

3.10.3. **Qualitative Analysis**

Samples were drawn from each treatment and analysed for the qualitative constituents.

3.10.3.1. ***Essential oil content in rhizomes***

Essential oil content in rhizomes was observed at bimonthly intervals for a period of six months as stated in 3.6.1.9.

3.10.3.2. ***Oleoresin content in rhizomes***

Oleoresin content in rhizomes was observed at bimonthly intervals for a period of six months as indicated in 3.6.1.10.

3.10.4. **Percentage of Insect Infestation in Stored Samples**

Infestation of the stored samples with insects was observed at different stages of storage.

3.10.5. **Microbial Load in Stored Samples**

One gram of sample was powdered and sieved through 2 mm sieve for the estimation of total microbial load. Quantitative assay of microflora was carried out by serial dilution plate technique (Johnson and Curl, 1972) as detailed in Table 3.

3.11. STATISTICAL ANALYSES

Data were statistically analysed using the MSTAT.C package. Treatment means were compared using DMRT (Freed, 1986).

Results

4. **RESULTS**

The present study was conducted at the Dept. of Plantation Crops and Spices, College of Horticulture, Vellanikkara, Thrissur during 2009-2011 with the objective of standardizing Good Agricultural Practices (GAP) in kacholam for yield and quality attributes and refinement of post harvest handling practices. The results of the study are presented in this chapter.

4.1. EXPERIMENT I- INFLUENCE OF ORGANIC MANURES, BIOFERTILIZERS AND MULCHES ON GROWTH, YIELD AND QUALITY OF KACHOLAM

4.1.1. **Growth Parameters**

Data on biometric characters of the experimental kacholam variety Kasthuri viz., germination percentage, earliness in germination, number of leaves and foliage spread in both directions, N-S and E-W, are presented in Tables 4.1 to 4.4

4.1.1.1. ***Germination percentage***

Results of the experiment, with respect to germination percentage of the experimental plants are presented in Table 4.1. The treatments showed no significant difference with respect to germination percentage of rhizomes. However, among the various treatments, the highest mean value of 98.61 per cent was recorded by the treatment T_3 (FYM + *Kalanchoe pinnata*), and all treatments were on par with one another. Least germination was observed in T_{10} (93.75 %). Control plots receiving inorganic fertilizers registered a germination percentage of 97.91, on par with the treatment registering the highest germination percentage (T_3).

4.1.1.2. ***Earliness in germination***

Number of days taken for germination of rhizomes in each treatment was counted and their mean was calculated as shown in Table 4.1. The treatment T_2

Table 4.1. Effect of organic manures, biofertilizers and mulches on earliness in germination and germination percentage of kacholam

Treatments	2nd week	3rd week	4th week	5th week	Germination %
T_1	2.00	20.00	39.67	45.00	95.83
T_2	1.67	22.33	40.00	46.00	97.91
T_3	1.67	15.00	41.00	46.00	98.61
T_4	1.00	12.33	36.00	44.33	96.52
T_5	3.00	15.67	38.67	44.33	94.44
T_6	0.33	16.00	42.00	45.67	95.83
T_7	0.33	16.00	37.00	45.67	95.14
T_8	0	12.67	36.33	45.33	95.13
T_9	1.33	19.00	41.00	45.67	95.83
T_{10}	1.00	18.67	39.00	43.33	93.75
T_{11}	0.66	20.67	40.33	45.33	97.91
Significance					NS

Treatment means with similar alphabets in superscript, do not differ significantly

T1-FYM , T2-FYM + COB, T3- FYM + *Kalanchoe pinnata*, T4- FYM + COB + *Kalanchoe pinnata*,T5-FYM + COB + *Kalanchoe pinnata* + *Chromolaena odorata*,

T6- Vermicompost, T7- Vermicompost + COB, T8- Vermicompost + *Kalanchoe pinnata*

T9- Vermicompost + COB + *Kalanchoe pinnata*

T10- vermicompost + COB + *Kalanchoe pinnata* + *Chromolaena odorata*

T11- POP recommendations of KAU

(FYM + biofertilizers) commenced germination in the first week after planting. In the second week after planting, the treatment T_5 recorded the maximum germination percentage of 3 followed by T_2 and T_3, each recording a germination count of 1.67. During the same period, plants receiving the treatment T_8, did not commence germination at all. In the third week after planting, treatment T_2, recorded the maximum germination count of 22.33 out of 48 plants, followed by T_{11} (20.67) and T_{10} (18.67). Treatment T_4 recorded the least germination count of 12.33. One month after planting, treatment T_6 and T_4 recorded the maximum and minimum germination count of 42 and 36 respectively. Among all the treatments, T_{10} recorded the maximum days for germination. Control plots receiving inorganic fertilizers registered a germination count of 40.33 at one month after planting.

4.1.1.3. ***Number of leaves***

Data regarding the number of leaves as influenced by different organic manures, biofertilizers and mulches at various stages of growth are presented in Table 2. Significant differences in leaf number among the various treatments were not observed upto 4 MAP. At 5 MAP, T_2 (FYM + Biofertilizers) recorded maximum leaf number. The same treatment itself recorded the highest leaf number at 5, 6 and 7 MAP (22.07, 30.66 and 30.98 respectively), Plate 4. Other treatments, including the treatment receiving inorganic fertilizers, showed no significant differences among themselves with respect to number of leaves, upto 6 MAP. The lowest mean values of 14.98, 18.32 and 19.03 for number of leaves, was recorded in T_3 (FYM + *Kalanchoe pinnata*) at 5, 6 and 7 MAP respectively.

4.1.1.4. ***Foliage spread***

Significant variation was recorded among treatments, with respect to foliage spread at various phases of crop growth, as indicated in Tables 4.3 and 4.4.

4.4.Foliage Spread N-S

Foliage spread in the N-S direction showed significant differences among the various treatments at 2 MAP, 4 MAP and 6 MAP. At 2 MAP, the highest

Plate.4. Vegetative growth of plants applied with FYM and biofertilizers

Table 4.2. Effect of organic manures, biofertilizers and mulches on leaf number of kacholam

Treatments	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
T_1	7.74	10.72	13.79	17.05^{a}	21.39^{ab}	22.84^{ab}
T_2	8.60	11.14	15.69	22.07^{a}	30.67^{a}	30.98^{a}
T_3	8.94	10.51	12.57	14.98^{b}	18.32^{ab}	19.03^{b}
T_4	8.61	9.34	12.44	16.48^{ab}	21.94^{ab}	22.50^{ab}
T_5	7.86	9.93	14.63	17.57^{ab}	23.82^{ab}	24.25^{ab}
T_6	7.47	11.89	14.70	19.06^{ab}	24.76^{ab}	25.56^{ab}
T_7	7.69	9.90	13.79	15.35^{ab}	23.47^{ab}	24.08^{ab}
T_8	7.73	10.67	13.48	17.77^{ab}	23.01^{ab}	23.37^{ab}
T_9	6.72	11.39	13.72	18.12^{ab}	21.76^{ab}	22.36^{ab}
T_{10}	8.83	11.09	14.18	17.30^{ab}	22.04^{ab}	22.81^{ab}
T_{11}	8.44	10.88	13.08	18.52^{ab}	24.58^{ab}	25.65^{ab}
Significance	NS	NS	NS			

Treatment means with similar alphabets in superscript, do not differ significantly

T1-FYM , T2-FYM + COB, T3- FYM + *Kalanchoe pinnata*, T4- FYM + COB + *Kalanchoe pinnata*, T5-FYM + COB + *Kalanchoe pinnata* + *Chromolaena odorata*, T6- Vermicompost

T7- Vermicompost + COB , T8- Vermicompost + *Kalanchoe pinnata*

T9- Vermicompost + COB + *Kalanchoe pinnata*

T10- Vermicompost + COB + *Kalanchoe pinnata* + *Chromolaena odorata*

T11- POP recommendations of KAU

mean value of 23.88 cm was recorded in the control plots (T_{11}), followed by T_{10} (21.33 cm), which were significantly superior to the rest of the treatments. The lowest value of 16.18 cm was noted in T_4. However at 3 and 5 MAP, no significant difference was shown by the different treatment combinations. At 4 MAP, T_{10} recorded the highest mean value of 28.01 cm for foliage spread in N-S direction which was significantly superior to the other treatments. Treatment T_8 recorded the highest mean values of 34.53 cm and 34.8 cm respectively at 6 and 7 MAP. The superiority registered by the control plots with respect to foliage spread in N-S direction at early stages of crop, was not evident at later stages (Table 4.3).

Foliage Spread E-W

Foliage spread of the plants in E-W direction also showed significant differences among the various treatments at early stages of crop growth (Table 4.4).

At 2 MAP, the treatment T_{10} (Vermicompost + Biofertilizers + *Kalanchoe pinnata* + mulching with *Chromolaena odorata*), showed the highest mean value of 19.99 cm which was significantly superior to the rest of the treatments. The lowest value for foliage spread (E-W) was observed for the treatment T_1 (FYM) with a mean value of 16.13 cm at 2 MAP. At 3 MAP, the treatment T_5 (FYM + biofertilizers + *Kalanchoe pinnata* + mulching with *Chromolaena odorata*) recorded the highest mean value of 24.04 which was significantly superior to all,other treatments. The lowest mean value of 19.35 cm was recorded in the case of T_3. The treatment T_8 (Vermicompost + *Kalanchoe pinnata*) recorded the highest mean value of 26.87 cm at 4 MAP. From 5^{th} month after planting, the treatments did not differ significantly. At no stage of crop growth, did the control plots register the highest value for foliage spread in E-W direction (Table 4.4).

4.1.2. **Yield and Yield Related Characters**

Data regarding the various yield related characters of the experimental plants, as observed in the experiment are furnished in Table 4.5.

Table 4.3. Effect of organic manures, biofertilizers and mulches on foliage spread (N-S) of kacholam

Treatments	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
T_1	16.37^{c}	22.81	25.92^{ab}	26.61	34.29^{ab}	34.73
T_2	17.04^{bc}	20.09	25.17^{b}	30.79	33.78^{ab}	34.38
T_3	16.75^{c}	20.17	24.82^{b}	27.58	31.41^{ab}	31.88
T_4	16.18^{c}	21.59	26.09^{ab}	27.31	32.59^{ab}	32.88
T_5	19.79^{abc}	22.33	24.49^{b}	29.47	33.14^{ab}	33.43
T_6	17.76^{bc}	22.31	25.16^{b}	30.59	34.15^{ab}	34.44
T_7	16.73^{c}	20.51	26.56^{ab}	29.27	32.86^{ab}	33.11
T_8	21.24^{ab}	24.26	26.5^{ab}	30.43	34.53^{a}	34.80
T_9	19.45^{abc}	22.84	25.06^{b}	29.05	30.02^{b}	30.37
T_{10}	21.33^{a}	21.33	28.01^{a}	30.02	33.01^{ab}	33.34
T_{11}	23.88^{a}	23.88	26.51^{ab}	29.21	31.19^{ab}	31.57
Significance		NS		NS		NS

Treatment means with similar alphabets in superscript, do not differ significantly

T1-FYM , T2-FYM + COB, T3- FYM + *Kalanchoe pinnata*, T4- FYM + COB + *Kalanchoe pinnata*, T5-FYM + COB + *Kalanchoe pinnata* + *Chromolaena odorata*, T6- Vermicompost

T7- Vermicompost + COB , T8- Vermicompost + *Kalanchoe pinnata*

T9- Vermicompost + COB + *Kalanchoe pinnata*

T10- Vermicompost + COB + *Kalanchoe pinnata* + *Chromolaena odorata*

T11- POP recommendations of KAU

Table 4.4. Effect of organic manures, biofertilizers and mulches on foliage spread (E-W) of kacholam

Treatments	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
T_1	16.13^{c}	20.43^{bc}	25.98^{ab}	30.09	33.39	33.73
T_2	19.00^{abc}	22.50^{abc}	25.69^{ab}	29.27	37.22	37.49
T_3	16.45^{bc}	19.35^{c}	23.74^{b}	27.81	33.24	33.24
T_4	19.46^{ab}	22.42^{abc}	24.75^{ab}	27.10	32.78	32.91
T_5	19.07^{abc}	24.04^{a}	26.33^{a}	28.91	33.84	34.04
T_6	18.93^{abc}	22.14^{abc}	25.29^{ab}	29.74	33.62	33.84
T_7	18.95^{abc}	21.57^{abc}	25.36^{ab}	28.98	34.01	34.21
T_8	19.76^{ab}	23.29^{ab}	26.87^{a}	29.93	33.99	34.23
T_9	17.47^{abc}	20.89^{abc}	25.54^{ab}	30.05	36.04	36.26
T_{10}	19.99^{a}	23.16^{ab}	26.82^{a}	30.55	32.99	36.22
T_{11}	19.07^{abc}	22.96^{ab}	24.93^{ab}	27.64	33.81	34.00
Significance				NS	NS	NS

Treatment means with similar alphabets in superscript, do not differ significantly

T1-FYM , T2-FYM + COB, T3- FYM + *Kalanchoe pinnata*, T4- FYM + COB + *Kalanchoe pinnata*, T5-FYM + COB + *Kalanchoe pinnata* + *Chromolaena odorata*, T6- Vermicompost

T7- Vermicompost + COB , T8- Vermicompost + *Kalanchoe pinnata*,

T9- Vermicompost + COB + *Kalanchoe pinnata*

T10- Vermicompost + COB + *Kalanchoe pinnata* + *Chromolaena odorata*

T11- POP recommendations of KAU

4.1.2.1. ***Fresh rhizome yield per plant***

No significant differences among the various treatments were observed with respect to fresh rhizome yield per plant (Table 4.5). The highest mean fresh rhizome yield per plant was observed in T_2 (80.3 g) followed by T_4 (78.26 g) and T_6 (77.52 g). The lowest value was registered in T_8 (61.85 g).

4.1.2.2. ***Fresh rhizome yield per plot***

Similar trends were noticed with respect to fresh rhizome yield per plot, which recorded no significant difference among the various treatments (Table 4.5). As in the case of fresh rhizome yield per plant, a higher mean value of 2.98 kg of fresh rhizome yield per plot was noted in T_2 (FYM + biofertilizers) followed by T_4 (FYM + biofertilizers + *Kalanchoe pinnata*) with 2.62 kg per plot. Lowest yield was recorded in T_{10} (2.16 kg) followed by the control plot, recording 2.22 kg fresh rhizomes per plot.

4.1.2.3***. Driage***

Analysis of data on driage showed significant differences among the various treatments (Table 4.5). Highest value for driage was noted in the treatment T_3 (36.4 %), followed by T_9 (34.83 %) and T_4 (34.36 %), the values of which were significantly superior. The lowest values for driage were observed in the control plot, T_{11} (31.42 %) and T_8 (31.51 %).

4.1.2.4. ***Dry yield per hectare***

Data on yield per hectare did not exhibit any significant difference among the various treatments. Highest dry yield of 3.19 t ha^{-1} was noted in the treatment T_2 followed by T_4 (2.99 t ha^{-1}). Dry yield was least in plots receiving inorganic fertilizers, (2.37 t ha^{-1}) followed by T_{10} and T_8, both recording 2.40 t ha^{-1}.

4.1.3 **Quality Attributes**

Data regarding quality attributes viz., contents of essential oil and oleoresin of *Kaempferia galanga* L. var. Kasthuri are presented in Table 4.6.

Table 4.5. Effect of organic manures, biofertlizers and mulches on yield and yield related characters of kacholam

Treatments	Fresh weight (g)	Yield plot^{-1} (kg)	Yield ha^{-1} (t ha^{-1})	Driage (%)	Dry yield (t ha^{-1})
T_1	61.94	2.51	8.35	34.20^{a}	2.86
T_2	80.30	2.98	9.93	32.10^{ab}	3.19
T_3	71.93	2.24	7.48	36.40^{a}	2.72
T_4	78.26	2.62	8.72	34.36^{a}	2.99
T_5	71.56	2.46	8.21	31.96^{b}	2.62
T_6	77.52	2.53	8.44	33.54^{ab}	2.83
T_7	70.88	2.53	8.43	32.16^{ab}	2.71
T_8	61.85	2.29	7.63	31.51^{b}	2.40
T_9	63.37	2.26	7.53	34.83^{a}	2.62
T_{10}	66.22	2.16	7.19	33.40^{ab}	2.40
T_{11}	69.10	2.22	7.39	31.42^{b}	2.37
Significance	NS	NS	NS		NS

Treatment means with similar alphabets in superscript, do not differ significantly

T1-FYM , T2-FYM + COB, T3- FYM + *Kalanchoe pinnata*, T4- FYM + COB + *Kalanchoe pinnata*, T5-FYM + COB + *Kalanchoe pinnata* + *Chromolaena odorata*, T6- Vermicompost

T7- Vermicompost + COB , T8- Vermicompost + *Kalanchoe pinnata*

T9- Vermicompost + COB + *Kalanchoe pinnata*

T10- Vermicompost + COB + *Kalanchoe pinnata* + *Chromolaena odorata*

T11- POP recommendations of KAU

4.1.3.1. ***Essential oil***

Data on essential oil content in experimental samples showed significant differences among the various treatments (Table 4.6). The treatment T_3 which recorded the highest mean value of 1.47 per cent differed significantly from the rest of the treatments. The lowest essential oil content was noted in T_{11} (0.87%), the control plot receiving inorganic fertilizers.

4.1.3.2. ***Oleoresin***

As in the case of essential oil, the oleoresin content among the various treatments also exhibited significant differences among one another (Table 4.6). Maximum oleoresin content was noted in the treatment T_4 (3.42 %) which was significantly superior to all other treatments, followed by T_8 (3.26 %). The treatment T_6 recorded the lowest oleoresin content (1.91 %).

4.1.4. **Percentage of Bacterial Wilt Incidence**

Incidence of bacterial wilt disease was observed from 3 MAP onwards. Data regarding the percentage incidence of disease are presented in Table 4.7. At 3 MAP, experimental plants manifested disease symptoms in all treatments as confirmed by ooze test. The treatment T_1 receiving FYM alone, recorded the highest percentage of incidence (10.87 %) followed by T_3 (8.45 %) and T_7 (8.04 %). The lowest incidence was noted in the control plots (2.13%). At 4 and 5 MAP, slight decrease in disease incidence, possibly due to drenching with *Pseudomonas fluorescens,* was noted. Highest incidence was noted in T_9 (3.63%) at 4 MAP and in T_3 (2.1%) at 5 MAP, while treatments T_1 and T_6 at 4 MAP and T_1, T_2, T_4, T_5, T_6 and T_7 at 5 MAP, recorded nil incidence of disease.

4.1.5. **Assessment of Soil Nutrient Status**

Analyses of soil samples taken from the experimental field were done before and after the experiment as detailed in 3.6.2. Data regarding the same are presented in Table 4. 8.

Table 4.6. Effect of organic manures, biofertilizers and mulches on quality attributes of kacholam

Treatments	Essential oil (%)	Oleoresin (%)
T_1	1.03^{ab}	2.08^{ab}
T_2	1.23^{ab}	2.68^{ab}
T_3	1.47^{a}	2.79^{ab}
T_4	1.07^{ab}	3.42^{a}
T_5	1.20^{ab}	3.13^{ab}
T_6	0.90^{b}	1.91^{b}
T_7	1.03^{ab}	2.97^{ab}
T_8	1.00^{b}	3.26^{ab}
T_9	1.03^{ab}	2.01^{ab}
T_{10}	1.10^{ab}	2.80^{ab}
T_{11}	0.87^{b}	3.12^{ab}

Treatment means with similar alphabets in superscript, do not differ significantly

T1-FYM , T2-FYM + COB, T3- FYM + *Kalanchoe pinnata*, T4- FYM + COB + *Kalanchoe pinnata*, T5-FYM + COB + *Kalanchoe pinnata* + *Chromolaena odorata*, T6- Vermicompost

T7- Vermicompost + COB , T8- Vermicompost + *Kalanchoe pinnata*

T9- Vermicompost + COB + *Kalanchoe pinnata*

T10- Vermicompost + COB + *Kalanchoe pinnata* + *Chromolaena odorata*

T11- POP recommendations of KAU

Table 4.7. Incidence of bacterial wilt in kacholam as influenced by organic manures, biofertilizers and mulches

Treatment	3 MAP (%)	4 MAP (%)	5 MAP (%)
T_1	10.87	0	0
T_2	7.81	0.70	0
T_3	8.45	0.70	2.10
T_4	5.03	0.71	0
T_5	5.89	1.46	0
T_6	5.80	0	0
T_7	8.04	0.72	0
T_8	3.66	0	0.72
T_9	4.35	3.63	0.72
T_{10}	2.96	0.73	0.73
T_{11}	2.13	0.70	0.70

T1-FYM , T2-FYM + COB, T3- FYM + *Kalanchoe pinnata*, T4- FYM + COB + *Kalanchoe pinnata*, T5-FYM + COB + *Kalanchoe pinnata* + *Chromolaena odorata*, T6- Vermicompost

T7- Vermicompost + COB , T8- Vermicompost + *Kalanchoe pinnata*

T9- Vermicompost + COB + *Kalanchoe pinnata*

T10- Vermicompost + COB + *Kalanchoe pinnata* + *Chromolaena odorata*

T11- POP recommendations of KAU

4.1.4.1. ***Organic carbon***

Significant variations existed among the various treatments with regard to the organic carbon content (Table 4.8). Before the commencement of the experiment, the soil in the experimental fields recorded an organic carbon content of 0.71 per cent. After the experiment, the highest value was recorded for T_6 (1.09 %) and the least value for T_3 (0.73 %).

4.1.4.2. ***Available nitrogen***

Analysis of soil for available nitrogen also showed significant variations among the various treatments (Table 4.8). At the pre planting stage, content of available nitrogen was 348 kg per hectare. After the experiment, the highest value was recorded in T_5 (503.8 kg ha^{-1}) which was significantly superior to all other treatments. The lowest value was recorded in T_8 (350.2 kg ha^{-1}). Control plots registered an available nitrogen content of 423.4 kg ha^{-1}, which was significantly inferior to T_5.

4.1.4.3. ***Available phosphorus***

Regarding available phosphorus content in the soil, the initial value recorded was 43 kg ha^{-1}. Estimation of available P content in the soil after the experiment, revealed significant differences among the treatments (Table 4.8). The highest value was recorded in the treatment T_3 (92.48 kg ha^{-1}) and the least in T_6 (45 kg ha^{-1}). P content in the control plot was 71.74 kg ha^{-1}. In general, enriched vermicompost based treatments (T_7, T_8, T_9 and T_{10}) as well as vermicompost applied singly (T_6), based treatments registered lower available P content in soil (Table 4.8).

4.1.4.4. ***Available potassium***

No significant difference was noted among the various treatments with regard to the available potassium present in the soil (Table 4.8). However, the highest value was recorded by the treatment T_8 (258.82 kg ha^{-1}) and the least by

Table 4.8. Content of major nutrients in soil as influenced by organic manures, biofertilizers and mulches

Treatments	Organic Carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	0.90^{abc}	454.20^{ab}	73.32^{ab}	219.15
T_2	0.80^{bc}	423.10^{ab}	72.47^{abc}	257.07
T_3	0.73^{c}	354.90^{b}	92.48^{a}	178.86
T_4	0.82^{bc}	352.80^{b}	91.13^{a}	212.44
T_5	0.97^{ab}	503.80^{a}	55.51^{bc}	252.43
T_6	1.09^{a}	434.70^{ab}	45.00^{c}	213.08
T_7	0.87^{abc}	422.50^{ab}	55.02^{bc}	253.73
T_8	0.85^{bc}	350.20^{b}	48.31^{bc}	258.82
T_9	0.86^{bc}	422.70^{ab}	59.29^{bc}	200.74
T_{10}	0.82^{bc}	439.50^{ab}	50.02^{bc}	257.24
T_{11}	0.99^{ab}	423.40^{ab}	71.74^{abc}	165.54
Significance				NS

Treatment means with similar alphabets in superscript, do not differ significantly

T1-FYM , T2-FYM + COB, T3- FYM + *Kalanchoe pinnata*, T4- FYM + COB + *Kalanchoe pinnata*, T5-FYM + COB + *Kalanchoe pinnata* + *Chromolaena odorata*, T6- Vermicompost

T7- Vermicompost + COB , T8- Vermicompost + *Kalanchoe pinnata*

T9- Vermicompost + COB + *Kalanchoe pinnata*

T10- Vermicompost + COB + *Kalanchoe pinnata* + *Chromolaena odorata*

T11- POP recommendations of KAU

T_{11} (165.5 kg ha^{-1}).Initial value of K recorded in the experimental plot was 160.82 kg ha^{-1}.

4.1.5. **Assessment of Content of Major Nutrients in Plant Samples**

Nutrient analyses of leaves as well as rhizomes, were done at the active rhizome formation stage and after harvest respectively. Data regarding the nutrient contents of leaves as well as rhizomes are presented in Table 4.9, 4.10 and 4.11.

4.1.5.1. ***Analysis of leaves for major nutrients***

Analysis of nitrogen and potassium content in the leaf as indicated in Table 4.9 showed significant differences in leaf N and K content among the treatments, whereas, the treatments were on par with one another in the case of phosphorus content. Highest nitrogen percentage was observed in the treatment T_2 (3.15 %) followed by T_6, T_7 and T_{11}, each treatment recording 2.90 per cent leaf nitrogen. Lowest value was observed in T_3 (2.06 %). Data on phosphorus content in leaves showed the highest value in T_4 (0.34 %) followed by T_8 (0.30 %) and T_{10} (0.28 %). T_2 (0.18 %) recorded the lowest phosphorus content followed by the control plot, T_{11} (0.21 %). Analysis of leaf potassium content recorded significant differences among treatments, with values significantly superior in T_8 (7.30 %), followed by T_9 (6.77 %) and T_{10} (6.71 %).

4.1.5.2. ***Analysis of rhizomes for major nutrients***

Significant differences were observed among various treatments with respect to nitrogen and phosphorus contents in rhizomes. Regarding potassium content, all the treatments were on par with one another (Table 4.10). Nitrogen content in rhizomes recorded the highest value in T_{10} (1.75 %) which was significantly superior to all other treatments. Plots receiving inorganic fertilizers recorded a rhizome nitrogen content of 1.68 per cent which was inferior only to T_{10}. The lowest values were observed in T_8 (1.12 %) and T_4 (1.19 %). Treatment T_6 (0.24 %) recorded the highest values for phosphorus content followed by T_2

Table 4.9. Major nutrient content in leaves as influenced by organic manures, biofertilizers and mulches

Treatments	Leaf N_2 (%)	Leaf P (%)	Leaf K (%)
T_1	2.71^{ab}	0.27	5.859^{abc}
T_2	3.15^{a}	0.18	6.06^{abc}
T_3	2.06^{b}	0.22	5.03^{c}
T_4	2.41^{ab}	0.34	6.49^{abc}
T_5	2.66^{ab}	0.27	5.78^{abc}
T_6	2.90^{ab}	0.24	6.50^{abc}
T_7	2.90^{ab}	0.25	6.14^{abc}
T_8	2.66^{ab}	0.30	7.30^{a}
T_9	2.8^{ab}	0.22	6.77^{ab}
T_{10}	2.31^{ab}	0.28	6.71^{ab}
T_{11}	2.90^{ab}	0.21	5.51^{bc}
Significance		NS	

Treatment means with similar alphabets in superscript, do not differ significantly

T1-FYM , T2-FYM + COB, T3- FYM + *Kalanchoe pinnata,* T4- FYM + COB + *Kalanchoe pinnata*, T5-FYM + COB + *Kalanchoe pinnata* + *Chromolaena odorata,*

T6- Vermicompost T7- Vermicompost + COB , T8- Vermicompost + *Kalanchoe pinnata,*

T9- Vermicompost + COB + *Kalanchoe pinnata*

T10- Vermicompost + COB + *Kalanchoe pinnata* + *Chromolaena odorata*

T11- POP recommendations of KAU

Table 4.10. Major nutrient content in rhizomes as influenced by organic manures, biofertilizers and mulches

Treatments	Rhizome N (%)	Rhizome P (%)	Rhizome K (%)
T_1	1.47^{abc}	0.09^{abc}	1.45
T_2	1.36^{cd}	0.21^{ab}	1.45
T_3	1.33^{cd}	0.19^{ab}	1.43
T_4	1.19^{cd}	0.18^{abc}	1.57
T_5	1.4^{cd}	0.04^{c}	1.29
T_6	1.47^{abc}	0.24^{a}	1.58
T_7	1.26^{cd}	0.21^{ab}	1.50
T_8	1.12^{d}	0.15^{abc}	1.49
T_9	1.21^{cd}	0.17^{abc}	1.24
T_{10}	1.75^{a}	0.08^{bc}	1.31
T_{11}	1.68^{ab}	0.11^{abc}	1.36
Significance			NS

Treatment means with similar alphabets in superscript, do not differ significantly

T1-FYM , T2-FYM + COB, T3- FYM + *Kalanchoe pinnata*, T4- FYM + COB + *Kalanchoe pinnata*, T5-FYM + COB + *Kalanchoe pinnata* + *Chromolaena odorata*, T6- Vermicompost

T7- Vermicompost + COB , T8- Vermicompost + *Kalanchoe pinnata*

T9- Vermicompost + COB + *Kalanchoe pinnata*

T10- Vermicompost + COB + *Kalanchoe pinnata* + *Chromolaena odorata*

T11- POP recommendations of KAU

(0.21 %) which was on par with the treatments T_7 (0.21 %), and T_3 (0.19 %). Lowest phosphorus content was noted in T_5 (0.04 %). Though the treatment effects were not significant with respect to potassium content, T_6 recorded the highest value of 1.58 per cent followed by T_4 (1.57 %), T_7 (1.5 %) and T_8 (1.49 %). Lowest value was shown by the treatment T_9 (1.24 %). Control plot recorded a rhizome K content of 1.36 per cent.

4.1.6. **Assessment of Plant Uptake of Major Nutrients**

Total plant nutrient uptake values in various treatments calculated as detailed in 3.6.3 are presented in Table 4.11.

Nitrogen and potassium uptakes showed significant differences among treatments (Table 4.11). Uptake of phosphorus recorded values on par with one another. Treatment T_6 recorded the highest values for N (82.45 kg ha^{-1}), P (10.86 kg ha^{-1}) and K (127.14 kg ha^{-1}) uptakes. N uptake of T_2 (81.87 kg ha^{-1}) was on par with T_6, the most superior treatment. Uptake was least in T_3 (53.35 kg ha^{-1}). Regarding the P uptake, the lowest value was noted in T_5 (4.14 kg ha^{-1}). Treatment T_2 recorded a K uptake of 119.04 kg ha^{-1}, which was on par with the best treatment T_6. Least uptake was recorded in T_3 (83.39 kg ha^{-1}).

4.1.7. **Correlation between Yield, Quality Parameters, Soil Nutrient Status and Plant Uptake of Nutrients**

Data presented in correlation Table (4.12) revealed that uptake of all major nutrients are positively correlated with one another. Fresh and dry rhizome yields are positively correlated with N, P and K uptakes. Soil phosphorus is negatively correlated with leaf potassium, which is negatively related with oil yield. Rhizome nitrogen is negatively related with rhizome phosphorus.

4.1.8. **Enumeration of Soil Microbial Population**

Data regarding enumeration of microbial population in soil, done at three stages viz., pre-planting, 5 MAP and at the end of the experiment, are presented in Tables 4.13, 4.14 and 4.15.

Table 4.11. Plant uptake of major nutrients in kacholam as influenced by organic manures, biofertilizers and mulches

Treatments	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})
T_1	69.22^{ab}	5.53	100.16^{abc}
T_2	81.87^{a}	8.76	119.04^{a}
T_3	53.35^{b}	7.68	83.39^{c}
T_4	59.98^{ab}	7.96	109.19^{abc}
T_5	66.54^{ab}	4.14	98.39^{abc}
T_6	82.45^{a}	10.86	127.14^{a}
T_7	67.68^{ab}	8.90	111.60^{abc}
T_8	56.07^{ab}	7.57	116.26^{ab}
T_9	59.27^{ab}	6.52	100.69^{abc}
T_{10}	70.99^{ab}	5.41	109.38^{abc}
T_{11}	68.58^{ab}	5.15	86.59^{bc}
Significance		NS	

Treatment means with similar alphabets in superscript, do not differ significantly

T1-FYM , T2-FYM + COB, T3- FYM + *Kalanchoe pinnata,* T4- FYM + COB + *Kalanchoe pinnata*, T5-FYM + COB + *Kalanchoe pinnata* + *Chromolaena odorata,* T6- Vermicompost

T7- Vermicompost + COB , T8- Vermicompost + *Kalanchoe pinnata*

T9- Vermicompost + COB + *Kalanchoe pinnata*

T10- Vermicompost + COB + *Kalanchoe pinnata* + *Chromolaena odorata*

T11- POP recommendations of KAU

Table 4.12. Correlation between yield, quality, soil nutrient status and content and plant uptake of major nutrients in kacholam

	FY	RP	RK	LK	N uptake	P uptake	K uptake
Oil				-.415*			-.382*
DY	.910**				.759**	.663**	.651**
SP				-.418*			
LN					.396*		
LP						.456**	
LK			.398*				.626**
RN		-.498**			.416*	-.390*	
RP						.843**	
RK							.671**
N uptake	.766**					.376*	.470**
P uptake	.567**						.533**
K uptake	.525**						

FY- Fresh Yield, DY- Dry Yield, Sp- Soil phosphorus, LN- Leaf nitrogen, LP- Leaf Phosphorus, LK- Leaf Potassium, RN- Rhizome nitrogen, RP- Rhizome Phosphorus, RK- Rhizome Potassium, N uptake- Nitrogen Uptake, P Uptake- Phosphorus Uptake, K Uptake- Potassium uptake

Before the commencement of the experiment, the microbial population in the soil registered lower values. The population of bacteria, fungi and actinomycetes were 15.73 x 10^6 cfu g^{-1}, 18.57 x 10^3 cfu g^{-1} and 9.3 x 10^5 cfu g^{-1} respectively.

Significant differences in the bacterial population were observed among the various treatments (Table 4.13). During the course of the experiment, at 4 MAP, the treatment T_2 recorded the highest value of 45.33 x 10^6 cfu g^{-1} which was on par with T_8 and T_1 which recorded a population of 44.67 x 10^6 cfu g^{-1} and 36.67 x 10^6 cfu g^{-1} respectively. The population was lowest in T_9 (15.67 x 10^6 cfu g^{-1}). After the experiment, T_1 recorded the highest population (38.67 x 10^6 cfu g^{-1}) which was significantly superior to the rest of the treatments. The lowest population was noted in T_{11} (7.67 x 10^6 cfu g^{-1}).

Data on fungal population also showed significant differences among the various treatments during the course of the experiment, (4 MAP) which is presented in table 4.14. Treatment T_6 recorded the highest fungal population of 51 x 10^3 cfu g^{-1} followed by T_7 (39.33 x 10^3 cfu g^{-1}). The least value was noted in T_4 (19.67 x 10^3 cfu g^{-1}).

No significant difference was observed among the various treatments with regard to the fungal population in the soil after the experiment. However, the highest value was noted in T_1 (27.67 x 10^3 cfu g^{-1}) followed by T_6 (24.33 x 10^3 cfu g^{-1}). The lowest value was noted in T_9 (13.33 x 10^3 cfu g^{-1}).

Regarding actinomycetes population in the soil, significant differences were observed among the treatments as well (Table 4.15). The maximum population of 27 x 10^5 cfu g^{-1} was noted in T_{10} followed by T_8 (24.33 x 10^5), T_6 (23.67 x 10^5) and T_4 (21.67 x 10^5), all values being on par with another and superior to the rest of the treatments. The lowest population of 10.33 x 10^5 cfu g^{-1} was noted in T_1.

After the experiment also, the population of actinomycetes differed significantly. T_1 recorded the lowest population of 7 x 10^5 cfu g^{-1}. The mean value Table 4.13.

Bacterial population in the soil at 5 MAP and at the end of the experiment as influenced by organic manures, biofertilizers and mulches

Treatments	During the course (x 10^6 cfu g^{-1})	End of experiment (x 10^6 cfu g^{-1})
T_1	36.67^{ab}	38.67^{a}
T_2	45.33^{a}	34.33^{ab}
T_3	24.67^{cd}	24.67^{bc}
T_4	28.42^{bc}	10.33^{ef}
T_5	25.33^{cd}	15.00^{cdef}
T_6	18.00^{cd}	23.33^{c}
T_7	27.33^{bc}	21.33^{cd}
T_8	44.67^{a}	11.67^{def}
T_9	15.67^{d}	17.00^{cdef}
T_{10}	18.33^{cd}	20.00^{cde}
T_{11}	19.33^{cd}	7.67^{f}

Treatment means with similar alphabets in superscript, do not differ significantly

T1-FYM , T2-FYM + COB, T3- FYM + *Kalanchoe pinnata*, T4- FYM + COB + *Kalanchoe pinnata*, T5-FYM + COB + *Kalanchoe pinnata* + *Chromolaena odorata*, T6- Vermicompost

T7- Vermicompost + COB , T8- Vermicompost + *Kalanchoe pinnata*

T9- Vermicompost + COB + *Kalanchoe pinnata*

T10- Vermicompost + COB + *Kalanchoe pinnata* + *Chromolaena odorata*

T11- POP recommendations of KAU

Table 4.14. Fungal population in soil at 5 MAP and at the end of the experiment as influenced by organic manures, biofertilizers and mulches

Treatments	During the course ($x\ 10^3$ cfu g^{-1})	End of experiment ($x\ 10^3$cfu g^{-1})
T_1	34.67^{bc}	27.67^{a}
T_2	32.33^{bcd}	16.67^{a}
T_3	35.00^{bc}	18.00^{a}
T_4	19.67^{d}	19.00^{a}
T_5	21.00^{cd}	16.67^{a}
T_6	51.00^{a}	24.33^{a}
T_7	39.33^{ab}	17.00^{a}
T_8	27.00^{bcd}	13.67^{a}
T_9	21.00^{cd}	13.33^{a}
T_{10}	32.67^{bcd}	17.33^{a}
T_{11}	21.33^{cd}	7.67^{a}

Treatment means having similar alphabets in superscript, do not differ significantly

T1-FYM , T2-FYM + COB, T3- FYM + *Kalanchoe pinnata*, T4- FYM + COB + *Kalanchoe pinnata*, T5-FYM + COB + *Kalanchoe pinnata* + *Chromolaena odorata*, T6- Vermicompost

T7- Vermicompost + COB , T8- Vermicompost + *Kalanchoe pinnata*

T9- Vermicompost + COB + *Kalanchoe pinnata*

T10- Vermicompost + COB + *Kalanchoe pinnata* + *Chromolaena odorata*

T11- POP recommendations of KAU

Table 4.15. Actinomycetes population in soil during the course and at the end of the experiment as influenced by organic manures, biofertilizers and mulches

Treatments	During the course ($x\ 10^5$ cfu g^{-1})	End of experiment ($x\ 10^5$ cfu g^{-1})
T1	10.33^{b}	7.00^{b}
T2	18.67^{ab}	16.67^{ab}
T3	10.67^{b}	11.00^{ab}
T4	21.67^{a}	17.67^{ab}
T5	17.33^{ab}	14.33^{ab}
T6	23.67^{a}	19.00^{a}
T7	12.89^{b}	12.13^{ab}
T8	24.33^{a}	17.00^{ab}
T9	$17.33a^{b}$	7.67^{ab}
T10	27.00^{a}	10.67^{ab}
T11	18.00^{ab}	10.67^{ab}

Treatment means having similar alphabets in superscript, do not differ significantly

T1- FYM , T2-FYM + COB, T3- FYM + *Kalanchoe pinnata*, T4- FYM + COB + *Kalanchoe pinnata*, T5-FYM + COB + *Kalanchoe pinnata* + *Chromolaena odorata*, T6- Vermicompost

T7- Vermicompost + COB , T8- Vermicompost + *Kalanchoe pinnata*

T9- Vermicompost + COB + *Kalanchoe pinnata*

T10- Vermicompost + COB + *Kalanchoe pinnata* + *Chromolaena odorata*

T11- POP recommendations of KAU

was highest in the treatment T_6 (19 x 10^5 cfu g^{-1}) followed by T_4 (17.67 x 10^5 cfu g^{-1}).

4.1.9 **Incidence of Pests and Diseases**

Attack of hedgehog was noted in the experimental plots after the rhizome formation stage. No disease other than bacterial wilt was observed throughout the course of the experiment.

4.2. EXPERIMENT II - REFINEMENT IN THE POSTHARVEST HANDLING PRACTICES OF KACHOLAM

Dry recovery and quality attributes of composite sample obtained by pooling together the samples from various nutrient sources and dried by the three methods of drying viz., sun drying, shade drying and oven drying are presented in Table 4.16.

4.2.1. **Dry Recovery Percentage**

The various drying treatments did not differ significantly among themselves with respect to dry recovery (Table 4.16). Shade dried rhizomes recorded the highest driage of 35.1 per cent followed by sun drying (34.2 per cent). Oven dried rhizomes recorded 33.5 per cent driage.

4.2.2. **Quality Attributes**

Data on estimation of quality attributes, viz content of oleoresin and essential oil in the composite samples, was carried out for comparing the various drying treatments, are presented in Table 4.16.

4.2.2.1. ***Essential oil***

Content of essential oil did not exhibit any significant variation among the treatments (Table 4.16). Essential oil content was maximum in sun dried sample (1.2 %) followed by shade dried (1.00 %) and oven dried samples (0.8 %).

Table.4.16. Effect of drying treatments on dry weight and quality parameters of composite samples of kacholam

Composite sample	Sun drying	Shade Drying	Oven drying
Dry recovery (%)	34.20	35.10	33.50
Essential oil (%)	1.20	1.00	0.80
Oleoresin (%)	3.40	3.31	2.24
Significance	NS	NS	NS

Treatment means having similar alphabets in superscript, do not differ significantly

T1- Sun drying

T2- Shade drying

T3- Drying in mechanical drier at 50º C

4.2.2.2. ***Oleoresin***

Oleoresin content also exhibited no significant variation in the different drying methods (Table 4.16). Sun dried sample recorded 3.4 per cent oleoresin. Shade dried and oven dried samples recorded 3.31 per cent and 2.24 per cent oleoresin respectively.

4.3. STORAGE OF CRUDE DRUG

Crude drug obtained by drying the samples which was rated as the best based on the content of qualitative constituents, i.e. sun drying, was stored employing various storage methods as detailed in 3.9.2. Data regarding the physical and chemical characteristics and microbial load in the stored samples at bimonthly intervals for a period of six months are presented in table 4.17 to 4.19.

4.3.1. **Physical Characteristics**

Effect of various storage methods on percentage loss in weight and residual moisture of the samples were worked out from the stored samples at various intervals.

4.3.1.1. ***Percentage loss in weight***

At two months after storage, the various treatments did not show any significant difference in percentage loss in weight (Table 4.17). However, the loss was minimum (0.89 %) during storage in PET bottles (T_5) followed by storage in polyethylene bags (T_4) where the samples registered a weight loss of 1.11 per cent (T_4). Maximum percentage of weight loss was noted in the control treatment (1.76 %).

At four months after storage also, significant differences were observed, among the various treatments with respect to percentage of weight loss (Table 4.17). Percentage of loss was significantly less in the treatment T_5 (0.96 %) followed by T_4 (1.14 %). Rhizomes stored in open (control) recorded the maximum loss of 3.2 per cent.

At the end of the storage period (after six months), samples stored in PET bottles recorded the minimum percentage loss in weight (0.98 %) followed by those in polyethylene cover (1.23 %). Gunny bags recorded more weight loss (2.1 %) than gunny bags with neem leaves (1.98 %). Maximum loss was recorded in samples stored in open (3.8 %).

4.3.1.2. ***Residual moisture***

Residual moisture content in the stored samples showed significant differences among the various treatments, at two months after storage (Table 4.17). Maximum residual moisture content of 10.34 per cent was noted in open storage, followed by T_2 (gunny bags) which recorded a moisture content of 10.12 per cent. Least residual moisture content was noted in PET bottles (6.27 %) followed by polyethylene bags (T_4), i.e. 7.21 per cent.

The residual moisture content in the stored samples showed significant differences at four months after storage as well. Control treatment recorded 13.3 per cent moisture content. Samples stored in PET bottles and polyethylene bags recorded the minimum residual moisture contents of 7.48 per cent and 7.86 per cent respectively, which were significantly superior to the rest of the treatments.

After six months of storage, residual moisture content in the stored samples exhibited a decreasing trend. Residual moisture content of 11.32 per cent was recorded in open storage. In samples stored in polyethylene covers, moisture content present was higher (7.91 %) at 6 MAP than that at 4 MAS (7.86 %). PET bottles recorded only 6.78 per cent of residual moisture, at six months of storage.

4.3.2. **Chemical Characteristics**

Data on quality constituents of the crude drug samples of kacholam i.e., essential oil and oleoresin contents estimated during the storage period are presented in Table 4.18.

Table.4.17. Effect of various storage treatments on the physical characteristics of dried samples of kacholam

Treatments	Percentage loss in weight			Residual moisture (%)		
	2 MAS	4 MAS	6 MAS	2 MAS	4 MAS	6 MAS
T_1	1.76^{a}	3.20^{c}	3.80^{c}	10.34^{c}	13.3^{c}	11.32^{d}
T_2	1.37^{a}	1.92^{a}	2.10^{b}	10.12^{c}	12.21^{b}	10.24^{c}
T_3	1.50^{a}	1.90^{a}	1.98^{b}	9.76^{c}	12.06^{b}	10.05^{c}
T_4	1.11^{a}	1.14^{b}	1.23^{ab}	7.21^{b}	7.86^{a}	7.91^{b}
T_5	0.89	0.96^{b}	0.98^{a}	6.27^{a}	7.48^{a}	6.78^{a}

Treatment means having similar alphabets in superscript, do not differ significantly

T1- Storage in open (control)

T2- Storage in gunny bags

T3- Storage in gunny bags with neem leaves

T4- Storage in 250 gauge polyethylene bags

T5- Storage in PET bottles

4.3.2.1. ***Essential oil content***

Crude drug samples stored under different treatments differed significantly among one another in the content of essential oil, throughout the storage period (Table 4.18). Except control, all treatments registered values on par with one another with respect to essential oil content. Samples stored in treatment T_5 recorded the maximum essential oil content of 1.54 per cent followed by those stored in T_3 (1.53 %). Lowest oil content was noted in control (1.3 %).

Essential oil content of the stored samples at four months after storage also showed significant differences among one another (Table 4.18). Highest essential oil content was noted in T_5 (1.52 %), which was significantly superior to all other treatments. Samples stored in open recorded the minimum value of 1.13 per cent. Storage in gunny bags (1.33 %), gunny bags with neem leaves (1.32 %) and in polyethylene covers (1.38 %), recorded values on par with one another.

At six months after storage, samples in PET bottles recorded 1.35 per cent essential oil followed by storage in polyethylene covers (1.21 %). Storage in gunny bags (1.16 %) recorded higher essential oil content than in gunny bags with neem leaves (1.08 %). The above values exhibited variation among one another that was significant.

4.3.2.2. ***Oleoresin content***

Oleoresin content also showed significant differences among the various treatments at second, fourth and sixth month after storage (Table 4.18). Control treatment recorded the lowest values of 2.2 per cent and 2.01 per cent oleoresin at two and four months after storage respectively. T_4 recorded the highest oleoresin content of 2.63 per cent at two months after storage followed by T_5 (2.62 %). At four months after storage, the contents of oleoresin were 2.46 per cent and 2.45 per cent in T_4 and T_5 respectively. Oleoresin content in the stored samples at six months after storage recorded highest value in PET bottles as well as polyethylene cover (2.47 %).

Table.4.18. Effect of various storage treatments on the chemical characteristics of dried samples of kacholam

Treatments	Essential oil content (%)			Oleoresin content (%)		
	2 MAS	4 MAS	6 MAP	2 MAS	4 MAS	6 MAP
T_1	1.30^{b}	1.13^{b}	1.05^{c}	2.20^{b}	2.01^{b}	1.45^{b}
T_2	1.50^{a}	1.33^{ab}	1.16^{b}	2.58^{a}	2.40^{a}	2.10^{a}
T_3	1.53^{a}	1.32^{ab}	1.08^{c}	2.52^{a}	2.42^{a}	1.57^{b}
T_4	1.52^{a}	1.38^{ab}	1.21^{b}	2.63^{a}	2.46^{a}	2.47^{a}
T_5	1.54^{a}	1.52^{a}	1.35^{a}	2.62^{a}	2.45^{a}	2.47^{a}

Treatment means having similar alphabets in superscript, do not differ significantly

T1- Storage in open (control)

T2- Storage in gunny bags

T3- Storage in gunny bags with neem leaves

T4- Storage in 250 gauge polyethylene bags

T5- Storage in PET bottles

Gunny bags and gunny bags with neem leaves recorded 2.1 per cent and 1.57 per cent oleoresin respectively. Open stored sample recorded the minimum content of 1.45 per cent.

4.3.3. **Microbial Load in Stored Samples**

Microbial load in the stored samples were analysed at bimonthly intervals for a period of six months and the data are presented in Table 4.19.

At 2 MAS, gunny bags (2 x 10^6 cfu g^{-1}) recorded the maximum bacterial population next to control (7 x 10^6 cfu g^{-1}). Storage in PET bottles and polyethylene covers recorded the minimum bacterial count of 1 x 10^6 cfu g^{-1}. Fungal count was also higher in control (15 x 10^3 cfu g^{-1}) followed by gunny bags (7 x 10^3 cfu g^{-1}). In gunny bags with neem leaves, no fungal colonies were observed. Polyethylene cover and PET bottles recorded low fungal infection, registering counts of 1.5 x 10^3 cfu g^{-1} and 2 x 10^3 cfu g^{-1} colonies respectively. Compared to other micro organisms, actinomycete population was comparatively less in the stored samples (Table 4.19). Maximum population of 7 x 10^5 cfu g^{-1} colonies were observed in open storage followed by storage in gunny bags (4 x 10^5 cfu g^{-1}). Minimum number of colonies of (1 x 10^5 cfu g^{-1}) was observed in polyethylene covers as well as in PET bottles.

Enumeration of microbial load at 4 MAS recorded maximum fungal population followed by that of bacteria and actinomycetes (Table 4.19). Significant differences existed among the treatments with respect to bacterial, fungal and actinomycetes population. Followed by storage in gunny bags with neem leaves (15.33 x 10^6 cfu g^{-1}), open storage recorded the maximum population (15.67 x 10^6 cfu g^{-1}) of actinomycetes. Minimum population was noted in stored samples in polyethylene covers (5 x 10^5 cfu g^{-1}). Lowest fungal population was recorded in samples stored in PET bottles (7 x 10^3 cfu g^{-1}) followed by those in polyethylene covers (11 x 10^3 cfu g^{-1}). Fungal population also recorded maximum values in open storage (35 x 10^3 cfu g^{-1}) followed by gunny bags with neem leaves (20.67 x 10^3 cfu g^{-1}). Compared to 2 MAS, actinomycetes population

showed a slight increase at 4 MAS (Table 4.19). Gunny bags with neem leaves recorded the highest population (7 x 10^5 cfu g^{-1}), next to open storage (10 x 10^5 cfu g^{-1}). Storage in PET bottles and polyethylene cover was superior with respect to minimizing actinomycete population (Table 4.19).

At the end of the storage period, enumeration of microbial population recorded significant differences among treatments. Bacterial population in the open stored samples increased to 27 x 10^6 cfu g^{-1} at 6 MAS. Stored samples in PET bottles and polyethylene covers recorded a bacterial population of 5.5 x 10^6 cfu g^{-1} and 5.6 x 10^6 cfu g^{-1}, respectively. Fungal population in the open stored samples was 41.3 x 10^3 cfu g^{-1} at 6 MAS, whereas gunny bags recorded a fungal population of only 16 x 10^3 cfu g^{-1} in stored samples. Gunny bags with neem leaves recorded a fungal count of 24.8 x 10^3 cfu g^{-1}. The population was least in PET bottles (7.3 x 10^3 cfu g^{-1}). Compared to 4 MAS, actinomycetes population showed a slight increase at 6 MAS and reached 12 x 10^5 cfu g^{-1} in open stored samples followed by samples stored in gunny bags with neem leaves (11 x 10^5 cfu g^{-1}). PET bottles and polyethylene bags recorded the least actinomycetes population of 5.13 x 10^5 and 7.6 x 10^5 cfu g^{-1} respectively.

Table.4.19. Effect of various storage treatments on the chemical characteristics of dried samples of kacholam

Two months after storage			
Treatments	Microbial load (cfu g^{-1})		
	Bacteria (x 10^6)	Fungi (x 10^3)	Actinomycetes (x10^5)
T_1	7.00	15.00	7.00
T_2	2.00	7.00	4.00
T_3	0.33	0.00	2.00
T_4	1.00	1.50	1.00
T_5	1.00	2.00	1.00
Four months after storage			
Treatments	Microbial load (cfu g^{-1})		
	Bacteria (x 10^6)	Fungi (x 10^3)	Actinomycetes (x10^5)
T_1	15.67^{b}	35.00^{c}	10.00^{b}
T_2	9.33^{ab}	13.00^{bc}	5.33^{a}
T_3	15.33^{b}	20.67^{b}	7.00^{ab}
T_4	5.00^{a}	11.00^{bc}	6.00^{ab}
T_5	5.33^{a}	7.00^{a}	5.00^{a}
Six months after storage			
Treatments	Microbial Load (cfu g^{-1})		
	Bacteria (x 10^6)	Fungi (x 10^3)	Actinomycetes (x10^5)
T_1	27.00^{d}	41.30^{d}	12.00^{b}
T_2	10.00^{c}	16.00^{b}	6.30^{ab}
T_3	16.20^{b}	24.80^{c}	11.00^{ab}
T_4	5.60^{a}	15.20^{b}	7.60^{ab}
T_5	5.50^{a}	7.30^{a}	5.13^{a}

Treatment means having similar alphabets in superscript, do not differ significantly

T1- Storage in open (control), T2- Storage in gunny bags

T3- Storage in gunny bags with neem leaves, T4- Storage in 250 gauge

polyethylene bags, T5- Storage in PET bottles

Discussion

5. **DISCUSSION**

Traditional medicines, particularly herbal medicines, have been increasingly used world wide, during the last two decades. Quality control directly impacts the safety and efficacy of herbal products. Good agricultural practices for medicinal plants is the preliminary step in quality assurance, on which safety and efficacy of herbal products depend upon. Based on the guidelines of WHO on the techniques and measures required for appropriate cultivation and collection of medicinal plants, it is imperative that GAP recommendations are formulated for commercially grown medicinal plants, whose supply to the user industries is mainly through cultivation.

The present study entitled "Standardization of good agricultural practices (GAP) in kacholam (*Kaempferia galanga* L.) for yield and quality" thus attempts to provide certain leads towards organic resource management and post harvest handling practices in kacholam (*Kaempferia galanga* L.), one of the prominent commercially grown medicinal plants of the state. The salient results obtained in the study are discussed hereunder :

5.1. EXPERIMENT I - INFLUENCE OF ORGANIC MANURES, BIOFERTILIZERS AND MULCHES ON GROWTH, YIELD AND QUALITY OF KACHOLAM

5.1.1. **Growth Parameters**

In the present investigations, influences of organic manures, biofertilizers and mulches on germination percentage, earliness in germination, number of leaves and foliage spread were assessed.

With respect to germination percentage, the treatments did not show any significant differences among one another (Table 4.1). Maximum germination percentage was observed in plots applied with FYM + *Kalanchoe pinnata* (98.61 %). Inorganic fertilizers recorded a germination percentage of 97.91 which was on par with the highest value (Fig 1).

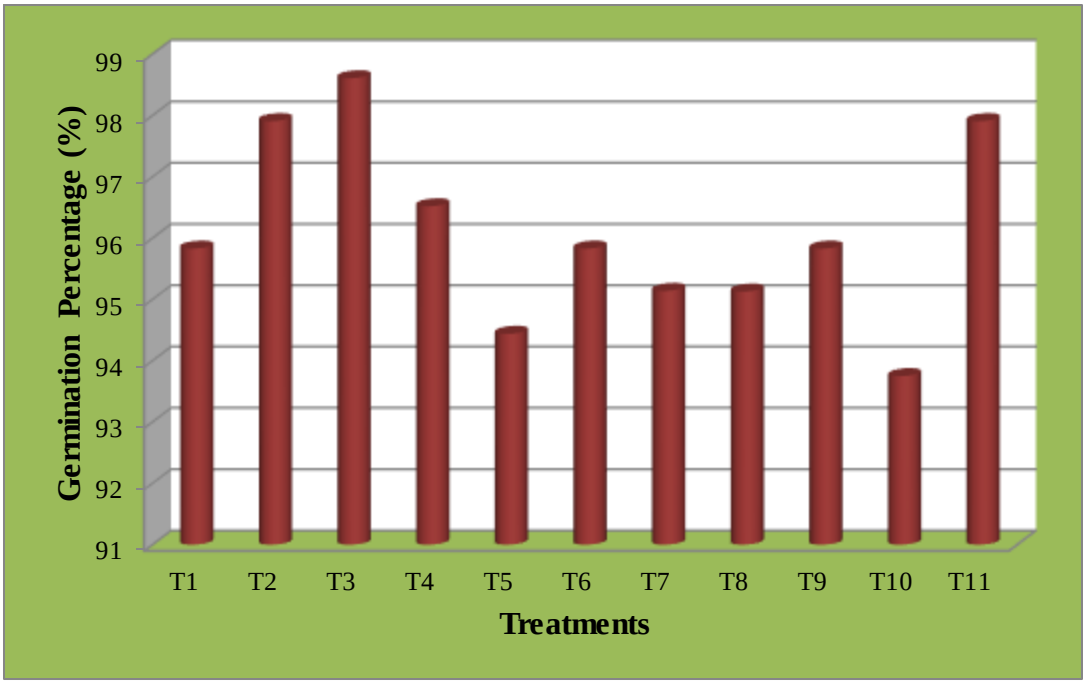


Fig.1. Effect of organic manures, biofertilizers and mulches on germination percentage of kacholam

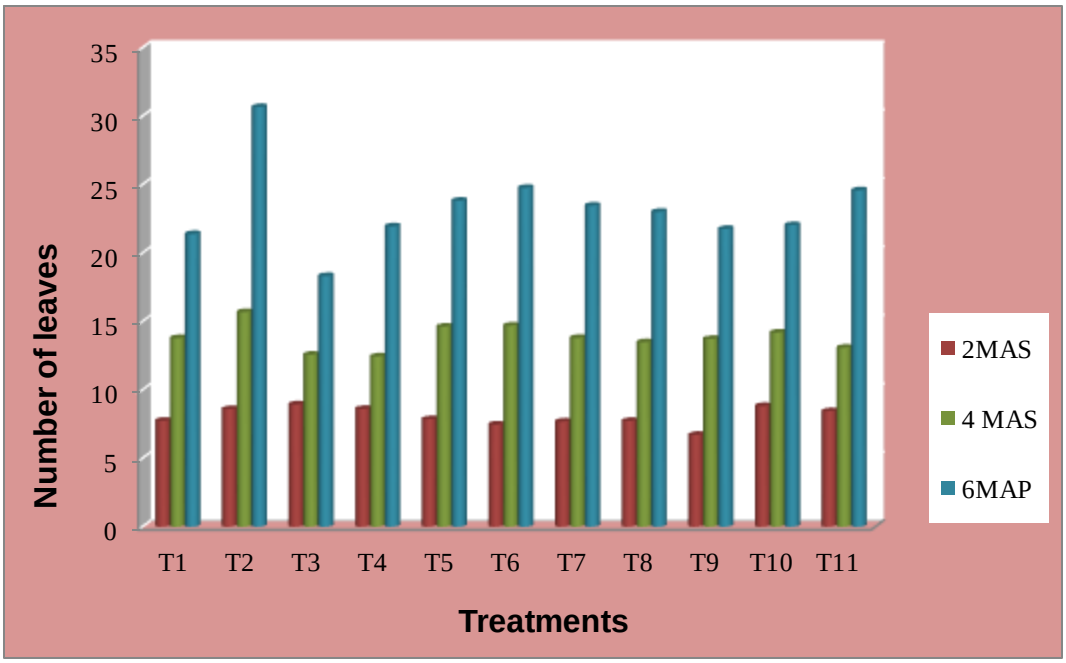


Fig.2. Effect of organic manures, biofertilizers and mulches on number of leaves of kacholam

Data presented in Table 4.1 depict the influence of treatments, with respect to earliness in germination. Seed rhizomes started germination from the first week of planting. In the first week, FYM supplemented with biofertilizers recorded maximum germination. In the second week, plots treated with FYM enriched with biofertilizers, kalanchoe and Chromolaena mulch recorded maximum germination. The present findings are in conformity with the reports of Hussain *et al*., (2001) in ginger and Padmapriya and Chezhiyan (2009) in turmeric, wherein, it was reported that organic acids produced by biofertilizers had a favourable effect on soil properties rendering the soil granular with better aeration, resulting in easy water absorption which might have triggered early sprouting of rhizomes. Regarding earliness in seed rhizome germination, it was evident that plots treated with FYM supplemented with biofertilizers showed maximum earliness in germination (Table 4.1). Similar observation was made by Krishna *et al*. (2008) in medicinal plants like *Andrographis paniculata*, *Withania somnifera* and *Ocimum tenuiflorum*. The probable reason for the earliness in germination in this treatment might be attributed to the role of Azospirillum and phosphorus solubilising bacteria, the component microorganisms of the consortium of biofertilizers applied in the treatment in the present study, in enhancing the metabolic activity in germinating seed rhizomes.

In the present study, number of leaves per plant was significantly higher in plots treated with FYM supplemented with biofertilizers, which was evident from 4 MAP onwards (Table 4.2 and Fig. 2). These results are in agreement with the findings of Das *et al*. (2008) in *Stevia rebaudiana* and Shivanna *et al*. (2010) in *Andrographis paniculata*. Combined application of FYM and biofertilizers increased the supply of nutrients and enhanced moisture availability due to better soil structure, due to growth promoting substances secreted by microbial inoculants, better translocation of water and increased nutrient uptake, leading to enhanced growth attributes (Shivanna *et al*., 2010).

Foliage spread showed significant differences among the various treatments in the early stages of planting (Table 4.3 and 4.4). At 2 MAP,

maximum spread was observed in T_{11} (plots receiving nutrients as per POP recommendations) in N-S direction. Foliage spread in the E-W direction also recorded the second highest spread in inorganic fertilizer applied plots. The superiority of inorganic fertilizers in the early stages of planting is due to quicker availability of nutrients to the plants in easily absorbable form, which is reflected in enhanced vegetative growth parameters (Shivanna *et al*., 2010).

At 4 MAP, T_{10} (Vermicompost + COB + *Kalanchoe pinnata* + mulching with Chromolaena), recorded the highest value for foliage spread in N-S direction and T_8 (Vermicompost + *Kalanchoe pinnata*) in E-W direction. As reported by Nirmalatha *et al*. (2010) presence of plant growth promoting hormones, easy availability of nutrients and enhanced enzyme activity in vermicompost might have contributed to the enhanced vegetative growth of the plants. But at 6 MAP, FYM + *Kalanchoe pinnata* and FYM + biofertlizers showed the maximum spread in N-S and E-W direction respectively (Fig.3, Fig 4 and Plate 5).

Trials conducted at various research stations has confirmed that application of biofertilizers and *Kalanchoe pinnata* contributed to the increase in the microbial activity of soil. Thus, biofertilizers directly supply beneficial microorganisms to the soil and *Kalanchoe pinnata* stimulate specific groups of microorganisms which in turn have a beneficial effect on other microorganisms through the production of growth promoting substances. These microbes get multiplied rapidly in FYM, which will improve the soil structure and as a consequence improve the ability of soil to supply nutrients. In the present study, superiority registered by the control plot with respect to foliage spread in N-S direction at early stages of crop growth, was not evident at later stages. During later stages of crop growth, treatments receiving nutrients from organic sources, with the exception of T_9, recorded values on par with those of control plot. This observation substantiates the fact that inorganic fertilizers exhibit an immediate favourable effect on vegetative growth, but sustenance of that favourable response at later stages of crop growth is often lacking.

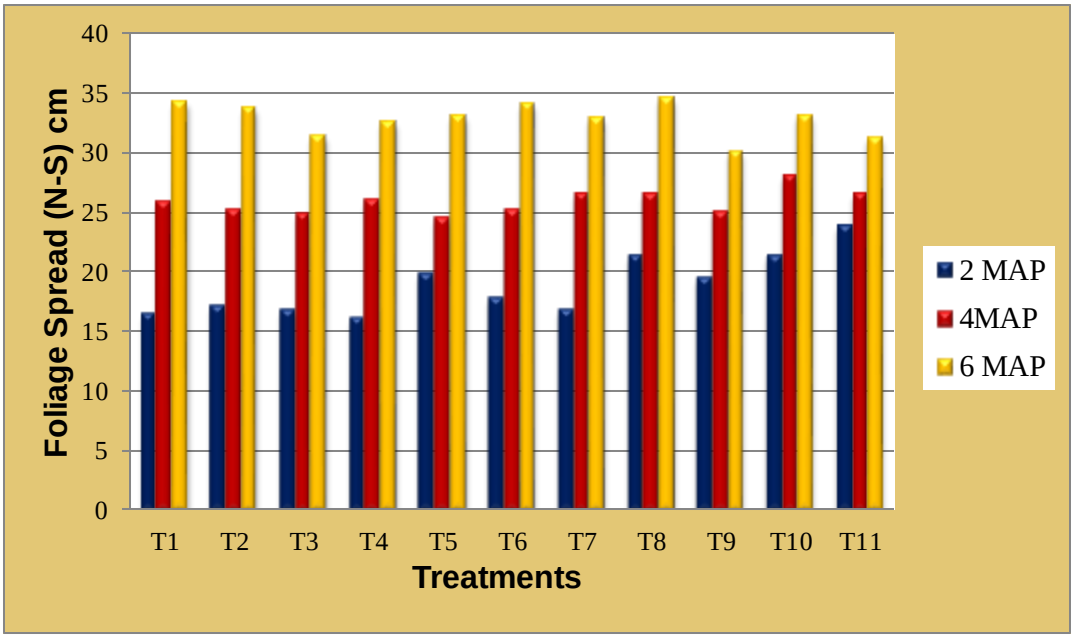


Fig.3. Effect of organic manures, biofertilizers and mulches on foliage spread (N-S) of kacholam

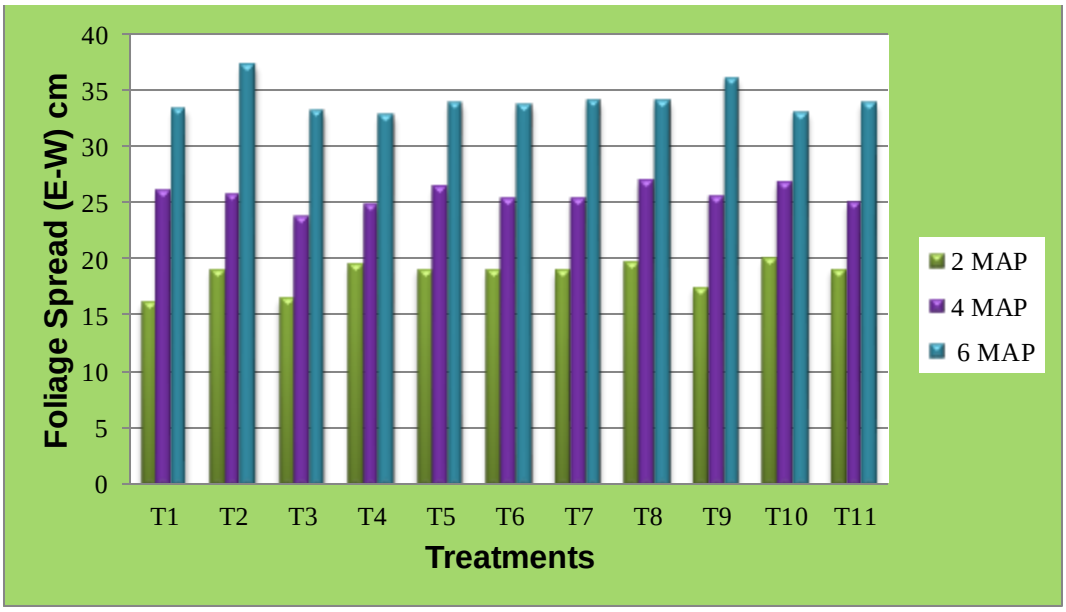


Fig.4. Effect of organic manures, biofertilizers and mulches on foliage spread (E-W) of kacholam

Plate 5a. Foliage spread in N-S direction in plots receiving vermicompost supplemented with kalanchoe

Plate 5.b. Foliage spread in E-W direction in plots receiving FYM supplemented with biofertilizers

Considering the two parameters, number of leaves and foliage spread, it was observed that maximum foliage spread was observed in treatment T_2 (FYM supplemented with biofertilizers) with maximum number of leaves which is more evident towards the later stages of planting (Table 4.2, 4.3 and 4.4). Some plants were characterized by the presence of large number of small leaves for which foliage spread was less. This may be due to the effect of type of seed rhizome material used for planting. Maheswarappa *et al.* (2001) has made a similar observation in kacholam, wherein number of tillers, number of leaves and leaf area produced with mother rhizomes were significantly more at 120 and 180 DAP compared to finger rhizomes.

5.1.2. **Yield and Yield Related Characters**

Yield and yield related characters like yield per plant, fresh rhizome yield and dry rhizome yield per hectare did not show any significant difference among the treatments (Table 4.5). However the highest fresh rhizome yield and dry rhizome yield per hectare as well as fresh rhizome yield per plant (Plate 6) were observed in plots receiving FYM enriched with biofertilizers followed by the treatment T_4, in which FYM was supplemented with biofertilizers and *Kalanchoe pinnata* (Fig 5). Similar results were observed in aswagandha by Gajbhiye and Deshmukh (2010) where application of 5 t FYM ha^{-1} + *Azospirillum* 4 kg ha^{-1} + PSB 4 kg ha^{-1} resulted in highest dry root yield of 9.40 q per ha. The present findings also support the study of Dharana *et al.* (2008) in *Coleus forskohlii* and Velmurugan *et al.* (2007) in turmeric. Higher yield with biofertilizers, could be ascribed to their capability to fix nitrogen, to solubilise the bound forms of phosphate in the soil and to produce phytohormones which result in enhanced availability of nutrients in soil, thereby realizing higher yields (Dube, 2011).The other supplement kalanchoe is also known to have beneficial effects in increasing crop yields. In one of the trials conducted at the Dept. of Plantation Crops and Spices, College of Horticulture, Vellanikkara, incorporation of *Kalanchoe pinnata* in turmeric plots resulted in increased rhizome yield by about 1.3 t ha^{-1} which benefited the crop by making nutrients more available due to its decomposition in

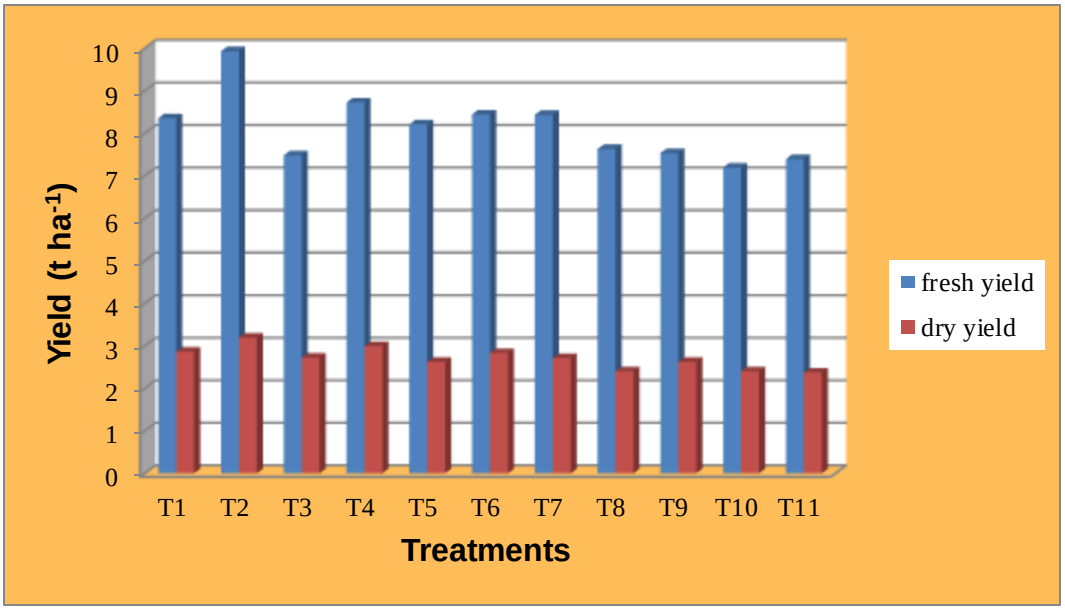


Fig.5. Effect of organic manures, biofertilizers and mulches on yield of kacholam

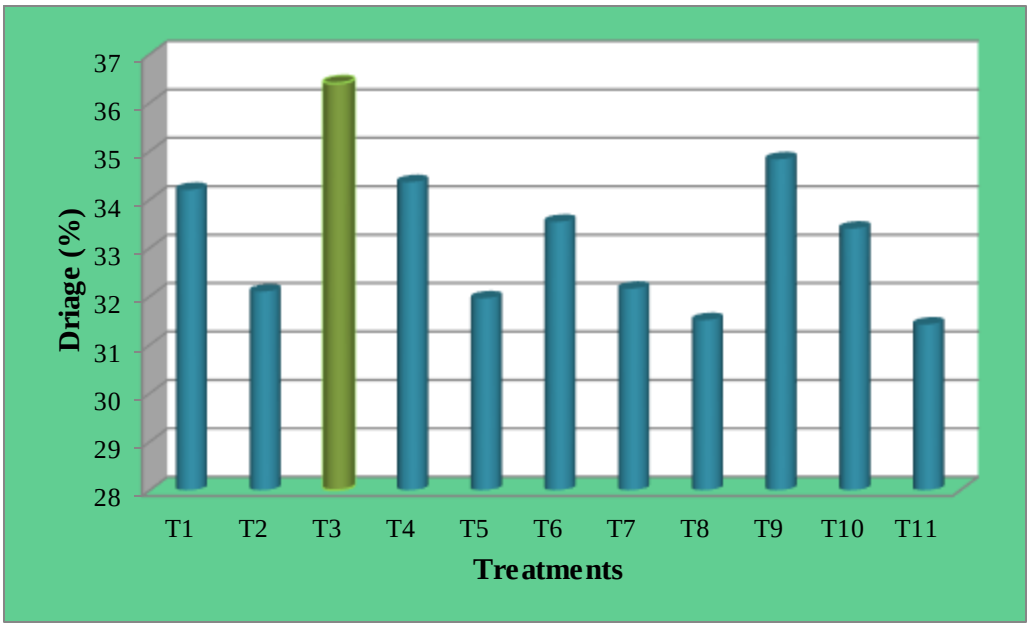
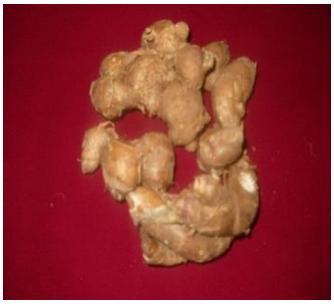


Fig.6.Effect of organic manures, biofertilizers and mulches on dry recovery of kacholam

T1

T2



T3

T4

T5

T6

T7

T8

T9

T10

T11

Plate 6. Effect of organic manures, biofertilizers and mulches on fresh rhizome yield per plant

soil, after being incorporated. Also, microbial activity of the soil incorporated with kalanchoe increases, as the soil microbes grow in the rhizosphere of the herb. During soil incorporation of kalanchoe, microbes grow and develop in the portion where the roots rot. Microbial biomass, which is an important attribute of soil quality, is known to increase by about 2.2 times in kalanchoe treated soil as is observed in trials conducted at BCKV, Kalyani. Hence, incorporating kalanchoe to organic manures will invite diverse microbial activity and as a consequence, ability of soil to supply nutrients will increase, resulting in higher yield.

Control plots applied with inorganic fertilizers recorded lowest fresh rhizome yield per hectare (7.39 t) compared to other organic based treatments, except the treatment T_7 wherein, vermicompost was supplemented with biofertilizers and Chromolaena mulch (Fig. 5). Fertilizer application in the experimental crop was carried out in rainy season leading to leaching of inorganic nitrogenous fertilizers which might have resulted in limited availability of nutrients to the crop. Also, inorganic phosphatic fertilizers, on application to the soil, undergoes fixation and remains unavailable to plants (Trivedi, 1961). Suggested reason for the same is that, compared to inorganic fertilizers, organic nutrient sources slowly release the nutrients throughtout the crop period, which result in continuous supply of macro and micro nutrients to the crops (Nirmalatha *et al.*, 2011). Well decomposed organic manures improve the soil condition which is favourable to rhizome development and thereby higher yield (Shaikh *et al.*, 2010). A direct and positive contribution to dry rhizome yield was by fresh rhizome yield which was also evident from the present study (Table 4.5). Higher yield in plots receiving FYM and biofertilizer is the result of maximum vegetative growth with more number of leaves and maximum foliage spread (Fig. 2, 3 and 4), substantiating the fact that optimum vegetative growth is a pre requisite for realizing high yield in kacholam.

Driage of rhizomes showed significant differences among the treatments and was maximum in plots receiving vermicompost supplemented with biofertilizers and *Kalanchoe pinnata* (Fig. 6). Control plots registered minimum

dry recovery (Table 4.5). The effect of combined organic nutrient resources exerted their synergistic beneficial effect through better nutrition of the crop leading to increased dry matter production in the crop and consequently higher dry recovery (Thakur *et al.*, 2011).

5.1.3. **Quality Attributes**

The quality attributes viz., essential oil and oleoresin content in the dried rhizomes were analysed and significant differences were observed among treatments (Table 4.6). The study gave indications that among the various nutrient management practices tried, use of organic manures either singly or enriched with other organic sources, improved oil quality parameters as compared to inorganic fertilizers. Kaplan *et al.* (2009) also reported that in sage, application of organic manures led to the increase in essential oil content as well as quality. In the present study, essential oil content was maximum in FYM and *Kalanchoe pinnata* treated plots followed by plots treated with FYM and biofertilizers (Fig. 7). Essential oil content was least in plots receiving inorganic fertilizers. Biosynthesis of essential oil is dependent on inorganic phosphorus content in the plant. But phosphatic fertilizers soon after their application get immobilized rapidly and become unavailable to plants which might have resulted in decreased oil content (Kapoor *et al.*, 2004). Other reports supporting the observations of the present study include the findings put forth by Srinivasappa *et al.* (2007) wherein, essential oil content in lemon balm (*Melissa officinalis* L.) recorded high values with high neral (8.67 %), geraniol (39.86 %) and geranyl acetate (8.67 %) with enriched FYM, while treatment with fully inorganic sources of nutrients, registered the lowest oil content.

Another observation made in the study is that treatments with relatively less number of leaves produced maximum qualitative components, which is evident in the treatment, wherein FYM was supplemented with kalanchoe and biofertilizers. This observation is in agreement with the findings of Gangadharan (2002) in kacholam who reported that production of photosynthates and their

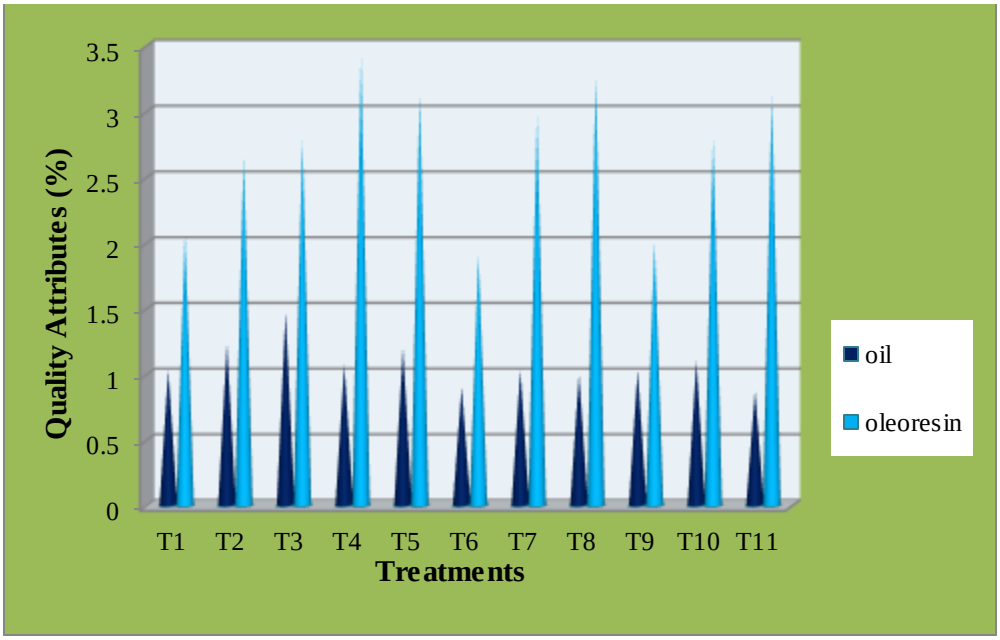


Fig.7. Effect of organic manures, biofertilizers and mulches on quality attributes of kacholam

conversion to qualitative components occur in plants registering high content of qualitative constituents. Here, the structural development is meant only for resynthesising the secondary product from primary product, at the expense of vegetative growth.

5.1.4. **Percentage of Bacterial Wilt Incidence**

Incidence of bacterial wilt disease was observed in the experimental plots from 3 MAP (Table 4.7). Control plot, recorded the lowest incidence of disease followed by T_{10} (Vermicompost + COB + *Kalanchoe pinnata* + *Chromolaena odorata*). Treatments receiving FYM alone recorded maximum percentage of incidence. Also, application of FYM with *Chromolaena odorata* recorded 5.89 per cent disease incidence, an observation which is contrary to findings made by Sukanya *et al*. (2009) and Ngane *et al*. (2007) in several medicinal plants, and Mathew (2004) in solanaceous crops, wherein, application of organic fertilizers and mulching with Chromolaena reduced the disease incidence.

In the present study, in all treatments, percentage of disease incidence progressively decreased with maximum disease incidence of 10.87 per cent at 3 MAP to no incidence of disease at 6 MAP (Table 4.7). Prophylatic drenching of *Pseudomonas flourescens* at the rate of two per cent uniformly, in all treatments, may have contributed to the reduction in disease incidence. A positive effect of *Chromolaena odorata* in reducing the percentage incidence of disease was not evident when applied as a mulch in farmyard manure based treatments. In general, vermicompost based treatments resulted in less incidence of disease as compared to application of FYM singly or in combination with other organic nutrient sources. Comparatively higher actinomycete population in the soil in vermicompost based treatment, as revealed in the present study (Fig.9) might have contributed to reduced disease incidence. Similar reports have been put forth by (Mathew, 2004), wherein, certain actinomycetes isolated from soils had antagonistic property resulting in reduced wilt incidence as well as delayed appearance of wilt symptoms in solanaceous vegetables.

5.1.5. **Assessment of Soil Nutrient Status**

In the present study, organic carbon content of the soil increased significantly following addition of different organic manures, biofertilizers and incorporation of kalanchoe (Table 4.8). This observation implies that organic sources of nutrients contributed to the improvement of organic carbon content in the soil. This is in conformity with the findings of Kalitha *et al*. (2010), who, while raising a crop of *Eclipta prostrata*, reported that application of FYM results in the addition of more carbonaceous materials to the soil.

Data presented in Table 4.8 indicate that treatment with vermicompost recorded the highest organic carbon content in the soil. Suggested reasons for the same include high residual effect of vermicompost, with regard to sequestration of carbon in soil. High biomass production and consequently high rhizodeposition of carbonaceous materials through root and sloughed off tissue may be the other reason for higher organic carbon in vermicompost treated soils (Franzluebbers *et al*, 1995). Moreover, composting stabilizes organic matter in the substrate, reduces the leaching losses of nutrients and increases the availability of nutrients in the soil (Bodamwad *et al*., 2009).

In the present study, available nitrogen content in soil was high in plots receiving FYM along with COB and *Kalanchoe pinnata* (Fig.8). Results supporting the favourable influence of kalanchoe in increasing nitrogen content of soil have been reported from Birsa Agricultural University, Ranchi, in trials conducted in rice, wherein incorporation of kalanchoe increased nitrogen content of soil by more than 10 per cent. Available P content in soil was highest in FYM based treatments and available K content in plots, applied with vermicompost and *Kalanchoe pinnata* as indicated in Table 4.8. Similar results were observed in turmeric, at trials conducted at Kerala Agricultural University, wherein application of kalanchoe resulted in increased nitrogen and potassium content in the soil by 26.65 kg ha^{-1} and 56 kg ha^{-1} respectively (Unpublished report). Application of FYM or vermicompost would have increased aeration and water

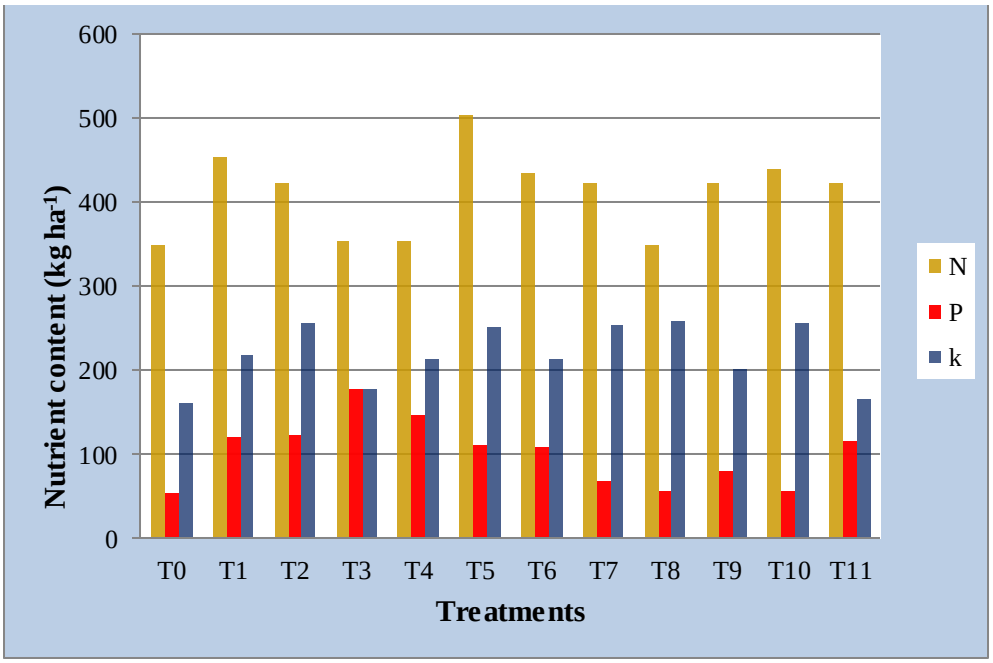


Fig.8. Effect of organic manures, biofertilizers and mulches on nutrient content in soil

holding capacity in soil, availability of essential nutrients for plant growth and conversion of unavailable nutrients to available form through microbial activity (Dube, 2011). In general, low soil P content was recorded in treatments receiving vermicompost singly and in combination with other organic sources. This result is contradictory to the reports of Garg *et al*. (2006) in which the available phosphorus content increased significantly in vermicompost prepared from different substrates like agroresidues and kitchen waste. Sample to sample variation in the vermicompost procured, depending on the substrates used, may account for the contradictory result, in the present study.

Plots applied with organic nutrient sources proved superior to inorganic fertilizer applied plots in enriching soil nutrient status as is evident from Table 4.8. Lowest available K was recorded in the control plots. Inorganic fertilizers did not prove its superiority over organic sources, with respect to available P content as well (Fig. 8). This can be substantiated by the report that application of organic nutrient sources singly or in combination with biofertilizers, resulted in increased NPK content in soil even after their utilization by plants as suggested by Shivanna *et al*., (2010), based on study in *Andrographis paniculata*.

5.1.6. **Assessment of Plant Uptake of Major Nutrients**

Nutrient uptake by plants varies with plant species, variety, soil type, source of applied nutrients and cultural practices (Anand, 1973). In the present study, it is evident that nitrogen and potassium uptakes differed significantly among the various treatments while the treatments were on par with one another with respect to phosphorus uptake (Table 4.11).

Results from the present study indicated that vermicompost treated plots recorded the highest uptakes of nitrogen and potassium. This observation is supported by the fact that, during the processing of various organic wastes to vermicompost by earth worms, many of the nutrients are changed to available form, that are more readily taken up by plants (Chaudhuri, 2005). During composting, microbial activity accelerates the composting process leading to

humification, thus oxidizing unstable organic matter to stable form, rendering the nutrients in available form. Thus vermicompost contributes to the biological fertility factor of the soil, by adding beneficial microbes, which aid in mineralization of nutrients to be taken up by plants and is hence superior to FYM (Devi *et al*., 2009). Pratibha *et al*. (2008) has also reported that increased availability of nutrients in soil might have increased the photosynthate accumulation, thus enhancing the dry matter production in the plant. In the present study also, increased dry matter production and comparatively higher rhizome N, P and K content by vermicompost application, might have resulted in increased nutrient uptake since, nutrient uptake by plants has a direct and positive correlation with dry matter content of plants and nutrient content in rhizomes. Also, since the plants were analysed at 4 MAP for leaves and 6 MAP for rhizomes, there was sufficient period for decomposition and mineralization. This may be the reason why application of inorganic fertilizers did not register any superiority in plant nutrient uptake over organic nutrient sources. Correlation worked out between the variables included in the study revealed that fresh and dry rhizome yield is positively correlated with N, P and K uptake and that, no correlation was observed with oil and oleoresin content (Table 4.12). This observation requires further confirmatory studies before being considered as a reliable inference.

In the present study, FYM in combination with biofertilizers also recorded N, P and K uptake values on par with vermicompost applied singly (Table 4.11). This observation lends support to the direct and positive correlation between N, P and K uptake and fresh and dry rhizome yield since the treatment FYM along with biofertilizers registered the highest fresh and dry rhizome yield per hectare. It is evident that various nutrient sources when combined with each other, exerted their synergistic beneficial effect through better nutrition of the crop. This is in consonance with the findings in sweet basil by Thakur *et al*., 2011.

Inorganic nutrients registered comparatively lower values for P and K uptakes. Inorganic fertilizers did not add micronutrients to soil, while organic

sources might have assured a balanced supply of micro and macro nutrients, which could have helped in increased uptake of nutrients (Prasanna, 1998).

Results from the correlation (Table 4.12) also revealed that uptake of all major nutrients are positively correlated with one another and that rhizome K is positively correlated with K uptake. This is evident in plots applied with vermicompost wherein highest N, P and K uptake as well as high rhizome K uptake were noticed. Another observation made in the present study is that treatments registering highest essential oil content recorded low values for leaf K content (Table 4.12). Effective partitioning of K to rhizomes is a prerequisite for registering enhanced content of essential oil in rhizomes.

5.1.7. **Enumeration of Soil Microbial Population**

Microbial population in the soil was significantly enhanced due to the application of organic manures and biofertilizers over initial values recorded prior to commencement of the experiment, as compared to inorganic fertilizers (Table 4.13, 4.14 and 4.15 and Fig. 9). During the course of the experiment, highest population of bacteria, fungi and reasonably high population of actinomycetes were observed in FYM + biofertilizers which recorded the highest yield indicating that enhanced soil microbial activity bears a direct and positive contribution to yield. Increased biological fertility of the soil by way of enhanced build up of soil microflora results in increased availability of nutrients and consequently higher yield. Nihad and Jessykutty (2010) also reported that higher available N,P and K in soil can be attributed due to the presence of microbial population in soil which converts unavailable nutrients to available form by solubilisation.

In the present study, treatment with vermicompost recorded highest fungal as well as comparatively higher actinomycete population and was on par with the treatment recording highest population of actinomycetes. The enhanced microbial population by vermicompost application may be caused by the congenial condition for the growth of microbes within the worm digestive tract. These nutrient rich organic wastes thus act as a substrate for the growth of micro

organisms. In the present study, enhanced actinomycetes population may have resulted in decreased incidence of bacterial wilt in plots applied with vermicompost as is evident from Table 4.15. .

Low population of soil microbes was recorded in treatments where inorganic fertilizers were applied (Plate 7). Limited access to substrate as well as lower organic matter content in the soil may have contributed to the lower microbial population in plots receiving inorganic fertilizers, as reported by Killham *et al*. 1993. In the present study, among the various groups of microorganisms enumerated, bacteria were the most abundant microbes followed by fungi and actinomycetes.

Population of soil microbes in all treatments reduced towards the end of the experiment. Utilization of organic matter content in the soil by the plants combined with leaching losses would have resulted in a reduction in the organic matter content in the soil leading to reduced population of microbes. FYM based treatments resulted in increased soil microbial population after the harvest of the crop. The slow build up of soil microbes by FYM as compared to vermicompost may explain the above phenomenon.

5.1.8. **Incidence of Other Pests and Diseases**

No major pests and diseases other than bacterial wilt were observed throughout the period of study.

5.2. EXPERIMENT II- REFINEMENT IN THE POST HARVEST HANDLING PRACTICES IN KACHOLAM

5.2.1. **Drying**

Drying is one of the oldest techniques of post harvest handling practices which affect the chemical composition and biological activities of plant material. During drying, moisture content of the product is decreased to extend its shelf life. Usually medicinal plants are harvested at 70-80 per cent moisture level, but for safe storage the moisture has to be reduced to 12 per cent, to prevent the growth

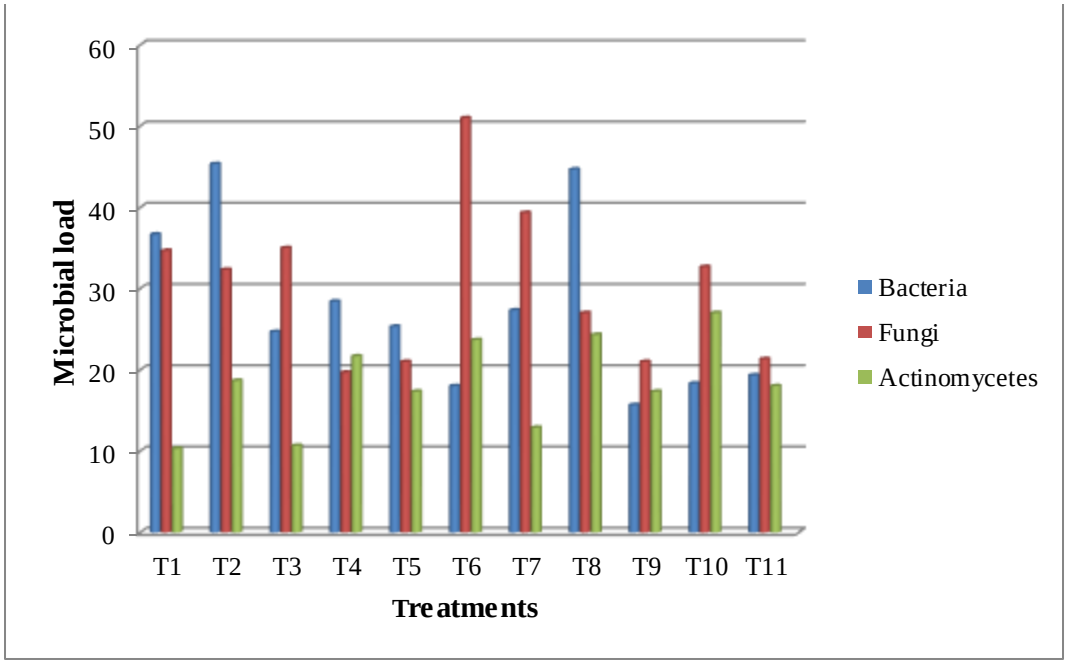
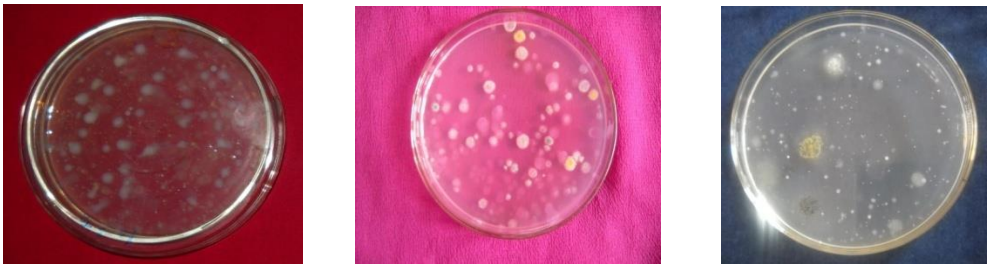
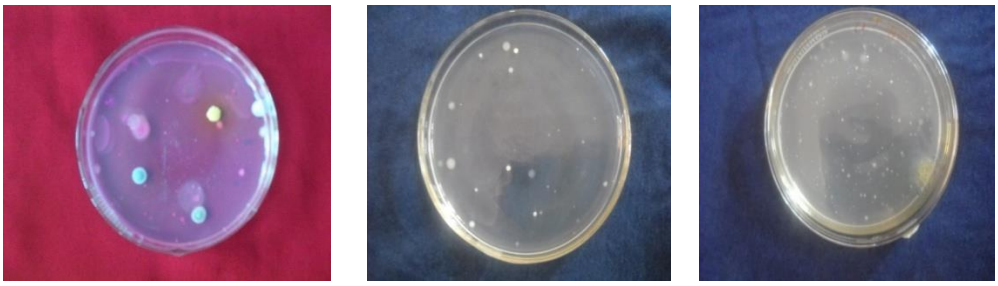


Fig.9. Effect of organic manures, biofertilizers and mulches on microbial load in soil



T_2 T_6 T_{10}



T_{11} T_{11} T_{11}

Plate 7. Comparison between microbial population in plots receiving organic nutrients and inorganic fertilizers

of micro organisms. Removal of moisture brings about a substantial reduction in weight and volume, minimizing packaging, storage and transportation costs and storability of the product under ambient temperatures and for longer periods. In the present study, in an attempt to refine postharvest handling techniques in kacholam, three methods of drying were adopted viz., sun drying, shade drying and oven drying. The results of the drying treatments are presented in Table 4.16.

5.2.2. **Recovery Percentage**

Water adds to the weight of any plant material, and when water is removed by drying, its weight will be proportionately reduced. Hence, a higher recovery percentage indicates a comparatively minimum loss of moisture from the sample. This fact is supported by Hall (1980) who conducted experiments on dehydration in several plant materials. In the present study, shade dried rhizomes recorded the highest recovery percentage (35.10) followed by sun dried samples (34.2) as indicated in Table (4.16). In shade dried samples, under natural conditions, escape of moisture is least due to slow drying process which resulted in high dry recovery, an observation, which can be supported by the reports of Hunge *et al* (2007) in chilli, who reported that shade dried material take a longer period for reducing the moisture content.

In mechanical drying in hot air oven, presence of uniform temperature of 50º C throughout the drying period resulting in maximum moisture loss and consequently lower recovery percentage (33.50) due to high drying rate was observed in the present study. These findings are in agreement with Padmapriya *et al.* (2009) who reported that in *Tinospora cordifolia* mechanical drying at 60º C of stem bits took the shortest time for drying and consequently lower recovery.

5.2.3. **Quality Constituents**

Presence of quality parameters viz., essential oil and oleoresin in substantial amounts, contribute to the quality of the crude drug. In the present study, dried rhizomes retained the maximum quality parameters upon sun drying which is indicated in Table 4.16. During sun drying, essential oil and oleoresin

contents recorded were 1.2 per cent and 3.4 per cent respectively. The findings of Ennajar *et al.* (2010) who reported that drying of leaves of *Juniperus phoenica* in the sun was superior for obtaining higher essential oil yield, support the above results. Similar observations were made by Mani *et al.* (2000) as well, wherein sun drying of ginger produced high volatile oil content (1.08-2 %). In the present study, recovery was least in oven drying, wherein the essential oil and oleoresin contents of dried samples were 0.8 and 2.24 per cent respectively. Diaz- Maroto *et al.* (2004) observed similar results in basil where the total quantity of volatiles decreased considerably in oven drying whereas air drying brought only small amount of losses of volatile compounds.

5.2.4. **Storage**

Medicinal and aromatic plants are mostly perishable and utmost care should be taken during the post harvest processing for improving the quality and efficacy of active ingredients (Misra, 2009). Dried materials upon exposure to atmosphere during storage, result in an increase in the moisture content of the sample. Increase in moisture content of the dried sample results in the formation of moulds which may produce aflatoxins leading to quality deterioration. So medicinal plant materials must be stored under specified conditions to avoid contamination and deterioration. Pattanshetty *et al.* (1979) reported that moisture content, packing materials and duration of storage have definite combined effect on the chemical contents of the products and the changes become rapid and significant after three to four months.

5.2.5. **Percentage Loss in Weight**

Crude drug samples on keeping for a long period register gradual loss of weight. This reduction in weight can be attributed to insect infestation and microbial infection. Insect and microbes cause degradation of the product leading to weight loss. The data presented in Table 4.17 depict that there was significant difference among the storage treatments with respect to percentage loss of weight in the samples. Open stored samples recorded maximum percentage of weight

loss as there is no barrier to atmosphere. Percentage weight loss which occurs, depends on the extent to which samples are exposed to external conditions. Samples stored in PET bottles and polyethylene cover recorded minimum percentage of weight loss. Chandrappa *et al*. (1997) also reported similar results in ginger wherein, storage of rhizomes in 100 gauge polyethylene bags containing dry sand with 5 per cent ventilation resulted in lowest weight loss (26.9 %).

5.2.6. **Residual Moisture**

Dried materials always tend to revert to their original state on exposure to ambient temperature and start absorbing moisture from the atmosphere. Moisture content of the material is dependent on the relative humidity of the air in the vicinity of the sample. In the present study, residual moisture of stored samples during the storage period as recorded at bimonthly intervals and presented in Table 4.17 and Fig. 10 indicates that throughout the storage period, residual moisture content was highest for samples kept in open where there is no barrier for entry of moisture. PET bottles and polyethylene bags, where the intrusion of moisture is least, recorded minimum residual moisture in stored samples of the crude drug. These results are in agreement with the observations of Yoonhee *et al*. (1995) who identified aluminium laminate and polyethylene film as the most effective packaging materials for ginger powder, in terms of residual moisture content. Six months after storage, residual moisture content of samples in various treatments showed reduction which may be due to the variation in relative humidity of the outside environment (Fig 10).

5.2.7. **Quality Parameters**

Quality of stored samples is affected by the residual moisture content as well as microbial contamination in the sample. In the present study, a decline in the content of essential oil and oleoresin during storage period was observed in all the treatments, but at varying levels (Table 4.18). Retention of essential oil and oleoresin governs the quality of raw drug of kacholam. The results obtained in the present study underlines the fact that crude drug samples of kacholam, after

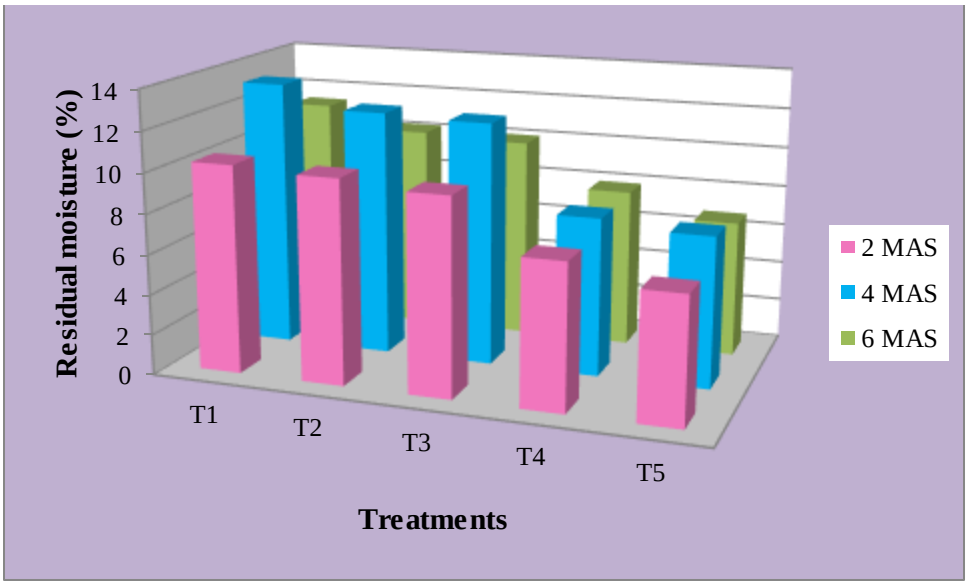


Fig.10. Effect of storage treatments on residual moisture content in stored samples of kacholam

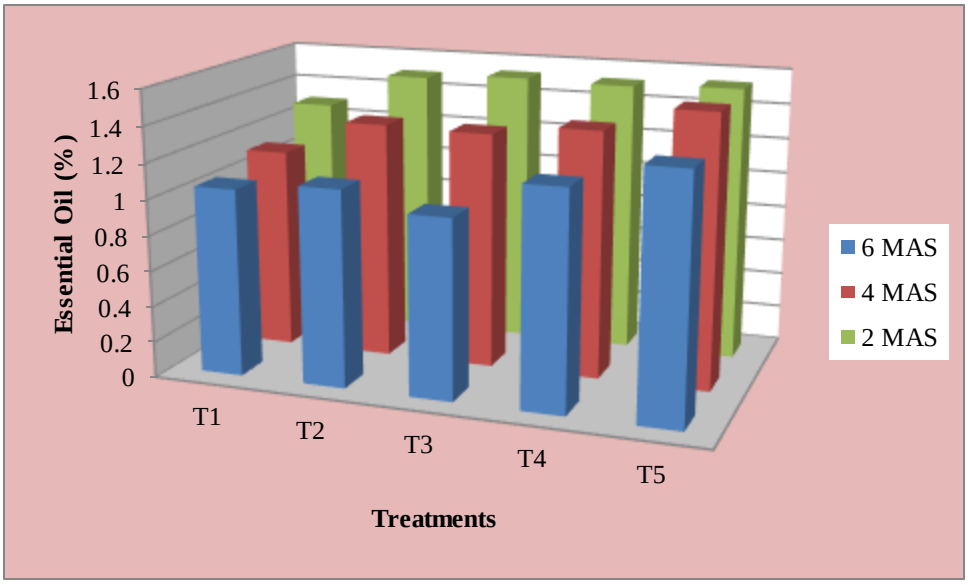


Fig.11. Effect of storage treatments on essential oil content in stored samples of kacholam

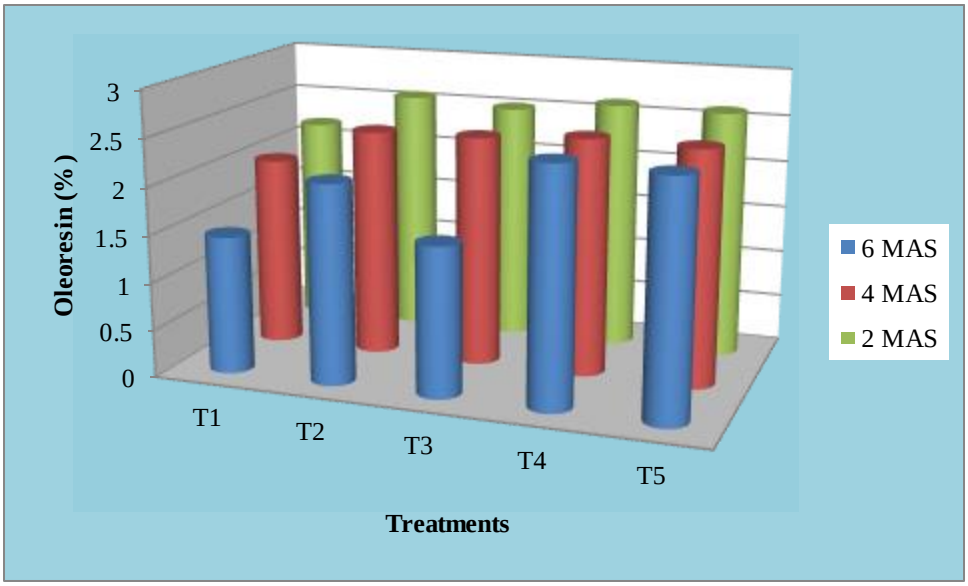


Fig.12. Effect of storage treatments on oleoresin content in stored samples of kacholam

inappropriate prolonged storage, are of questionable quality. Baritaux *et al*. (1992) observed that in *Ocimum basilicum* L. after storing for a period of three, six and seven months, the total losses in the essential oil were 19 per cent, 62 per cent and 66 per cent respectively. Misharina *et al*. (2003) reported that in marjoram chemical transformation of components in the essential oil proceed intensively after storage for four to five months. Organoleptic properties of the oil stored for more than three months changed markedly. The present study indicates that, irrespective of the containers used, stored samples of kacholam maintained their quality upto two months after storage. Dried materials irrespective of packaging materials are known to retain their quality upto one and a half to two months of storage without any significant difference as observed by Perry *et al*. (2000). Polyethylene cover and PET bottles, where the intrusion of moisture is minimum due to air tight packaging, recorded higher values of essential oil and oleoresin content in the crude drug sample stored in them as revealed in the Table 4.18 in the present study. At the end of the storage period, it is clear that samples stored in PET bottles and polyethylene cover retained maximum quality constituents compared to other storage treatments (Fig. 11 and Fig. 12). Over a six month period, percentage loss in essential oil and oleoresin content in stored samples ranged from approximately 5-30 per cent and 22-55 per cent respectively depending upon method of storage (Fig. 13). Sujatha (2002) has also observed a drastic reduction in vasicine content from 1.25 per cent to 0.13 per cent, in samples of *Adhatoda zeylanica*, five months after storage.

5.2.8. **Microbial Load in Stored Samples**

Medicinal plants are associated with a broad spectrum of microbial contaminants, which are represented by bacteria, fungi and viruses. This microbiological background depends on several environmental factors and exerts an important effect on the overall quality of herbal products and preparations (Kniefe *et al*., 2002). In countries like India, traditional methods of collection, storage and marketing are still employed for processing of herbal raw materials. The faulty post harvest technology coupled with humid climatic conditions make

the raw material of herbal drugs prone to fungal infection which is a major reason for the decline of their demand in global herbal market. Results of the experiment in the present study on assessment of microbial load in the dried samples of kacholam stored in different packing materials are discussed here.

During the initial month of storage of crude drug samples of kacholam, the population of microbes was considerably low, with fungi dominating over bacteria and actinomycetes. Actinomycetes were considerably low as the distribution of actinomycetes is erratic. But at 4 MAS, fungal and bacterial population increased considerably and actinomycetes population increased at a slower rate. Throughout the period of storage, microbial population was more in open stored samples as residual moisture content and consequently water activity were more in these samples (Table 4.19 and Plate 8). This condition will provide a favourable environment for the growth of microbes. These facts were already observed and reported by Desrosier (1970), Somogyi and Luh (1975), Brody (2001) and Sujatha (2002).

In the present study, samples stored in gunny bags exhibited more microbial contamination as compared to samples stored in polyethylene bags and PET bottles. At 4 MAS the bacterial, fungal and actinomycete population in samples stored in gunny bags were 9.33×10^6, 13×10^3, 5.33×10^5 respectively. Ventilation in gunny bags allows more water vapour transmission which increases the water activity in the dried samples leading to microbial growth during storage. Gunny bags with neem leaves recorded higher population of bacteria, fungi and actinomycetes in samples stored in them than gunny bags alone. These results are contradictory to the findings of Sujatha, (2002) who reported that antimicrobial property of neem leaves reduced microbial population in samples of crude drug of adathoda stored in gunny bags with neem leaves.

With the advancement of storage period, due to the increase in the water activity of stored samples, the population of microbes also increases. In the present study also, the population of microbes showed considerable increase at

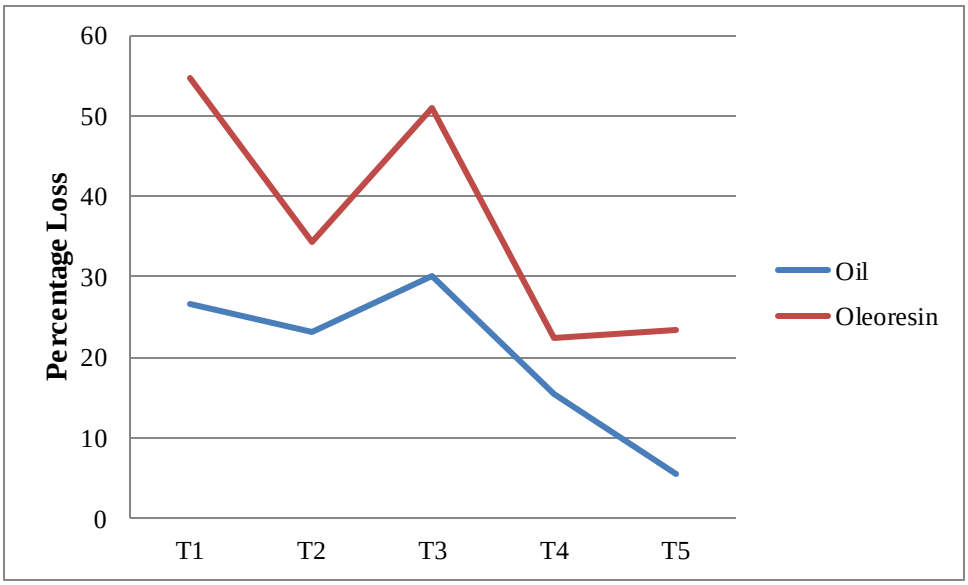


Fig.13. Percentage loss of quality constituents in storage method after six months

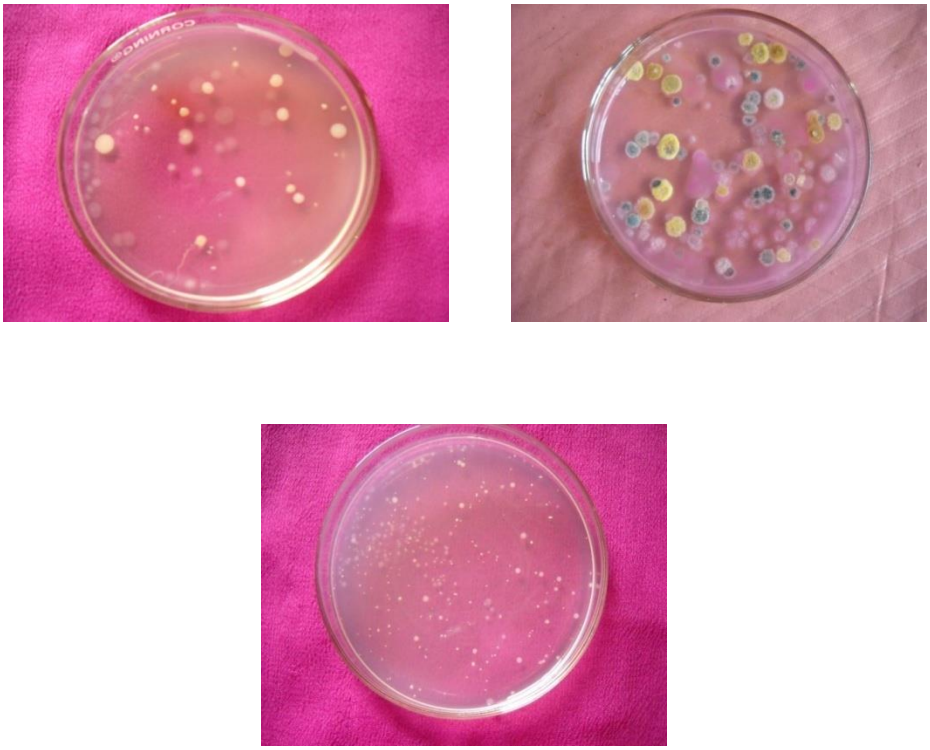


Plate 8. Microbial population in the open stored samples of crude drug

advanced stages but at varying rates. Sujatha (2002) has reported a drastic change in the microbial population in stored samples of *Adhatoda* beyond three months of storage. In the present study, fungal population increased at a faster rate. Relatively dry substrates can also support the growth of fungi like Penicillium and Aspergillus, which proliferate under storage (Jha, 1998). This may explain the phenomenal growth of fungi during storage as observed in the present study. Reduction in the microbial population of the crude drug samples stored in PET bottles and polyethylene covers, as observed in the present study, may be attributed to the prevention of moisture intrusion into these materials. This supports the findings of Nambiar (2002) who recommended storage of plant raw drugs in airtight containers for enhanced storage life. Another relevant observation made in the present study is that, over a six month period, percentage loss in essential oil and oleoresin content in stored samples was higher in samples registering more microbial contamination. This may be the reason why storage of samples in gunny bags along with neem leaves did not derive the expected favourable response, since the unnoticed microbial load in neem leaves may have served as a source of inoculum for microbial infection of the stored samples.

After concluding the experiment, certain promising leads with practical relevance have emerged which could be summarized as follows:

1. FYM singly, as a source of nutrients, proved inferior as compared to application of vermicompost
2. Enrichment of FYM and vermicompost with biofertilizers and kalanchoe appear promising for improvement in growth, yield and quality parameters
3. Mulching with Chromolaena did not always have an inhibitory effect on bacterial wilt incidence

4. Supply of nutrients through inorganic fertilizers did not register any superiority over organic nutrient sources in improving growth, yield and quality parameters
5. Organic nutrient sources generally result in an enhanced soil microflora build up
6. Open storage as well as storage for long periods of the raw drug samples cannot be recommended since it adversely affect the crude drug quality


Summary

6. SUMMARY

A study entitled "Standardization of Good Agricultural Practices (GAP) in kacholam (*Kaempferia galanga* L.) for yield and quality" was conducted at the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara during 2009-2010.

The experiment envisaged to standardize organic resource management and post harvest handling practices in kacholam for optimizing yield and quality, leading to formulation of good agricultural practices in the crop.

- A higher seed rhizome germination percentage of 98.61 was observed in plots receiving FYM supplemented with *Kalanchoe pinnata* and all treatments were on par.
- Regarding earliness in germination, FYM enriched with biofertilizers started germination in the first week after planting itself. The same treatment also recorded the maximum germination after the fifth week. The control plot receiving inorganic fertilizers figured among the treatments, which did not exhibit earliness in germination.
- Significant difference was observed among the treatments with respect to number of leaves. The treatment T_2 wherein FYM was supplemented with biofertilizers, recorded the maximum leaf number of 22.07, 30.66 and 30.98 at 5, 6 and 7 MAP respectively. Minimum number of leaves was recorded in FYM + *Kalanchoe pinnata* treated plots.
- Foliage spread showed significant differences among the treatments in the early stages of growth. Vermicompost supplemented with *Kalanchoe pinnata* (T_8) recorded the maximum foliage spread of 34.5 cm at 6 MAP in N-S direction. In the E-W direction, the maximum foliage spread (37.22 cm) was recorded by the treatment, FYM supplemented with biofertilizers.

The positive response of inorganic fertilizers with respect to foliage spread in the early stages of crop was not evident at later stages.

- Various yield parameters like fresh rhizome yield per plant, fresh rhizome yield per hectare and dry rhizome yield per hectare did not register any significant difference among treatments. FYM enriched with biofertilizers recorded the maximum fresh (9.93 t ha^{-1}) and dry rhizome yield per hectare (3.19 t ha^{-1}). Driage showed significant differences among treatments and was maximum in FYM + *Kalanchoe pinnata* (36.4 %). Control plots receiving inorganic fertilizers recorded lowest percentage of dry recovery.

- Quality attributes recorded significant difference among treatments as affected by organic nutrients, biofertilizers and mulches. Maximum essential oil content (1.47 %) and oleoresin content (3.42 %) were noted in plots supplied with FYM enriched with kalanchoe singly and with kalanchoe and COB. Oil content was the lowest in plots treated with inorganic fertilizers (0.87 %) while with respect to oleoresin content, the lowest value was recorded in vermicompost treated plots.

- Incidence of bacterial wilt was noted in the experimental plants from 3 MAP onwards. FYM treated plots recorded the highest percentage of incidence (10.87 %). Application of inorganic fertilizers resulted in the minimum disease incidence at early stages of crop growth (2.13 %). Drenching with *Pseudomonas flourescens* was effective in controlling the disease. Mulching with Chromolaena did not register any superiority in minimizing disease incidence.

- Assessment of soil nutrient status revealed significant differences among treatments with respect to organic carbon, available nitrogen and phosphorus. Available K content in soil was on par with one another in all the treatments. Plots receiving vermicompost recorded the maximum organic carbon content (1.09 %).

- Highest values for soil nitrogen (503.8 kg ha^{-1}) were recorded in plots receiving FYM supplemented with biofertilizers, kalanchoe and Chromolaena mulch. Treatments receiving FYM enriched with kalanchoe proved superior with respect to available phosphorus content (176.34 kg ha^{-1}). Vermicompost supplemented with kalanchoe recorded the highest soil K content (258.82 kg ha^{-1}) and all treatments were on par. Inorganic fertilizers did not exhibit any superiority with respect to available N and P contents of soil and registered the lowest value of available K in soil (165.54 kg ha^{-1}).

- Plant uptake studies identified application of vermicompost as the best treatment, recording the highest N, P and K uptakes of 82.45 kg ha^{-1}, 10.86 kg ha^{-1} and 127.14 kg ha^{-1} respectively. FYM supplemented with biofertilizers registered N (81.87 kg ha^{-1}), P (8.76 kg ha^{-1}) and K (119.04 kg ha^{-1}) uptake on par with the highest values. Inorganic fertilizers registered comparatively lower values for P (5.15 kg ha^{-1}) and K uptake (86.59 kg ha^{-1}).

- Analysis of nitrogen and potassium contents in the leaf indicated significant differences among the treatments. Highest leaf nitrogen percentage was observed in the treatment, FYM supplemented with biofertilizers (3.15 %). FYM enriched with kalanchoe and biofertilizers registered the highest leaf phosphorus content (0.34 %) which was on par with other treatments. Leaf potassium content recorded significant differences among treatments and registered the highest value in treatment receiving vermicompost + *Kalanchoe pinnata* (7.30 %). Inorganic fertilizers registered the lowest value for leaf P (0.21 %) and K (5.51%) content.

- Rhizome analysis for nutrient uptake revealed significant difference among various treatments with respect to N and P contents in rhizomes. Highest rhizome N content (1.75 %) was recorded in vermicompost

supplemented with kalanchoe, biofertilizers and Chromolaena. Vermicompost treated plot recorded the highest phosphorus content (0.24 %). Treatment with vermicompost recorded the highest K content of 1.58 per cent and all other treatments were on par. Plots applied with inorganic fertilizers figured among treatments registering lowest values for rhizome N (1.68 %) and K (1.36 %).

- Correlation studies revealed that N, P and K uptakes were positively correlated with one another. Fresh and dry rhizome yields are positively correlated with N, P and K uptake. No positive correlation observed with respect to N, P and K uptakes and quality constituents.

- Microbial population in the soil differed significantly among the treatments both during the course and at the end of the experiment. During the course of the experiment maximum soil bacterial (45.33×10^6 cfu g^{-1}) and fungal (39.33×10^3 cfu g^{-1}) population were recorded by the plots receiving biofertilizers enriched with FYM and vermicompost, respectively. The treatment T_{10} wherein vermicompost was supplemented biofertilizers, kalanchoe and mulched with Chromolaena recorded the maximum actinomycetes population. Bacteria as well as fungi recorded the maximum population of 38.67×10^6 cfu g^{-1} and 27.67×10^3 cfu g^{-1} in FYM treated plots at the end of the experiment. Inorganic fertilizers treated plots (7.67×10^6 cfu g^{-1}) recorded low values for soil bacteria and fungal population (13.67×10^3 cfu g^{-1}) at the end of the experiment. Superior organic treatments recorded approximately three times the initial population at 5 MAP.

- Composite sample of kacholam did not reveal any significant difference with respect to percentage of dry recovery during sun drying, shade drying and oven drying. Regarding quality attributes, sun dried rhizomes retained the maximum content of essential oil (1.2%) and oleoresin (3.4%). Oven

dried samples proved inferior in the content of quality attributes viz., essential oil (0.8 %) and oleoresin (2.24 %).

- Storage studies in sun dried crude drug samples of kacholam revealed that, all treatments were on par with one another with respect to percentage loss in weight at 2 MAS, whereas the treatments differed significantly at 4 and 6 MAS. Storage in PET bottles recorded the minimum percentage of loss in weight at 2 MAS (0.89 %), 4 MAS (0.96 %) and 6 MAS (0.98 %) followed by storage in polyethylene bags. Weight loss was maximum in open storage at 6 MAS (3.8 %) followed by gunny bags with neem leaves (2.1 %).

- Various storage treatments showed significant differences with respect to residual moisture at 2, 4 and 6 MAS. Samples stored in PET bottles resulted in minimum residual moisture content of 6.27 per cent, 7.48 per cent and 6.78 per cent at 2, 4 and 6 MAS which was followed by storage in polyethylene bags. Open stored samples registered maximum residual moisture content of 10.34, 13.3 and 11.32 per cent at 2, 4 and 6 MAS. Residual moisture content was less in samples stored in gunny bags with neem leaves as compared to those in gunny bags at all stages of storage.

- Essential oil content in stored samples of kacholam revealed significant differences among treatments at all stages of storage. Open stored samples recorded the lowest essential oil content. PET bottles recorded an essential oil content of 1.54 per cent at 2 MAS which decreased gradually and reached 1.35 per cent at 6 MAS. The second highest recovery of essential oil was noted in polyethylene bags. Gunny bags with neem leaves recorded the least essential oil content (1 %) at 6 MAS.

- Oleoresin content in stored samples of crude drug revealed significant differences among treatments at all stages of storage. Open stored samples recorded the lowest values of 2.2, 2.01 and 1.45 % at 2, 4 and 6 MAS

respectively. Polyethylene bags recorded higher oleoresin content than PET bottles at all stages of storage.

- Microbial population in samples exhibited significant differences among treatments from four months after storage. Samples stored in PET bottles recorded the minimum infection at all stages of storage. Throughout the storage period, fungi dominated the microbial population. Storage in gunny bags with neem leaves did not reduce microbial contamination and recorded 16.2 x 106 cfu g^{-1} bacteria, 20.67 x 103 $cfug^{-1}$ fungi and 11 x 105 $cfug^{-1}$ actinomycetes at 6 MAS, which was greater than that in gunny bags alone. Open stored samples registered the highest microbial population throughout the storage period.

- With respect to insect infestation in stored samples, psosids were observed after four months of storage. Maximum population was recorded in open storage and samples in PET bottles recorded no infestation. Gunny bag with neem leaves showed reduction in insect infestation as compared to gunny bags alone.

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Appendices

APPENDIX I

Weather data during crop season (June- December, 2010)

Standard week	Max temp ^{0}C	Min Temp ^{0}C	RH (Morning) %	RH (Noon) %	Rainfall (mm)
26	30.2	23.1	96	76	28.6
27	28.6	22.8	96	81	26.6
28	31.2	24	95	72	33.2
29	27.8	30	97	84	23.9
30	29.6	22.3	95	81	14.8
31	28.6	22.3	96	74	19.2
32	30.6	24.1	95	73	4.4
33	29.5	23	94	79	6.2
34	28.7	23.3	94	83	1.9
35	28.6	22.8	95	76	9.1
36	29.9	23.1	94	73	5.6
37	29.8	23.2	96	72	21.2
38	30.2	23	95	72	8.1
39	31.9	23	92	68	10.8
40	30.6	22.7	95	78	41.4
41	29.5	23.3	74	70	5.1
42	28.3	21.9	95	78	18.6
43	29.3	27.3	94	76	13.4
44	30.6	22.2	95	71	22
45	30.4	22.3	96	73	17
46	31.3	22.5	92	67	8.5
47	30.8	22.5	91	71	8.7
48	28.1	22.8	83	71	1.2
49	31	21.3	89	59	0.3
50	31.4	21.5	91	59	0.4

APPENDIX-II

Nutrient composition of the media for enumeration of microbial population in soil (1000 ml)

Bacteria –Nutrient Agar Media

Beef extract	3 g
Peptone	5 g
Sodium Chloride	5 g
Agar	15 g
Distilled Water	1000 ml
P^H	6.8-7

Fungi- Martins Rose Bengal Agar Media

Dextrose	10 g
Peptone	5 g
KH_2PO_4	1 g
$MgSO_4$	0.5 g
Rose Bengal	0.003 g
Agar	20 g
Streptomycin Sulphate	0.03 g

Kenghiti's Media- Actinomycetes

Glucose	1 g
$MgSO_4$	0.1 g
KCl	0.1 g
KH_2PO_4	0.1 g
Ammonium Sulphate	0.1 g
Agar	15 g
Distilled water	1000 ml
P^H	7

STANDARDIZATION OF GOOD AGRICULTURAL PRACTICES (GAP) IN KACHOLAM (*Kaempferia galanga* L.) FOR YIELD AND QUALITY

By

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ABSTRACT OF THE THESIS

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ABSTRACT

An investigation on "Standardization of good agricultural practices (GAP) in kacholam (*Kaempferia galanga* L.) for yield and quality", was carried out at the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara, during 2010-2011 to standardize organic resource management and post harvest handling practices in kacholam for optimizing yield and quality, leading to formulation of good agricultural practices in the crop.

Results of the study revealed that the treatments which included FYM along with biofertilizers proved superior in terms of earliness in germination whereas FYM supplemented with *Kalanchoe pinnata* recorded the maximum germination percentage of 98.61 and all other treatments were on par. Plants which receive FYM along with biofertilizers recorded the maximum leaf number (30.67) at 6 MAP. Vermicompost supplemented with kalanchoe and FYM enriched with biofertilizers recorded the highest values for foliage spread at later stages of crop growth. In the present study, the superiority registered by the control plots receiving inorganic fertilizers with respect to vegetative growth parameters at early stages of growth was not evident at later stages.

Experimental plots applied with FYM enriched with biofertilizers recorded the highest value for fresh rhizome yield per plant (80.30 g) and fresh (9.93 t ha^{-1}) as well as dry (3.19 t ha^{-1}) rhizome yields per hectare, which were on par with the rest of the treatments. Plots incorporated with FYM and kalanchoe, recorded significantly higher values for dry recovery (36.4 %). Control plots applied with inorganic fertilizers recorded the lowest dry recovery percentage (31.42 %) as well as dry rhizome yield (2.32 t ha^{-1}).

Essential oil content was significantly higher in plots applied with FYM supplemented with kalanchoe (1.47 %) and oleoresin content recorded a significantly higher recovery percentage of 3.42 per cent in plots applied with FYM supplemented with kalanchoe and biofertilizers. Control plots which received inorganic fertilizers recorded the least recovery of essential oil (0.87 %).

FYM supplemented with kalanchoe, singly and along with biofertilizers and chromolaena mulch, recorded highest available P (92.48 kg ha^{-1}) and N (503.8 kg ha^{-1}) content in soil respectively. Vermicompost supplemented with kalanchoe recorded high content of soil K and all other treatments were on par. Control plots registered the lowest soil K content.

Higher plant uptake of major nutrients was observed in vermicompost treated plots. Enhanced population of soil microbes was recorded by the use of organic nutrients and biofertilizers. FYM supplemented with biofertilizers and vermicompost applied singly and along with kalanchoe and biofertilizers recorded the maximum bacterial, fungal and actinomycetes population. During the course of experiment, maximum incidence of bacterial wilt was observed in FYM manure received plots.

Composite samples of kacholam registered no significant variation in dry recovery during sun drying, shade drying and oven drying. Maximum quality constituents were retained in sun dried samples of the crude drug, recording 1.2 per cent essential oil and 3.4 per cent oleoresin though the variations were not significant.

Storage studies revealed the least percentage loss in weight (0.98 %) and residual moisture content (6.78 %) in samples stored in polyethyleneterephthalate (PET) bottles, at 6 months after storage. Essential oil and oleoresin contents recorded the maximum values during storage in PET bottles and polyethylene bags respectively. Samples stored in polyethylene bags and PET bottles did not record any insect infestation and had registered minimum microbial infection. Percentage loss of essential oil and oleoresin ranged from 5-30 per cent and 22-55 percent depending on method of storage.