# STANDARDISATION OF AGRO TECHNIQUES FOR TRANSPLANTED GINGER (*Zingiber officinale* Rosc.)

*by*


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**(2015-12-009)**


**THESIS**

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# DECLARATION

I, hereby declare that this thesis, entitled **"STANDARDISATION OF AGRO TECHNIQUES FOR TRANSPLANTED GINGER( *Zingiber officinale* Rosc.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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## CERTIFICATE

Certified that this thesis, entitled **"STANDARDISATION OF AGRO TECHNIQUES FOR TRANSPLANTED GINGER( *Zingiber officinale* Rosc.)"** is a record of bonafide research work done independently by **Ms. Sandra Merin Mathew (2015-12-009)** 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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We, the undersigned members of the advisory committee of Ms.Sandra Merin Mathew a candidate for the degree of **Master of Science in Horticulture** with major in Plantation Crops and Spices agree that the thesis entitled **"Standardisation of agro techniques for transplanted ginger. (** ***Zingiber officinale*** **Rosc.)"** may be submitted by Ms. Sandra Merin Mathew, in partial fulfilment of the requirement for the degree.

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## ABBREVIATIONS

| | | |
|---|---|---|
| % | : | per cent |
| ANUE | : | Agronomic Nitrogen Use Efficiency |
| CD | : | Critical Difference |
| CGR | : | Crop growth rate |
| cm | : | Centimeter |
| *et . al* | : | et alia |
| Fig. | : | Figure |
| g | : | gram |
| ha | : | Hectare |
| LAD | : | Leaf area duration |
| LAI | : | Leaf area index |
| MAT | : | Months after transplanting |
| mg | : | milligram |
| mm | : | milli meter |
| N | : | Nitrogen |
| NAR | : | Net assimilation rate |
| RGR | : | Relative growth rate |
| t | : | tonne |

# INTRODUCTION

# 1. INTRODUCTION

Ginger (*Zingiber officinale* Rosc ), one of the earliest known oriental spices of the family Zingiberaceae is being cultivated in India for underground modified stem called rhizomes which is used both as a fresh vegetable and as a dried spice, since time immemorial. It is a herbaceous perennial which is commercially cultivated as an annual. Ginger is mainly used as spice and flavoring agent in a wide variety of foods. It is also having excellent therapeutic values, and finds use in various pharmaceutical preparations of different systems of medicine. India is a leading producer of ginger in the world producing 10.25 lakh t (Spices Board, 2016) . The ginger produced in Kerala are superior as they have better intrinsic quality and are more acceptable in global market. Therefore the role of Kerala in ginger cultivation is more vital in upholding the global markets. In conventional planting of ginger about 1500 to 2500 kg $ha^{-1}$ of seed rhizome is used depending on seed size and spacing. The conventional propagation methods using rhizome bits being slow, a suitable method of raising ginger seedlings in portrays and transplanting them to main field has been devised by Kerala Agricultural University and Indian Institute of Spices Research. This technique has been found to be cost effective and at par in yield with conventional method.

The advantages of this technology are production of healthy uniform planting materials coupled with reduction in seed rhizome quantity which eventually leads to reduced cost on seeds. However, the management practices associated with this technology has not been standardized . Mulching of the field , the time, quantity and dosage of fertilizer need to be thus standardized for the transplanted ginger. Under conventional planting system organic mulching in ginger is very important that it provides a congenial microenvironment for germination of the rhizomes besides adding nutrients to the soil, improving soil texture, controlling weed growth etc . The availability of organic mulches is getting reduced nowadays and the efficacy of plastic mulches are reported in several crops in increasing yield, controlling weed growth, retaining nutrients etc. Hence , assessing the extent upto which the quantity of organic mulches can be reduced and the possibility of using plastic mulch in ginger cultivation needs to be investigated in the case of transplanted ginger crops.

Ginger is a soil-exhaustive crop, and shows good response to added nutrients. The nutritional recommendation for conventional planting of ginger is FYM @ 30 t $ha^{-1}$ and N, P and K @ 75:50:50 kg $ha^{-1}$ (KAU,2016). When we follow the transplantation method, this recommendation needs to be modified because the cultivation practise will be different from the conventional method. Hence the present investigation on "Standardisation of agro techniques for transplanted ginger. ( *Zingiber officinale* Rosc.)" was taken up with the objective of evaluating the efficacy of different levels of mulch and nutrients on the growth, yield, quality and profitability of transplanted ginger intercropped in coconut garden.

# REVIEW OF LITERATURE

## 2. REVIEW OF LITERATURE

The investigations on standardization of agro techniques for transplanted ginger ( *Zingiber officinale* R.) were taken up to evaluate the efficacy of different levels of mulch and nutrients on the growth, yield, quality and profitability of transplanted ginger . It is known that ginger is a soil nutrient exhausting crop and requires heavy mulching to obtain high yields. The relevant literature on effect of mulch and nutrients on growth , yield , physiological ,weed count , agronomic indices of ginger and the effect on soil nutrient status are reviewed.

### 2.1. Response of crop to mulch

Mulching in ginger is a common practice in many parts of India and its beneficial effects in enhancing sprouting, reducing soil erosion, conserving moisture, adding organic matter, improving temperature and physical properties of soil and minimizing weed competition in rhizomatous crops have been reported under various agro-climatic situations by several workers (Gill *et al*., 1999 ; Chandra and Govind, 2001). Andrews *et al*. (2001) defined mulching as a covering material that acts as a blanket and also helps to prevent excessive evaporation of soil moisture during hot weather conditions. Annual rhizome yield losses of 30-40% has been reported by farmers in India who failed to mulch their ginger plots ( Kumar *et al*., 2004). According to Awodoyin and Ogunyemi ( 2005 ) mulching is an effective method of manipulating crop growing environment to increase yield and improve product quality by controlling weed growth, ameliorating soil temperature, conserving soil moisture, reducing soil erosion, improving soil structure and enhancing organic matter content. Mulching is a compulsory agronomic requirement for ginger production (RMRDC, 2005). Mulching the crop with 30 t $ha^{-1}$ green leaves of trees such as *Garuga pinnata* Roxb., *Ailanthus malabarica* Candolle., *Terminalia paniculata* Roth., *Swietenia mahagani* (L.), *Glyricidia sepium* Jacq has been recommended in Kerala (Nybe and Miniraj, 2005)

Plastic mulch also helps to protect the soil from erosion and helps to create a microclimate favourable for the growth of crops (Otsuki *et al.*, 2000). Black mulch applied to the planting bed prior to planting warm the soil (Lamont, 2005). Bhardwaj (2013) reported that soil under the mulch remains loose, friable and leading to suitable environment for root penetration and conserve more moisture. It was also reported that white coloured polythene mulch decreased soil temperature while clear transparent plastic mulch increased soil temperature. Increased temperature in soil due to use of black colour polythene mulch have resulted in poor root growth, absorption of water and nutrients, shrinking of rhizomes and poor yield in ginger( Thankamani *et al.*, 2016).

### 2.1.1 Influence of mulches on morphological, physiological , yield and quality parameters of crops

Mohanty *et al.* (1991) have reported higher yield of turmeric with mulching. Gill *et al.* (1999) reported that application of straw mulch resulted in quick emergence of the crop, taller plants with more number of leaves, tillers and fingers per plant resulting in high yield in turmeric . The greatest plant height was observed at the rate of 10 ton/ha of mulch, applied at the time of planting in turmeric (Akinwumi *et al.*, 2000). Mishra *et al.* (2000) reported that the yield attributes of turmeric improved by mulch application, and mulch applied at the rate of 5 tonnes farmyard manure along with 30:30:30 kg of NPK $ha^{-1}$, respectively, produced highest yield per plant. Zaman *et al.* (2002) reported an increase in plant height and number of leaves in turmeric over unmulched plants. Mulching with paddy straw gave maximum average plant height (84.40 cm.) as compared to other treatments in turmeric .Yield of turmeric was also maximum with the paddy straw mulch (169.33 q/ha.) followed by mulching with dry grass (131.33 q/ha) ( Verma and Sarnaik, 2006). ( Kumar *et al.*, 2008) revealed that the plant height and stem girth of turmeric was significantly higher due to application of paddy straw mulch followed by grass mulch .

Kumar *et al.* (2003) revealed that the application of mulches at the rate of 10 tonnes $ha^{-1}$ conserved more moisture and increased the yield of turmeric by 12 per cent. Increase in the number and weight of rhizomes per plant due to mulch has been reported by Junior *et al.* (2005) in turmeric and all the mulching treatments were superior over control. Number of leaves did not differ significantly but the leaf size , number of tillers, total biomass production , root dry weight increased with paddy straw mulch application. Turmeric yield and yield contributing characters revealed that maximum yield per plant was recorded in paddy straw mulched plots which was significantly superior over control. Paddy straw mulch significantly increased the number and weight of finger rhizomes and weight of mother rhizome by 35.6, 25 and 33%, respectively over control treatment. The maximum finger size was recorded in plots with paddy straw mulch followed by grass mulch and the minimum in control. According to Sanyal and Dhar (2008) dry leaf mulch significantly increased the plant height in turmeric and greatest plant height was observed with mulch at the rate of 10 ton/ha , applied at the time of planting .

Application of paddy straw mulch @ 9.38 t/ha produced significantly taller plants with more tillers and leaves per plant resulting in higher fresh yield than application of mulch @ 6.25 t/ha, which in turn was significantly superior to no mulch . Increase in mulch level increased the oil and curcumin yield significantly, and the highest oil and curcumin yield was obtained with the mulch application @ 9.38 t/ha, which was significantly higher than mulch application @ 6.25 t/ha and no mulch (Manhas, 2011). The lowest plant height was observed for 5 tons/ha of mulch applied 12 weeks after planting while the highest average number of leaves per plant was observed in the treatment comprising 8 ton/ha of mulch applied at the time of planting in turmeric (Akinwumi *et al.*, 2013).

Application of 12.5, 5.0 and 5.0 t/ ha of mulch for the first, second and third mulching, respectively, are considered optimum in turmeric (Randhawa and Nandpuri, 1970). Mohanty and Sarma (1978) used 15 t $ha^{-1}$ green leaves at planting and 7.5 t/ha each at 45 and 90 DAP. Owadally *et al.* (1981) stated that mulching with sugarcane trash and rice straw was beneficial. Turmeric responds to applications of organic matter and experimental evidences are available on the beneficial effects of organic matter either alone or in combination with inorganic fertilizers on growth, productivity and quality of turmeric (Gopalakrishna *et al.*, 1997).

Aclan and Quisumbing (1976) reported that mulching with leaf was found to increase growth parameters, rhizome yield and starch content in ginger. Tree leaf and paddy straw as mulch have been reported to increase the yield of ginger in Bihar (Jha *et al.*, 1986). Saha (1989) reported that application of 90 kg N, 60kg $P_2O_5$ and 90 kg $K_2O$ $ha^{-1}$ produced maximum rhizome yield in ginger. Polythene as mulch material gave 19.9 t of fresh rhizome per ha compared to 12.0 t in unmulched plots (Mohanty *et al.*, 1990). Performances of different live mulches were similar but superior to unmulched plots (AICRPS, 1990). Mulching three times with leaves and growing intercrop of soybean as live mulch, was equally effective (AICRPS, 1992). Studies conducted by Jayachandran (1993a) have shown that in ginger upto 90 days after planting , the roots were confined to within 30 cm soil depth and within 10cm laterally and by 150 DAP roots grew beyond 30 cm soil depth and within 10 cm laterally. The influence of varieties was distinctly different from one another with respect to root length. The effect of plants derived from 5g seed rhizomes was the least .However the effects of plants obtained from 10 and 15g seed rhizome size were superior and were on par on root growth (Nizam, 1995). Babu and Jayachandran (1997) reported that dry ginger yield showed an increasing trend with increasing levels of mulch and also significant yield reduction was noticed in ginger cultivated under open condition when the quantity of mulch was reduced from 30 to 22.5 t/ha. The mulch requirement of ginger *(Zingiber officinale)* under various shade levels indicated that under 25 per cent shade, 22.5 t $ha^{-1}$ of green leaf mulch was only required and one-fourth quantity (7.5 t $ha^{-1}$) of green leaf mulch could be saved. Growth parameters namely, number of tillers ,leaves per clump and size of leaf , fresh rhizome yield of ginger increased significantly as compared to no mulch in ginger (Chandra and Govind , 2001) . Agarwal *et al.* (2001) in a field experiment on ginger found that the mulch treatment was better over control in terms of plant height, number of tillers per plant, number of leaves per plant and rhizome yield and also reported that the performance of organic mulches was better than synthetic mulches. Influence of varieties and seed sizes were significant in root growth of ginger. Among the different mulching materials, dry leaves used as mulching material showed maximum height, number of leaves and yield in ginger as reported by Sengupta *et al.* (2008). Sengupta *et al.* (2009) reported that use of polythene resulted in increase in plant height and use of organic mulch and polyethylene responded almost equally to that of control and were at par and organic mulch showed an increase in number of leaves and produced pronounced effect in yield against other treatments in ginger compared to polythene mulch in ginger . The highest yield and dry matter production were recorded in a low-shade condition of 25 percent and at the mulch level of 30 t/ha.

Ginger was grown under red, green, white and black shade nets with open as control. Light (par) intensity in shade nets varied from 58-63% of open light intensity. Results at harvest revealed that rhizome dry weight was about 10-12% higher in ginger under red shade net compared to open condition ( IISR, 2015) . Mulch had significant influence on plant height, number of leaves, number of tillers and these were the maximum in the treatment with rice straw mulch while these were lowest in control treatment at 125 days after planting . Different mulching treatments had significant effect on the weight of primary and secondary rhizome per plant. The maximum weight of primary rhizome (281.85 g/plant) was found from rice straw mulch and the lowest (197.17 g/plant) was obtained from control treatment.

The maximum dry yield of rhizome was found under rice straw mulch (23.82% ) and control ( 21.00% ) respectively in ginger. (Islam *et al.*, 2015) .

The growth and yield performance of ginger varieties under open and oil palm plantations in Nigeria revealed that mulching is required under both conditions for increased plant height and yield ( Nwaogu *et al.*, 2011). Kushwah *et al.* (2013) reported that maximum plant height, number of tillers, number of leaves, rhizome spread and weight of rhizome was recorded in mulching with leaves of palas, which was significantly superior over other materials during both years and mulching with paddy straw secured second place followed by polyethylene and dry grass and minimum was recorded in no mulch.

Abraham *et al.* (2016) reported that root length and rhizome thickness was significantly greater when mulched with 30 kg $ha^{-1}$ of *panal* (53.52 cm) and rubber leaves (47.18cm) and was on par with the control (47.52cm) , root volume were significantly greater under *matty* ( 25.15 cm $^{3}plant^{-1}$) , wild jack (22.71 cm $^{3}plant^{-1}$) and control (25.88 cm $^{3}plant^{-1}$) . He also reported that rhizome spread was significantly greater in plants mulched with *panal* leaves ( 28.80 cm) and was on par with control (28.16 cm) in ginger.

**2.1.7. Weed count and dry weight of weed**

Chandra and Govind (2001) reported that application of mulch enhanced the sprouting of ginger rhizomes and minimized weeds and total weed biomass production was highest in unmulched plots compared to mulched plots. Mahey *et al.* (1986) reported that application of paddy husk and wheat straw mulch increased the rhizome yield of turmeric by 59.5 and 21.8 % as compared to no-mulch plots, respectively, due to improved weed control and augmented soil moisture retention through reduced evaporation. Mohanty *et al.* (1991) reported that application of mulch delayed the emergence of weeds and would have also had a smothering effect on them. This quick and better establishment of the plants along with reduced competition by weeds had a favourable effect on all growth parameters of turmeric. Better performance of the ginger in the beds in which paddy straw applied was due to increased yield attributing characters, the optimized soil temperature, controlled evaporation losses, increased soil moisture conservation, due to suppression of weeds and uptake of major, secondary and minor nutrients.( Rair *et al* . 2011). Manhas *et al.* (2011) reported that weed population and weed dry matter were significantly lower with 6.25 t/ha mulch than with no mulch. Kaur and Brar (2016) reported that weed dry matter was also significantly reduced in mulched plots as compared to no mulch and weed dry matter was 81.5 % and 163.5 % less in mulch plots as compared to no-mulch plots at 45 and 90 days after planting respectively. The effect of different organic mulches and plastic mulches on weed suppression and yield of ginger revealed that application of paddy straw @ 6 t $ha^{-1}$ along with green leaf mulch of 7.5 t $ha^{-1}$ at 45 and 90 days after planting and application of dried coconut leaves at the time of planting @ 5.4 t $ha^{-1}$ recorded higher weed control efficiency, higher economic returns compared to application of *Glycosmis pentaphylla* leaf mulch ( Thankamani *et al.*, 2016)

**2.1.8.Agronomic indices**

The values of agronomic N use efficiency were lowest in heavy and mixed mulching treatment and higher level of N increased agronomic efficiency in rice. (Cho and Korean, 1999)

**2.1.11. Plant NPK uptake**

According to Mohankumar *et al.* (1973) the green leaf mulch was found to be efficient in increasing the content of soil nutrients in yams. The increased availability of NPK content for mulch over other mulch materials might be due to the nutrient addition by decomposition of the leaf mulch Increased mulch and FYM levels significantly increased N, P and K uptake by leaves and rhizomes of turmeric (Manhas, 2011). Priya and Shashidhara (2016) reported that nitrogen uptake was significantly influenced due to mulching treatments in maize and wheat ( 0.5 kg $m^{-2}$ and 0.8 kg $m^{-2}$ respectively). Application of mulch during both kharif and rabi recorded significantly higher nitrogen, phosphorous and potassium uptake at harvest stage as compared to control. This was due to higher yield and higher soil nutrient status and also of higher biomass and decomposition of residue. This resulted in higher availability of N, P,K which resulted in increase uptake of nutrients.

## 2.2.Response of crop to major nutrients

The requirement of nitrogen (N) is the most critical among the major nutrients. Although the nutrient is directly available to the plant in nitrate form, it is easily lost by leaching. Ammonium ions perform better than nitrates under heavy leaching situations. Phosphorus, (P), is highly immobile in the soil because of its reaction with iron and aluminum hydroxides. Therefore, the amount of phosphatic fertilizer needed for the crop is relatively high. When ginger is grown as a homestead crop, potassium, (K), nutrition plays an important role. Only under high rates of K application can the crop be grown successfully under shade conditions (Jayaraj, 1990). For quick-growing crop like ginger, fertilizer containing a high proportion of water-soluble $P_2O_5$ is needed for a better yield (Sushma and Jose, 1994).

### 2.2.1 Response of nutrients in morphological, physiological , yield ,quality parameters

Aiyadurai (1966) reported increase in yield due to higher rates of P application. In turmeric moderate levels of nitrogen and potassium application had significant influence on crop growth and weight of mother rhizome per plant. Positive response were obtained by way of increased plant height and tillering with 112.5 kg N, 112.5 kg $P_2O_5$ and 200 kg $K_2O$ $ha^{-1}$ in turmeric (Rao *et al.*, 2005).

NPK 30:30:60 kg $ha^{-1}$ recorded the maximum height in the shade and NPK 20:20: 40 kg $ha^{-1}$ in the open conditions in turmeric ( KAU, 1983) . Rathinavel (1983) found that application of $K_2O$ upto 180 kg $ha^{-1}$ increased the curing percentage, curcumin, oleoresin and essential oil contents of rhizomes besides the yield. Govind *et al.* (1990) in turmeric, an increasing trend in the number of tillers as well as leaf production with increasing fertilization up to 40:40:80 kg NPK $ha^{-1}$ in the shade was observed and also explained that application of N nutrients significantly increase vegetative growth parameters of turmeric than any other nutrients. Ratna *et al.* (1993) also reported that the fibre content of rhizomes gradually increased with higher levels of nitrogen and phosphorus application in turmeric . Meerabai *et al.* (2000) found that application of 120 kg N and 120 kg $K_2O$ $ha^{-1}$ together with trace elements boron (2 kg $ha^{-1}$) and zinc (10 kg $ha^{-1}$) showed higher yield in turmeric. Hossain and Ishimine (2005) revealed that turmeric yield increased with application of NPK. Padmapriya *et al.* (2009) reported that highest harvest index (80.62) was recorded in partial shade condition with 100 % N, $P_2O_5$ and $K_2O$ + 50 % FYM (15 t $ha^{-1}$) + coir compost (10 t $ha^{-1}$) + *Azospirillum* (10 kg $ha^{-1}$) + Phosphobacteria (10 kg $ha^{-1}$) + 3 % panchaghavya at 180 days after planting. Shinde ( 2016) revealed that increasing levels of fertilizer N significantly increased plant height in turmeric and he also noticed that maximum number of leaves per plant was observed when 25 t FYM + 150 kg N + 50 kg $P_2O_5$ + 150 kg $K_2O$ and it was on par with 25 t FYM + 200 kg N + 50 kg $P_2O_5$ + 150 kg $K_2O$. Integrated nutrient mangement involving a combination of inorganic fertilizers (30:50:120 kg $ha^{-1}$ NPK) and organic manure (20.0 t $ha^{-1}$ FYM) registered higher rhizome yield and increased nutrient uptake and soil quality ( Srinivasan *et al.*, 2016).

Poor response to K application has been reported by Muralidharan and Kamalam (1973). They recommended that 60 kg of $K_2O$ $ha^{-1}$ applied in two split doses was the best for ginger. Muralidharan *et al.* (1974) reported that nitrogen application significantly increased the number of shoots per plant in ginger and higher K content in the leaf was found to be related with higher yield in ginger Johnson (1978) reported that higher levels of N produced a significant effect on dry matter production in ginger and also found that there was an yield reduction when the fertilizer levels was increased from 80 to 120 kg $ha^{-1}$ . Sadanandan and Sashidharan (1979) found that the effect of N on yield of ginger was significant and the highest yield was recorded at 50 kg N $ha^{-1}$. Patil and Konde (1988) reported that the yield of ginger at 50 kg N $ha^{-1}$ plus inoculants was on par with that of 75 kg N $ha^{-1}$ without inoculants, indicating a saving of 25 kg N $ha^{-1}$ through inoculation. Joseph( 1992) reported that ginger under all shade levels ( 25 per cent, 50 per cent , 75 per cent) fertilizer treatments showed a positive influence on plant height, leaf number and dry matter production. Roy *et al* . (1992) reported that yield per plant as well as per hectare was recorded maximum when the plants were sprayed with all the three micronutrients Zn+Fe+B. Nitrogen at 150 kg $ha^{-1}$ was found to increase the leaf area index of ginger and higher levels of N and P significantly increased dry matter production( Joseph and Jayachandran, 1993). Potassium application (0 to 90 kg $ha^{-1}$) increased rhizome yield significantly by increasing various yield contributing characters up to 60 kg $ha^{-1}$. The optimum dose worked was 76 kg $K_2O$ $ha^{-1}$ (Singh *et al.*, 1993). Xu *et al.* (1993) reported that the N fertilizer utilization by ginger plant increased with delay in application, being the greatest with application as a dressing during the middle of vigorous plant growth stage. Govind *et al.* (1995) reported that 90 kg of $P_2O_5$/ha produced taller plants, more tillers and leaves per plant, more secondary rhizomes per plant, and higher fresh and dry yields of rhizome in cv. Nadia. Thakur and Sharma (1997) showed that N and P up to 100 and 60 kg/ha, respectively, increased the rhizome yield significantly in ginger . Dayankatti and Sulikeri (2000) reported that all growth parameters were significantly influenced by nitrogen levels and an increase in rhizome spread was recorded at 125 kg N $ha^{-1}$.

Mridula and Jayachandran (2001) reported that varying levels of the nutrients significantly influenced the quality of mango ginger rhizome. The volatile oil content was significantly increased with nitrogen application and 30 kg $ha^{-1}$ recorded maximum value and there was a progressive increase in volatile oil content with increasing phosphorus levels and also potassium application at higher levels reduced the volatile oil content.

The root morphological factors such as length, thickness,surface area and volume have profound effects on plant's ability to acquire and absorb nutrients in soil ( Barber, 1995). Rhizome spread was influenced by phosphorus application and 30kg $P_2O_5$ $ha^{-1}$ resulted in higher spread (28.93 cm) in mango ginger ( Mridula, 1997) . Enhanced root elongation ,lateral root emergence and plasma membrane H+ATPase activity of maize roots by humic acid extracts have been reported by Canellas *et al.* (2000). Nirmalatha (2009) reported that vermicompost 25 t $ha^{-1}$ ,Neem cake 6 t $ha^{-1}$ ,FYM 40 t $ha^{-1}$ recorded maximum rhizome spread, rhizhome thickness , root spread, root length, root weight in kasthuri turmeric than their respective lower level of application.

**2.1.7.Agronomic indices**

Agronomic nitrogen use efficiency (ANUE) was defined as the ratio of grain yield with N application minus grain yield without N application to N application and was used to describe the capability of yield increase per kilogram of N. Jagadeeshwaran (2004) reported that in turmeric agronomic efficiency varied from 18.8 kg dry rhizome per kg of N applied with NPK level at 75% to 29.2 kg dry rhizome per kg of N applied with 100% NPK level. The agronomic efficiency was maximum with 100% NPK level. Dobermann (2007) reported that AEN for cereals in developing countries ranged between 10 and 30 kg $kg^{-1}$. Zhang *et al* . (2007) reported that the capability of yield increase per kilogram pure N declined remarkably with increasing N application in rice. Szmigiel *et al.* (2016) reported that the highest N agronomic efficiency, of 32.7 kg kg-1 was observed for the rate of 60 kg N $ha^{-1}$ in wheat .

In phosphorus use efficiency Jagadeeshwaran (2004) reported that in turmeric efficiency was high with 100% NPK level . Agronomic efficiency varied from 47.1 kg dry rhizome per kg of $P_2O_5$ applied with 75% NPK level to 73.1kg dry rhizome per kg of $P_2O_5$ applied at 100% NPK level. In potassium use efficiency agronomic efficiency varied from 26.2kg with 75% NPK level to 40.6 kg at 100% NPK level. The partial productivity decline with increasing levels of NPK.

One of the methods for measuring the efficiency of N,P,K utilization is using the index of physiological efficiency of absorbed (uptake) N,P and K. The index indicates how absorbed N,P and K is used by the plant to produce yield. It is related to many physiological processes such as absorption, nutrient reduction efficiency , nutrient remobilization, translocation, assimilation and stockage (Novoa and Loomis, 1981)

Physiological N use efficiency (PNUE) was defined as the ratio of yield increased with N application to total plant N uptake increased with N application and it reflected the use efficiency of N absorbed by rice plant. It showed that yield increased per kilogram N accumulated in rice plant was decreased with increasing N application (Quanbao *et al.*, 2007).

Sources of nitrogen registered significant influence on nitrogen physiological and agronomic efficiency of nitrogen. Large sized urea granules recorded higher physiological (52.83, 53.25 and 52.99 kg grain $kg^{-1}$ N uptake) and agronomic efficiency (60.53, 48.27 and 54.40 kg grain $kg^{-1}$ N applied) (Jayadeva *et al.*, 2008)

Giller *et al.*(2004) reported that significant increases in nitrogen use efficiency was achieved through reduction in N fertilizer use by 10-30% while increases in yield tended to be small. Higher levels indicate a higher amount of nutrient input while lower indicate productivity limiting deficit. Partial factor productivity index is the simplest form of yield efficiency and is calculated per units of crop yield per unit nutrient element (Fixen, 2009). Typical values of the partial productivity of nitrogen are about 40-80 kg $kg^{-1}$. The rates higher than 60 kg $kg^{-1}$ are used is very efficiency managed systems at low nitrogen rates or low soil nitrogen supply (Panayotova and Kostadinova, 2016) .

### 2.1.8.Soil chemical analysis

Mohankumar *et al.* (1973) reported that green leaf mulch was found to be efficient in increasing the contents of soil nutrients and the increased availability of NPK content for leaf mulch over other mulch materials may be due to the nutrient addition by decomposition of leaf mulch.

### 2.1.9.Nutrient analysis of FYM, organic mulch

NPK content of FYM was reported to be 1% of N , 0.5% of P, 1% of K ( KAU, 2011). According to TNAU (2016) on an average well decomposed FYM contains 0.5% N, 0.2% $P_2O_5$ and 0.5% $K_2O$. An anlaysis of 100 muncipal leaf sample reported an average nutrient concenteration of 1%, 0.1%, 0.38% NPK on dry weight basis ( Heckman *et al.*, nd)

### 2.1.10. Plant NPK uptake

The total N in ginger shoots and rhizomes increased with increasing fertilizer N application and leaf N concenterations and the yield of ginger shoots and rhizomes increased with the total amount of N applied up to highest level (Lee *et al* .,1981). Thakur and Sharma (1997) reported that the uptake of nutrients by ginger crop can be increased by the application of inorganic fertilizers. Maheshwarappa *et al.* (1999) reported in galangal that Nitrogen, phosphorus and potassium uptake was significantly higher with mother rhizome compared to finger rhizome due to better vegetative growth of the crop in the initial stages which resulted in higher uptake of nutrients. Ajithkumar and Jayachandran (2001) reported that uptake of nitrogen, phosphorus and potassium was significantly increased with higher rate of application and higher uptake of nutrients was under N 150 kg ha$^{-1}$, $P_2O_5$ 100 kg ha$^{-1}$ and $K_2O$ 100 kg ha$^{-1}$ attributed to better availability of nutrients which reflected in better growth and rhizome yield.

Singh and Singh (2007) have shown increased uptake of nutrients in ginger crop under Nagaland conditions with combined application of organic manures and inorganic fertilizers. Shaikh *et al.* (2010) reported that in ginger uptake of nitrogen, phosphorous, potassium was the highest with 75:50:50 kg/ha + 25t FYM/ha followed by application of 50 % N through 75:50:50 kg ha$^{-1}$ + 50 % N through poultry manure. Potassium uptake ranged from 68 to 180 kg K ha$^{-1}$ as the rate of application increased ( Noor *et al.*, 2014).

Nitrogen, phosphorus and potassium uptake was significantly higher with mother rhizome compared to finger rhizome and because of better vegetative growth of the crop in the initial stages which resulted in higher uptake of these nutrients in galangal ( Maheswarappa *et al.*, 1999)

**2.1.11.Nutrient balance sheet for NPK**

The maximum residual status of available nitrogen and potassium was observed in application of 100 per cent 120:60:60 kg NPK followed 50 per cent 120:60:60 kg NPK and lowest nutrient balance of nitrogen and potassium was in control treatment of sorghum (Gawai and Pawar, 2007). Noor *et al.* (2014) reported an annual removal of 180 kg K ha$^{-1}$ turmeric through harvested produce at the highest rate of K application of 160 kg K ha$^{-1}$ and also A negative K balance was observed even with balanced fertilization, implying the importance of K management in achieving sustainable yields and maintaining soil health.

### 2.1.12. Pest and disease incidence

Leaf spot disease of ginger can be managed by one or two sprays of Bordeaux mixture (1%) (Sohi *et al* ., 1973). Proper diagnosis of diseases is essential for their management and prevention (Dake *et al*., 1988). The fungal ( *Pythium* spp, *Fusarium* spp.) and bacterial ( *P. solanacearum* ) infections occur simultaneously in field (Dake and Edison 1989) . In Kerala 23.6 to 25.0 percent of pseudostems were damaged by the shoot borer at Kottayam and Idukki district. Yield losses of 25 percent have also been reported when 23 to 24 percent of a plant's pseudostems are infested and the pest was reported to cause 40 percent yield loss in Kottayam and Idukki districts in Kerala (Nybe, 2001)

### 2.1.13.Benefit cost analysis

Rao (1991) reported that under rainfed conditions coconut + elephant foot yam combination could fetch the highest return followed by coconut+ ginger. The profitability of coconut from holdings of size below 0.5 ha was Rs 3829 $ha^{-1}$ but it rose to Rs 9114 when intercrop was practiced. Likewise in 0.5-1 ha holdings, the profitability rose from Rs 12867 to Rs 15081 $ha^{-1}$ when intercropping was adopted (Thampan, 1999) . Nath and Karla (2000) calculated economics of ginger and found maximum net profit (Rs. 97,175) and cost benefit ratio of ginger with application of 100:50:50 kg $ha^{-1}$ NPK along with biofertilizers. There was a significant increase in net return and B: C ratio with each increase in mulch level and the maximum net return and B: C ratio were obtained with 9.38 t/ha mulch, significantly higher than mulch application at 6.25 t/ha and no mulch. (Manhas, 2011). Kushwah *et al* . (2013) reported that economic evaluation of different treatments showed that cost of cultivation was maximum with polyethylene mulch whereas highest total income, net return and Input : Output ratio were obtained with application of palas leaves and concluded that use of mulching material in ginger is beneficial with regard to yield as well as economics as compared to no mulch.

In turmeric application of N, $P_2O_5$ and $K_2O$ at the rate of 150:125:250 kg $ha^{-1}$ respectively resulted in the highest benefit: cost ratio as reported by Venkatesha *et al.* (1998). Swain *et al.* (2007) reported higher economic benefits with higher doses of NPK in ginger and turmeric.

# MATERIALS AND METHODS

# 3. MATERIALS AND METHODS

The investigation on "Standardization of agrotechniques for transplanted ginger ( *Zingiber officinale* Rosc)" was undertaken in the Department of Plantation Crops and Spices, College of Agriculture, Vellayani. during the period 2016-2017 to evaluate the efficacy of different levels of mulch and nutrient on the growth, yield, quality and profitability of transplanted ginger intercropped in coconut garden.

## 3.1 EXPERIMENTAL SITE

### 3.1.1 Location

Field experiments were carried out at the Instructional Farm , College of Agriculture, Vellayani, Kerala located at a $8^0$ 30' North latitude and $76^0$ 54' East longitude at an altitude of 29m above MSL.

### 3.1.2 Soil

The soil of the experimental location was red loam belonging to the Vellayani series and texturally classed as sandy clay loam.

## 3.2 Season

The field experiment was conducted during Apirl 2016 to January 2017.

## 3.3 MATERIALS

### 3.3.1 Seed material and variety

Good quality seed material of ginger variety "Karthika" was collected from Agricultural Research Station, Mannuthy .

### 3.3.2 Seed treatment

Collected seed material was cut into two noded rhizome bits weighting 10-15 g. Rhizome bits were dipped in 2 per cent *Pseudomonas* for 20 minutes and partially dried under shade . These materials were used for planting in protrays as well as for conventional planting for the absolute control plot ($C_2$)

**3.3.3 Manures and fertilizers**

Trichoderma enriched farmyard manure in the ratio 1:10 was uniformly applied to all plots except those under absolute control. Urea (46% of N) , Superphosphate ( 16 per cent $P_2O_5$ ), Muriate of potash (60 per cent $K_2O$) were used as inorganic sources of N,P , K and 19:19:19 was used in treatments where foliar application was included

**3.3.3 Mulch**

Two types of mulches were used in the experiment . Organic mulch of green leaves and Plastic mulch of 30 micron thickness

3.4 METHODS

**3.4.1 Design of the experiment**

Split plot

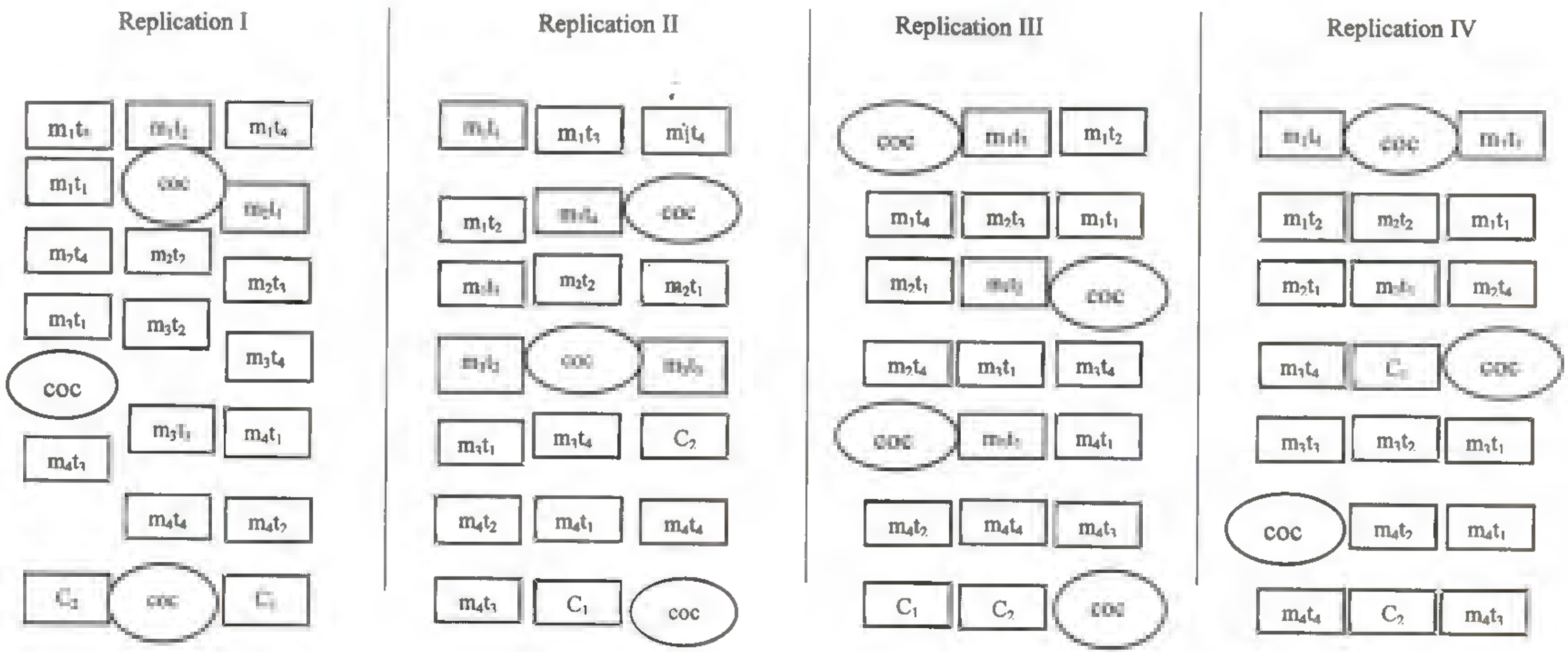
Main plot treatments - 4

Sub plot treatments - 4

Replication – 4

Sub plot size- 3m x 1m

Spacing- 25 cm x 25 cm




$M_1$ - Organic mulch @ 30 t ha$^{-1}$
$M_2$ - Organic mulch @ 15 t ha$^{-1}$
$M_3$ - Organic mulch @ 7.5 t ha$^{-1}$
$M_4$ – Plastic mulch

COC- Coconut tree

$T_1$ - 75:50:50 kg ha$^{-1}$ NPK
$T_2$ - 150: 100: 100 kg ha$^{-1}$ NPK
$T_3$ - $T_1$ + foliar application of 19:19:19 @ 0.5% applied at 1, 3, 4 MAT
$T_4$ - 100:75:75 kg ha$^{-1}$ + foliar application of 19:19:19 @ 0.5% at 1, 3, 4 MAT

Fig 1: Layout of the experimental plot

3.4.1.1 **Treatments**

**Main plot treatments : Mulching(M )**

$M_1$ - Organic mulch @ 30 t ha $^{-1}$ , 15t ha$^{-1}$ of organic mulch was applied in two equal split doses

$M_2$ - Organic mulch @ 15 t ha$^{-1}$ , 7.5t ha$^{-1}$ of organic mulch was applied in two equal split doses

$M_3$ - Organic mulch @ 7.5 t ha$^{-1}$ , applied as single dose

$M_4$ – Plastic mulch

**Sub plot: Fertilizers (T )**

$T_1$ - 75:50:50 kg ha$^{-1}$ NPK

(½ N+ full P+ ½ K at the time of transplanting ½ N + $^1/_2$ K 2 months after transplanting (MAT)

$T_2$ - 150: 100: 100 kg ha$^{-1}$ NPK

(½ N+ full P+ ½ K at the time of transplanting ½ N + $^1/_2$ K 2 MAT)

$T_3$ - $T_1$ + foliar application of 19:19:19 @ 0.5% applied at 1, 3, 4 MAT

(½ N+ full P+ ½ K at the time of transplanting ½ N + $^1/_2$ K 2 MAT)

$T_4$ - 100:75:75 kg ha$^{-1}$ + foliar application of 19:19:19 @ 0.5% at 1, 3, 4 MAT

(½ N+ full P+ ½ K at the time of transplanting ½ N + $^1/_2$ K 2 MAT)

**Control** – Two control plots were maintained of plot size 3m X 1 m

**$C_1$- POP recommendation**

Direct planting of rhizome bits as per the Kerala Agricultural University Package of practice's recommendation (KAU, 2016)

**$C_2$- Absolute control**

Ginger transplants of 55 days old ginger seedlings were raised without applying any manures and fertilizers.

**3.4.2 Layout of the experiment**

The field plan of the experiment is presented in Fig 1 and field overview are presented in Plate 1

**3.4.2. Raising the ginger seedlings in protrays**

Pretreated rhizome bits were planted in protrays filled with *Trichoderma* enriched coir pith compost and FYM (2:1) and kept in automated polyhouse for 55 days. The seedlings were used for planting the treatments except control, $C_2$. For control $C_1$ rhizome bits of size 15 g were dipped in 2 % pseudomonas for 20 minutes were partially dried and planted directly in the field.

**3.4.3 Land preparation and planting**

The field was worked to a fine tilth and beds of size of 3m X 1m and at 25 cm height were prepared in the interspaces of coconut garden. A channel of 40 cm was provided. In those plots were plastic mulching was followed mulching sheet was laid out in the bed before planting. Holes were made in it at 25 cm X 25cm spacing and ginger seedlings were planted in these holes. In other plots also 55 days old ginger plants raised in portray were transplanted to main field at spacing of 25 cm X 25cm.

**3.4.4 Organic manure and fertilizer application**

Ginger plants of 50-55 day old was transplanted to the plot size of 3m X 1m at a spacing of 25 cm X 25 cm . The seedlings were planted and treatments applied as mentioned. Trichoderma enriched FYM @ 30 t /ha was applied uniformly to all plots

except control $C_2$. The treatments consisted of four mulches (main plot) .Three organic mulch ($M_1$, $M_2$ and $M_3$) applied @ 30 t $ha^{-1}$, 15t $ha^{-1}$ and 7.5t $ha^{-1}$ .The ash

Plate 1: Field overview

Two nodded Ginger rhizome bits

Treatment using *Pseudomonas*

Shade drying after treating with *Pseudomonas*

Planting in protray

Ginger seedling ready for transplantation

Plate 2 : Raising the ginger seedlings in protrays

colour plastic mulch ($M_4$) was of 30 micron. The sub plot treatment consisted of four levels of fertilizers, $T_1$ , $T_2$ , $T_3$ and $T_4$ as mentioned .

3.5 AFTER CULTIVATION

Irrigation and weeding were carried out as and when necessary

**3.5.2 Plant protection**

Leaf spot disease was observed during the intial stages of growth. The same was controlled by spraying Mancozeb (0.3%).The crop was free from from pest infestation.

3.6 OBSERVATION

Two plots of size 3m X 1m per replication were maintained. One plot was used for biometric observations and the other for destructive. The observations were taken from five sample plants selected at random at bimonthly intervals from each plot maintained for observation and the mean was worked out.

**3.6.1 Growth parameters**

***3.6.1.1 Plant height***

The height of the plant was measured from the base of the plant to the base of the young fully opened leaf and expressed in cm

***3.6.1.2 Number of leaves/plant***

The number of fully opened leaves of the tillers from each sample plant were counted and the mean expressed.

*3.6.1.3 Number of tillers/ plant*

The number of aerial shoots produced by each observed plant was counted and mean expressed.

*3.6.1.4 Shoot weight*

The yield of above ground portion of plants maintained for destructive sampling was collected at random and dried in oven at $70^{o} \pm 5^{o}$ C till constant weight . The mean weight was experienced as g $plant^{-1}$ on dry weight basis.

**3.6.2 Root characters**

The root length, root weight, root volume were measured at bimonthly interval from 4 months after planting (MAP) from plots maintained for destructive sampling.

*3.6.2.1 Root length*

Maximum length of roots from uprooted plants was measured and mean length expressed in centimeter.

*3.6.2.2 Root weight*

Roots separated from individual plants plots maintained for destructive sampling were washed and dried in hot air oven at $70^{o} \pm 5^{o}$ C until constant weight and mean value expressed as g $plant^{-1}$

*3.6.2.3 Root volume*

Root volume per plant was found out by displacement method at $4^{th}$ ,$6^{th}$ and $8^{th}$ month and mean value expressed in $cm^3$ $plant^{-1}$.

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*3.6.2.4 Root shoot ratio*

Root and shoot dry weight of was worked out and the mean value experssed as the ratio between the mean of root weight and shoot weight.

**3.6.3. Yield characters**

***3.6.3.1. Fresh yield***

The fresh rhizome yield of five plants uprooted from plots maintained for destructive sampling was recorded at biomonthly intervals from 4 MAP and expressed in kg $ha^{-1}$ .

***3.6.3.2. Dry yield***

Dry ginger yield was recorded from five ginger plants harvested from plots maintained for destructive sampling at bimonthly intervals from 4 MAP. The fresh rhizomes were washed and kept in hot air oven at $70^{\circ} \pm 5^{\circ}$ C till constant weight was obtained and at harvest dry ginger was measured from net plot and expressed in kg $ha^{-1}$.

***3.6.3.3 Harvest Index***

Harvest index was calculated at final harvest as the ratio of dry weight of rhizome to the dry weight of rhizome and shoot ( whole plant)

Harvest Index (HI) = $\frac{Yeco}{Ybio}$ where

Y eco = total dry weight of rhizome

Y bio = total dry weight of plant

#### *3.6.3.4 Dry recovery*

Dry recovery (%) content was calculated at bimonthly intervals in 4th, 6th and at final harvest . Fresh rhizomes after washing was weighted and kept in drier at 60-70° C till constant weight was obtained . The dry weight was then noted and the mean dry recovery was expressed as given below.

Dry recovery (%) = B /A X 100

Where, A = Sample weight of rhizome (g)

B = Weight of sample after drying (g)

### 3.6.4 Rhizome characters

#### *3.6.4.1 Rhizome thickness*

Rhizome thickness was measured at bimonthly intervals starting from 4th month using micrometer and mean expressed in cm.

#### *3.6.3.2 Rhizome spread*

The horizondal width of the rhizomes at bimonthly interval starting from 4th month was measured using a scale and mean value expressed in cm.

### 3.6.5 Quality Analysis

#### *3.6.5.1 Starch*

Starch content was analysed at biomonthly intervals from 4 MAP by Acid hydrolysis method (Pruthi ,1989) and mean value expressed as percentage on dry weight basis.

*3.6.5.2 Fibre*

The crude fibre content was estimated at biomonthly intervals from 4 MAP (Pruthi, 1989) and mean value expressed as percentage on dry weight basis.

*3.6.5.3 Volatile oil*

The content of volatile oil was estimated at biomonthly intervals at 4 months of age by Clevenger distillation method (Pruthi, 1989) and mean value expressed as percentage (w/w) on dry weight basis.

*3.6.5.4 Non volatile ether extract*

Non volatile ether extract (NVEE) was estimated at biomonthly intervals at 4 MAP (Pruthi,1989) and mean value expressed as percentage on dry weight basis.

**3.6.6.Physiological Analysis**

Observation on dry matter production , Net assimilation rate , Crop growth rate , Leaf area index, Relative growth rate , Leaf area duration, Bulking rate and Chlorophyll content were made from plants maintained for destructive sampling at 4, 6 and 8 MAP

*3.6.6.1 Dry matter production*

The leaves, petioles, pseudostem, rhizomes and roots of the uprooted plants were separated and dried to a constant weight at $70^{\circ} \pm 5^{\circ}$ C in a hot air oven. The sum of dry weights of component parts gave the total dry matter production of the plant and mean value expressed as g plant $^{-1}$.

*3.6.6.2 Net Assimilation Rate*

Net assimilation rate was calculated as per the procedure given by Watson (1958) as modified by Buttery (1970). The following formula was used to derive Net Assimilation rate and mean expressed in g $m^{-2}$ $day^{-1}$

NAR $= W_2 - W_1 / t_2 - t_1 (A_1 + A_2)/2$

Where

$W_1$ – total dry weight of the plant in g at time $t_1$

$W_2$ – total dry weight of the plant in g at time $t_2$

$(t_2 - t_1)$ = time interval in days

$A_1$ = leaf area ($m^2$) at time $t_1$

$A_2$ = leaf area ($m^2$) at time $t_2$

*3.6.6.3 Crop Growth Rate*

Crop growth rate (CGR) was calculated using the formula of Watson (1958) and mean value expressed as g $m^{-2}$ $day^{-1}$

CGR = Net Assimilation Rate X Leaf Area Index

*3.6.6.4 Leaf Area Index*

Leaf area index (LAI) was computed based on the following relationship (Williams ,1946)

$$\text{Leaf area Index (LAI)} = \frac{\text{Sum of leaf area of N sample plant (m2)}}{\text{Area of land covered by N plants (m2)}}$$

*3.6.6.5 Relative growth rate*

Relative growth rate (RGR) was calculated as per the formula suggested by Blackman (1919) and mean value as expressed in g g $^{-1}$day$^{-1}$.

$$\text{RGR} = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

$W_1$ = Total dry weight of the plant at time $t_1$

$W_2$ = Total dry weight of the plant at time $t_2$

*3.6.6.6 Leaf area duration*

Leaf area duration (LAD) was calculated using the formula given by Power *et al* (1967) and expressed in days

$$\text{LAD} = \frac{L_1 + (L_1 + 1)X(t_2 - t_1)}{2}$$

Where

$L_1$ = LAI at first stage

$L_1+1$ = LAI at second stage

$t_2 - t_1$ = Time interval between these stages

*3.6.6.7 Bulking rate*

The bulking rate in rhizome was worked out on the basis of increase in dry weight of rhizome per plant per day and mean expressed as g plant$^{-1}$ day$^{-1}$.

Bulking Rate = $\frac{W_2 - W_1}{t_2 - t_1}$

Where $W_1$ and $W_2$ are dry weight of rhizome at two time units $t_1$ and $t_2$.

#### *3.6.6.8 Chlorophyll content*

Chlorophyll content of leaf samples was estimated following procedure of Arnon (1949). Total chlorophyll contents was calculated using the formulae given below and expressed in mg $g^{-1}$ of fresh leaf weight.

Total Chlorophyll= $\{[20.2(OD\ at\ 645) + 8.01\ (OD\ at\ 663)] \times V\}/(W \times 100)$

Chlorophyll a = $\{[12.7(OD\ at\ 663) - 2.69(OD\ at\ 645)] \times V\}/(W \times 100)$

Chlorophyll b = $\{[222.9(OD\ at\ 645) - 4.68(OD\ at\ 663)] \times V\}/(W \times 100)$

Where V= volume of the solution made up

W= fresh weight of leaves

OD = Optical density

### 3.6.7 Weed count and dry weight per unit area

The total number of weeds present in 1 $m^2$ area was counted at $45^{th}$ day, $90^{th}$ day, and $120^{th}$ day . Dry weight of weeds was recorded by oven driying to a constant weight at $70^{\circ} \pm 5^{\circ}$ C .

### 3.6.8 Agronomic indices

#### *3.6.8.1 Agronomic efficiency*

It indicates crop yield increase $kg^{-1}$ of nutrient applied and was calculated by the formula ( Dobermann and Fairhurst , 2000)

$$AE = \frac{\text{Crop yield (kg/ha) with applied nutrient } (Y_N) - \text{Crop yield (kg/ha) without nutrient } (Y_O)}{\text{Amount of nutrient applied (kg/ha)}}$$

#### *3.6.8.2 Partial factor productivity*

It indicates crop yield per amount of nutrient applied. ( Dobermann and Fairhurst, 2000)

$$PFP = \frac{\text{Yield obtained (Y)}}{\text{amount of nutrient applied (F)}}$$

#### *3.6.8.3 Physiological efficiency*

It indicates increase in yield per kg nutrient uptake from fertilizer and expressed in kg grain kg-1 plant N uptake. ( Dobermann and Fairhurst, 2000)

$$PE = \frac{\text{Yield in treatment plot- Yield in control plot}}{\text{Plant uptake in treatment plot-Plant uptake in control plot}}$$

### 3.6.9 Soil Chemical analysis

The soil samples were collected from each plot before starting the crop and then after the cultivation period. The samples were analysed for available N, available P and available K.

Details of method used for chemical analysis of soils

| Sl.No. | Parameters | Method of estimation | Reference |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 1. | Nitrogen | Alkaline permanganate method | Subbaiah and Asija (1956) |
| 2. | Phosphorus | Bray No. 1 method | Jackson (1973) |
| 3 | Potassium | Direct reading in flame photometer after dilution | Jackson (1973) |

**3.6.10.Nutrient analysis of FYM, organic mulch**

Nitrogen, Phosphorus, Potassium content of Farm Yard Manure , Organic mulch was analyzed using the methods and the mean value expressed

**3.6.11 Plant NPK uptake**

Modified microkjeldahl method, Vandomolybdo phosphoric yellow colour method and flame photometry (Jackson , 1973) were employed to determine total nitrogen, total phosphorus and total potassium contents respectively in various plant parts. The contents were calculated and expressed in percentage. The uptake of nitrogen, phosphorus and potassium by the plant was calculated by multiplying the nutrient content of the plant with respective dry weight of the plant parts and expressed as kg $ha^{-1}$.

### 3.6.12 Nutrient balance sheet for NPK

Nutrient balance sheets were worked out for available N, $P_2O_5$ and $K_2O$ as per the procedure outline by Sadanandan and Mahapatra (1973). The following parameters were taken into account.

1. Initial status of nutrients in the soil (Y) kg $ha^{-1}$

2. Total amount of nutrient added through manures and fertilizers (A)kg $ha^{-1}$

3. Amount of nutrient removed by the crop or uptake [B] (kg$ha^{-1}$)

4. Expected nutrient balance C = (Y+A) – B (kg $ha^{-1}$)

5. Actual nutrient balance or available nutrient status of soil after the experiment (D) (kg $ha^{-1}$)

6. Net loss (-) or gain (+) = D-C (kg $ha^{-1}$)

### 3.6.13 Pest and Disease Incidence

The crop was monitored for the incidence of pests and diseases. There was no incidence of pest and leaf spot disease was observed at one month after transplanting and was controlled using mancozeb 0.3%

### 3.6.14 Benefit cost analysis

The economics of cultivation was worked out after taking into account the cost of cultivation of ginger and the existing price of ginger rhizomes. For calculating the cost, different variable cost items like planting material, manures, fertilizers, plant protection chemicals, irrigation, labour charges etc prevailed during period of study were considered .

The net income was calculated as follows, Net return (Rs $ha^{-1}$) = Gross income- Cost of cultivation

$$\text{Benefit cost ratio} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

**3.6.15. Statistical analysis**

The design was analysed employing the technique for analysis of variance for split plot design ( Gomez and Gomez , 1984) . Critical difference (cd) values at 5% level of significance were provided where ever the effects were found to be significant.

# RESULTS

# 4. Results

The results of the experiment conducted during 2016-2017 to standardize the agro techniques for transplanted ginger are presented in this chapter

## 4.1 GROWTH PARAMETERS

### 4.1.1 Plant height

The main and interaction effects of treatments on height of ginger plants at different periods of crop growth during 2016-2017 are furnished in Table 1

A significant difference in plant height was observed due to the application of different mulches throughout the crop growth periods. Plants that received $M_1$ (30 t ha $^{-1}$) in main plot resulted in maximum height at all growth periods. At 8 months a plant height of 44.84 cm was recorded. With regard to the effect of fertilizer application, treatment $T_2$ (150:100:100 kg ha $^{-1}$) resulted in highest plant height on all periods of observation and a plant height of 43.33 cm was recorded at $8^{th}$ month in $T_2$. Interaction effect between mulching and fertilizer application, was significant throughout the periods of observation and combination of mulches @ 30 t ha$^{-1}$ and fertilizer dose of 150:100:100 kg ha$^{-1}$ ($m_1t_2$) resulted in maximum plant height of 48 cm at 8 months. A significant difference in plant height in all periods of growth was recorded between treatment and control, the control $C_1$ as well as $C_2$ varied significantly from treatments in all periods of observation. Significant difference in plant height between $C_1$ and $C_2$ was also observed.

### 4.1.2 Number of leaves / plant

The main and interaction effects of treatments on number of leaves/ plant at different periods of growth are presented in Table 2

Table No:1 Effect of mulches and nutrients on the plant height (cm)

| Treatments | 4th month | 6th month | 8th month |
|---|---|---|---|
| (Mulches) $M_1$ | 37.48 | 41.51 | 44.84 |
| $M_2$ | 36.10 | 40.21 | 42.74 |
| $M_3$ | 28.84 | 33.85 | 35.76 |
| $M_4$ | 33.64 | 38.99 | 41.50 |
| CD | 0.607 | 0.668 | 0.417 |
| (Fertilizers) $T_1$ | 30.36 | 36.68 | 38.45 |
| $T_2$ | 36.8 | 41.01 | 43.33 |
| $T_3$ | 34.91 | 37.17 | 40.25 |
| $T_4$ | 34.9 | 40.24 | 42.81 |
| CD | 0.669 | 0.294 | 0.357 |
| (Interaction) $m_1t_1$ | 35.20 | 39.15 | 43.08 |
| $m_1t_2$ | 39.60 | 44.10 | 48.00 |
| $m_1t_3$ | 38.01 | 40.90 | 43.80 |
| $m_1t_4$ | 36.55 | 41.90 | 44.48 |
| $m_2t_1$ | 33.95 | 39.20 | 39.85 |
| $m_2t_2$ | 36.8 | 42.25 | 44.93 |
| $m_2t_3$ | 37.90 | 39.58 | 42.18 |
| $m_2t_4$ | 38.16 | 41.95 | 44.00 |
| $m_3t_1$ | 27.20 | 30.35 | 32.75 |
| $m_3t_2$ | 31.55 | 36.95 | 37.35 |
| $m_3t_3$ | 27.40 | 31.50 | 34.05 |
| $m_3t_4$ | 29.23 | 36.60 | 38.90 |
| $m_4t_1$ | 25.08 | 38.00 | 38.13 |
| $m_4t_2$ | 38.22 | 40.75 | 43.03 |
| $m_4t_3$ | 35.08 | 36.70 | 40.98 |
| $m_4t_4$ | 35.15 | 40.53 | 43.88 |
| CD | 1.34 | 0.60 | 0.72 |
| $C_1$ | 24.48 | 30.75 | 34.63 |
| $C_2$ | 22.85 | 29.4 | 33.08 |
| $C_1$ Vs Treatment | S* | S* | S* |
| $C_2$ Vs Treatment | S* | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* | S* |

* Significant at 5% level

Table 2: Effect of mulch and nutrients on number of leaves/plant

| Treatments | $4^{th}$ month | $6^{th}$ month | $8^{th}$ month |
|---|---|---|---|
| (Mulches) $M_1$ | 113.92 | 165.25 | 230.78 |
| $M_2$ | 93.65 | 149.48 | 186.46 |
| $M_3$ | 80.57 | 124.40 | 143.91 |
| $M_4$ | 105.05 | 148.12 | 176.97 |
| CD | 3.510 | 3.840 | 1.660 |
| (Fertilizers) $T_1$ | 69.78 | 120.08 | 163.68 |
| $T_2$ | 127.10 | 173.38 | 210.24 |
| $T_3$ | 90.25 | 141.41 | 172.89 |
| $T_4$ | 106.17 | 152.38 | 191.32 |
| CD | 2.560 | 3.550 | 4.090 |
| (Interaction) $m_1t_1$ | 78.12 | 134.41 | 190.82 |
| $m_1t_2$ | 152.99 | 206.31 | 284.79 |
| $m_1t_3$ | 86.36 | 150.26 | 199.90 |
| $m_1t_4$ | 102.76 | 170.01 | 247.63 |
| $m_2t_1$ | 67.88 | 111.55 | 152.94 |
| $m_2t_2$ | 125.59 | 189.59 | 212.66 |
| $m_2t_3$ | 84.03 | 135.79 | 182.88 |
| $m_2t_4$ | 97.10 | 161.02 | 197.37 |
| $m_3t_1$ | 55.04 | 110.17 | 139.17 |
| $m_3t_2$ | 102.45 | 132.49 | 157.16 |
| $m_3t_3$ | 75.57 | 127.89 | 135.95 |
| $m_3t_4$ | 89.25 | 127.07 | 143.39 |
| $m_4t_1$ | 78.08 | 124.19 | 171.79 |
| $m_4t_2$ | 126.96 | 165.14 | 186.37 |
| $m_4t_3$ | 115.07 | 151.73 | 172.83 |
| $m_4t_4$ | 135.59 | 151.42 | 176.90 |
| CD | 5.100 | 7.110 | 8.180 |
| $C_1$ | 68.95 | 106.51 | 156.36 |
| $C_2$ | 40.69 | 77.74 | 115.22 |
| $C_1$ Vs Treatment | S* | S* | S* |
| $C_2$ Vs Treatment | S* | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* | S* |

* Significant at 5% level

Mulching treatment, fertilizer treatment and their interaction had significant influence in the number of leaves at all periods of growth among the mulches, treatment $M_1$ (30 t $ha^{-1}$) produced significantly higher number of leaves in all periods with 230.78 number of leaves/plant at $8^{th}$ month of observation . In sub plot treatment $T_2$ (150:100:100 kg $ha^{-1}$) recorded highest number of leaves of 210.24 in $8^{th}$ month. In interaction highest number of leaves was recorded from the combination of mulches @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ ($m_1t_2$) in all periods of observation and 284.79 number of leaves/ plant was recorded from $8^{th}$ month. The comparison of $C_1$ as well as $C_2$ with the treatments also indicated significant difference in the number of leaves in all periods of growth. A significant difference was noticed between the control $C_1$ as well as $C_2$ .

### 4.1.3 Number of tillers / plant

The effect of treatments on number of tillers at different growth periods are presented in Table 3

Main plot treatment of mulching significantly influenced the number of tillers in all periods of growth and highest tiller was obtained in main plot treatment $M_1$ (30 t $ha^{-1}$) in all periods of observation and in $6^{th}$ month $M_2$ ( 15 t $ha^{-1}$) was on par with $M_1$ . In sub plot, treatment $T_2$ significantly higher number of tillers were observed in all periods of observation and recorded 14.59 in $8^{th}$ month. Interaction was significant during the periods of observation and treatment combination $m_1t_2$ ( mulches @30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$) noted highest number of tillers in all periods of observation while in the $6^{th}$ months $m_2t_2$ ( 12.85),$m_4t_2$ (13.00),$m_4t_4$ ( 12.75) was on par with $m_1t_2$ ( 13.10 ) and on $8^{th}$ months $m_1t_4$ ( 15.80) was on par with $m_1t_2$ (15.95) . A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ and $C_2$ also has shown a significant difference between them.

**4.1.4 Shoot weight**

The main and interaction effects of treatment on shoot weight is provided in Table 4

Main plot treatment of different mulches significantly differed on all periods of observation and $M_1$ (30 t $ha^{-1}$) recorded highest shoot weight on all periods . The treatment $M_1$ recorded a shoot weight of 45.05 g in the $8^{th}$ month .In sub plot $T_2$ treatment recorded highest shoot weight on all periods of observation and was significantly different from each other and a shoot weight of 43.80g was obtained in the $8^{th}$ month . Among the interaction mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:10:100 kg $ha^{-1}$ ($m_1t_2$) recorded highest shoot weight on all periods of observation . In $4^{th}$ month $m_2t_2$ (25.68) and $m_2t_4$ ( 25.03) was on par with $m_1t_2$ (25.93) and in the $6^{th}$ and $8^{th}$ months $m_1t_4$ was on par with $m_1t_2$. Treatment effects varied significantly from both control $C_1$ as well as $C_2$. A significant difference was noticed between the control $C_1$ as well as $C_2$ .

4.2. ROOT CHARACTERS

**4.2.1 Root length**

The effect of treatments on root length at different growth periods are presented in Table 5

A significant variation was observed among the main plot treatments on all periods of growth and main plot treatment of $M_1$ recorded highest root length ( 32.24 cm) on $8^{th}$ month and was on par with $M_4$ ( 32.16 cm ) In sub plot treatment, $T_2$ recorded highest root length on all periods of observation while in $8^{th}$ month $T_4$ was on par with $T_2$ ( 32.23 cm) and was significant throughout the periods of observation. In interaction treatment $m_1t_2$ which is the combination of mulches @ 30 t $ha^{-1}$ and

Table 3: Effect of mulches and nutrients on the no of tillers/plant

| Treatments | 4th month | 6th month | 8th month |
|---|---|---|---|
| (Mulches) $M_1$ | 8.89 | 11.9 | 14.88 |
| $M_2$ | 8.46 | 11.70 | 13.33 |
| $M_3$ | 7.53 | 11.05 | 12.56 |
| $M_4$ | 8.51 | 11.21 | 14.00 |
| CD | 0.233 | 0.418 | 0.456 |
| (Fertilizers) $T_1$ | 7.56 | 10.15 | 12.70 |
| $T_2$ | 9.92 | 12.74 | 14.59 |
| $T_3$ | 7.41 | 11.10 | 13.03 |
| $T_4$ | 8.49 | 12.18 | 14.13 |
| CD | 0.369 | 0.355 | 0.334 |
| (Interaction) $m_1t_1$ | 8.43 | 10.20 | 13.80 |
| $m_1t_2$ | 10.90 | 13.10 | 15.95 |
| $m_1t_3$ | 8.55 | 11.45 | 13.95 |
| $m_1t_4$ | 9.40 | 12.30 | 15.80 |
| $m_2t_1$ | 7.05 | 11.00 | 12.30 |
| $m_2t_2$ | 9.18 | 12.85 | 14.30 |
| $m_2t_3$ | 7.80 | 11.05 | 13.15 |
| $m_2t_4$ | 8.10 | 12.05 | 13.55 |
| $m_3t_1$ | 7.25 | 9.55 | 12.15 |
| $m_3t_2$ | 9.55 | 11.90 | 13.08 |
| $m_3t_3$ | 6.10 | 11.15 | 11.90 |
| $m_3t_4$ | 7.20 | 11.60 | 13.10 |
| $m_4t_1$ | 7.53 | 9.85 | 12.55 |
| $m_4t_2$ | 10.05 | 13.00 | 15.20 |
| $m_4t_3$ | 7.20 | 10.75 | 13.15 |
| $m_4t_4$ | 9.25 | 12.75 | 15.10 |
| CD | 0.738 | 0.711 | 0.678 |
| $C_1$ | 7.70 | 10.38 | 11.60 |
| $C_2$ | 5.35 | 8.48 | 9.53 |
| $C_1$ Vs Treatment | S* | S* | S* |
| $C_2$ Vs Treatment | S* | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* | S* |

* Significant at 5% level

Table4: Effect of mulches and nutrients on the shoot weight (g plant $^{-1}$)

| Treatments | $4^{th}$ month | $6^{th}$ month | $8^{th}$ month |
|---|---|---|---|
| (Mulches) $M_1$ | 24.54 | 30.72 | 45.05 |
| $M_2$ | 23.35 | 28.74 | 42.11 |
| $M_3$ | 20.46 | 28.23 | 40.31 |
| $M_4$ | 23.26 | 29.68 | 43.88 |
| CD | 0.55 | 0.976 | 0.631 |
| (Fertilizers) $T_1$ | 20.41 | 28.31 | 41.16 |
| $T_2$ | 24.59 | 31.26 | 43.80 |
| $T_3$ | 22.66 | 28.39 | 43.30 |
| $T_4$ | 23.95 | 30.22 | 43.08 |
| CD | 0.48 | 0.994 | 0.38 |
| (Interaction) $m_1t_1$ | 21.5 | 29.43 | 44.13 |
| $m_1t_2$ | 25.93 | 33.93 | 47.73 |
| $m_1t_3$ | 22.65 | 31.78 | 44.88 |
| $m_1t_4$ | 24.15 | 30.95 | 43.48 |
| $m_2t_1$ | 19.23 | 28.73 | 41.10 |
| $m_2t_2$ | 25.68 | 28.00 | 43.15 |
| $m_2t_3$ | 23.48 | 27.88 | 41.35 |
| $m_2t_4$ | 25.03 | 30.38 | 42.85 |
| $m_3t_1$ | 18.55 | 27.03 | 38.38 |
| $m_3t_2$ | 22.00 | 27.88 | 39.20 |
| $m_3t_3$ | 20.23 | 28.10 | 41.20 |
| $m_3t_4$ | 21.08 | 29.93 | 42.45 |
| $m_4t_1$ | 22.38 | 28.08 | 41.05 |
| $m_4t_2$ | 24.75 | 27.10 | 42.25 |
| $m_4t_3$ | 23.30 | 30.58 | 45.78 |
| $m_4t_4$ | 24.55 | 33.78 | 46.43 |
| CD | 0.96 | 1.889 | 0.771 |
| $C_1$ | 18.95 | 28.15 | 41.05 |
| $C_2$ | 17.5 | 19.08 | 37.05 |
| $C_1$ Vs Treatment | S* | S* | S* |
| $C_2$ Vs Treatment | S* | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* | S* |

* Significant at 5% level

double the recommended dose of fertilizer as per package of practices recommendation of Kerala Agriculture University ensued in highest root length throughout the observation periods. The treatments were significantly different from both the controls and there was significant difference between the control as well.

### 4.2.2 Root weight

The main and interaction effects on root weight at different periods of growth are presented in Table 6

Main plot treatment of different levels of organic mulches and plastic mulch was significantly influenced the root weight of ginger on all periods of observation and $M_1$ recorded highest root weight of 1.17 g on $8^{th}$ month and sub plot treatment $T_2$ was highest on all periods of observation and was on par with $T_4$ on $4^{th}$ and $6^{th}$ months. Among the interaction mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ resulted in higher root weight on all periods of observation and recorded 1.32g in $8^{th}$ month while in $6^{th}$ month $m_1t_4$ (30.95 g) was on par with $m_1t_2$ (33.93g) . A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ and $C_2$ also showed a significant difference between them.

Table 5: Effect of mulches and nutrients on the Root length (cm)

| Treatments | 4th month | 6th month | 8th month |
|---|---|---|---|
| (Mulches) $M_1$ | 22.22 | 27.54 | 32.24 |
| $M_2$ | 20.96 | 26.19 | 31.73 |
| $M_3$ | 21.56 | 26.04 | 31.08 |
| $M_4$ | 22.01 | 26.84 | 32.16 |
| CD | 0.181 | 0.218 | 0.245 |
| (Fertilizers)$T_1$ | 20.84 | 25.47 | 31.17 |
| $T_2$ | 22.25 | 27.36 | 32.23 |
| $T_3$ | 22.03 | 26.90 | 31.68 |
| $T_4$ | 21.81 | 26.88 | 32.13 |
| CD | 0.149 | 0.209 | 0.216 |
| (Interaction) $m_1t_1$ | 20.43 | 25.40 | 31.28 |
| $m_1t_2$ | 23.98 | 29.68 | 33.38 |
| $m_1t_3$ | 22.03 | 27.30 | 32.58 |
| $m_1t_4$ | 22.45 | 27.78 | 31.75 |
| $m_2t_1$ | 20.58 | 25.68 | 31.85 |
| $m_2t_2$ | 21.20 | 26.55 | 32.65 |
| $m_2t_3$ | 20.60 | 25.58 | 30.68 |
| $m_2t_4$ | 21.45 | 26.95 | 31.73 |
| $m_3t_1$ | 20.60 | 25.45 | 30.63 |
| $m_3t_2$ | 21.48 | 25.78 | 30.15 |
| $m_3t_3$ | 22.03 | 26.38 | 31.38 |
| $m_3t_4$ | 22.13 | 26.55 | 32.15 |
| $m_4t_1$ | 21.78 | 25.35 | 30.93 |
| $m_4t_2$ | 22.35 | 27.43 | 32.75 |
| $m_4t_3$ | 23.45 | 28.35 | 32.10 |
| $m_4t_4$ | 21.23 | 26.25 | 32.88 |
| CD | 0.289 | 0.418 | 0.423 |
| $C_1$ | 23.43 | 25.50 | 29.78 |
| $C_2$ | 19.95 | 24.45 | 28.10 |
| $C_1$ Vs Treatment | S* | S* | S* |
| $C_2$ Vs Treatment | S* | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* | S* |

* Significant at 5% level

Table 6: Effect of mulches and nutrients on the Root weight (g plant $^{-1}$)

| Treatments | 4$^{th}$ month | 6$^{th}$ month | 8$^{th}$ month |
|---|---|---|---|
| (Mulches) $M_1$ | 0.65 | 1.01 | 1.17 |
| $M_2$ | 0.59 | 0.78 | 1.00 |
| $M_3$ | 0.51 | 0.59 | 0.81 |
| $M_4$ | 0.53 | 0.6 | 0.77 |
| CD | 0.03 | 0.036 | 0.059 |
| (Fertilizers)$T_1$ | 0.50 | 0.63 | 0.88 |
| $T_2$ | 0.60 | 0.81 | 1.02 |
| $T_3$ | 0.57 | 0.74 | 0.80 |
| $T_4$ | 0.59 | 0.81 | 0.96 |
| CD | 0.02 | 0.024 | 0.020 |
| (Interaction) $m_1t_1$ | 0.55 | 0.76 | 0.96 |
| $m_1t_2$ | 0.76 | 1.15 | 1.32 |
| $m_1t_3$ | 0.62 | 1.03 | 1.17 |
| $m_1t_4$ | 0.68 | 1.11 | 1.21 |
| $m_2t_1$ | 0.52 | 0.65 | 0.10 |
| $m_2t_2$ | 0.58 | 0.90 | 1.07 |
| $m_2t_3$ | 0.61 | 0.75 | 0.99 |
| $m_2t_4$ | 0.65 | 0.83 | 0.97 |
| $m_3t_1$ | 0.47 | 0.52 | 0.79 |
| $m_3t_2$ | 0.50 | 0.63 | 0.85 |
| $m_3t_3$ | 0.53 | 0.59 | 0.73 |
| $m_3t_4$ | 0.55 | 0.64 | 0.87 |
| $m_4t_1$ | 0.50 | 0.58 | 0.77 |
| $m_4t_2$ | 0.53 | 0.62 | 0.86 |
| $m_4t_3$ | 0.53 | 0.59 | 0.67 |
| $m_4t_4$ | 0.55 | 0.62 | 0.79 |
| CD | 0.014 | 0.058 | 0.051 |
| $C_1$ | 0.53 | 0.71 | 0.81 |
| $C_2$ | 0.26 | 0.40 | 0.56 |
| $C_1$ Vs Treatment | S* | S* | S* |
| $C_2$ Vs Treatment | S* | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* | S* |

* Significant at 5% level

### 4.2.3 Root volume

The effect of treatments on root volume at different growth periods are presented in Table 7

A significant variation was observed among the main plot treatment and main plot treatment of $M_1$ resulted in higher root volume on all periods of observation and root volume of $M_1$ was had 114.20 $cm^3$ $plant^{-1}$ during the $8^{th}$ months of observation. In sub plot $T_2$ treatment resulted in high root volume on all periods of observation. Among the combination, $m_1t_2$, i.e., mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ recorded highest root volume on all periods while in $6^{th}$ month $m_1t_1$ (95.23 $cm^3$ $plant^{-1}$ ) was on par with $m_1t_2$ ( 95.38 $cm^3$ $plant^{-1}$ ) ,while at $8^{th}$ month $m_1t_4$ ( 115.05 $cm^3$ $plant^{-1}$) was on par with $m_1t_2$ with root volume of 115.45 $cm^3$ $plant^{-1}$. Treatment effects varied significantly with both control $C_1$ as well as $C_2$. A significant difference was noticed between the control $C_1$ as well as $C_2$ .

### 4.2.4 Root shoot ratio

The main and interaction effects on root shoot ratio at different periods of growth are presented in Table 8

A significant difference in the root shoot ratio of main plot treatments was noticed in 4$^{th}$ and 6$^{th}$ month of observation however no significant difference root shoot ratio in 8$^{th}$ month was noted in the main plot treatments and Treatment $M_1$ with mulching @ 30 t $ha^{-1}$ recorded highest root shoot ratio in 4$^{th}$ ( 0.028) and 6$^{th}$ (0.033) months . The root shoot ratio of sub plot treatments was insignificant in 4$^{th}$ and 8$^{th}$ month and in 6$^{th}$ month, $T_2$ recorded highest root shoot ratio of 0.029 and was on par with $T_4$ . Treatment combination was significant throughout the periods of observation and combination of mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ resulted in higher root shoot ratio and in 6$^{th}$ month it was on par with $m_1t_3$ (0.032) ,$m_1t_4$(0.035) and $m_2t_2$ (0.032) while in 8$^{th}$ month it was on par with $m_1t_3$ (0.026) ,$m_1t_4$ (0.028) ,$m_2t_2$ (0.025) ,$m_2t_3$(0.027) ,$m_2t_4$ (0.025) ,$m_3t_1$(0.025) ,$m_3t_2$ (0.027),$m_3t_4$(0.017) . Treatments varied significantly with both) the controls. A significant variation was observed within the controls $C_1$ and $C_2$

Table 7: Effect of mulches and nutrients on Root volume ( $cm^3$ $plant^{-1}$)

| Treatments | $4^{th}$ month | $6^{th}$ month | $8^{th}$ month |
|---|---|---|---|
| (Mulches) $M_1$ | 30.59 | 94.66 | 114.20 |
| $M_2$ | 27.95 | 92.98 | 111.18 |
| $M_3$ | 27.86 | 90.46 | 109.49 |
| $M_4$ | 30.12 | 91.98 | 111.32 |
| CD | 0.316 | 0.885 | 0.707 |
| (Fertilizers) $T_1$ | 26.98 | 91.44 | 110.18 |
| $T_2$ | 30.76 | 93.68 | 112.49 |
| $T_3$ | 29.21 | 92.25 | 111.76 |
| $T_4$ | 29.57 | 92.69 | 111.38 |
| CD | 0.588 | 0.361 | 0.479 |
| (Interaction) $m_1t_1$ | 27.18 | 95.23 | 111.78 |
| $m_1t_2$ | 33.20 | 95.38 | 115.45 |
| $m_1t_3$ | 30.03 | 94.05 | 114.42 |
| $m_1t_4$ | 31.35 | 93.98 | 115.05 |
| $m_2t_1$ | 26.45 | 91.50 | 109.65 |
| $m_2t_2$ | 28.35 | 93.75 | 112.03 |
| $m_2t_3$ | 27.53 | 92.60 | 111.08 |
| $m_2t_4$ | 29.43 | 94.05 | 111.95 |
| $m_3t_1$ | 26.40 | 89.35 | 109.55 |
| $m_3t_2$ | 27.90 | 90.73 | 108.60 |
| $m_3t_3$ | 28.13 | 90.30 | 109.70 |
| $m_3t_4$ | 29.00 | 91.45 | 110.10 |
| $m_4t_1$ | 27.90 | 90.95 | 109.73 |
| $m_4t_2$ | 30.10 | 91.05 | 110.98 |
| $m_4t_3$ | 31.15 | 92.05 | 111.73 |
| $m_4t_4$ | 31.93 | 93.85 | 112.85 |
| CD | 1.16 | 0.723 | 0.948 |
| $C_1$ | 24.84 | 84.98 | 102.00 |
| $C_2$ | 21.53 | 49.38 | 69.09 |
| $C_1$ Vs Treatment | S* | S* | S* |
| $C_2$ Vs Treatment | S* | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* | S* |

* Significant at 5% level

Table 8: Effect of mulches and nutrients on Root shoot ratio

| Treatments | $4^{th}$ month | $6^{th}$ month | $8^{th}$ month |
|---|---|---|---|
| (Mulches) $M_1$ | 0.028 | 0.033 | 0.026 |
| $M_2$ | 0.026 | 0.024 | 0.024 |
| $M_3$ | 0.025 | 0.021 | 0.021 |
| $M_4$ | 0.024 | 0.019 | 0.019 |
| CD | 0.0010 | 0.0080 | NS |
| (Fertilizers) $T_1$ | 0.024 | 0.021 | 0.021 |
| $T_2$ | 0.026 | 0.029 | 0.024 |
| $T_3$ | 0.026 | 0.024 | 0.021 |
| $T_4$ | 0.026 | 0.027 | 0.022 |
| CD | NS | 0.004 | NS |
| (Interaction) $m_1t_1$ | 0.022 | 0.025 | 0.022 |
| $m_1t_2$ | 0.035 | 0.037 | 0.028 |
| $m_1t_3$ | 0.022 | 0.032 | 0.026 |
| $m_1t_4$ | 0.028 | 0.035 | 0.028 |
| $m_2t_1$ | 0.027 | 0.025 | 0.022 |
| $m_2t_2$ | 0.025 | 0.032 | 0.025 |
| $m_2t_3$ | 0.022 | 0.025 | 0.027 |
| $m_2t_4$ | 0.027 | 0.022 | 0.025 |
| $m_3t_1$ | 0.025 | 0.019 | 0.025 |
| $m_3t_2$ | 0.025 | 0.025 | 0.027 |
| $m_3t_3$ | 0.027 | 0.027 | 0.017 |
| $m_3t_4$ | 0.027 | 0.021 | 0.025 |
| $m_4t_1$ | 0.025 | 0.025 | 0.017 |
| $m_4t_2$ | 0.027 | 0.025 | 0.022 |
| $m_4t_3$ | 0.027 | 0.012 | 0.017 |
| $m_4t_4$ | 0.022 | 0.015 | 0.017 |
| CD | 0.0040 | 0.0080 | 0.0040 |
| $C_1$ | 0.030 | 0.025 | 0.020 |
| $C_2$ | 0.010 | 0.021 | 0.015 |
| $C_1$ Vs Treatment | S** | S** | S** |
| $C_2$ Vs Treatment | S** | S** | S** |
| $C_1$ Vs $C_2$ | S** | S** | S** |

* Significant at 1% level

Table 9: Effect of mulches and nutrients on Fresh Yield (kg $ha^{-1}$)

| Treatments | $4^{th}$ month | $6^{th}$ month | Harvest |
|---|---|---|---|
| (Mulches) $M_1$ | 5435.78 | 10574.03 | 18093.53 |
| $M_2$ | 4675.43 | 10011.45 | 17241.15 |
| $M_3$ | 4053.15 | 9197.775 | 16385.18 |
| $M_4$ | 5234.23 | 9958.80 | 17567.25 |
| CD | 154.027 | 153.580 | 175.023 |
| (Fertilizers) $T_1$ | 4501.65 | 9512.55 | 16746.15 |
| $T_2$ | 5241.23 | 10195.88 | 17855.03 |
| $T_3$ | 4660.95 | 9907.05 | 17230.35 |
| $T_4$ | 5082.75 | 10026.58 | 17455.58 |
| CD | 156.37 | 167.364 | 121.861 |
| (Interaction) $m_1t_1$ | 4902.00 | 10181.10 | 17545.80 |
| $m_1t_2$ | 6120.90 | 10537.20 | 18644.40 |
| $m_1t_3$ | 5187.60 | 10118.20 | 18045.30 |
| $m_1t_4$ | 5532.60 | 10159.60 | 18138.60 |
| $m_2t_1$ | 4473.60 | 9606.60 | 16756.80 |
| $m_2t_2$ | 4969.80 | 10193.00 | 17717.10 |
| $m_2t_3$ | 4537.50 | 9923.40 | 17196.90 |
| $m_2t_4$ | 4720.80 | 10162.80 | 17293.80 |
| $m_3t_1$ | 3728.70 | 8687.40 | 15931.80 |
| $m_3t_2$ | 4246.20 | 9685.50 | 16923.30 |
| $m_3t_3$ | 3906.00 | 9127.50 | 16208.70 |
| $m_3t_4$ | 4331.70 | 9290.70 | 16476.90 |
| $m_4t_1$ | 4902.30 | 9575.10 | 16750.20 |
| $m_4t_2$ | 5628.00 | 10201.80 | 18135.30 |
| $m_4t_3$ | 5012.70 | 9959.10 | 17377.20 |
| $m_4t_4$ | 5793.90 | 10093.20 | 18006.30 |
| CD | 312.729 | 334.729 | 257.722 |
| $C_1$ | 4839.90 | 9566.40 | 16274.10 |
| $C_2$ | 3547.80 | 5949.60 | 8770.80 |
| $C_1$ Vs Treatment | S* | S* | S* |
| $C_2$ Vs Treatment | S* | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* | S* |

* Significant at 5% level

## 4.3 YIELD CHARACTERS

### 4.3.1 Fresh yield

The effect of treatments on fresh yield at different periods of growth are presented in Table 9

The fresh yield of ginger differed significantly among main plot treatments throughout the periods of observation .The main plot treatment of mulching @ 30 t $ha^{-1}$ ($M_1$) recorded highest fresh yield on all periods and obtained 18093.53 kg $ha^{-1}$ in harvest . The fresh ginger yield obtained from plots treated with plastic mulch ,$M_4$ recorded 17567.25 kg $ha^{-1}$ which was the second best treatment . In subplot, treatments were significant throughout the periods of observation and treatment $T_2$ recorded highest fresh yield on all periods and obtained 17855.03 kg $ha^{-1}$ at harvest. This was followed by $T_4$ (17455.58 kg/ha) ,$T_3$ ( 17230.35 kg/ha) and $T_1$ (16746.15 kg/ha). Interaction effects were significant throughout the periods and among interaction combination of mulches @ 30 t $ha^{-1}$ and double the recommended dose of fertilizer as per KAU POP (Plate 3) obtained highest yield on all periods of observation and recorded 18644.40 kg $ha^{-1}$ at harvest followed by $m_1t_4$ (Plate 4) of 18138.60 kg $ha^{-1}$ which was on par with $m_4t_2$ of 18135.30 kg $ha^{-1}$ . A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ (Plate 5) and $C_2$ also shown a significant difference between them.


Plate 3. Fresh rhizome of $m_1t_2$


Plate 4.Fresh rhizome of $m_1t_4$


Plate 5. Fresh rhizome of $C_1$( POP)

#### 4.3.2 Dry yield

The effect of treatments on dry yield at different growth periods are presented in Table 10

The main plot treatments showed significant difference in dry yield throughout the periods of observation . The treatment $M_1$ mulching @ 30 t $ha^{-1}$ recorded highest dry yield on all periods and obtained 3828.15 kg $ha^{-1}$ at harvest. The dry ginger yield in plastic mulch treatment recorded 3564.38t $ha^{-1}$ . In subplot, treatments showed significant difference throughout the periods of observation and treatment $T_2$ recorded highest dry yield on all periods and obtained 3911.10 kg $ha^{-1}$ on harvest. Interaction effects were significant throughout the periods and among interaction combination of mulches @ 30 t $ha^{-1}$ and double the recommended dose of fertilizer as per KAU POP obtained highest dry yield on all periods of observation and recorded 4316.10 kg $ha^{-1}$ in harvest followed by $m_1t_4$ ( 3842.10 kg $ha^{-1}$ ) which was on par with $m_4t_2$ 3881.80 kg $ha^{-1}$ . A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ and $C_2$ showed a significant difference between them.

Table 10: Effect of mulches and nutrients on Dry yield (kg $ha^{-1}$)

| Treatments | $4^{th}$ month | $6^{th}$ month | Harvest |
|---|---|---|---|
| (Mulches) $M_1$ | 1024.58 | 2172.60 | 3828.15 |
| $M_2$ | 821.78 | 1910.93 | 3504.75 |
| $M_3$ | 729.45 | 1757.93 | 3328.05 |
| $M_4$ | 961.88 | 1867.50 | 3564.38 |
| CD | 27.525 | 35.941 | 44.317 |
| (Fertilizers) $T_1$ | 765.68 | 1746.15 | 3319.73 |
| $T_2$ | 1013.25 | 2120.78 | 3911.10 |
| $T_3$ | 815.03 | 1879.95 | 3406.73 |
| $T_4$ | 943.73 | 1962.08 | 3587.78 |
| CD | 24.736 | 25.169 | 35.806 |
| (Interaction) $m_1t_1$ | 863.10 | 1990.20 | 3640.50 |
| $m_1t_2$ | 1286.40 | 2489.40 | 4316.10 |
| $m_1t_3$ | 919.80 | 1995.90 | 3513.90 |
| $m_1t_4$ | 1029.00 | 2214.90 | 3842.10 |
| $m_2t_1$ | 733.50 | 1722.60 | 3257.40 |
| $m_2t_2$ | 971.10 | 2180.40 | 3811.10 |
| $m_2t_3$ | 750.90 | 1800.30 | 3299.10 |
| $m_2t_4$ | 831.60 | 1940.40 | 3581.40 |
| $m_3t_1$ | 614.40 | 1517.40 | 3096.00 |
| $m_3t_2$ | 830.10 | 2002.80 | 3635.40 |
| $m_3t_3$ | 672.30 | 1707.30 | 3164.70 |
| $m_3t_4$ | 801.00 | 1804.20 | 3416.10 |
| $m_4t_1$ | 851.70 | 1754.40 | 3285.00 |
| $m_4t_2$ | 965.40 | 1810.50 | 3881.80 |
| $m_4t_3$ | 917.10 | 2016.30 | 3649.20 |
| $m_4t_4$ | 1113.30 | 1888.80 | 3511.50 |
| CD | 49.473 | 50.329 | 71.612 |
| $C_1$ | 859.20 | 2121.90 | 3472.80 |
| $C_2$ | 519.30 | 978.00 | 1713.00 |
| $C_1$ Vs Treatment | S* | S* | S* |
| $C_2$ Vs Treatment | S* | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* | S* |

* Significant at 5% level

### 4.3.4 Harvest index

The main and interaction effects of treatments on harvest index at different periods of growth are presented in Table 11

Significant differences in harvest index was observed throughout the periods of observation . Plants that received $M_1$ (30 t ha $^{-1}$ ) in main plot resulted in maximum harvest index at all growth periods. At 8 months a harvest index of 0.414 was recorded . Sub plot treatment ,$T_2$ ( 150:100:100 kg ha $^{-1}$) recorded highest harvest index of 0.170,0.210 and 0.423 at $4^{th}$ , $6^{th}$ and $8^{th}$ month respectively . The interaction between main plot and sub plot, was significant throughout the periods of observation and combination of mulches @ 30 t ha $^{-1}$ and fertilizer dose of 150:100:100 kg /ha ($m_1t_2$) resulted in maximum harvest index of 0.435 at $8^{th}$ month. A significant difference in harvest index in all periods of growth was recorded between treatment and control. The control $C_1$ as well as $C_2$ varied significantly from treatments in all periods. The harvest index recorded between control $C_1$ and $C_2$ also varied significantly.

### 4.3.5 Dry recovery

The main and interaction effects of treatments on dry recovery at different periods of growth are presented in Table 12

Main plot treatment, sub plot treatment and interaction had significant influence in dry recovery at all periods of growth among the main plot treatment $M_1$ (30 t ha$^{-1}$) retained significantly higher dry recovery in all periods and recorded 21.24% at harvest . In sub plot treatment $T_2$ (150:100:100 kg/ha) recorded highest dry recovery of 21.89% at harvest . Interaction effect showed highest dry recovery was recorded from the combination of mulches @ 30 t ha $^{-1}$ and fertilizer dose of 150:100:100 kg/ha ($m_1t_2$) in all periods of observation and at harvest dry recovery of 23.15% was recorded . The dry recovery recorded by the treatment varied

Table 11: Effect of mulches and nutrients on Harvest Index

| Treatments | $4^{th}$ month | $6^{th}$ month | $8^{th}$ month |
|---|---|---|---|
| (Mulches) $M_1$ | 0.190 | 0.220 | 0.414 |
| $M_2$ | 0.160 | 0.200 | 0.411 |
| $M_3$ | 0.140 | 0.180 | 0.408 |
| $M_4$ | 0.150 | 0.190 | 0.409 |
| CD | 0.007 | 0.003 | 0.002 |
| (Fertilizers) $T_1$ | 0.150 | 0.190 | 0.406 |
| $T_2$ | 0.170 | 0.210 | 0.423 |
| $T_3$ | 0.160 | 0.190 | 0.404 |
| $T_4$ | 0.160 | 0.200 | 0.409 |
| CD | 0.003 | 0.002 | 0.004 |
| (Interaction) $m_1t_1$ | 0.140 | 0.210 | 0.405 |
| $m_1t_2$ | 0.210 | 0.240 | 0.435 |
| $m_1t_3$ | 0.190 | 0.210 | 0.395 |
| $m_1t_4$ | 0.180 | 0.220 | 0.425 |
| $m_2t_1$ | 0.150 | 0.180 | 0.405 |
| $m_2t_2$ | 0.150 | 0.220 | 0.425 |
| $m_2t_3$ | 0.170 | 0.180 | 0.400 |
| $m_2t_4$ | 0.140 | 0.200 | 0.415 |
| $m_3t_1$ | 0.160 | 0.170 | 0.410 |
| $m_3t_2$ | 0.150 | 0.200 | 0.430 |
| $m_3t_3$ | 0.130 | 0.170 | 0.390 |
| $m_3t_4$ | 0.140 | 0.190 | 0.405 |
| $m_4t_1$ | 0.140 | 0.190 | 0.405 |
| $m_4t_2$ | 0.180 | 0.180 | 0.400 |
| $m_4t_3$ | 0.170 | 0.200 | 0.420 |
| $m_4t_4$ | 0.180 | 0.200 | 0.400 |
| CD | 0.016 | 0.005 | 0.009 |
| $C_1$ | 0.170 | 0.180 | 0.414 |
| $C_2$ | 0.140 | 0.160 | 0.278 |
| $C_1$ Vs Treatment | S** | S** | S** |
| $C_2$ Vs Treatment | S** | S** | S** |
| $C_1$ Vs $C_2$ | S** | S** | S** |

* Significant at 1% level

Table 12: Effect of mulches and nutrients on Dry recovery (%)

| Treatments | $4^{th}$ month | $6^{th}$ month | Harvest |
|---|---|---|---|
| (Mulches) $M_1$ | 18.75 | 20.57 | 21.14 |
| $M_2$ | 17.53 | 19.06 | 20.31 |
| $M_3$ | 17.94 | 19.07 | 20.29 |
| $M_4$ | 18.02 | 18.76 | 20.29 |
| CD | 0.318 | 0.292 | 0.188 |
| (Fertilizers) $T_1$ | 16.97 | 18.32 | 19.81 |
| $T_2$ | 19.32 | 20.51 | 21.89 |
| $T_3$ | 17.45 | 19.10 | 19.77 |
| $T_4$ | 18.48 | 19.53 | 20.56 |
| CD | 0.307 | 0.301 | 0.229 |
| (Interaction) $m_1t_1$ | 17.61 | 19.56 | 20.75 |
| $m_1t_2$ | 21.03 | 22.56 | 23.15 |
| $m_1t_3$ | 17.73 | 19.30 | 19.37 |
| $m_1t_4$ | 18.60 | 20.85 | 21.30 |
| $m_2t_1$ | 16.39 | 17.93 | 19.44 |
| $m_2t_2$ | 19.53 | 21.07 | 21.03 |
| $m_2t_3$ | 16.56 | 18.14 | 19.19 |
| $m_2t_4$ | 17.63 | 19.09 | 20.71 |
| $m_3t_1$ | 16.48 | 17.47 | 19.44 |
| $m_3t_2$ | 19.56 | 20.69 | 21.49 |
| $m_3t_3$ | 17.22 | 18.71 | 19.53 |
| $m_3t_4$ | 18.48 | 19.43 | 20.74 |
| $m_4t_1$ | 17.38 | 18.33 | 19.62 |
| $m_4t_2$ | 17.16 | 17.74 | 21.91 |
| $m_4t_3$ | 18.31 | 20.25 | 21.01 |
| $m_4t_4$ | 19.23 | 18.72 | 19.51 |
| CD | 0.604 | 0.613 | 0.448 |
| $C_1$ | 17.77 | 19.18 | 21.34 |
| $C_2$ | 15.92 | 16.45 | 19.53 |
| $C_1$ Vs Treatment | S* | S* | S* |
| $C_2$ Vs Treatment | S* | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* | S* |

* Significant at 5% level

significantly from the control on all periods of growth . The comparison of $C_1$ as well as $C_2$ with the treatments also indicated significant difference in the dry recovery at all periods of growth. A significant difference was noticed between the control $C_1$ as well as $C_2$ .

## 4.4. RHIZOME CHARACTERISTICS

### 4.4.1 Rhizome thickness

The effect of treatments on rhizome thickness at different periods of growth are presented in Table 13

A significant variation in rhizome thickness was observed among the main plot treatments .The main plot treatment of $M_1$ recorded highest rhizome thickness and noted 1.69 cm followed by $M_3$ (1.62 cm) on at harvest. In sub plot treatment $T_2$ recorded highest rhizome thickness on all periods of observation and recorded 1.67cm at harvest and was significantly different from other treatments throughout the periods of observation. In interaction treatment $m_1t_2$ which is the combination of mulches @ 30 t $ha^{-1}$ and double the recommended dose of fertilizer as per package of practices of KAU resulted in highest rhizome thickness throughout the observation periods and at harvest the rhizome thickness was 1.79cm and was on par with $m_1t_4$. The treatments were significantly different from both the controls and there was significant difference between the control as well.

### 4.4.2 Rhizome spread

The main and interaction effects on rhizome spread at different periods of observation are presented in Table 14

Main plot treatment of application of different mulches have significantly influenced the rhizome spread of ginger on all periods of observation and $M_1$

Table 13: Effect of mulches and nutrients on Rhizome thickness (cm )

| Treatments | $4^{th}$ month | $6^{th}$ month | Harvest |
|---|---|---|---|
| (Mulches) $M_1$ | 1.46 | 1.58 | 1.69 |
| $M_2$ | 1.39 | 1.51 | 1.58 |
| $M_3$ | 1.35 | 1.48 | 1.62 |
| $M_4$ | 1.39 | 1.52 | 1.59 |
| CD | 0.038 | 0.029 | 0.018 |
| (Fertilizers) $T_1$ | 1.34 | 1.54 | 1.62 |
| $T_2$ | 1.53 | 1.59 | 1.67 |
| $T_3$ | 1.33 | 1.41 | 1.58 |
| $T_4$ | 1.40 | 1.54 | 1.60 |
| CD | 0.028 | 0.017 | 0.015 |
| (Interaction) $m_1t_1$ | 1.33 | 1.54 | 1.64 |
| $m_1t_2$ | 1.61 | 1.74 | 1.79 |
| $m_1t_3$ | 1.33 | 1.43 | 1.63 |
| $m_1t_4$ | 1.40 | 1.66 | 1.79 |
| $m_2t_1$ | 1.34 | 1.55 | 1.62 |
| $m_2t_2$ | 1.53 | 1.63 | 1.71 |
| $m_2t_3$ | 1.30 | 1.40 | 1.53 |
| $m_2t_4$ | 1.34 | 1.44 | 1.47 |
| $m_3t_1$ | 1.25 | 1.54 | 1.62 |
| $m_3t_2$ | 1.47 | 1.54 | 1.66 |
| $m_3t_3$ | 1.26 | 1.33 | 1.55 |
| $m_3t_4$ | 1.44 | 1.54 | 1.64 |
| $m_4t_1$ | 1.43 | 1.55 | 1.61 |
| $m_4t_2$ | 1.52 | 1.57 | 1.62 |
| $m_4t_3$ | 1.46 | 1.50 | 1.64 |
| $m_4t_4$ | 1.42 | 1.46 | 1.52 |
| CD | 0.046 | 0.024 | 0.020 |
| $C_1$ | 1.31 | 1.33 | 1.5 |
| $C_2$ | 1.04 | 1.12 | 1.25 |
| $C_1$ Vs Treatment | S* | S* | S* |
| $C_2$ Vs Treatment | S* | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* | S* |

* Significant at 5% level

Table 14:Effect of mulches and nutrients on Rhizome spread (cm)

| Treatments | $4^{th}$ month | $6^{th}$ month | Harvest |
|---|---|---|---|
| (Mulches) $M_1$ | 9.63 | 11.01 | 13.31 |
| $M_2$ | 8.58 | 10.33 | 12.29 |
| $M_3$ | 7.64 | 9.96 | 12.43 |
| $M_4$ | 7.86 | 9.69 | 11.66 |
| CD | 0.188 | 0.216 | 0.182 |
| (Fertilizers) $T_1$ | 8.12 | 9.85 | 12.42 |
| $T_2$ | 8.68 | 10.84 | 13.08 |
| $T_3$ | 8.39 | 10.15 | 11.39 |
| $T_4$ | 8.31 | 10.16 | 12.79 |
| CD | 0.18 | 0.162 | 0.169 |
| (Interaction) $m_1t_1$ | 9.18 | 10.33 | 11.50 |
| $m_1t_2$ | 10.35 | 13.15 | 14.30 |
| $m_1t_3$ | 9.65 | 10.33 | 14.23 |
| $m_1t_4$ | 9.33 | 10.25 | 13.23 |
| $m_2t_1$ | 9.45 | 10.43 | 12.25 |
| $m_2t_2$ | 8.40 | 10.18 | 13.35 |
| $m_2t_3$ | 8.18 | 10.30 | 11.18 |
| $m_2t_4$ | 8.30 | 10.43 | 12.38 |
| $m_3t_1$ | 7.62 | 10.55 | 12.38 |
| $m_3t_2$ | 7.23 | 8.48 | 11.53 |
| $m_3t_3$ | 7.55 | 10.38 | 13.58 |
| $m_3t_4$ | 8.18 | 10.45 | 12.23 |
| $m_4t_1$ | 8.48 | 9.30 | 9.43 |
| $m_4t_2$ | 7.20 | 10.43 | 11.58 |
| $m_4t_3$ | 8.30 | 9.53 | 13.35 |
| $m_4t_4$ | 7.45 | 9.50 | 12.28 |
| CD | 0.362 | 0.335 | 0.339 |
| $C_1$ | 8.15 | 9.18 | 10.2 |
| $C_2$ | 7.5 | 8.68 | 9.18 |
| $C_1$ Vs Treatment | S* | S* | S* |
| $C_2$ Vs Treatment | S* | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* | S* |

* Significant at 5% level

recorded highest rhizome spread of 13.31cm at harvest .The sub plot treatment, $T_2$ showed highest rhizome spread on all periods of observation and recorded 13.08cm at harvest . Among the interaction, mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ resulted in higher rhizome spread on all periods of observation and recorded 14.30 cm which was on par with $m_1t_3$ . A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ and $C_2$ also showed a significant difference in rhizome spread.

## 4.5.QUALITY ANALYSIS

### 4.5.1 Starch

The effect of treatments on starch content at different periods of growth are presented in Table 15

Main plot treatment of mulching significantly influenced the starch content in all periods of observation and produced highest starch content in main plot treatment $M_1$ (30 t $ha^{-1}$) in all periods of growth and recorded 37.63% at harvest and was on par with $M_4$ ( 34.34 %) .In sub plot, treatment $T_2$ was significantly higher in all periods of observation and recorded 37.72% at harvest. Interaction showed significant effect on starch content during the periods of observation and treatment combination $m_1t_2$ ( mulches @30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$) noted highest starch content in all periods of observation. A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ and $C_2$ also showed a significant difference in starch content between them.

### 4.5.2 Fibre

The effect of treatments on fibre content at different growth periods of observation are presented in Table 1

Table 15: Effect of mulches and nutrients on Starch (%)

| Treatments | $4^{th}$ month | $6^{th}$ month | Harvest |
|---|---|---|---|
| (Mulches) $M_1$ | 21.06 | 25.10 | 37.63 |
| $M_2$ | 19.08 | 22.98 | 33.79 |
| $M_3$ | 17.63 | 22.66 | 32.46 |
| $M_4$ | 19.67 | 24.39 | 37.34 |
| CD | 0.388 | 0.657 | 0.524 |
| (Fertilizers) $T_1$ | 16.84 | 20.55 | 33.59 |
| $T_2$ | 21.49 | 25.86 | 37.72 |
| $T_3$ | 18.61 | 23.15 | 34.14 |
| $T_4$ | 20.49 | 25.38 | 35.77 |
| CD | 0.318 | 0.370 | 0.467 |
| (Interaction) $m_1t_1$ | 14.45 | 19.40 | 32.10 |
| $m_1t_2$ | 24.65 | 31.00 | 42.45 |
| $m_1t_3$ | 18.28 | 23.97 | 36.13 |
| $m_1t_4$ | 21.30 | 26.02 | 38.70 |
| $m_2t_1$ | 15.05 | 18.98 | 34.58 |
| $m_2t_2$ | 19.08 | 23.18 | 34.88 |
| $m_2t_3$ | 20.10 | 23.85 | 30.28 |
| $m_2t_4$ | 22.10 | 25.93 | 35.45 |
| $m_3t_1$ | 17.20 | 20.63 | 31.50 |
| $m_3t_2$ | 19.20 | 23.25 | 34.25 |
| $m_3t_3$ | 16.78 | 21.70 | 32.88 |
| $m_3t_4$ | 17.33 | 25.08 | 31.20 |
| $m_4t_1$ | 20.65 | 23.20 | 36.18 |
| $m_4t_2$ | 23.05 | 26.00 | 39.30 |
| $m_4t_3$ | 19.30 | 23.08 | 37.30 |
| $m_4t_4$ | 21.23 | 25.30 | 37.73 |
| CD | 0.637 | 0.741 | 0.925 |
| $C_1$ | 12.2 | 18.03 | 30.50 |
| $C_2$ | 9.83 | 14.63 | 22.20 |
| $C_1$ Vs Treatment | S* | S* | S* |
| $C_2$ Vs Treatment | S* | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* | S* |

* Significant at 5% level

Table 16: Effect of mulches and nutrients on Fibre (%)

| Treatments | 4th month | 6th month | Harvest |
|---|---|---|---|
| (Mulches) $M_1$ | 1.51 | 2.64 | 4.25 |
| $M_2$ | 1.49 | 2.20 | 3.92 |
| $M_3$ | 1.28 | 1.62 | 3.55 |
| $M_4$ | 1.36 | 1.93 | 3.9 |
| CD | 0.146 | 0.112 | 0.181 |
| (Fertilizers) $T_1$ | 1.24 | 1.77 | 3.66 |
| $T_2$ | 1.54 | 2.33 | 4.08 |
| $T_3$ | 1.42 | 2.01 | 3.81 |
| $T_4$ | 1.44 | 2.19 | 3.87 |
| CD | 0.132 | 0.121 | 0.141 |
| (Interaction) $m_1t_1$ | 1.55 | 2.28 | 3.97 |
| $m_1t_2$ | 1.86 | 2.90 | 4.41 |
| $m_1t_3$ | 1.31 | 2.63 | 4.10 |
| $m_1t_4$ | 1.25 | 2.58 | 4.05 |
| $m_2t_1$ | 1.35 | 1.77 | 3.94 |
| $m_2t_2$ | 1.50 | 2.38 | 4.09 |
| $m_2t_3$ | 1.44 | 2.10 | 3.65 |
| $m_2t_4$ | 1.48 | 2.55 | 4.02 |
| $m_3t_1$ | 0.95 | 1.56 | 3.45 |
| $m_3t_2$ | 1.30 | 1.68 | 3.60 |
| $m_3t_3$ | 1.51 | 1.55 | 3.38 |
| $m_3t_4$ | 1.35 | 1.68 | 3.80 |
| $m_4t_1$ | 1.13 | 1.48 | 3.31 |
| $m_4t_2$ | 1.43 | 2.16 | 4.10 |
| $m_4t_3$ | 1.40 | 1.76 | 3.95 |
| $m_4t_4$ | 1.50 | 2.34 | 4.10 |
| CD | 0.274 | 0.253 | 0.293 |
| $C_1$ | 1.13 | 1.70 | 3.55 |
| $C_2$ | 0.39 | 1.20 | 2.93 |
| $C_1$ Vs Treatment | S* | S* | S* |
| $C_2$ Vs Treatment | S* | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* | S* |

* Significant at 5% level

A significant variation in fibre content was observed among the main plot treatments . The main plot treatment , $M_1$ resulted in higher fibre content on all periods of observation and a fibre content of 4.25% was recorded at harvest while in $4^{th}$ month main plot treatment $M_1$ was on par with $M_2$ and $M_4$. In subplot $T_2$ treatment resulted in high fibre content on all periods of observation and resulted in 4.08% of fibre at harvest and in $4^{th}$ month treatment $T_2$ was on par with $T_3$ and $T_4$ . Among the combination mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ , $m_1t_2$ recorded highest fibre content on all periods and recorded 4.41% at harvest . Treatment effects varied significantly with both control $C_1$ as well as $C_2$. A significant difference was noticed between the control $C_1$ as well as $C_2$ .

**4.5.3 Oil**

The main and interaction effects of treatments on oil content at different periods of crop growth is furnished in Table 17.

Significant differences in oil content was observed throughout the crop growth periods. Plants that received $M_1$ (30 t $ha^{-1}$ ) in main plot resulted in maximum oil content at all growth periods. At harvest an oil content of 2.76% was recorded . Sub plot treatment, $T_2$ ( 150:100:100 kg $ha^{-1}$) recorded highest oil content on all periods of observation. At 8 months an oil content of 2.43% was recorded which was on par with $T_4$. The interaction between main plot and sub plot, was significant throughout the periods of observation and combination of mulches @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg /ha ($m_1t_2$) resulted in maximum oil content of 2.92% at harvest . A significant difference in oil content in all periods of growth was recorded between treatment and control. The control $C_1$ as well as $C_2$ varied significantly from treatments in all periods of observation . The oil content recorded between control also varied significantly.

Table 17: Effect of mulches and nutrients on oil content (%)

| Treatments | $4^{th}$ month | $6^{th}$ month | Harvest |
|---|---|---|---|
| (Mulches) $M_1$ | 1.66 | 2.61 | 2.76 |
| $M_2$ | 1.38 | 2.28 | 2.24 |
| $M_3$ | 1.29 | 2.04 | 2.18 |
| $M_4$ | 1.58 | 2.37 | 2.09 |
| CD | 0.020 | 0.069 | 0.078 |
| (Fertilizers) $T_1$ | 1.27 | 1.10 | 2.19 |
| $T_2$ | 1.63 | 2.56 | 2.43 |
| $T_3$ | 1.50 | 2.35 | 2.22 |
| $T_4$ | 1.52 | 2.41 | 2.42 |
| CD | 0.069 | 0.112 | 0.072 |
| (Interaction) $m_1t_1$ | 1.25 | 2.08 | 1.99 |
| $m_1t_2$ | 1.98 | 2.88 | 2.92 |
| $m_1t_3$ | 1.62 | 2.34 | 1.99 |
| $m_1t_4$ | 1.83 | 2.54 | 2.20 |
| $m_2t_1$ | 1.19 | 1.73 | 2.27 |
| $m_2t_2$ | 1.54 | 2.52 | 2.34 |
| $m_2t_3$ | 1.39 | 2.39 | 2.05 |
| $m_2t_4$ | 1.40 | 2.51 | 2.33 |
| $m_3t_1$ | 1.14 | 1.83 | 2.06 |
| $m_3t_2$ | 1.27 | 1.10 | 2.22 |
| $m_3t_3$ | 1.36 | 2.05 | 2.17 |
| $m_3t_4$ | 1.39 | 2.31 | 2.25 |
| $m_4t_1$ | 1.49 | 2.37 | 2.45 |
| $m_4t_2$ | 1.74 | 2.58 | 2.58 |
| $m_4t_3$ | 1.64 | 2.62 | 2.68 |
| $m_4t_4$ | 1.71 | 2.54 | 2.20 |
| CD | 0.129 | 0.225 | 0.144 |
| $C_1$ | 0.9 | 1.73 | 1.80 |
| $C_2$ | 0.45 | 1.15 | 1.53 |
| $C_1$ Vs Treatment | S* | S* | S* |
| $C_2$ Vs Treatment | S* | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* | S* |

* Significant at 5% level

Table 18: Effect of mulches and nutrients on NVEE (%)

| Treatments | 4th month | 6th month | Harvest |
|---|---|---|---|
| (Mulches) $M_1$ | 6.30 | 8.43 | 8.72 |
| $M_2$ | 5.55 | 7.83 | 8.47 |
| $M_3$ | 5.24 | 7.31 | 7.69 |
| $M_4$ | 6.21 | 8.26 | 8.68 |
| CD | 0.220 | 0.253 | 0.212 |
| (Fertilizers) $T_1$ | 5.27 | 7.60 | 8.04 |
| $T_2$ | 6.14 | 8.20 | 8.71 |
| $T_3$ | 5.93 | 7.96 | 8.29 |
| $T_4$ | 5.94 | 8.00 | 8.52 |
| CD | 0.171 | 0.190 | 0.174 |
| (Interaction) $m_1t_1$ | 5.39 | 7.88 | 8.38 |
| $m_1t_2$ | 6.70 | 8.68 | 9.08 |
| $m_1t_3$ | 6.23 | 8.17 | 8.70 |
| $m_1t_4$ | 6.28 | 8.27 | 8.65 |
| $m_2t_1$ | 5.30 | 7.58 | 8.30 |
| $m_2t_2$ | 5.60 | 8.10 | 8.63 |
| $m_2t_3$ | 5.40 | 7.90 | 8.28 |
| $m_2t_4$ | 5.90 | 7.73 | 8.68 |
| $m_3t_1$ | 4.88 | 6.96 | 7.43 |
| $m_3t_2$ | 5.18 | 7.53 | 8.10 |
| $m_3t_3$ | 5.40 | 7.30 | 7.58 |
| $m_3t_4$ | 5.53 | 7.45 | 7.68 |
| $m_4t_1$ | 5.53 | 7.80 | 8.08 |
| $m_4t_2$ | 6.32 | 8.20 | 8.65 |
| $m_4t_3$ | 6.33 | 8.08 | 8.55 |
| $m_4t_4$ | 6.23 | 8.25 | 8.71 |
| CD | 0.342 | 0.381 | 0.349 |
| $C_1$ | 4.18 | 6.30 | 7.05 |
| $C_2$ | 2.90 | 4.73 | 6.20 |
| $C_1$ Vs Treatment | S* | S* | S* |
| $C_2$ Vs Treatment | S* | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* | S* |

* Significant at 5% level

#### 4.5.4 Non Volatile Ether Extract

The main and interaction effects on non volatile ether extract at different periods of observation are presented in Table 18

Main plot treatment of mulching significantly influenced the NVEE on all periods of observation. $M_1$ recorded the highest NVEE of 8.72% at harvest which was on par with $M_4$ in all periods of observation and sub plot treatment $T_2$ had the highest nvee on all periods of observation and recorded 8.71% at harvest . Among the interaction mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ resulted in higher NVEE on all periods of observation and recorded 9.08% . A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ and $C_2$ also showed a significant difference between them.

### 4.6. PHYSIOLOGICAL ANALYSIS

#### 4.6.1 Dry matter production

The effect of treatments on dry matter production at different periods of observation are presented in Table 19

Main plot treatments significantly affected the dry matter production of ginger throughout the periods of observation. The main plot treatment $M_1$ with mulches @ 30 t $ha^{-1}$ recorded the highest dry matter production on all periods and obtained 76.95 g $plant^{-1}$ in $8^{th}$ month . In subplot treatments dry matter production were significant throughout the periods of observation and treatment $T_2$ recorded highest dry matter production on all periods and obtained 75.67 g $plant^{-1}$ on $8^{th}$ month. Interaction effects were significant throughout the periods and among interaction combination of mulches @ 30 t $ha^{-1}$ and double the recommended dose of fertilizer as per package of practices of KAU obtained highest dry matter production on all periods of observation and recorded 83.70 g plant$^{-1}$ at 8$^{th}$ month . A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ and $C_2$ also showed a significant difference between them.

**4.6.2 Net assimilation rate**

The main and interaction effects of treatments on net assimilation rate at different periods of crop growth are furnished in Table 20

Significant differences in net assimilation rate was observed throughout the crop growth periods. Plants that received $M_1$ (30 t ha $^{-1}$ ) in main plot resulted in maximum net assimilation rate at all growth periods. During the crop growth period from 6 to 8 month net assimilation rate of 0.290 g m$^{-2}$ day$^{-1}$ was recorded . Sub plot treatment $T_2$ ( 150:100:100 kg ha $^{-1}$) recorded highest net assimilation rate on all periods of observation. At 6 to 8 months a net assimilation rate of 0.266 g m$^{-2}$ day$^{-1}$ was recorded. In the interaction between main plot and sub plot, significant variation was observed throughout the periods of observation and treatments $m_1t_2$, $m_1t_3$,$m_1t_4$ were on par for 4 to 6 month. The highest net assimilation rate of 0.365 g m$^{-2}$ day$^{-1}$ was noticed during the period of 6$^{th}$ to 8$^{th}$ month. The control $C_1$ as well as $C_2$ varied significantly from treatments in all periods. The net assimilation rate recorded between control also varied significantly.

**4.6.3 Crop growth rate**

The effect of treatments on crop growth rate at different growth periods are presented in Table 21

Main plot treatment of mulching was significant only in period of 6$^{th}$ to 8$^{th}$ month and produced highest crop growth rate in main plot treatment $M_1$ and $M_4$ (0.029 g/m$^2$/day) .In sub plot, treatment were significant only in 4$^{th}$ to 6$^{th}$ months of

Table 19: Effect of mulches and nutrients on Dry matter production (g plant $^{-1}$)

| Treatments | $4^{th}$ month | $6^{th}$ month | $8^{th}$ month |
|---|---|---|---|
| (Mulches) $M_1$ | 31.80 | 48.79 | 76.95 |
| $M_2$ | 30.20 | 44.67 | 71.07 |
| $M_3$ | 26.54 | 42.88 | 67.72 |
| $M_4$ | 31.05 | 46.28 | 73.58 |
| CD | 0.646 | 0.963 | 0.536 |
| (Fertilizers) $T_1$ | 26.79 | 42.86 | 68.27 |
| $T_2$ | 33.03 | 47.61 | 75.67 |
| $T_3$ | 29.45 | 46.09 | 71.69 |
| $T_4$ | 31.81 | 46.06 | 73.70 |
| CD | 0.530 | 0.979 | 0.424 |
| (Interaction) $m_1t_1$ | 28.70 | 46.01 | 74.47 |
| $m_1t_2$ | 35.47 | 51.32 | 83.70 |
| $m_1t_3$ | 30.32 | 48.41 | 74.16 |
| $m_1t_4$ | 32.73 | 49.31 | 75.50 |
| $m_2t_1$ | 25.34 | 43.08 | 67.27 |
| $m_2t_2$ | 33.77 | 46.17 | 75.50 |
| $m_2t_3$ | 29.74 | 42.88 | 68.85 |
| $m_2t_4$ | 31.96 | 46.55 | 72.70 |
| $m_3t_1$ | 23.67 | 39.67 | 62.91 |
| $m_3t_2$ | 28.92 | 44.57 | 69.50 |
| $m_3t_3$ | 25.83 | 42.33 | 67.58 |
| $m_3t_4$ | 27.75 | 44.96 | 70.92 |
| $m_4t_1$ | 29.48 | 42.70 | 68.43 |
| $m_4t_2$ | 33.97 | 42.19 | 74.02 |
| $m_4t_3$ | 31.95 | 49.13 | 76.19 |
| $m_4t_4$ | 34.23 | 49.32 | 75.69 |
| CD | 1.071 | 1.948 | 0.858 |
| $C_1$ | 26.11 | 45.83 | 69.99 |
| $C_2$ | 21.83 | 27.23 | 51.33 |
| $C_1$ Vs Treatment | S* | S* | S* |
| $C_2$ Vs Treatment | S* | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* | S* |

* Significant at 5% level

Table 20: Effect of mulch and nutrients on net assimilation rate (g $m^{-2}day^{-1}$)

| Treatments | $4^{th}$ to $6^{th}$ month | $6^{th}$ to $8^{th}$ month |
|---|---|---|
| (Mulches) $M_1$ | 0.150 | 0.290 |
| $M_2$ | 0.100 | 0.224 |
| $M_3$ | 0.090 | 0.161 |
| $M_4$ | 0.100 | 0.210 |
| CD | 0.005 | 0.004 |
| (Fertilizers) $T_1$ | 0.100 | 0.193 |
| $T_2$ | 0.120 | 0.266 |
| $T_3$ | 0.110 | 0.205 |
| $T_4$ | 0.110 | 0.221 |
| CD | 0.006 | 0.016 |
| (Interaction) $m_1t_1$ | 0.135 | 0.275 |
| $m_1t_2$ | 0.155 | 0.365 |
| $m_1t_3$ | 0.155 | 0.255 |
| $m_1t_4$ | 0.155 | 0.270 |
| $m_2t_1$ | 0.105 | 0.175 |
| $m_2t_2$ | 0.105 | 0.285 |
| $m_2t_3$ | 0.085 | 0.205 |
| $m_2t_4$ | 0.110 | 0.235 |
| $m_3t_1$ | 0.085 | 0.135 |
| $m_3t_2$ | 0.095 | 0.175 |
| $m_3t_3$ | 0.090 | 0.160 |
| $m_3t_4$ | 0.100 | 0.175 |
| $m_4t_1$ | 0.085 | 0.190 |
| $m_4t_2$ | 0.065 | 0.240 |
| $m_4t_3$ | 0.130 | 0.200 |
| $m_4t_4$ | 0.110 | 0.210 |
| CD | 0.0130 | 0.0230 |
| $C_1$ | 0.100 | 0.160 |
| $C_2$ | 0.020 | 0.110 |
| $C_1$ Vs Treatment | S** | S** |
| $C_2$ Vs Treatment | S** | S** |
| $C_1$ Vs $C_2$ | S** | S** |

** Significant at 1% level

Table 21: Effect of mulch and nutrients on crop growth rate (g $m^{-2}$ $day^{-1}$)

| Treatments | $4^{th}$ to $6^{th}$ month | $6^{th}$ to $8^{th}$ month |
|---|---|---|
| (Mulches) $M_1$ | 0.018 | 0.029 |
| $M_2$ | 0.015 | 0.018 |
| $M_3$ | 0.016 | 0.016 |
| $M_4$ | 0.014 | 0.029 |
| CD | NS | 0.009 |
| (Fertilizers) $T_1$ | 0.013 | 0.027 |
| $T_2$ | 0.017 | 0.031 |
| $T_3$ | 0.016 | 0.027 |
| $T_4$ | 0.017 | 0.027 |
| CD | 0.001 | NS |
| (Interaction) $m_1t_1$ | 0.018 | 0.027 |
| $m_1t_2$ | 0.019 | 0.035 |
| $m_1t_3$ | 0.015 | 0.027 |
| $m_1t_4$ | 0.015 | 0.022 |
| $m_2t_1$ | 0.015 | 0.022 |
| $m_2t_2$ | 0.017 | 0.035 |
| $m_2t_3$ | 0.017 | 0.027 |
| $m_2t_4$ | 0.015 | 0.022 |
| $m_3t_1$ | 0.017 | 0.022 |
| $m_3t_2$ | 0.015 | 0.026 |
| $m_3t_3$ | 0.017 | 0.022 |
| $m_3t_4$ | 0.012 | 0.027 |
| $m_4t_1$ | 0.017 | 0.027 |
| $m_4t_2$ | 0.005 | 0.032 |
| $m_4t_3$ | 0.017 | 0.025 |
| $m_4t_4$ | 0.015 | 0.022 |
| CD | 0.002 | NS |
| $C_1$ | 0.021 | 0.025 |
| $C_2$ | 0.006 | 0.025 |
| $C_1$ Vs Treatment | S** | S** |
| $C_2$ Vs Treatment | S** | S** |
| $C_1$ Vs $C_2$ | S** | NS |

** Significant at 1% level

NS- Not Significant

observation and highest was recorded by treatment $T_2$ and $T_4$ which was on par with $T_3$ Interaction was significant during the periods of $4^{th}$ to $6^{th}$ months of observation and treatment combination $m_1t_2$ ( mulches @30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$) noted highest crop growth rate on $4^{th}$ to $6^{th}$ months of observation which was on par with $m_1t_1$,$m_2t_2$,$m_2t_3$,$m_3t_1$,$m_3t_2$,$m_4t_1$,$m_4t_2$ . A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ and $C_2$ also showed a significant difference between them in $4^{th}$ to $6^{th}$ months .

**4.6.4 Leaf area index**

The main and interaction effects of treatments on leaf area index at different periods of growth in ginger are presented in Table 22

Main plot treatment, sub plot treatment and interaction had significant influence in the leaf area index at all periods of growth. Among the main plot treatment $M_1$ (30 t $ha^{-1}$) retained significantly higher leaf area index in all periods of growth and recorded 8.64 at $8^{th}$ month . In sub plot treatment $T_2$ (150:100:100 kg/ha) recorded highest leaf area index of 8.11 in $8^{th}$ month. Interaction effect resulted in significant difference in all periods of growth and highest leaf area index was recorded from the combination of mulches @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg/ha ($m_1t_2$) in all periods of observation and in $8^{th}$ month leaf area index of 9.20 was recorded . Leaf area index of treatments varied significantly from the control on all periods of growth . The comparison of $C_1$ as well as $C_2$ with the treatments also indicated significant difference in the number of leaves in all periods of growth. A significant difference was noticed in leaf area index between the control $C_1$ and $C_2$ .

#### 4.6.5 Relative growth rate

The main and interaction effects on relative growth rate at different growth periods are presented in Table 23

Relative growth rate recorded showed significant difference between main plots in $6^{th}$ to $8^{th}$ month and Treatment $M_1$ and $M_4$ recorded highest relative growth rate in 6 to 8 months (0.072 g/g/day). In sub plot, treatments were insignificant for relative growth rate in 4 to 6 months and $T_2$ recorded highest relative growth rate on 6 to 8 month . Treatment combination was significant throughout the periods of observation and combination of mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ resulted in higher relative growth rate in 4 to 6 months . The relative growth rate during $6^{th}$ to $8^{th}$ months for $m_1t_2$ recorded highest and was on par with $m_1t_3$ and $m_4t_2$ . Treatments varied significantly with both the controls. A significant variation was observed within the controls $C_1$ and $C_2$ as well.

#### 4.6.6 Leaf area duration

The main and interaction effects of treatment on leaf area duration is provided in Table 24

Leaf area duration differed significantly among all periods of observation . $M_1$ (30 t $ha^{-1}$) recorded highest leaf area duration on all periods . The leaf area duration of 263.39 days were obtained for $M_1$ for the period of $6^{th}$ to $8^{th}$ month . In sub plot , $T_2$ treatment recorded highest leaf area duration on all periods of observation and was significantly different from other treatment . Among the interaction mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:10:100 kg $ha^{-1}$ ($m_1t_2$) recorded highest leaf area duration on all periods of observation . Treatment effects varied significantly with both control $C_1$ as well as $C_2$. A significant difference was noticed between the control $C_1$ as well as $C_2$ .

Table 22: Effect of mulch and nutrients on leaf area index

| Treatments | 4th month | 6th month | 8th month |
|---|---|---|---|
| (Mulches) $M_1$ | 7.33 | 8.38 | 8.64 |
| $M_2$ | 6.31 | 7.33 | 7.70 |
| $M_3$ | 5.23 | 5.80 | 6.22 |
| $M_4$ | 6.63 | 6.96 | 7.42 |
| CD | 0.205 | 0.132 | 0.061 |
| (Fertilizers) $T_1$ | 5.68 | 6.42 | 6.77 |
| $T_2$ | 7.04 | 7.72 | 8.11 |
| $T_3$ | 6.19 | 6.92 | 7.30 |
| $T_4$ | 6.58 | 7.41 | 7.80 |
| CD | 0.170 | 0.111 | 0.063 |
| (Interaction) $m_1t_1$ | 6.42 | 7.68 | 8.00 |
| $m_1t_2$ | 8.31 | 8.92 | 9.20 |
| $m_1t_3$ | 7.02 | 8.32 | 8.56 |
| $m_1t_4$ | 7.56 | 8.60 | 8.80 |
| $m_2t_1$ | 5.30 | 6.39 | 6.72 |
| $m_2t_2$ | 7.31 | 8.00 | 8.32 |
| $m_2t_3$ | 6.23 | 7.01 | 7.52 |
| $m_2t_4$ | 6.39 | 7.93 | 8.24 |
| $m_3t_1$ | 4.91 | 5.33 | 5.81 |
| $m_3t_2$ | 5.66 | 6.47 | 6.90 |
| $m_3t_3$ | 5.01 | 5.60 | 5.92 |
| $m_3t_4$ | 5.35 | 5.82 | 6.24 |
| $m_4t_1$ | 6.07 | 6.28 | 6.56 |
| $m_4t_2$ | 6.89 | 7.48 | 8.01 |
| $m_4t_3$ | 6.51 | 6.78 | 7.20 |
| $m_4t_4$ | 7.03 | 7.31 | 7.90 |
| CD | 0.350 | 0.223 | 0.137 |
| $C_1$ | 3.97 | 5.62 | 6.73 |
| $C_2$ | 2.40 | 3.55 | 4.82 |
| $C_1$ Vs Treatment | S* | S* | S* |
| $C_2$ Vs Treatment | S* | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* | S* |

* Significant at 5% level

Table 23: Effect of mulch and nutrients on relative growth rate ($g\ g^{-1} day^{-1}$)

| Treatments | 4th to 6th month | 6th to 8th month |
|---|---|---|
| (Mulches) $M_1$ | 0.063 | 0.072 |
| $M_2$ | 0.062 | 0.071 |
| $M_3$ | 0.061 | 0.068 |
| $M_4$ | 0.063 | 0.072 |
| CD | NS | 0.001 |
| (Fertilizers) $T_1$ | 0.060 | 0.069 |
| $T_2$ | 0.064 | 0.072 |
| $T_3$ | 0.062 | 0.070 |
| $T_4$ | 0.063 | 0.07 |
| CD | NS | 0.001 |
| (Interaction) $m_1t_1$ | 0.065 | 0.079 |
| $m_1t_2$ | 0.069 | 0.079 |
| $m_1t_3$ | 0.064 | 0.078 |
| $m_1t_4$ | 0.067 | 0.071 |
| $m_2t_1$ | 0.064 | 0.062 |
| $m_2t_2$ | 0.065 | 0.072 |
| $m_2t_3$ | 0.062 | 0.065 |
| $m_2t_4$ | 0.067 | 0.075 |
| $m_3t_1$ | 0.059 | 0.060 |
| $m_3t_2$ | 0.068 | 0.067 |
| $m_3t_3$ | 0.061 | 0.062 |
| $m_3t_4$ | 0.061 | 0.071 |
| $m_4t_1$ | 0.061 | 0.064 |
| $m_4t_2$ | 0.064 | 0.078 |
| $m_4t_3$ | 0.062 | 0.073 |
| $m_4t_4$ | 0.068 | 0.072 |
| CD | 0.001 | 0.002 |
| $C_1$ | 0.063 | 0.070 |
| $C_2$ | 0.053 | 0.065 |
| $C_1$ Vs Treatment | S** | S** |
| $C_2$ Vs Treatment | S** | S** |
| $C_1$ Vs $C_2$ | S** | S** |

** Significant at 1% level

Table 24: Effect of mulch and nutrients on leaf area duration (days)

| Treatments | $4^{th}$ to $6^{th}$ month | $6^{th}$ to $8^{th}$ month |
|---|---|---|
| (Mulches) $M_1$ | 255.06 | 263.39 |
| $M_2$ | 223.03 | 234.67 |
| $M_3$ | 176.61 | 189.39 |
| $M_4$ | 212.11 | 225.93 |
| CD | 4.103 | 1.888 |
| (Fertilizers) $T_1$ | 195.36 | 206.30 |
| $T_2$ | 235.01 | 247.06 |
| $T_3$ | 210.82 | 222.46 |
| $T_4$ | 225.63 | 237.55 |
| CD | 3.375 | 2.002 |
| (Interaction) $m_1t_1$ | 233.62 | 243.84 |
| $m_1t_2$ | 271.76 | 280.46 |
| $m_1t_3$ | 253.11 | 260.96 |
| $m_1t_4$ | 261.78 | 268.30 |
| $m_2t_1$ | 194.29 | 204.80 |
| $m_2t_2$ | 243.65 | 253.60 |
| $m_2t_3$ | 213.30 | 229.11 |
| $m_2t_4$ | 240.90 | 251.17 |
| $m_3t_1$ | 162.21 | 176.86 |
| $m_3t_2$ | 196.78 | 210.19 |
| $m_3t_3$ | 170.33 | 180.40 |
| $m_3t_4$ | 177.13 | 190.11 |
| $m_4t_1$ | 191.34 | 199.72 |
| $m_4t_2$ | 227.85 | 244.00 |
| $m_4t_3$ | 206.54 | 219.39 |
| $m_4t_4$ | 222.74 | 240.64 |
| CD | 6.751 | 4.005 |
| $C_1$ | 170.59 | 204.68 |
| $C_2$ | 107.85 | 146.34 |
| $C_1$ Vs Treatment | S* | S* |
| $C_2$ Vs Treatment | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* |

* Significant at 5% level

### 4.6.7 Bulking rate

The effect of treatments on bulking rate at different growth periods are presented in Table 25

The bulking rate recorded significant variation among main plot treatments on $6^{th}$ to $8^{th}$ month of observation. Highest bulking rate was recorded due to main plot treatment $M_1$ (30 t ha $^{-1}$) during this period (0.237 g plant$^{-1}$ day$^{-1}$). In sub plot, treatment $T_2$ was significantly higher in all periods of observation while in $4^{th}$ to $6^{th}$ month $T_2$ was on par with $T_3$. Interaction was significant during the periods of observation and treatment combination $m_1t_2$ ( mulches @ 30 t ha$^{-1}$ and fertilizer dose of 150:100:100 kg ha$^{-1}$) resulted in the highest bulking rate in $4^{th}$ to $6^{th}$ months and was on par with $m_1t_4$,$m_2t_2$ and $m_3t_2$ . A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ and $C_2$ also showed a significant difference between them.

### 4.6.8 Chlorophyll content

The main and interaction effects of treatments on chlorophyll content at different periods of growth in ginger are presented in Table 26

Significant differences in chlorophyll content among main plot treatments was observed throughout the crop growth periods. Plants that received $M_1$ (30 t ha $^{-1}$ ) in main plot resulted in maximum chlorophyll content in all growth periods. At 8 months chlorophyll content of 1.33 mg g$^{-1}$ was recorded from $M_2$ . Sub plot treatment $T_2$ ( 150:100:100 kg ha $^{-1}$) recorded highest chlorophyll content on $4^{th}$ and $6^{th}$ months observation while in 8 months chlorophyll content of 1.24 mg g$^{-1}$ was recorded for $T_2$ and $T_4$ . The interaction between main plot and sub plot, was significant throughout the periods of observation and combination of mulches @ 30 t ha $^{-1}$ and fertilizer dose of 150:100:100 kg /ha ($m_1t_2$) resulted in maximum chlorophyll content while in $4^{th}$ month interactions $m_1t_2$ was on par with

Table 25: Effect of mulch and nutrients on bulking rate (g $plant^{-1}$ $day^{-1}$)

| Treatments | $4^{th}$ to $6^{th}$ month | $6^{th}$ to $8^{th}$ month |
|---|---|---|
| (Mulches) $M_1$ | 0.158 | 0.237 |
| $M_2$ | 0.151 | 0.221 |
| $M_3$ | 0.143 | 0.218 |
| $M_4$ | 0.127 | 0.229 |
| CD | NS | 0.002 |
| (Fertilizers) $T_1$ | 0.136 | 0.219 |
| $T_2$ | 0.154 | 0.249 |
| $T_3$ | 0.146 | 0.212 |
| $T_4$ | 0.141 | 0.227 |
| CD | 0.008 | 0.001 |
| (Interaction) $m_1t_1$ | 0.157 | 0.229 |
| $m_1t_2$ | 0.168 | 0.272 |
| $m_1t_3$ | 0.145 | 0.217 |
| $m_1t_4$ | 0.165 | 0.226 |
| $m_2t_1$ | 0.135 | 0.215 |
| $m_2t_2$ | 0.167 | 0.235 |
| $m_2t_3$ | 0.147 | 0.202 |
| $m_2t_4$ | 0.154 | 0.222 |
| $m_3t_1$ | 0.125 | 0.215 |
| $m_3t_2$ | 0.163 | 0.227 |
| $m_3t_3$ | 0.144 | 0.205 |
| $m_3t_4$ | 0.135 | 0.224 |
| $m_4t_1$ | 0.125 | 0.215 |
| $m_4t_2$ | 0.115 | 0.254 |
| $m_4t_3$ | 0.153 | 0.225 |
| $m_4t_4$ | 0.107 | 0.225 |
| CD | 0.007 | 0.013 |
| $C_1$ | 0.154 | 0.190 |
| $C_2$ | 0.064 | 0.100 |
| $C_1$ Vs Treatment | S** | S** |
| $C_2$ Vs Treatment | S** | S** |
| $C_1$ Vs $C_2$ | S** | S** |

** Significant at 1% level

Table 26: Effect of mulch and nutrients on chlorophyll content (mg $g^{-1}$)

| Treatments | $4^{th}$ month | $6^{th}$ month | $8^{th}$ month |
|---|---|---|---|
| (Mulches) $M_1$ | 0.52 | 0.86 | 1.33 |
| $M_2$ | 0.51 | 0.81 | 1.18 |
| $M_3$ | 0.43 | 0.82 | 1.16 |
| $M_4$ | 0.49 | 0.83 | 1.20 |
| CD | 0.016 | 0.006 | 0.016 |
| (Fertilizers) $T_1$ | 0.47 | 0.79 | 1.18 |
| $T_2$ | 0.51 | 0.85 | 1.24 |
| $T_3$ | 0.49 | 0.83 | 1.22 |
| $T_4$ | 0.49 | 0.82 | 1.24 |
| CD | 0.013 | 0.003 | 0.008 |
| (Interaction) $m_1t_1$ | 0.50 | 0.835 | 1.22 |
| $m_1t_2$ | 0.54 | 0.91 | 1.39 |
| $m_1t_3$ | 0.53 | 0.86 | 1.33 |
| $m_1t_4$ | 0.52 | 0.87 | 1.37 |
| $m_2t_1$ | 0.51 | 0.77 | 1.18 |
| $m_2t_2$ | 0.52 | 0.81 | 1.21 |
| $m_2t_3$ | 0.50 | 0.84 | 1.19 |
| $m_2t_4$ | 0.51 | 0.86 | 1.15 |
| $m_3t_1$ | 0.42 | 0.79 | 1.10 |
| $m_3t_2$ | 0.48 | 0.83 | 1.16 |
| $m_3t_3$ | 0.43 | 0.82 | 1.17 |
| $m_3t_4$ | 0.44 | 0.84 | 1.19 |
| $m_4t_1$ | 0.46 | 0.79 | 1.18 |
| $m_4t_2$ | 0.52 | 0.86 | 1.21 |
| $m_4t_3$ | 0.49 | 0.85 | 1.22 |
| $m_4t_4$ | 0.52 | 0.83 | 1.23 |
| CD | 0.026 | 0.017 | 0.017 |
| $C_1$ | 0.43 | 0.75 | 0.99 |
| $C_2$ | 0.35 | 0.7 | 1.02 |
| $C_1$ Vs Treatment | S** | S** | S** |
| $C_2$ Vs Treatment | S** | S** | S** |
| $C_1$ Vs $C_2$ | S** | S** | S** |

** Significant at 1% level

$m_1t_3$,$m_1t_4$,$m_2t_2$,$m_4t_2$ and $m_4t_4$ and in 8th month interaction $m_1t_2$ resulted higher chlorophyll content of 1.39 mg $g^{-1}$ .A significant difference in chlorophyll content in all periods of growth was recorded between treatment and control. The control $C_1$ as well as $C_2$ varied significantly from treatments in all periods. Chlorophyll content recorded between controls $C_1$ and $C_2$ also varied significantly.

## 4.7 WEED COUNT AND DRY WEIGHT OF WEED PER UNIT AREA

### 4.7.1 Weed count

The main and interaction effects of treatment on weed count is provided in Table 27

Weed count differed significantly between all periods of observation and lowest weed count was recorded from $M_4$ (plastic mulch ) on all periods .Weed count of 9.21 was obtained in the 120th day of observation . In sub plot, $T_1$ treatment recorded lowest weed count on all periods of observation and was significantly different from other treatments and weed count of 29.75 was obtained in the 120th day . Among the interaction mulching with plastic mulch and fertilizer dose of 75:50:50 kg $ha^{-1}$ ($m_4t_1$) recorded lowest weed count on 45th and 90th days of observation. Treatment effects varied significantly with both control $C_1$ as well as $C_2$. A significant difference was noticed between the control $C_1$ and $C_2$ .

### 4.7.2 Dry weight of weed per unit area

The effect of treatments on dry weight of weed per unit area at different growth periods of ginger are presented in Table 28

A significant variation in dry weight of weed per unit area was observed among the main plot treatment The main plot treatment of $M_4$ resulted in lowest dry weight of weed of 32.72g/$m^2$ was recorded in 120th day . In subplot $T_1$ treatment resulted in lowest dry weight of weed on 45th and 90th days of observation.

Table 27: Effect of mulch and nutrients on weed count

| Treatments | 45th day | 90th day | 120th day |
|---|---|---|---|
| (Mulches) $M_1$ | 11.06 | 20.5 | 30.38 |
| $M_2$ | 17.63 | 25.25 | 34.5 |
| $M_3$ | 25.25 | 35.75 | 43.31 |
| $M_4$ | 4.06 | 7.24 | 9.21 |
| CD | 0.545 | 0.294 | 0.659 |
| (Fertilizers) $T_1$ | 14.19 | 21.81 | 29.75 |
| $T_2$ | 15.00 | 24.19 | 33.19 |
| $T_3$ | 14.16 | 22.50 | 30.81 |
| $T_4$ | 14.21 | 22.63 | 31.25 |
| CD | 0.734 | 0.515 | 0.441 |
| (Interaction) $m_1t_1$ | 11.50 | 20.50 | 30.30 |
| $m_1t_2$ | 10.80 | 22.00 | 31.5 |
| $m_1t_3$ | 11.30 | 19.80 | 29.80 |
| $m_1t_4$ | 10.80 | 19.8 | 30.00 |
| $m_2t_1$ | 19.30 | 24.50 | 34.30 |
| $m_2t_2$ | 18.30 | 26.50 | 35.80 |
| $m_2t_3$ | 18.30 | 25.50 | 33.50 |
| $m_2t_4$ | 14.80 | 24.50 | 34.50 |
| $m_3t_1$ | 22.30 | 34.50 | 39.50 |
| $m_3t_2$ | 24.20 | 35.80 | 44.00 |
| $m_3t_3$ | 27.80 | 37.30 | 46.50 |
| $m_3t_4$ | 25.80 | 35.50 | 43.30 |
| $m_4t_1$ | 3.75 | 7.75 | 12.40 |
| $m_4t_2$ | 3.75 | 10.50 | 9.50 |
| $m_4t_3$ | 4.75 | 7.50 | 11.50 |
| $m_4t_4$ | 4.00 | 8.21 | 9.78 |
| CD | 1.478 | 1.020 | 0.892 |
| $C_1$ | 15.75 | 25.75 | 33.50 |
| $C_2$ | 7.00 | 11.25 | 14.75 |
| $C_1$ Vs Treatment | S* | S* | S* |
| $C_2$ Vs Treatment | S* | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* | S* |

* Significant at 5% level

Table 28: Effect of mulch and nutrients on dry weight of weed (g $m^{-2}$)

| Treatments | 45$^{th}$ day | 90$^{th}$ day | 120$^{th}$ day |
|---|---|---|---|
| (Mulches) $M_1$ | 52.39 | 67.08 | 85.39 |
| $M_2$ | 69.18 | 81.51 | 142.77 |
| $M_3$ | 80.87 | 92.79 | 161.01 |
| $M_4$ | 21.58 | 28.54 | 32.72 |
| CD | 1.542 | 0.808 | 4.896 |
| (Fertilizers) $T_1$ | 53.82 | 68.54 | 107.00 |
| $T_2$ | 57. 31 | 73.4 | 113.28 |
| $T_3$ | 55.61 | 71.73 | 106.99 |
| $T_4$ | 57. 27 | 71.58 | 111.39 |
| CD | 1.115 | 0.802 | 6.238 |
| (Interaction) $m_1t_1$ | 48.63 | 64.05 | 82.90 |
| $m_1t_2$ | 58.13 | 69.25 | 87.23 |
| $m_1t_3$ | 50.85 | 68.15 | 85.05 |
| $m_1t_4$ | 51.98 | 66.85 | 86.40 |
| $m_2t_1$ | 67.88 | 79.33 | 130.60 |
| $m_2t_2$ | 71.50 | 82.60 | 135.50 |
| $m_2t_3$ | 67.15 | 81.63 | 157.23 |
| $m_2t_4$ | 70.18 | 82.48 | 147.75 |
| $m_3t_1$ | 77.90 | 92.15 | 163.50 |
| $m_3t_2$ | 83.65 | 94.70 | 168.00 |
| $m_3t_3$ | 82.55 | 91.33 | 153.15 |
| $m_3t_4$ | 79.38 | 93.00 | 159.40 |
| $m_4t_1$ | 20.88 | 38.65 | 52.10 |
| $m_4t_2$ | 20.08 | 42.08 | 54.83 |
| $m_4t_3$ | 21.90 | 52.50 | 52.55 |
| $m_4t_4$ | 23.45 | 42.28 | 59.58 |
| CD | 2.231 | 1.605 | 12.467 |
| $C_1$ | 55.00 | 55.00 | 93.00 |
| $C_2$ | 63.13 | 71.53 | 106.78 |
| $C_1$ Vs Treatment | S* | S* | S* |
| $C_2$ Vs Treatment | S* | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* | S* |

* Significant at 5% level

Among the combination mulching with plastic mulch and fertilizer dose of 75:50:50 kg $ha^{-1}$($m_4t_1$ ) recorded lowest dry weight of weed on all periods. Treatment effects varied significantly from both control $C_1$ as well as $C_2$. A significant difference was noticed between the control $C_1$ and $C_2$ as well.

4.8 AGRONOMIC INDICIES

**4.8.1 Agronomic efficiency**

The effect of treatments on agronomic efficiency at different growth periods are presented in Table 29

Main plot treatments significantly influenced agronomic efficiency of Nitrogen, Phosphorus and Potassium in all periods of growth in ginger. Highest agronomic efficiency of Nitrogen, Phosphorus and Potassium was recorded in main plot treatment $M_1$ (30 t $ha^{-1}$) in all periods of growth . The agronomic efficiency of N,P and K recorded in main plot treatment was 20.18, 28.34 and 28.34 kg $kg^{-1}$ . In sub plot, treatment $T_2$ showed significant higher agronomic efficiency of Nitrogen, Phosphorus and Potassium in all periods of observation. The treatment, $T_2$ resulted in agronomic efficiency of 18.58, 32.13 and 32.13 kg $kg^{-1}$ for N , P and K respectively of ginger. Interaction effect on agronomic efficiency of Nitrogen, Phosphorus and Potassium was significant during the periods of observation and treatment combination $m_1t_2$ ( mulches @30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$) noted highest agronomic efficiency for Nitrogen, Phosphorus and Potassium in all periods of observation. A significant difference in agronomic efficiency of N,P and K was observed between the treatments and the control, $C_1$ on all periods of growth.

#### 4.8.2 Partial factor productivity

The main and interaction effects on partial factor productivity of nitrogen, phosphorus and potassium at different periods of crop growth are furnished in Table 30

Significant differences in partial factor productivity of nitrogen , phosphorus and potassium was observed among main plot treatments . Plants that received $M_1$ (30 t ha $^{-1}$ ) as main plot resulted in maximum partial factor productivity of nitrogen , phosphorus and potassium. The partial factor productivity of N,P and K recorded from main plot treatment $M_1$ was 36.75, 51.94 kg kg$^{-1}$ respectively. Sub plot treatment $T_1$ ( 75:50:50 kg ha $^{-1}$) recorded highest partial factor productivity of nitrogen , phosphorus and potassium of 44.26,66.39 and 66.39 respectively . In the interaction between mulch and nutrients , significant variation in partial factor productivity of N,p and K was noticed and treatments $m_1t_1$ resulted in maximum partial factor productivity of nitrogen , phosphorus and potassium of 48.54,72.81 and 72.81 kg kg$^{-1}$ respectively . A significant difference in partial factor productivity of N,P,K was recorded between treatment and control. The partial factor productivity of N,P and K for control $C_1$ was 46.30,69.46 and 69.46 kg kg$^{-1}$ respectively.

#### 4.8.3 Physiological efficiency

The main and interaction effects of treatment on physiological efficiency of nitrogen, phosphorus and potassium is provided in Table 31

Physiological efficiency of nitrogen, phosphorus and potassium recorded shown significant variation among main plot treatments and $M_1$ (30 t ha$^{-1}$) recorded highest physiological efficiency of nitrogen, phosphorus and potassium of 45.37 , 708.83 and 36.58 kg kg$^{-1}$ . While in physiological efficiency of nitrogen and potassium $M_4$ was on par with $M_1$ .In sub plot, $T_2$ treatment recorded highest physiological efficiency of nitrogen, phosphorus and potassium however physiological efficiency of nitrogen in

Table 29: Agronomic efficiency in ginger (kg kg $^{-1}$ )

| Treatments | Agronomic effiency of N | Agronomic effiency of P | Agronomic effiency of K |
|---|---|---|---|
| (Mulches) $M_1$ | 20.18 | 28.34 | 28.34 |
| $M_2$ | 18.06 | 23.86 | 23.86 |
| $M_3$ | 16.00 | 21.50 | 21.50 |
| $M_4$ | 15.39 | 24.91 | 24.91 |
| CD | 0.916 | 0.597 | 0.597 |
| (Fertilizers) $T_1$ | 17.11 | 21.98 | 21.98 |
| $T_2$ | 18.58 | 32.13 | 32.13 |
| $T_3$ | 17.09 | 24.55 | 24.55 |
| $T_4$ | 16.04 | 19.95 | 19.95 |
| CD | 1.418 | 0.506 | 0.506 |
| (Interaction) $m_1t_1$ | 17.4 | 26.03 | 26.03 |
| $m_1t_2$ | 25.7 | 38.55 | 38.55 |
| $m_1t_3$ | 18.5 | 22.65 | 22.65 |
| $m_1t_4$ | 19.2 | 26.13 | 26.13 |
| $m_2t_1$ | 17.8 | 30.88 | 30.88 |
| $m_2t_2$ | 18.1 | 21.70 | 21.70 |
| $m_2t_3$ | 20.1 | 23.00 | 23.00 |
| $m_2t_4$ | 16.3 | 19.88 | 19.88 |
| $m_3t_1$ | 16.0 | 27.65 | 27.65 |
| $m_3t_2$ | 16.0 | 19.20 | 19.20 |
| $m_3t_3$ | 17.4 | 21.03 | 21.03 |
| $m_3t_4$ | 14.6 | 18.13 | 18.13 |
| $m_4t_1$ | 14.8 | 31.43 | 31.43 |
| $m_4t_2$ | 17.4 | 21.00 | 21.00 |
| $m_4t_3$ | 14.6 | 28.05 | 28.05 |
| $m_4t_4$ | 14.8 | 19.15 | 19.15 |
| CD | 2.826 | 1.012 | 1.012 |
| $C_1$ | 23.5 | 35.2 | 35.2 |
| $C_1$ Vs Treatment | S* | S* | S* |

* Significant at 5% level

Table 30: Partial factor productivity (kg $kg^{-1}$)

| Treatments | Partial factor productivity of N | Partial factor productivity of P | Partial factor productivity of K |
|---|---|---|---|
| (Mulches) $M_1$ | 36.75 | 51.94 | 51.94 |
| $M_2$ | 33.62 | 47.47 | 47.47 |
| $M_3$ | 31.97 | 45.12 | 45.12 |
| $M_4$ | 34.38 | 48.52 | 48.52 |
| CD | 0.417 | 0.587 | 0.587 |
| (Fertilizers) $T_1$ | 44.26 | 66.39 | 66.39 |
| $T_2$ | 26.07 | 39.11 | 39.11 |
| $T_3$ | 36.24 | 49.37 | 49.37 |
| $T_4$ | 30.15 | 38.17 | 38.17 |
| CD | 0.315 | 0.452 | 0.452 |
| (Interaction) $m_1t_1$ | 48.54 | 72.81 | 72.81 |
| $m_1t_2$ | 28.78 | 43.16 | 43.16 |
| $m_1t_3$ | 37.38 | 50.93 | 50.93 |
| $m_1t_4$ | 32.29 | 40.88 | 40.88 |
| $m_2t_1$ | 43.44 | 65.15 | 65.15 |
| $m_2t_2$ | 25.88 | 38.82 | 38.82 |
| $m_2t_3$ | 35.10 | 47.82 | 47.82 |
| $m_2t_4$ | 30.10 | 38.10 | 38.10 |
| $m_3t_1$ | 41.28 | 61.92 | 61.92 |
| $m_3t_2$ | 24.24 | 36.36 | 36.36 |
| $m_3t_3$ | 33.67 | 45.87 | 45.87 |
| $m_3t_4$ | 28.71 | 36.34 | 36.34 |
| $m_4t_1$ | 43.80 | 65.70 | 65.70 |
| $m_4t_2$ | 25.41 | 38.12 | 38.12 |
| $m_4t_3$ | 38.82 | 52.89 | 52.89 |
| $m_4t_4$ | 29.51 | 37.36 | 37.36 |
| CD | 0.620 | 0.904 | 0.904 |
| $C_1$ | 46.30 | 69.46 | 69.46 |
| $C_1$ Vs Treatment | S* | S* | S* |

* Significant at 5% level

Table 31: Physiological efficiency (kg kg $^{-1}$)

| Treatments | Physiological efficiency of N | Physiological efficiency of P | Physiological efficiency of K |
|---|---|---|---|
| (Mulches) $M_1$ | 45.37 | 708.82 | 36.58 |
| $M_2$ | 37.58 | 658.08 | 30.67 |
| $M_3$ | 31.24 | 675.74 | 24.42 |
| $M_4$ | 44.00 | 668.76 | 35.08 |
| CD | 2.155 | 13.312 | 2.133 |
| (Fertilizers) $T_1$ | 37.26 | 627.07 | 28.90 |
| $T_2$ | 41.11 | 731.96 | 34.23 |
| $T_3$ | 39.55 | 697.61 | 31.23 |
| $T_4$ | 40.22 | 654.77 | 32.38 |
| CD | 1.545 | 10.421 | 1.572 |
| (Interaction) $m_1t_1$ | 43.50 | 675.76 | 34.32 |
| $m_1t_2$ | 47.99 | 780.85 | 39.70 |
| $m_1t_3$ | 43.93 | 701.48 | 35.57 |
| $m_1t_4$ | 46.08 | 648.83 | 36.73 |
| $m_2t_1$ | 35.84 | 606.26 | 29.43 |
| $m_2t_2$ | 38.32 | 622.85 | 31.84 |
| $m_2t_3$ | 38.37 | 759.96 | 31.40 |
| $m_2t_4$ | 37.82 | 668.63 | 30.02 |
| $m_3t_1$ | 30.90 | 778.47 | 21.87 |
| $m_3t_2$ | 33.30 | 633.19 | 26.34 |
| $m_3t_3$ | 29.40 | 655.60 | 24.02 |
| $m_3t_4$ | 31.37 | 635.72 | 25.45 |
| $m_4t_1$ | 38.84 | 692.76 | 30.01 |
| $m_4t_2$ | 46.78 | 645.97 | 39.04 |
| $m_4t_3$ | 42.61 | 670.41 | 32.79 |
| $m_4t_4$ | 47.78 | 665.93 | 38.49 |
| CD | 3.091 | 20.842 | 3.154 |
| $C_1$ | 36.34 | 617.64 | 25.18 |
| $C_1$ Vs Treatment | S* | S* | S* |

* Significant at 5% level

treatment $T_4$ was on par with $T_2$. Among the interaction mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ ($m_1t_2$) recorded highest physiological efficiency of nitrogen, phosphorus and potassium and while in physiological efficiency of nitrogen and potassium $m_1t_2$ was on par with $m_1t_4$, $m_4t_2$, $m_4t_4$. However with physiological efficiency of phosphorus of the treatment combination $m_3t_1$ was on par with $m_1t_2$.

## 4.9 SOIL CHEMICAL ANALYSIS

Soil chemical analysis done before and after the experiment is presented in Table 32

Soils of the experimental plots before the experiment were in medium range of nitrogen and remains in medium range even after the experiment . Phosphorus range of soils in the experimental plots were in medium range and after the experiment, there was increase in phosphorus content of the soil. Potassium content of the soils were in low range and after the experiment only a slight increase in soil potassium content was noticed .The nitrogen content of experimental plot before the experiment ranged from 357.06 to 400.4 kg $ha^{-1}$. The soil phosphorus content of the experimental site ranged from 16.32 to 21.88 kg $ha^{-1}$. The potassium content of the experimental site from before and after the experiment ranged from 105.86 to 120.35 kg $ha^{-1}$.

## 4.10 NUTRIENT ANALYSIS OF FYM, ORGANIC MULCH

Nutrient analysis of FYM and organic mulch is furnished in Table 33

The NPK content of organic mulch used was 0.5 %,0.4% and 0.42 % respectively . The FYM applied contained 0.5% N,0.4% P and 0.64% K .

## 4.11 NPK UPTAKE BY PLANT

The main and interaction effects of treatment on uptake of nitrogen, phosphorus and potassium is provided in Table 34

Table 32: Soil chemical analysis before and after the experiment (kg ha$^{-1}$)

| Treatments | NITROGEN (kg ha$^{-1}$) | | PHOSPHORUS (kg ha$^{-1}$) | | POTASSIUM(kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|
| | Before | After | Before | After | Before | After |
| $m_1t_1$ | 399.31 | 409.70 | 20.16 | 94.87 | 109.78 | 142 |
| $m_1t_2$ | 357.06 | 483.90 | 18.64 | 115.1 | 110.21 | 156 |
| $m_1t_3$ | 334.4 | 440.10 | 17.84 | 105.32 | 109.65 | 140 |
| $m_1t_4$ | 365.2 | 462.80 | 21.62 | 110.64 | 115.2 | 146 |
| $m_2t_1$ | 378.4 | 421.40 | 20.48 | 76.54 | 105.86 | 130 |
| $m_2t_2$ | 385 | 471.90 | 16.32 | 102.53 | 118.23 | 148 |
| $m_2t_3$ | 400.4 | 458.00 | 18.31 | 91.75 | 111.32 | 139 |
| $m_2t_4$ | 376.2 | 466.90 | 21.75 | 96.86 | 120.35 | 145 |
| $m_3t_1$ | 363 | 405.10 | 20.87 | 69.64 | 109.31 | 120 |
| $m_3t_2$ | 354.2 | 469.70 | 21.88 | 95.53 | 110.53 | 140 |
| $m_3t_3$ | 380.6 | 461.40 | 20.75 | 86.91 | 114.75 | 126 |
| $m_3t_4$ | 391.6 | 447.90 | 20.55 | 97.42 | 113.87 | 134 |
| $m_4t_1$ | 382.8 | 395.80 | 21.64 | 73.2 | 110.63 | 122 |
| $m_4t_2$ | 367.41 | 436.30 | 19.64 | 99.51 | 108.53 | 138 |
| $m_4t_3$ | 400.4 | 409.00 | 19.55 | 80.9 | 106.89 | 130 |
| $m_4t_4$ | 393.8 | 425.90 | 18.56 | 94.6 | 110.55 | 134 |
| $c_1$ | 385.4 | 407.20 | 19.54 | 91.63 | 110.34 | 131 |
| $c_2$ | 376.85 | 110.10 | 18.45 | 32.12 | 106.53 | 112.3 |

Table 33: Nutrient analysis of FYM, organic mulch

| SL No | | N(%) | P(%) | K(%) |
|---|---|---|---|---|
| 1. | Organic mulch | 0.5 | 0.4 | 0.42 |
| 2. | FYM | 0.5 | 0.41 | 0.64 |

Table 34: Effect of mulch and nutrients on uptake of nitrogen , phosphorus, potassium (kg $ha^{-1}$)

| Treatments | uptake of N | uptake of P | uptake of K |
|---|---|---|---|
| (Mulches) $M_1$ | 86.57 | 14.09 | 85.76 |
| $M_2$ | 84.77 | 11.98 | 82.42 |
| $M_3$ | 81.37 | 11.27 | 78.87 |
| $M_4$ | 82.66 | 13.05 | 82.01 |
| CD | 0.40 | 0.32 | 0.27 |
| (Fertilizers) $T_1$ | 80.01 | 10.88 | 78.88 |
| $T_2$ | 87.78 | 14.35 | 85.38 |
| $T_3$ | 82.94 | 12.03 | 81.75 |
| $T_4$ | 84.64 | 13.12 | 83.04 |
| CD | 0.32 | 0.361 | 0.42 |
| (Interaction) $m_1t_1$ | 82.94 | 12.86 | 82.48 |
| $m_1t_2$ | 91.10 | 16.11 | 88.33 |
| $m_1t_3$ | 84.94 | 13.23 | 86.10 |
| $m_1t_4$ | 87.30 | 14.15 | 86.15 |
| $m_2t_1$ | 81.37 | 10.14 | 78.68 |
| $m_2t_2$ | 88.91 | 14.21 | 86.09 |
| $m_2t_3$ | 83.70 | 10.95 | 81.43 |
| $m_2t_4$ | 85.13 | 12.62 | 83.47 |
| $m_3t_1$ | 76.84 | 9.11 | 76.22 |
| $m_3t_2$ | 85.28 | 12.74 | 82.84 |
| $m_3t_3$ | 81.10 | 11.23 | 77.40 |
| $m_3t_4$ | 82.27 | 12.00 | 79.02 |
| $m_4t_1$ | 78.89 | 11.41 | 78.16 |
| $m_4t_2$ | 85.85 | 14.35 | 84.28 |
| $m_4t_3$ | 82.03 | 12.71 | 82.07 |
| $m_4t_4$ | 83.89 | 13.73 | 83.53 |
| CD | 0.65 | 0.732 | 0.83 |
| $C_1$ | 76.06 | 12.02 | 77.14 |
| $C_2$ | 62.31 | 6.73 | 72.09 |
| $C_1$ Vs Treatment | S* | S* | S* |
| $C_2$ Vs Treatment | S* | S* | S* |
| $C_1$ Vs $C_2$ | S* | S* | S* |

* Significant at 5% level

The plant NPK uptake differed significantly and main plot treatment $M_1$ (30 t $ha^{-1}$) recorded highest uptake of nitrogen, phosphorus and potassium on all periods .In sub plot , $T_2$ treatment recorded highest uptake of nitrogen, phosphorus and potassium and was significantly different from other treatments . Among the interaction mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ ($m_1t_2$) recorded highest uptake of nitrogen, phosphorus and potassium . Treatment effects varied significantly with both control $C_1$ as well as $C_2$. A significant difference was noticed between the control $C_1$ and $C_2$ as well .

4.12 NUTRIENT BALANCE SHEET FOR NPK

**4.12.1 Nutrient balance sheet for nitrogen**

Nutrient balance sheet for nitrogen is provided in Table 35

The nutrient balance sheet analyzed revealed a higher uptake for $m_1t_2$ followed by $m_2t_2$ however the net loss of nitrogen was comparatively higher for all the combinations of $m_1$ ,while in the all fertilizer plots treated with plastic mulch a reduction in the net loss of nitrogen was observed . The initial N content of the plot ranged from 354.40 kg $ha^{-1}$ to 348.40 kg $ha^{-1}$ .After the experiment the available N status ranged from 310.00 kg $ha^{-1}$ to 484 kg $ha^{-1}$

**4.12.2 Nutrient balance sheet for phosphorus**

Nutrient balance sheet for phosphorus is provided in Table 36

The nutrient balance sheet prepared for phosphorus revealed that phosphorus of the experimental plot during the initial period was in the medium range and an addition in soil P has been noticed after the experiment. Net loss was minimum for treatments with plastic mulches. The net loss of P was minimum for $C_2$. Among the treatments least net loss of P was for treatment combination $m_4t_1$ (-110.03kg $ha^{-1}$)

Table 35: Nutrient balance sheet of Nitrogen

| Treatments | Initial (Y) (kg ha$^{-1}$) | N addition (A) (kg ha$^{-1}$) | N uptake (B) (kg ha$^{-1}$) | Expected balance (C) (kg ha$^{-1}$) | Available N status (D) (kg ha$^{-1}$) | Net loss/gain (kg ha$^{-1}$) |
|---|---|---|---|---|---|---|
| $m_1t_1$ | 360.40 | 375.00 | 82.93 | 652.47 | 410.00 | -242.47 |
| $m_1t_2$ | 370.80 | 450.00 | 91.10 | 729.70 | 484.00 | -245.70 |
| $m_1t_3$ | 354.40 | 394.00 | 84.94 | 663.47 | 440.00 | -223.47 |
| $m_1t_4$ | 365.20 | 419.00 | 87.30 | 696.91 | 462.00 | -234.91 |
| $m_2t_1$ | 370.50 | 300.00 | 81.37 | 589.13 | 421.00 | -168.13 |
| $m_2t_2$ | 362.10 | 375.00 | 88.91 | 648.19 | 472.00 | -176.19 |
| $m_2t_3$ | 378.40 | 319.00 | 83.69 | 613.71 | 458.00 | -155.71 |
| $m_2t_4$ | 376.20 | 344.00 | 85.12 | 635.08 | 467.00 | -168.08 |
| $m_3t_1$ | 370.30 | 262.50 | 76.83 | 555.97 | 397.30 | -158.67 |
| $m_3t_2$ | 372.60 | 337.50 | 85.27 | 624.83 | 400.20 | -224.63 |
| $m_3t_3$ | 374.30 | 281.50 | 81.10 | 574.70 | 410.00 | -164.70 |
| $m_3t_4$ | 380.60 | 306.50 | 82.27 | 604.84 | 448.00 | -156.84 |
| $m_4t_1$ | 382.80 | 225.00 | 78.89 | 528.91 | 396.00 | -132.91 |
| $m_4t_2$ | 367.41 | 300.00 | 85.84 | 581.57 | 436.00 | -145.57 |
| $m_4t_3$ | 376.30 | 244.00 | 82.03 | 538.27 | 409.00 | -129.27 |
| $m_4t_4$ | 372.10 | 269.00 | 83.89 | 557.21 | 426.00 | -131.21 |
| $C_1$ | 375.40 | 375.00 | 76.06 | 674.34 | 407.00 | -267.34 |
| $C_2$ | 376.85 | 0.00 | 62.31 | 314.54 | 310.00 | -4.54 |

Table 36: Nutrient balance sheet of Phosphorus

| Treatments | Initial (Y) (kg ha$^{-1}$) | P addition (A) (kg ha$^{-1}$) | P uptake (B) (kg ha$^{-1}$) | Expected balance (C) (kg ha$^{-1}$) | Available P status (D) (kg ha$^{-1}$) | Net loss/gain (kg ha$^{-1}$) |
|---|---|---|---|---|---|---|
| $m_1t_1$ | 20.16 | 293.00 | 12.86 | 300.30 | 94.87 | -205.43 |
| $m_1t_2$ | 18.64 | 343.00 | 16.11 | 345.53 | 115.10 | -230.43 |
| $m_1t_3$ | 17.84 | 312.00 | 13.23 | 316.61 | 105.32 | -211.29 |
| $m_1t_4$ | 21.62 | 337.00 | 14.15 | 344.47 | 110.64 | -233.83 |
| $m_2t_1$ | 20.48 | 233.00 | 10.14 | 243.34 | 76.54 | -166.80 |
| $m_2t_2$ | 16.32 | 283.00 | 14.21 | 285.11 | 102.53 | -182.58 |
| $m_2t_3$ | 18.31 | 252.00 | 10.95 | 259.36 | 91.75 | -167.61 |
| $m_2t_4$ | 21.75 | 277.00 | 12.62 | 286.13 | 96.86 | -189.27 |
| $m_3t_1$ | 20.87 | 203.00 | 9.11 | 214.76 | 69.64 | -145.12 |
| $m_3t_2$ | 21.88 | 253.00 | 12.74 | 262.14 | 95.53 | -166.61 |
| $m_3t_3$ | 20.75 | 222.00 | 11.23 | 231.52 | 86.91 | -144.61 |
| $m_3t_4$ | 20.55 | 247.00 | 12.00 | 255.56 | 97.42 | -158.14 |
| $m_4t_1$ | 21.64 | 173.00 | 11.41 | 183.23 | 73.20 | -110.03 |
| $m_4t_2$ | 19.64 | 223.00 | 14.35 | 228.29 | 99.51 | -128.78 |
| $m_4t_3$ | 19.55 | 192.00 | 12.71 | 198.84 | 80.90 | -117.94 |
| $m_4t_4$ | 18.56 | 217.00 | 13.73 | 221.83 | 94.60 | -127.23 |
| $C_1$ | 19.54 | 293.00 | 12.02 | 300.52 | 91.63 | -208.89 |
| $C_2$ | 18.45 | 0.00 | 6.73 | 11.72 | 15.43 | 3.71 |

Table 37 : Nutrient balance sheet of Potassium

| Treatments | Initial ( Y ) (kg $ha^{-1}$) | K addition (A) (kg $ha^{-1}$) | K uptake (B) ( kg $ha^{-1}$) | Expected balance (C) ( kg $ha^{-1}$) | Available K status (D) (kg $ha^{-1}$) | Net loss/gain (kg $ha^{-1}$) |
|---|---|---|---|---|---|---|
| $m_1t_1$ | 109.78 | 356.00 | 82.47 | 383.31 | 142.00 | -241.31 |
| $m_1t_2$ | 110.21 | 406.00 | 88.33 | 427.88 | 156.00 | -271.88 |
| $m_1t_3$ | 109.65 | 375.00 | 86.10 | 398.56 | 140.00 | -258.56 |
| $m_1t_4$ | 115.20 | 400.00 | 86.15 | 429.05 | 146.00 | -283.05 |
| $m_2t_1$ | 105.86 | 293.00 | 78.68 | 320.19 | 130.00 | -190.19 |
| $m_2t_2$ | 118.23 | 343.00 | 86.09 | 375.14 | 148.00 | -227.14 |
| $m_2t_3$ | 111.32 | 312.00 | 81.43 | 341.89 | 139.00 | -202.89 |
| $m_2t_4$ | 120.35 | 337.00 | 83.47 | 373.88 | 145.00 | -228.88 |
| $m_3t_1$ | 109.31 | 261.50 | 76.22 | 294.59 | 120.00 | -174.59 |
| $m_3t_2$ | 110.53 | 311.50 | 82.83 | 339.20 | 140.00 | -199.20 |
| $m_3t_3$ | 114.75 | 280.50 | 77.40 | 317.85 | 126.00 | -191.85 |
| $m_3t_4$ | 113.87 | 305.50 | 79.01 | 340.36 | 134.00 | -206.36 |
| $m_4t_1$ | 110.63 | 230.00 | 78.16 | 262.48 | 122.00 | -140.48 |
| $m_4t_2$ | 108.53 | 280.00 | 84.28 | 304.26 | 138.00 | -166.26 |
| $m_4t_3$ | 106.89 | 249.00 | 82.07 | 273.82 | 130.00 | -143.82 |
| $m_4t_4$ | 110.55 | 274.00 | 83.53 | 301.02 | 134.00 | -167.02 |
| $C_1$ | 110.34 | 356.00 | 68.50 | 397.84 | 131.00 | -266.84 |
| $C_2$ | 106.53 | 0.00 | 62.25 | 44.28 | 57.80 | 13.52 |

Table 38: Benefit cost analysis

| Treatment | Fresh yield (kg/ha) | Value (Rs) | Cost of cultivation(Rs) | Profit (Rs) | B:C ratio |
|---|---|---|---|---|---|
| $m_1t_1$ | 17545.8 | 877290 | 490982 | 386308 | 1.79 |
| $m_1t_2$ | 18644.4 | 932220 | 499367 | 432853 | 1.87 |
| $m_1t_3$ | 18045.3 | 902265 | 490992 | 411273 | 1.84 |
| $m_1t_4$ | 18138.6 | 906930 | 494778 | 412152 | 1.83 |
| $m_2t_1$ | 16756.8 | 837840 | 474432 | 363408 | 1.77 |
| $m_2t_2$ | 17717.1 | 885855 | 482817 | 403038 | 1.83 |
| $m_2t_3$ | 17196.9 | 859845 | 474442 | 385403 | 1.81 |
| $m_2t_4$ | 17293.8 | 864690 | 478228 | 386462 | 1.81 |
| $m_3t_1$ | 15931.8 | 796590 | 477082 | 319508 | 1.67 |
| $m_3t_2$ | 16923.3 | 846165 | 485467 | 360698 | 1.74 |
| $m_3t_3$ | 16208.7 | 810435 | 477092 | 333343 | 1.70 |
| $m_3t_4$ | 16476.9 | 823845 | 480878 | 342967 | 1.71 |
| $m_4t_1$ | 16750.2 | 837510 | 532657 | 304853 | 1.57 |
| $m_4t_2$ | 18135.3 | 906765 | 541042 | 365723 | 1.68 |
| $m_4t_3$ | 17377.2 | 868860 | 532667 | 336193 | 1.63 |
| $m_4t_4$ | 18006.3 | 900315 | 536453 | 363862 | 1.68 |
| $C_1$ | 16274.1 | 813705 | 496982 | 316723 | 1.64 |
| $C_2$ | 8770.8 | 438540 | 468000 | -29460 | 0.94 |

### 4.12.3 Nutrient balance sheet for potassium

Nutrient balance sheet for potassium is provided in Table 37

The nutrient balance sheet prepared for potassium revealed that potassium status of experimental soil was low and addition of potassium has resulted in net increase in the available potassium status after the experiment , Here also the net loss was less for combination of plastic mulch . The initial soil K content of the experiment site ranged from 105.86 kg $ha^{-1}$ to 118.23 kg $ha^{-1}$. The K added ranged from 230 kg $ha^{-1}$ to 406 kg $ha^{-1}$ . The plant uptake of K ranged from 62.25 in $C_2$ to 88.33kg $ha^{-1}$ in $m_1t_2$.

## 4.13 PEST AND DISEASE INCIDENCE

There was no pest incidence in the field. However leaf spot was noticed in few plants one month after transplanting which was controlled by a single dose of mancozeb @ 0.3 per cent.

## 4.14 BENEFIT COST ANALYSIS

Benefit cost analysis for the treatments is provided in Table 38 and average input cost and market price of produce is given in Appendix I.

The treatment of 30 t $ha^{-1}$ of mulches applied in two split doses with a fertiliser dose of 150: 100: 100 kg of NPK per hectare along with 30 t $ha^{-1}$ of FYM generated a higher net profit compared to all other treatment and had a BC ratio of 1.87 . The cost of cultivation was more for all the combinations which used plastic mulch. All the treatment combinations except $m_4t_1$ resulted in higher B:C ratio than control $C_1$ which is the crop raised and nutrients applied as per recommended package of practises of Kerala Agricultural University.

# DISCUSSION

# 5. DISCUSSION

## 5.1 GROWTH PARAMETERS

### 5.1.1 Plant height

The plant height showed significant variation between main plot treatment of mulches , subplot treatment with different levels of fertilizers and their interaction ( Fig.2 )

The plant height was significantly higher for the mulch treatment, $M_1$ (30 t ha $^{-1}$ ) throughout the observed crop growth period. The height increased from 37.48 cm to 44.84 cm from $4^{th}$ to $8^{th}$ month of observation in plots treated with 30 t ha$^{-1}$ of mulch and it was the least in $M_3$ (7.5 t ha$^{-1}$) varied from 28.84 to 35.76cm . Babu (1993) reported that under shade levels there was an increasing trend in plant height in ginger with increasing mulch levels. Among the different mulching materials, dry leaves used as mulching material showed maximum height, in ginger ( Sengupta *et al*., 2008 ). The growth and yield performance of ginger varieties under open and oil palm plantations in Nigeria revealed that mulching is required under both conditions for increased plant height and yield ( Nwaogu *et al*., 2011). The increase in plant height might be due to the beneficial effect through increased levels of organic mulch.

The fertilizer level $T_2$ ( 150:100:100 kg ha $^{-1}$) resulted in the highest plant height on all periods of observation and a plant height of 43.33 cm was recorded at $8^{th}$ month in $T_2$ . Muralidharan *et al.* (1974) reported a progressive increase in plant height with an increase in the amount of N applied up to 90 kg ha$^{-1}$. Ajithkumar (1999) reported the effect of N and K in enhancing plant height and observed maximum plant height at highest levels of N and K. Akanwumi *et al.* (2013) reported that in turmeric N applied alone or in combination with P , K or PK alone resulted in significantly higher plant height . Ginger is a soil exhaustive crop and shows good response to added to nutrients. In this study also application of double the fertilizer dose of recommendation of KAU have resulted in highest plant height in all growth periods compared to other fertilizer levels.

Interaction between mulch and fertilizer, was significant throughout the periods of observation and highest level of mulch and double the recommended dose of fertilizer recorded the highest plant height on all periods . This might be due to the congenial conditions provided by the mulch and increased fertilizer level which resulted in better growth.

The comparison of $C_1$ as well as $C_2$ with the treatments also indicated significant difference in the plant height in all periods of growth. A significant difference was noticed between the control $C_1$ as well as $C_2$ . The present study clearly indicates more difference in plant height between the different levels of fertilizers and mulches compared to the recommended package of practice of KAU.

**5.1.2 Number of leaves / plant**

Significant difference was noticed among the treatments of mulch , fertilizer and their interaction and the interaction effect is presented in Fig 3

Significantly higher number of leaves was produced due to higher level of mulch of 30 t $ha^{-1}$ (230.78 in $8^{th}$ month ) and Islam *et al.* (2015) reported that maximum number of leaves (129.28) were recorded from rice straw while the minimum number of leaves (70.55) was recorded from control treatment.

Leaves per clump increased significantly as compared to no mulch in ginger (Chandra and Govind , 2001). Zaman *et al.* (2002) reported an increase in plant height and number of leaves in turmeric over unmulched plants. The higher number of leaves under higher mulch might be due to the higher nutrient content provided by the mulch.

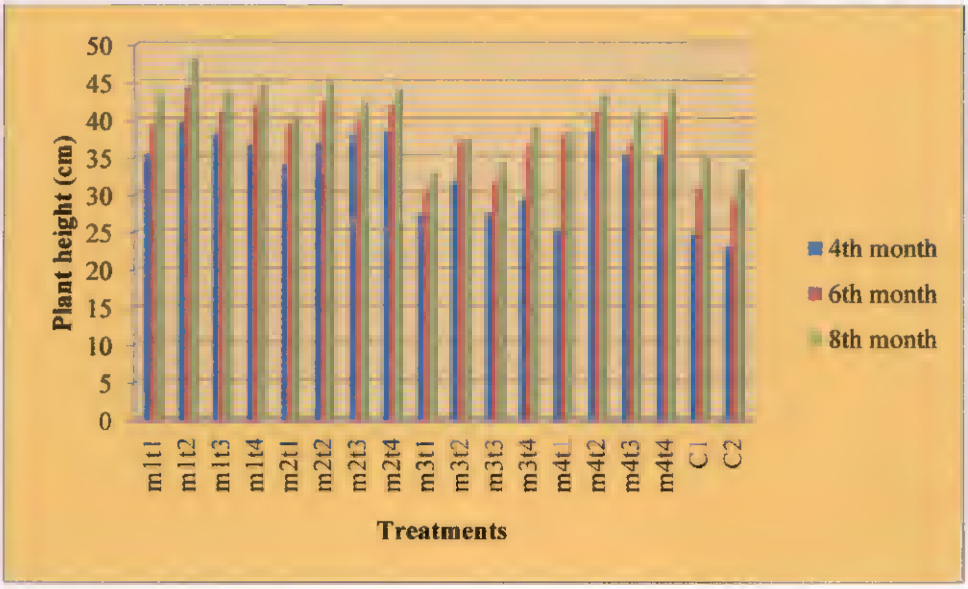


Fig 2: Effect of mulch and nutrients on plant height (cm)

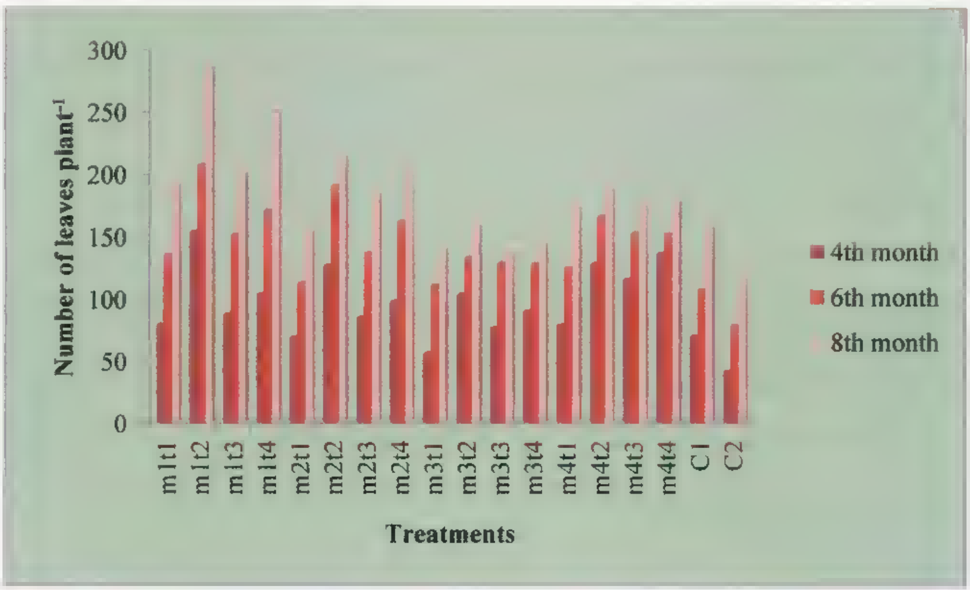


Fig 3: Effect of mulch and nutrients on number of leaves/ plant

Fertilizer treatment, $T_2$ (150:100:100 kg $ha^{-1}$) recorded the highest number of leaves at 8th month ( 210.24) and the least number was in 75:50:50 kg $ha^{-1}$. Similar studies conducted by Ajithkumar (1999) reported that with increasing rate of N up to 150 kg $ha^{-1}$ and $P_2O_5$ up to 100 kg $ha^{-1}$ significantly increase in number of leaves $plant^{-1}$ was noticed but the increasing rate of $K_2O$ had no significant effect on leaf production in ginger. Dayankatti and Sulikeri (2000 ) studied the effects of different levels nitrogen on (50, 75, 100 and 125 kg $ha^{-1}$) on ginger and reported that number of leaves (13.36 per shoot) were highest at 125 kg N $ha^{-1}$. Leaf number increased tremendously with increase of N levels up to 150 kg $ha^{-1}$ and increase of K up to 100 kg $ha^{-1}$ in ginger (Haque *et al.*, 2007) .

In interaction combination of mulches @ 30 t ha $^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ ($m_1t_2$) recorded the highest number of leaves in all periods. This might be due to the combined effect of mulch and double the fertilizer dose which resulted in higher number of leaves.

The comparison of $C_1$ and $C_2$ with treatments also indicated significant difference in the number of leaves on all periods of growth. A significant difference was noticed between the control $C_1$ as well as $C_2$ . The result clearly indicates that NPK fertilization along with mulching is necessary to increase the number of leaves in ginger.

**5.1.3 Number of tillers/plant**

Significant difference was noticed among the treatments of mulch , fertilizer and their combination on all periods and the interaction effects are presented in Fig 4

Organic Mulches increased the number of tillers and the highest tiller was obtained in 4th to 8th month in $M_1$ ( 30 t $ha^{-1}$ ) followed by plastic mulch ($M_4$) . The number of tillers at 8th month was 14.88 for $M_1$ and 14 for $M_4$ .

Gill *et al.* (1999) reported that application of straw mulch resulted in more number of tillers plant$^{-1}$ resulting in high yield in turmeric . Agarwal *et al.* (2001) in a field experiment on ginger found that the mulch treatment was better over control in terms of plant height, number of tillers per plant, number of leaves per plant and also reported that the performance of organic mulches was better than synthetic mulches. Application of paddy straw mulch @ 9.38 t/ha produced significantly more tillers than application of mulch @ 6.25 t/ha, which in turn was significantly superior to no mulch in turmeric (Manhas, 2011). Islam *et al.* (2015) obtained similar reports by mulching with rice straw in ginger.

An increase in tiller was observed in treatment $T_2$ (150:100:100 kg ha$^{-1}$) at all periods of observation and it was in accordance with the findings of Pradeepkumar *et al.* (2001) who reported that the increase in N and K rates (0,75,150 , 225 kg ha$^{-1}$ ) increased the number of tillers in ginger.

Tiller number was more at 8$^{th}$ months in mulches @ 30 t ha$^{-1}$ and fertilizer dose of 150:100:100 kg ha$^{-1}$ ( $m_1t_2$) which was on par with $m_1t_4$. while in the 6$^{th}$ month $m_2t_2$, $m_4t_2$, $m_4t_4$ were on par with $m_1t_2$ and on 8$^{th}$ months $m_1t_4$ was on par with $m_1t_2$ .The combination of higher level of mulch and nutrient might have resulted in higher rates of availability of nutrients leading to increase in number of tillers

A significant difference was observed between the treatments and the control at all stages of growth. The comparison of $C_1$ and $C_2$ also has shown a significant difference between them. This means that the treatments were in adequate quantity and was essential for good tiller production. This shows that a higher dose of fertilizer recommendation than the normal recommendation of package of practice of KAU along with 30 t ha$^{-1}$ of mulch was superior in increasing the number of tillers.

### 5.1.4 Shoot weight

The shoot weight was influenced significantly on main plot treatment of mulches, subplot treatment with different levels of fertilizers and their interaction , the interaction effect is given in ( Fig.5 )

$M_1$ (30 t $ha^{-1}$) recorded the highest shoot weight on all periods of observation and an increase in shoot weight was observed from 24.54g to 45.05g from $4^{th}$ month to $8^{th}$ month of observation. However Ajithkumar (1999) reported no significant effect of mulch on shoot weight in ginger with increasing levels of N and K. Abraham *et al.* (2016) reported that mulching with rubber leaves was on par with control, *panal* and *matty*.

In sub plot $T_2$, treatment of double the dose of fertilizer recorded the highest shoot weight at all observations and a shoot weight of 43.80g was obtained in the $8^{th}$ month . This was in agreement with findings of Joseph (1992) in ginger who reported that shoot weight increased with increasing levels of NPK.

Among the interaction, mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:10:100 kg $ha^{-1}$ ($m_1t_2$) recorded the highest shoot weight on all periods of observation . In $4^{th}$ month $m_1t_2$ and $m_2t_4$ were on par and in the $6^{th}$ and $8^{th}$ months $m_1t_2$ recorded highest shoot weight. The higher shoot weight of $m_1t_2$ might be due to the more number of tillers ,leaves and plant height contributed due to increased mulch and nutrient level.

Treatment effects varied significantly from both control $C_1$ as well as $C_2$. A significant difference was noticed between the control $C_1$ as well as $C_2$ . This was due to the general trend observed in tiller number and plant height with the increase in mulch and nutrient level.

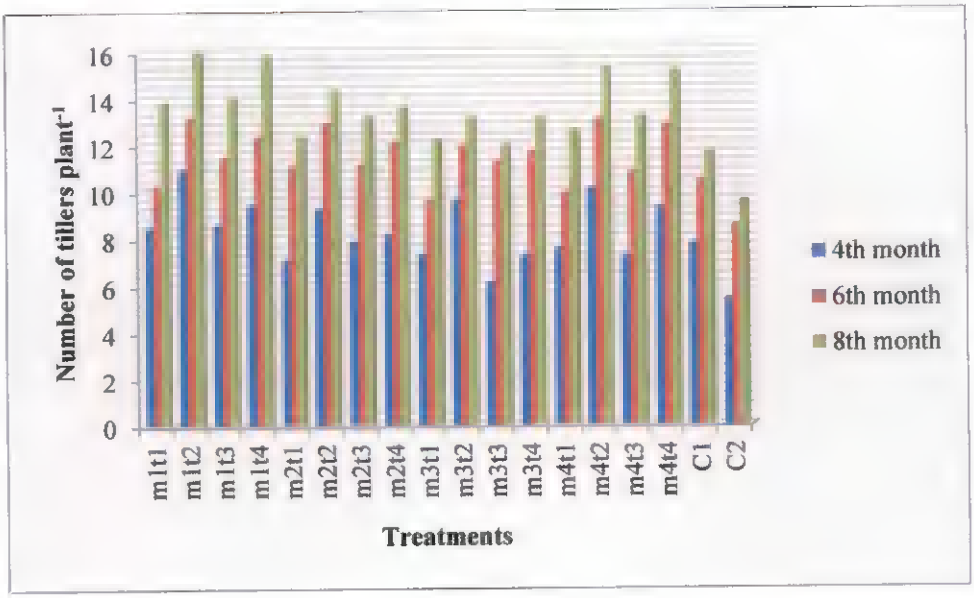


Fig 4 : Effect of mulch and nutrients on number of tillers / plant

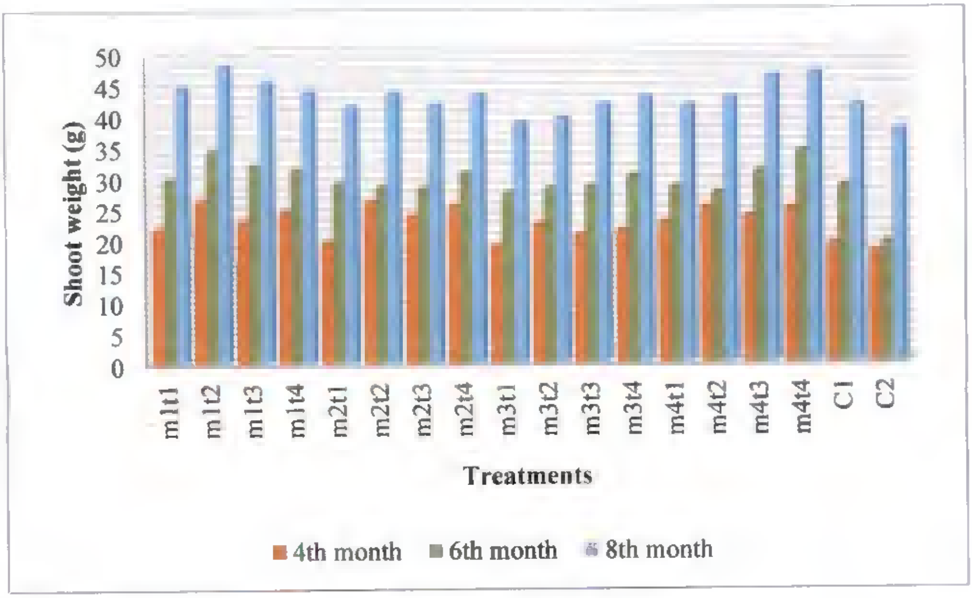


Fig 5 : Effect of mulch and nutrients on shoot weight (g)

5.2 ROOT CHARACTERS

**5.2.1 Root length**

The plots treated with 30 t $ha^{-1}$ of organic mulch ( $M_1$) recorded the highest root length ( 32.24 cm) on $8^{th}$ month as well as on all periods of growth and least root length was observed in plots mulched with 7.5 t $ha^{-1}$ of organic mulch i.e. $M_3$ (Table 5). Studies conducted by Jayachandran (1993a) revealed that in ginger up to 90 days after planting , the roots were confined to within 30 cm soil depth and 10cm laterally and by 150 DAP roots grew beyond 30 cm soil depth and 10 cm laterally. Abraham *et al.* (2016) reported that root length was significantly greater when mulched with *panal* (53.52 cm) and rubber leaves (47.18cm) and was on par with the control (47.52cm) in ginger .

Among sub plot treatments, the highest root length was recorded by $T_2$ at all periods of observation while in $8^{th}$ month $T_2$ (32.23cm) was on par with $T_4$ ( 32.12 cm). Phosphorus plays a key role in the formation of fibrous and strong root system and thereby helping absorption of nutrients from the soil, metabolic process of plants and thus ample availability of P might have resulted in better root growth (Tisdale *et al.*, 1995)

In interaction, the highest root length was observed in treatment $m_1t_2$ which is the combination of mulches @ 30 t $ha^{-1}$ and double the recommended dose of fertilizer as per package of practices recommendation of KAU. The root length of $m_1t_2$ at $8^{th}$ month was 33.38 cm while that for $C_1$ was only 29.78 cm.

The treatments were significantly different from both the controls and there was significant difference between the controls as well.

### 5.2.2 Root weight

Main plot treatment of different levels of organic mulches and plastic mulch significantly influenced the root weight of ginger on all periods of observation and $M_1$ recorded the highest root weight of 1.17 g on 8th month. This was in accordance with the findings of Junior *et al.* (2005) in turmeric , all the mulching treatments were superior over control and root dry weight increased with paddy straw mulch application.

Fertilizer treatment $T_2$ of double the dose of recommended dose as per KAU POP was the highest on all periods of observation and was on par with $T_4$ (100:75:75 kg ha$^{-1}$ + foliar application of 0.5% of 19:19:19) on 4th and 6th months.

Among the interactions, mulching @ 30 t ha$^{-1}$ and fertilizer dose of 150:100:100 kg ha$^{-1}$ resulted in higher root weight on all periods of observation (Table 6) and recorded 1.32g in 8th month while in 6th month $m_1t_4$ was on par with $m_1t_2$ . A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ and $C_2$ also showed a significant difference between them.

### 5.2.3 Root volume

Main plot treatment of 30 t ha$^{-1}$ of mulch resulted in higher root volume on all periods of observation and recorded 114.20 cm$^3$ plant$^{-1}$ during the 8th months of observation. Abraham *et al.* (2016) observed higher root volume under *matty* ( 25.15 cm$^3$plant$^{-1}$) , wild jack (22.71 cm$^3$plant$^{-1}$) and control (25.88 cm$^3$plant$^{-1}$) in ginger.

In sub plot treatment , double the dose of recommended fertilizer resulted in high root volume on all periods of observation and recorded 112.49 cm$^3$ plant$^{-1}$ in the 8th month and the least root volume was observed in fertilizer dose of 75:50:50 kg ha$^{-1}$ (110.18 cm$^3$ plant$^{-1}$ in 8th month )

Among the combination, mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ recorded the highest root volume on all periods (Table 7 ) while in $6^{th}$ month $m_1t_1$ was on par with $m_1t_2$ ,and at $8^{th}$ month $m_1t_4$ was on par with $m_1t_2$ with root volume of 115.45 $cm^3$ plant $^{-1}$.

Treatment effects varied significantly with both control $C_1$ as well as $C_2$. A significant difference was noticed between the control $C_1$ as well as $C_2$.

**5.2.4 Root : Shoot**

Significant difference was noticed among the treatments of mulch in $4^{th}$ and $6^{th}$ month, fertilizer treatments in $6^{th}$ month and their interaction was significant throughout the periods of observation and are presented in Table 8

No significant difference root shoot ratio in $8^{th}$ month was noted in the main plot treatments and treatment of mulching @ 30 t $ha^{-1}$ recorded highest root shoot ratio in $4^{th}$ and $6^{th}$ months.

The root shoot ratio of sub plot treatments was insignificant in $4^{th}$ and $8^{th}$ month and in $6^{th}$ month, $T_2$ (150:100:100 kg $ha^{-1}$) recorded the highest root shoot ratio of 0.029 and was on par with $T_4$ . Ajithkumar (1999) reported that different levels of nitrogen , potassium, phosphorus had no significant difference in root: shoot ratio . Root: shoot ratio was inconsistent over different periods of growth

Treatment combination was significant throughout the periods of observation and combination of mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ resulted in higher root shoot ratio and in $6^{th}$ month it was on par with $m_1t_3$,$m_1t_4$ and $m_2t_2$ while in $8^{th}$ month it was on par with $m_1t_3$,$m_1t_4$,$m_2t_2$,$m_2t_3$,$m_2t_4$,$m_3t_1$,$m_3t_2$,$m_3t_4$. Treatments varied significantly with both the controls . A significant variation was observed within the controls $C_1$ and $C_2$

5.3 YIELD CHARACTERS

**5.3.1 Fresh yield**

The interaction of mulches and nutrients on the fresh yield of rhizome is presented in the Fig.6

The main plot treatment using mulch $M_1$ @ 30 t ha$^{-1}$ recorded the highest fresh yield on all periods of observation and resulted in 18093.53 kg ha$^{-1}$ in 8$^{th}$ month . This was followed by plots treated with plastic mulch ( $M_4$ ) which recorded 17567.25 kg/ha . Fresh rhizome yield of ginger increased significantly as compared to no mulch in ginger (Chandra and Govind , 2001) . Junior *et al.* (2005) reported that in turmeric maximum yield plant$^{-1}$ was recorded in paddy straw mulched plots which was significantly superior to control. Yield of turmeric was maximum with the paddy straw mulch which gave maximum yield (169.33 q ha$^{-1}$) followed by mulching with dry grass (131.33 q/ha) ( Verma and Sarnaik, 2006) .

Mahey *et al.* (1986) reported that application of paddy husk and wheat straw mulch increased the rhizome yield of turmeric by 59.5 and 218 % as compared to no-mulch plots, respectively, due to improved weed control and augmented soil moisture retention through reduced evaporation. Better performance of the ginger in the beds treated with 30 t ha$^{-1}$ of organic mulch might be due to the optimized soil temperature, controlled evaporation losses, increased soil moisture conservation, suppression of weeds and higher uptake of major, secondary and minor nutrients

Treatment $T_2$ recorded the highest fresh yield on all periods and obtained 17855.03 kg ha$^{-1}$ at harvest followed by $T_4$ (17455.58 kg/ha) $T_3$ and $T_1$ . Similar findings have been reported by Ajithkumar and Jayachandran (2001) that enhanced nitrogen application from 75 kg ha$^{-1}$ to 150 kg ha$^{-1}$ increased rhizome yield to 290 kg ha$^{-1}$ and application of phosphorus significantly increased the rhizome yield and enhanced P application, from 50 kg ha$^{-1}$ to 100 kg ha$^{-1}$ increased rhizome yield to 202 kg $ha^{-1}$ . Satyareddi and Angadi (2014) showed higher fresh rhizomes yield per plot (34.45 kg $plot^{-1}$) and yield per ha (23.41 t $ha^{-1}$) with application of 270:135:180 kg $N:P_2O_5:K_2O$ $ha^{-1}$ over other fertilizer levels in ginger . The higher application of NPK (150:100:100 kg $ha^{-1}$) have resulted in higher uptake of NPK (Table 34) which might have contributed to higher rhizome yield compared to other nutrient levels.

Among interactions, combination of mulches @ 30 t $ha^{-1}$ and double the recommended dose of fertilizer as per KAU package of practices ($m_1t_2$) gave the highest yield on all periods of observation and recorded 18.64 t $ha^{-1}$ in $8^{th}$ month followed by $m_4t_2$(18135.30 kg $ha^{-1}$) which was on par with $m_1t_4$ , $m_1t_3$ and $m_4t_4$. The increase in plant height, number of leaves $plant^{-1}$, number of tillers $plant^{-1}$, dry matter production, net assimilation rate due to higher uptake of NPK at increasing levels of mulches and fertilizer might have contributed to the increase in yield in $m_1t_2$.

A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ and $C_2$ have also shown a significant difference between them.

**5.3.2 Dry yield**

The dry yield was significant on main plot treatment of mulches, subplot treatment with different levels of fertilizers and their interaction ( Fig. 7 )

The treatment $M_1$ mulching with @ 30 t $ha^{-1}$ recorded highest dry yield on different stages of observation and recorded 3828.15 kg $ha^{-1}$ during harvest. The dry ginger yield in plastic mulch treatment was 3564.38t $ha^{-1}$ . The higher dry ginger yield $m_1t_2$ might be due to the higher nutrient (NPK) uptake as well as better soil conditions provided by highest quantity of mulch (30 t $ha^{-1}$). Babu and Jayachandran (1997) reported that dry ginger yield showed an increasing trend with increasing levels of mulch and a significant yield reduction was noticed in ginger cultivated under open condition when the quantity of mulch was reduced from 30 to 22.5 t/ha. Among the different mulching materials, dry leaves used as mulching material

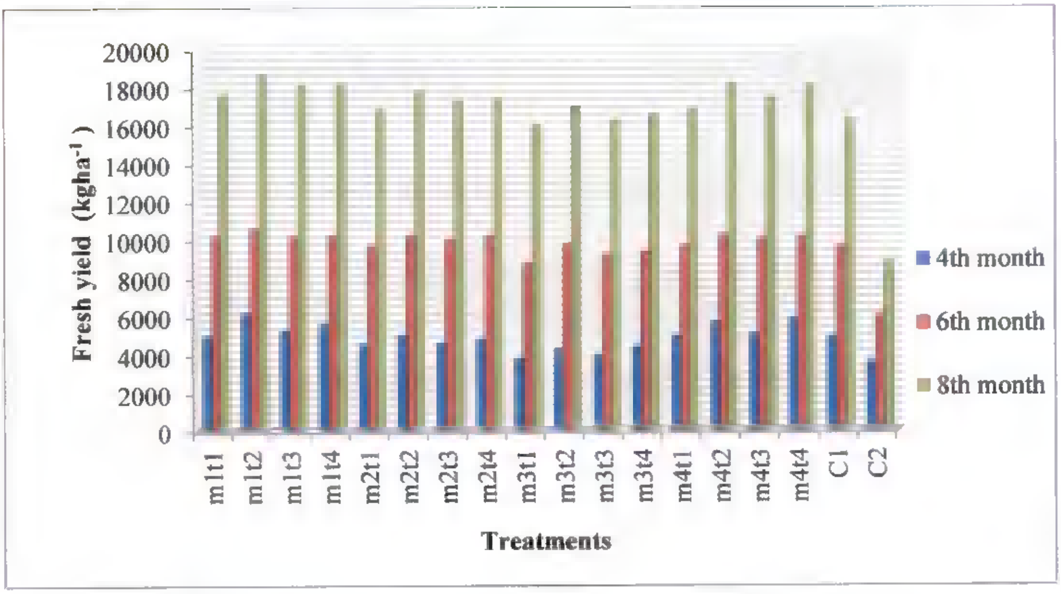


Fig 6 : Effect of mulch and nutrients on fresh yield (kg ha$^{-1}$)

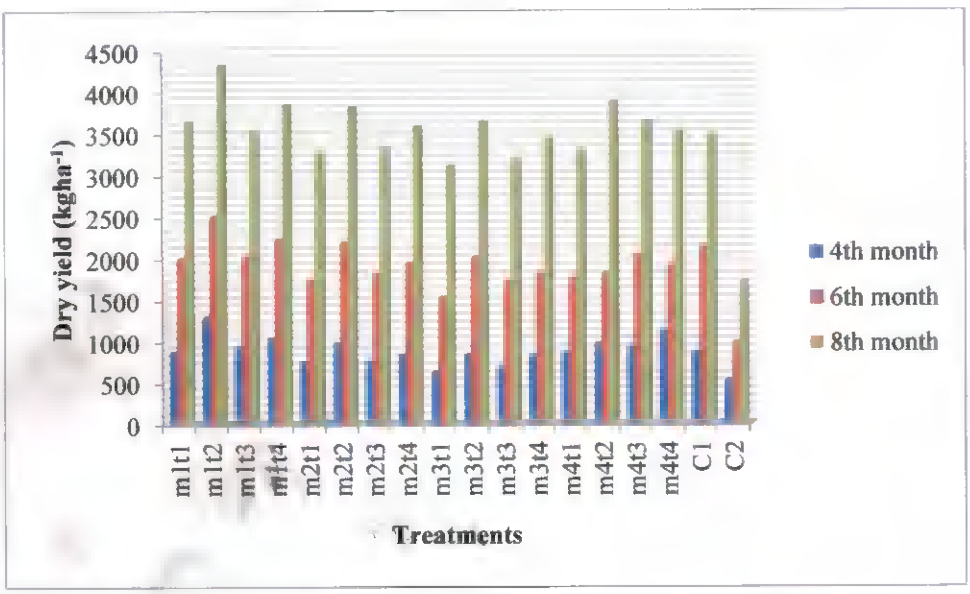


Fig 7 : Effect of mulch and nutrients on dry yield (kg ha$^{-1}$)

showed increased yield in ginger as reported by Sengupta *et al.* (2008). The yield performance of ginger varieties under open and oil palm plantations in Nigeria revealed that mulching is required under both conditions for increased yield ( Nwaogu *et al.*, 2011)

In subplot, treatments showed significant difference throughout the periods of observation and treatment $T_2$ recorded highest dry yield on all periods and obtained 3.91 t $ha^{-1}$ at harvest. The dry ginger yield of $T_4$ was 3.58 t $ha^{-1}$ while that for $T_3$ and $T_1$ were 3406.73 and 3319.73 kg $ha^{-1}$ respectively. Govind *et al.* (1995) reported that more secondary rhizomes per plant, and higher dry yields of rhizome in cv. Nadia with 90 kg of $P_2O_5$ $ha^{-1}$.

Interaction effects were significant throughout the periods of observation and among interaction combination of mulches @ 30 t $ha^{-1}$ and double the recommended dose of fertilizer as per KAU package of practice ( $m_1t_2$) obtained highest dry yield on all periods of observation and recorded 4316.10 kg $ha^{-1}$ at harvest followed by $m_4t_2$ (3881.80 kg $ha^{-1}$) which was on par with $m_1t_4$ ( 3842.10 kg $ha^{-1}$ ) . The treatment combinations except $m_2t_1$, $m_2t_3$, $m_3t_1$, $m_3t_3$ , $m_3t_4$ and $m_4t_1$ were significantly superior to conventional raising of ginger following recommended package of practices of KAU.

A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ and $C_2$ revealed a significant difference between them.

### 5.3.3 Harvest index

Significant differences in harvest index was observed throughout the periods of observation in main plot, sub plot and interactions . The interaction effect is presented in Fig 8

Plants that received $M_1$ (30 t ha $^{-1}$ ) in main plot resulted in the maximum harvest index at all growth periods. A harvest index of 0.414 was recorded in $M_1$ and the least harvest index was recorded with mulching @ 7.5t ha $^{-1}$ ($M_3$)

Among sub plot treatments, $T_2$ ( 150:100:100 kg ha $^{-1}$) recorded the highest harvest index of 0.17, 0.21 and 0.42 at 4$^{th}$ , 6$^{th}$ and 8$^{th}$ month respectively . Padmapriya *et al.* (2009) reported that highest harvest index was recorded in partial shade condition with 100 % N, $P_2O_5$ and $K_2O$ + 50 % FYM (15 t ha$^{-1}$) + coir compost (10 t ha$^{-1}$) + *Azospirillum* (10 kg ha$^{-1}$) + Phosphobacteria (10 kg ha$^{-1}$) + 3 % panchaghavya at 180 days after planting in turmeric.

The interaction between main plot and sub plot, was significant throughout the periods of observation and combination of mulches @ 30 t ha $^{-1}$ and fertilizer dose of 150:100:100 kg ha$^{-1}$ ($m_1t_2$) resulted in maximum harvest index of 0.435 at 8$^{th}$ month. Thus the efficiency of translocation of assimilates to economic part was found to be increasing with increasing fertilizer levels and mulches.

A significant difference in harvest index in all periods of growth was recorded between treatment and control. The control $C_1$ as well as $C_2$ varied significantly from treatments in all periods. The control $C_2$ registered lower value for harvest index indicating that the application of fertilizer significantly influenced assimilate partitioning.

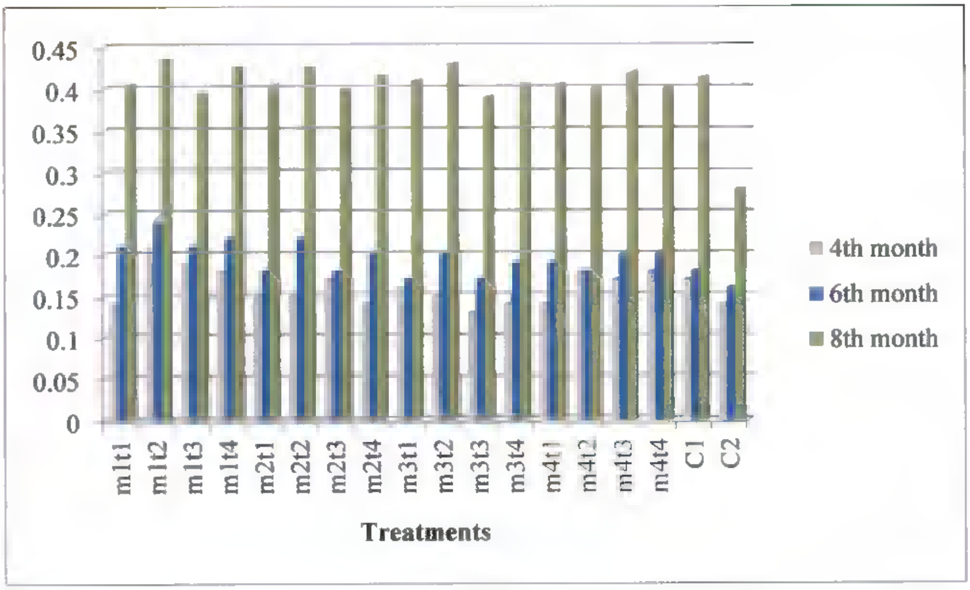


Fig 8 : Interaction effect of mulch and nutrients on Harvest Index

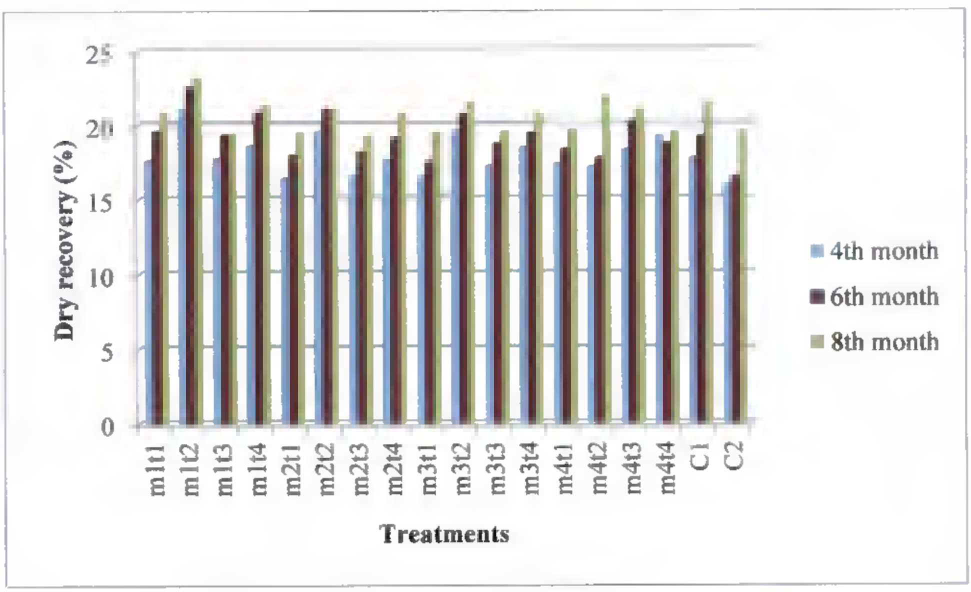


Fig 9 : Effect of mulch and nutrients on dry recovery (%)

### 5.3.4 Dry recovery

Significant difference was noticed among the treatments of mulch , fertilizer and their interaction ( Fig 9 )

Higher dry recovery of ginger was retained by main plot treatment $M_1$ (30 t $ha^{-1}$) in all periods of observation and the recovery at harvest was 21.14% .

The fertilizer level $T_2$ of 150:100:100 kg $ha^{-1}$($T_2$) recorded highest dry recovery of 21.89% at harvest. This is in contrary to the result of Joseph (1992) who observed that the dry recovery was not influenced by fertilizer levels.

Interaction effect showed the highest dry recovery was recorded from the combination of mulches @ 30 t ha $^{-1}$ and fertilizer dose of 150:100:100 kg/ha ($m_1t_2$) in all periods of observation and at harvest a dry recovery of 23.15% was recorded . This was followed by the treatment $m_4t_2$ (21.91%) which was on par with $m_3t_2$ (21.49 %). The dry recovery recorded by the treatment varied significantly from the control on all periods of growth .

The comparison of $C_1$ as well as $C_2$ with the treatments also indicated significant difference in the dry recovery at all periods of growth. A significant difference was noticed between the control $C_1$ and $C_2$ .

## 5.4 RHIZOME CHARACTERISTICS

### 5.4.1 Rhizome thickness

Significant variation in treatments on rhizome thickness at different periods of growth was observed (Table 13 )

Mulching @ 30 t $ha^{-1}$( $M_1$ ) recorded the highest rhizome thickness 1.69 cm at harvest and the least rhizome thickness of 1.58 cm was observed in mulching @ 15 t $ha^{-1}$ ($M_2$) . Abraham *et al.* (2016) reported that plants mulched with *panal* (1.92

cm) and rubber leaves (2.03 cm) had considerably greater rhizome thickness and was on par with control (1.98 cm) in ginger.

In sub plot treatment $T_2$ (150:100:100 kg/ha) recorded highest rhizome thickness on all periods of observation and recorded 1.67cm at harvest and was significantly different from other treatments throughout the periods of observation.

In treatment combination of mulches @ 30 t $ha^{-1}$ and double the recommended dose of fertilizer as per package of practices of KAU ($m_1t_2$) resulted in the highest rhizome thickness throughout the observation periods and at harvest the rhizome thickness of $m_1t_2$ and $m_1t_4$ was 1.79 cm . The treatments were significantly different from both the controls and there was significant difference between the control as well.

**5.4.2 Rhizome spread**

The main plot treatment with application of higher level of mulches ($M_1$-30t $ha^{-1}$) recorded the highest rhizome spread of 13.31cm at harvest (Table 14 ). The rhizome spread for the treatment was the least in $M_4$ (11.66 cm) where plastic mulch was utilized thus showing that under plastic mulch the rhizome spread was affected. Babu (1993) reported that rhizome spread observed was same in mulching @ 30 t $ha^{-1}$ and 22.5 t $ha^{-1}$ and was superior to lower levels of mulch (7.5 t $ha^{-1}$ and 15 t $ha^{-1}$ ). The effect of different bio mulching practices on growth of organic ginger revealed a higher rhizome length (6.50 cm), rhizome width (3.80cm) and rhizome fingers $plant^{-1}$ (35.30) in plants mulch with oak leaves compared to *chir pine* leaves, mixed grass mulch ,animal wastage fodder mulch and with no mulch (Singh *et al.,* 2014). Abraham *et al.* (2016) reported that rhizome spread was significantly greater in plants mulched with *panal* leaves ( 28.80 cm) and was on par with control (28.16 cm) in ginger. Rhizome spread is measured in order to know the extend of growth of rhizomes.

The sub plot treatment, $T_2$ (150:100:100 kg $ha^{-1}$) showed the highest rhizome spread on all periods of observation and recorded 13.08 cm at harvest showing that higher fertilizer resulted in higher rhizome spread compared to conventional ($T_1$) fertilizer level.

Among the interaction mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ resulted in higher rhizome spread on all periods of observation and recorded 14.30 cm which was on par with $m_1t_3$(14.23 cm) . Rhizome spread was influenced by phosphorus application and 30 kg $P_2O_5$ $ha^{-1}$ resulted in higher spread (28.93 cm) in mango ginger (Mridula, 1997). Nirmalatha (2009) reported that vermicompost @ 25 t $ha^{-1}$, neem cake @ 6 t $ha^{-1}$ ,FYM @ 40 t $ha^{-1}$ recorded maximum rhizome spread in Kasthuri turmeric than their respective lower level of application. The higher dose of fertilizer level along with higher mulch had resulted in better rhizome spread. All the combinations except $m_4t_1$ recorded higher rhizome spread than conventional type of planting with recommended package of practices of KAU.

A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ and $C_2$ also showed a significant difference in rhizome spread.

## 5.5 QUALITY ANALYSIS

### 5.5.1 Starch

The effect of treatments on starch content is presented in Fig 10

Starch is the most abundant of the constituents, comprising of 40 to 60 percent of the weight of the dry rhizome (Lawrence, 1984). The highest starch content was obtained in plots mulched with 30 t ha $^{-1}$ in all periods of growth and recorded 37.63% at harvest. According to Aclan and Quisumbing (1976) mulching with leaf increased the starch content in ginger.

In sub plot treatment $T_2$ ( 150:100:100 kg $ha^{-1}$) starch was significantly higher in all periods of observation and recorded 37.72% at harvest. The increased mulch level as well as fertilizer had increased the starch content in ginger. The starch macromolecule is formed by two polysaccharides, amylose and amylopectins. Majority being amylopection (75%) and amphorus amylase constitute 25%.

Interaction showed significant effect on starch content during the periods of observation and treatment combination mulches @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ noted the highest starch content in all periods of observation. This might be due to the enhanced starch accumulation observed with the application of fertilizers

A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ and $C_2$ also showed a significant difference in starch content between them. All the treatments significantly improved the starch content compared to conventional cultivation method with recommended package of practices of KAU.

**5.5.2. Fibre**

Fig 11 clearly indicates the significance of treatments at different growth periods of observation of fibre in ginger.

Fibre is an important criteria to access the suitability of ginger rhizome for processing (Purseglove *et al.*, 1981) .The crude fibre content of improved cultivars of IISR ranged from 3.3. to6.4% (FAO, 2002) . Mulching @ 30 t $ha^{-1}$ ($M_1$) resulted in higher fibre content on all periods of observation and a fibre content of 4.25% was recorded at harvest. Babu (1993) reported that there was an increasing trend in fibre content with increase in mulch and maximum fibre content was observes in mulching @ 30 t $ha^{-1}$

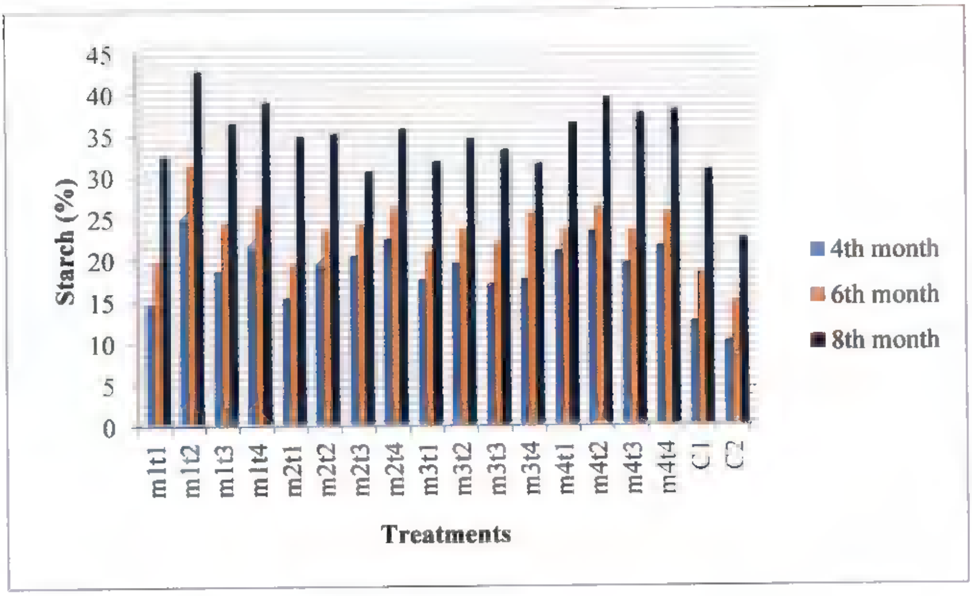


Fig 10 : Effect of mulch and nutrients on starch (%)

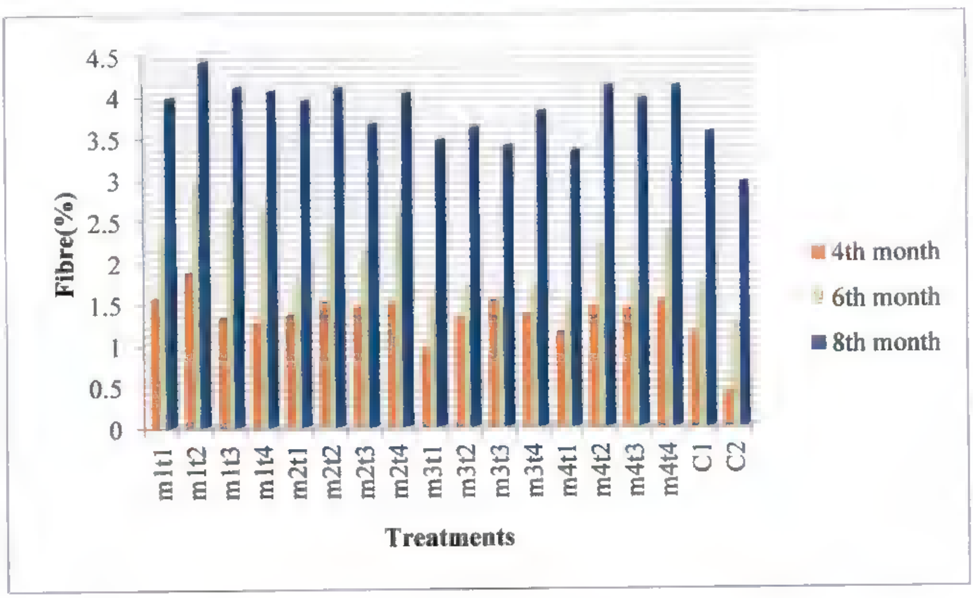


Fig 11 : Effect of mulch and nutrients on fibre (%)

In subplot treatment double the dose of fertilizer resulted in high fibre content on all periods of observation and resulted in 4.08% of fibre at harvest. Increasing trend in fibre content with increasing in level of nutrients. Nair (1982) reported that there was no significant variation in fibre content with N application in ginger while Azezee *et al.* ( 2011) reported that application of 125 kg N/ha and phosphorus @ 60 kg $ha^{-1}$, K @ 60 kg $ha^{-1}$ had significantly increased in the crude fibre content. Among the combination mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ ($m_1t_2$) recorded the highest fibre content on all periods and recorded 4.41% at harvest . Treatment effects varied significantly with both control $C_1$ as well as $C_2$. A significant difference was noticed between the control $C_1$ as well as $C_2$. The fibre content of absolute plot were significantly lower. Fibre content in the rhizome forms from the time it begins to develop , but the amount is insignificant in the intial stages.As physiological age of rhizome increase, so does the diameter and strength of fibre.

**5.5.3. Oil**

The difference in essential oil content in main plot, sub plot and interaction effect in (Fig 12)

Plants that received $M_1$ (30 t $ha^{-1}$ ) in main plot resulted in maximum oil content at all growth periods and recorded 2.76% at harvest.

Sub plot treatment, $T_2$ (150:100:100 kg $ha^{-1}$) recorded the highest oil content on all periods of observation and recorded 2.43% at harvest. Ahmedshah *et al.* (1988) revealed little effect of potassium application (60-90 kg $ha^{-1}$) on essential oil content of turmeric. Azezee *et al.* ( 2011) reported that application of 125 kg N/ha phosphorus @ 60 kg $ha^{-1}$ and K @ 60 kg $ha^{-1}$ had significant increase in the quality of ginger with respect of volatile oil .

The interaction between mulching and fertilizer , was significant throughout the periods of observation and combination of mulches @ 30 t ha $^{-1}$ and fertilizer

dose of 150:100:100 kg ha$^{-1}$ ($m_1t_2$) resulted in maximum oil content of 2.92% at 8 month. A significant difference in oil content in all periods of growth was recorded between treatment and control. The control $C_1$ as well as $C_2$ varied significantly from treatments in all periods of observation . The oil content recorded between control also varied significantly.However Ratna *et al.* (1993) in turmeric did not observe any significant difference in essential oil content between plants treated with higher levels of nitrogen , phosphorus and control.

**5.5.4. NVEE**

Significant effects was noticed on non volatile ether extract at different periods in plots treated with mulching, fertilizers and their combination (Fig 13)

Mulching treatment significantly influenced the NVEE on all periods of observation. Mulching @ 30 t ha$^{-1}$ recorded the highest NVEE of 8.72% on 8$^{th}$ month in all periods of observation . Babu (1993) reported that non volatile ether extract was maximum in 30 t ha$^{-1}$ and showed an increasing trend of NVEE with increase in levels of mulch.

Sub plot treatment of double the dose of fertilizer resulted in highest NVEE on all periods of observation and recorded 8.71% at harvest .The results of the experiment were in confirmity with the findings of Nair and Das (1982) in ginger. Pawar and Patil (1987) observed an increase in oleoresin content due to nutrition in ginger but Ratna *et al.* (1993) observed no significant difference in NVEE content between control and treated plants. Joseph and Jayachandran (1993) revealed that the NVEE of ginger rhizomes was not adversely affected by increasing levels of fertilizers. Azezee *et al.* ( 2011) reported that application of 125 kg N/ha and

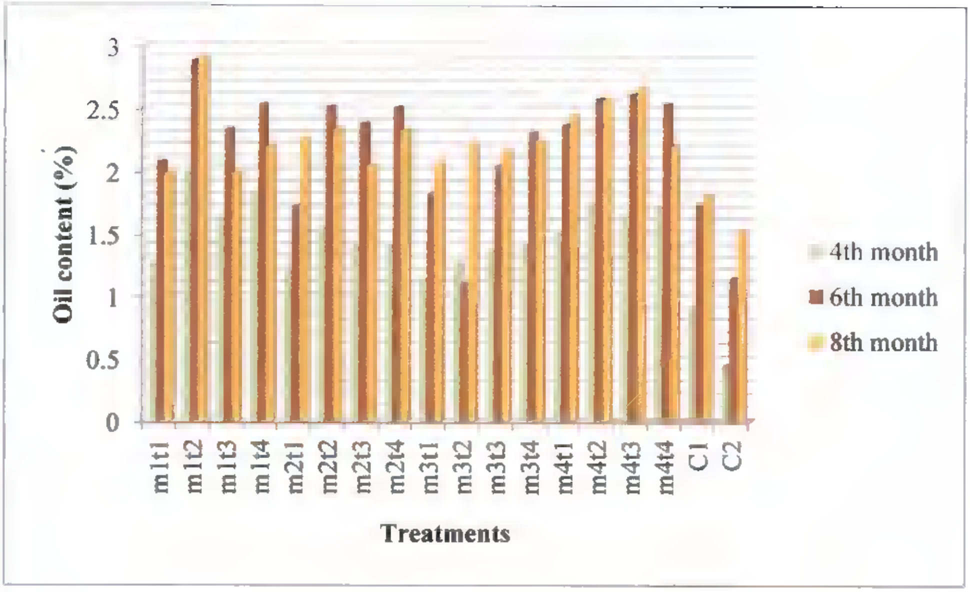


Fig 12 : Effect of mulch and nutrients on oil content (%)

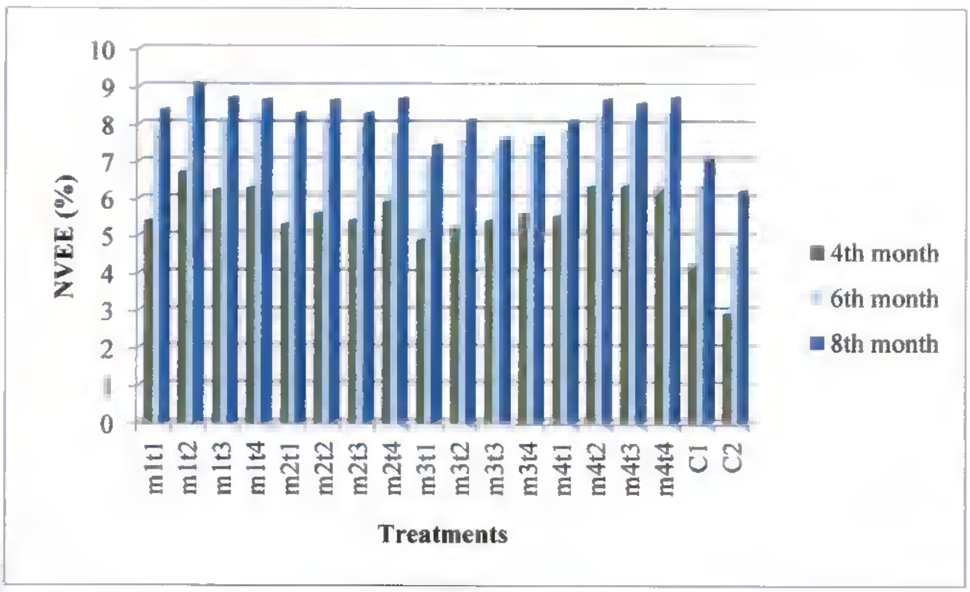


Fig 13 : Effect of mulch and nutrients on NVEE (%)

phosphorus @ 60 kg $ha^{-1}$ and K @ 60 kg $ha^{-1}$ had significantly increased the quality of ginger with respect of oleoresin.

Among the interaction, mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ ($m_1t_2$) resulted in higher NVEE on all periods of observation and recorded 9.08% NVEE at harvest

A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ and $C_2$ also showed a significant difference between them.

## 5.6 PHYSIOLOGICAL ANALYSIS

### 5.6.1 Dry matter production

Dry matter production was significant on main plot treatment of mulches ,subplot treatment with different levels of fertilizers and their interaction ( Fig. 14 ).

Treatment $M_1$ with mulches @ 30 t $ha^{-1}$ recorded highest dry matter production on all periods and obtained 76.95 g $plant^{-1}$ in $8^{th}$ month. Singh *et al.* ( 2014) reported that mulching with oak leaves in ginger resulted in maximum average soil moisture conservation (54.5%) and with less average soil temperature (20.4° C) and thus favoured yield . In the present study also higher mulch (30 t $ha^{-1}$) might have helped in retaining more soil moisture as well as reducing soil temperature thus favouring good growth resulting in higher dry matter production.

Double the dose of recommended fertilizers recorded the highest dry matter production on all periods and obtained 75.67 g $plant^{-1}$ on $8^{th}$ month. This was similar to the results obtained by Mridula (1997) in mango-ginger that higher dose of N produced higher DMP. This shows that the supply of nutrients might have activated many metabolic processes leading to production of complex substances which in turn influenced the growth and yield of mango ginger.

Interaction effects were significant throughout the periods and among interaction combination of mulches @ 30 t ha$^{-1}$ and double the recommended dose of fertilizer as per package of practices of KAU obtained the highest dry matter production on all periods of observation and recorded 83.70 g plant$^{-1}$ at 8$^{th}$ month . The congenial conditions provided by mulch together with the higher nutrient combination ($m_1t_2$) might have resulted in higher dry matter production.

A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ and $C_2$ also showed a significant difference between them. A significantly lower DMP was shown by the control compared to all other treatments. This shows that the nutrients had a greater influence on both vegetative growth and rhizome yield .

### 5.6.2 Net assimilation rate

Net assimilation rate is a physiological index which is closely connected with physiological efficiency of plant . It is the measure of the amount of photosynthates going into plant material. Significant variation in mulching, fertilizers and their combination on net assimilation rate at different periods of crop growth are presented in Fig 15

Plants that received 30 t ha$^{-1}$ ($M_1$) of mulch in main plot resulted in maximum net assimilation rate at all growth periods and recorded 0.290 g m$^{-2}$ day$^{-1}$ in 6 to 8 months . The positive influence of mulch on NAR might be due to low soil temperature , high moisture retention and the nutrients supplied by additional quantity of mulch. A relatively cool microclimate produced as a result of mulching might have negatively influenced the respiration rate and increased the accumulation. Babu (1993) found the positive influence of NAR under low shade in ginger. Ajithkumar

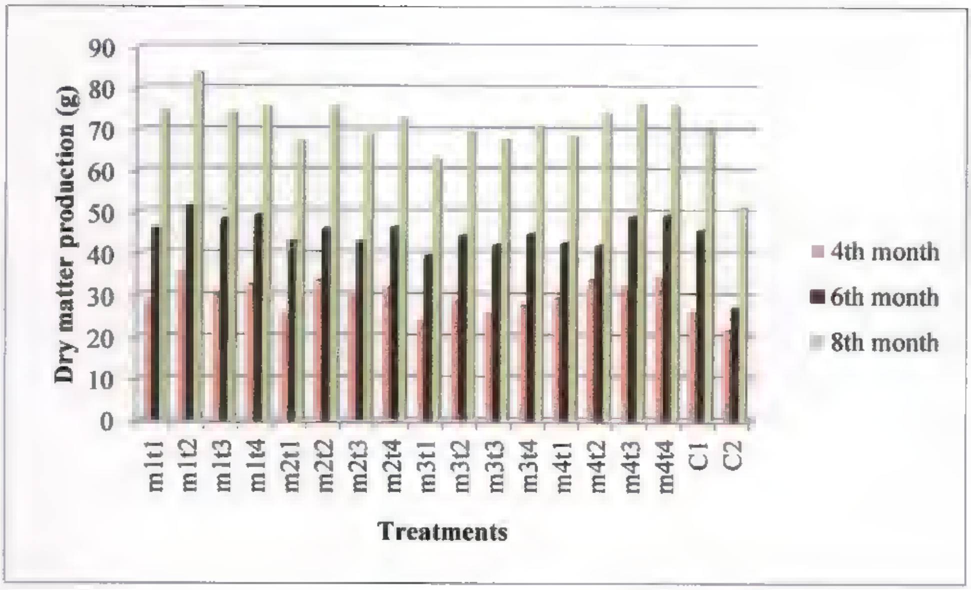


Fig 14 : Effect of mulch and nutrients on dry matter production

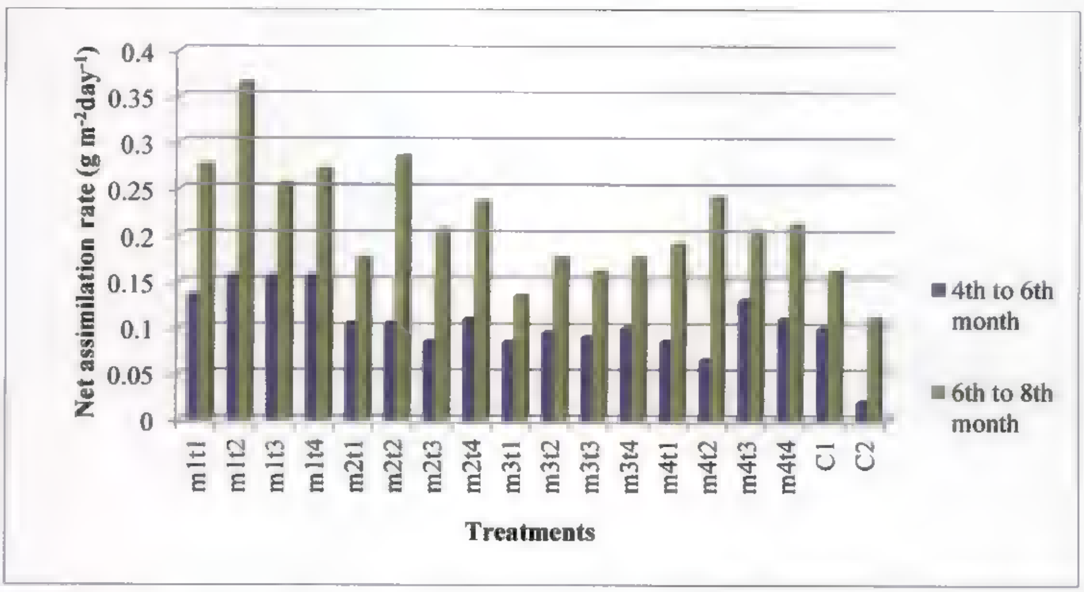


Fig 15 : Effect of mulch and nutrients on net assimilation rate

(1999) reported that application of mulch had no significant effect on NAR during both the phases of growth in ginger.

Sub plot treatment $T_2$ (150:100:100 kg $ha^{-1}$) recorded the highest net assimilation rate on all periods of observation and recorded net assimilation rate of 0.266 g $m^{-2}$ $day^{-1}$ in $6^{th}$ to $8^{th}$ months . Ajithkumar (1999) reported that different levels of potassium application had no significant effect on NAR in ginger.

In the interaction between mulching and fertilizer, significant variation was observed throughout the periods of observation and combination of mulching @ 30 t $ha^{-1}$ with double the recommended dose of fertilizer ($m_1t_2$) recorded the highest net assimilation rate of 0.365 g $m^{-2}$ $day^{-1}$ in $6^{th}$ to $8^{th}$ month.

The control $C_1$ as well as $C_2$ varied significantly from treatments in all periods. The net assimilation rate recorded between controls also varied significantly. Reich *et al* (1998) explained the association of net assimilation rate with maximum photosynthetic rate and leaf nitrogen concentration. The higher net assimilation rate under higher mulch ($M_1$) , fertilizer ($T_2$) and in their combination ($m_1t_2$) might be due to the higher photosynthetic rate and higher nitrogen uptake by these treatments. This might have resulted in higher increase in plant dry mass per unit leaf area per unit time. In other words as Li *et al.* (2016) suggested fast growing plants had high NAR and plants with high NAR always grew fast.

**5.6.3 Crop growth rate**

Significant effects on crop growth rate (CGR) was observed at different periods of observation due to mulching, fertilizers and their combination

Main plot treatment of mulching was significant only in period of $6^{th}$ to $8^{th}$ month and produced highest CGR in mulching @ 30 t $ha^{-1}$ and plastic mulch (0.029 g $m^{-2}day^{-2}$) . Babu (1993) reported an increasing trend in CGR with increasing levels of mulch and also observed that under open condition mulching @ 22.5 t $ha^{-1}$ and was on par with mulches @ 30 t $ha^{-1}$ .

In sub plot, fertilizer treatment were significant only in $4^{th}$ to $6^{th}$ months of observation and the highest was recorded by NPK dose of both 150:100:100 kg $ha^{-1}$ and 100:75:75 kg $ha^{-1}$ and foliar application of 19:19:19 @ 0.5% ($T_4$) .Maximum CGR and increased response to nutrients in terms of CGR under 25 and 50 per cent shade levels were observed by Joseph (1992) and Babu (1993) in ginger . Ajithkumar (1999) reported that a significant increase in CGR at higher levels of potassium (100 kg $K_2O$) at the later stages .

Interaction was significant during the periods of $4^{th}$ to $6^{th}$ months of observation and treatment combination of mulches @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ noted the highest CGR on $4^{th}$ to $6^{th}$ months of observation

A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ and $C_2$ also showed a significant difference between them in $4^{th}$ to $6^{th}$ months . The CGR also increased with the advancement of growth from $4^{th}$ to $6^{th}$ month and $6^{th}$ to $8^{th}$ month. For all the subplot treatment and interaction the CGR increased with the advancement in growth, but for the main plot treatment $M_2$, CGR remained the same during $4^{th}$ to $6^{th}$ and $6^{th}$ to $8^{th}$ months. Thus mulching @ 30 t $ha^{-1}$ and use of plastic mulch had shown a rapid growth during the period for $6^{th}$ to $8^{th}$ month, while other main plot treatments had shown a slow steady growth rate. The lower CGR during the early phase in $M_3$ and $M_2$ favoured more of weed growth and development ultimately affecting the growth and yield of the crop.

### 5.6.4 Leaf area index

Treatment with mulch treatment, fertilizer and their interaction had significant influence in the leaf area index (LAI) at all periods of growth and interaction effect is presented in Fig 16.

Application of 30 t $ha^{-1}$ of mulch ($M_1$) retained significantly higher LAI in all periods of growth and recorded 8.64 at $8^{th}$ month . Under open and shade levels the application of higher quantities of mulch enhanced total leaf area (Babu,1993) . Ajithkumar (1999) reported no significant effect of mulch on leaf area.

In sub plot treatment double the recommended dose of fertilizer, $T_2$ ( 150:100:100 kg $ha^{-1}$) recorded the highest LAI of 8.11 in $8^{th}$ month. Potassium is important in the photosynthetic process and it increases leaf area and carbon dioxide assimilation (Russell,1973).Joseph (1992) observed an increase in LAI with increase in fertilizer level in ginger. Ajithkumar (1999) reported that higher LAI was observed with increase in fertilizer levels.

Interaction effect resulted in significant difference in all periods of growth and the highest LAI was recorded from the combination of mulches @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ ($m_1t_2$) in all periods of observation and in $8^{th}$ month LAI of 9.20 was recorded .

LAI of treatments varied significantly from the control on all periods of growth . The comparison of $C_1$ as well as $C_2$ with the treatments also indicated significant difference in the number of leaves in all periods of growth. A significant difference was noticed in LAI between the control $C_1$ and $C_2$ . Mridula ( 1997) in mango ginger reported positive and significant correlation of LAI with yield. LAI is an important agronomic parameter which reflects crop growth and predicts crop yield (Fageria *et al.*, 2006) .Differences in leaf area can affect plant spatial distribution and the microenvironment within population (Giunta *et al.*, 2008) which plays a decisive

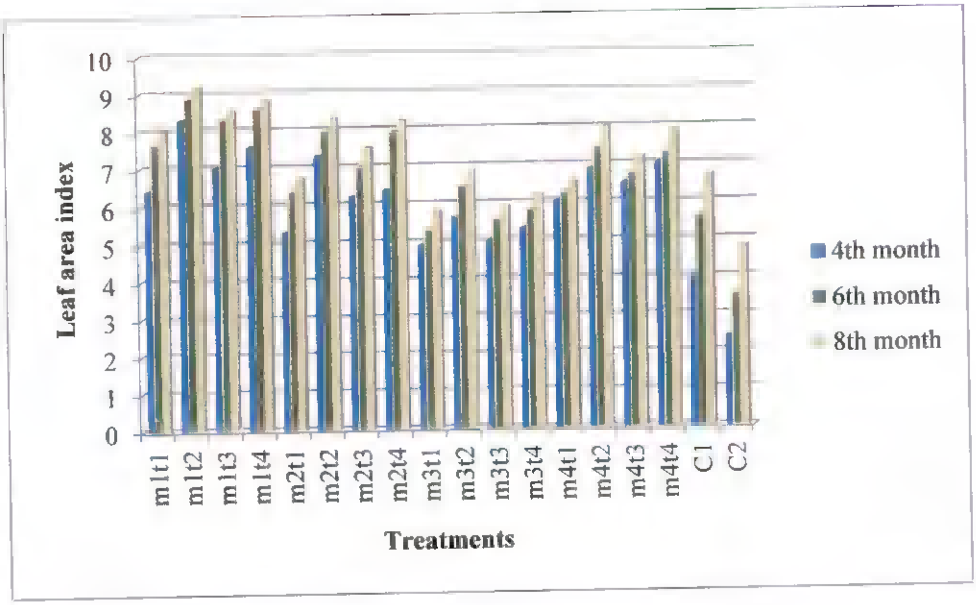


Fig 16 : Effect of mulch and nutrients on leaf area index

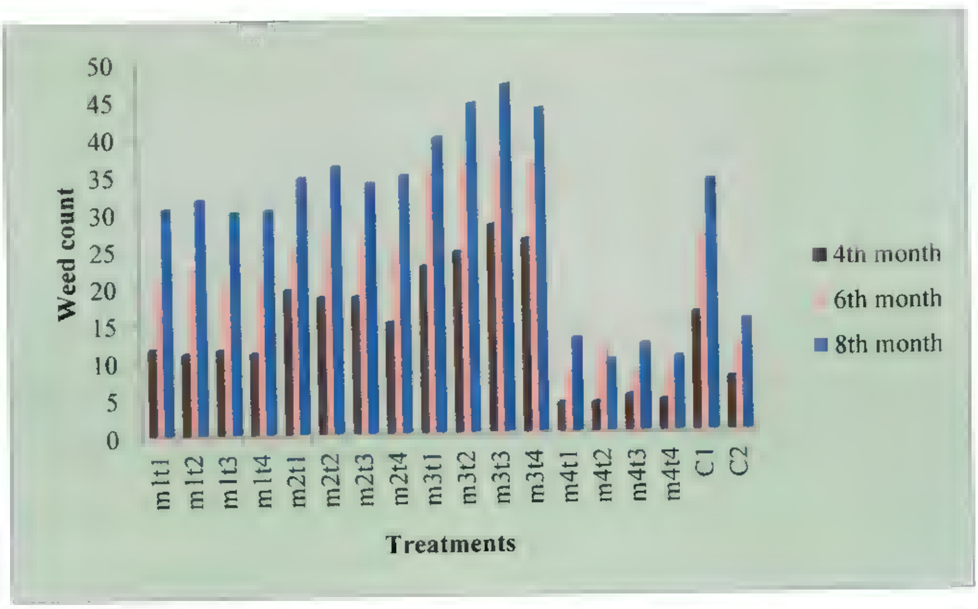


Fig 17 : Effect of mulch and nutrients on weed count role in the photosynthetic efficiency and light energy distribution of crops (Boedhran *et al.*, 2001; Elings, 2000) . Higher LAI noticed is $M_1$, $T_2$ and $m_1t_2$ might have helped in harvesting more light which together with more uptake of nutrients producing more photosynthates and translocation to rhizomes.

### 5.6.5 Relative growth rate

Relative growth rate (RGR) recorded showed significant difference between main plots and sub plots in $6^{th}$ to $8^{th}$ month . Both 30 t $ha^{-1}$ and plastic mulch recorded the highest relative growth rate in 6 to 8 months (0.072 g $g^{-1}day^{-1}$). ( Table 23)

In sub plot, fertilizer treatments were insignificant for RGR in 4 to 6 months and treatment $T_2$ ( 150:100:100 kg/ha ) recorded highest RGR on 6 to 8 month. (0.072 g $g^{-1}day^{-1}$). DMP is influenced by the higher rate of potassium application. RGR is influenced by the physiological activity like photosynthesis, respiration and mineral uptake and metabolic balance. Increased photosynthetic efficiency at higher levels of potassium application was evident from DMP. At higher levels of potassium, increased DMP and this in turn will increase the RGR. Ajithkumar (1999) reported no significant effect on RGR in ginger.

Treatment combination was significant throughtout the periods of observation and combination of mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ ($m_1t_2$) resulted in higher RGR in 4 to 6 months . The RGR during $6^{th}$ to $8^{th}$ months for the same treatment recorded highest .

Treatments varied significantly with both the controls. A significant variation was observed within the controls $C_1$ and $C_2$ as well. The RGR of the main plot and sub plot treatments has increased from $4^{th}$ to $6^{th}$ month to $6^{th}$ to $8^{th}$ month. This shows that the RGR increases more during the period from $6^{th}$ to $8^{th}$ month. According to

Evans (1975) RGR is the rate of increase in plant mass per unit plant mass already present. This shows the efficiency of growth with respect to biomass .

### 5.6.6 Leaf area duration

Leaf area duration differed significantly among all periods of observation ( Table 24)

Application of mulch @ 30 t $ha^{-1}$ recorded the highest leaf area duaration on all periods . The leaf area duration of 263.39 days were obtained for the period of $6^{th}$ to $8^{th}$ month . Babu (1993) reported that LAD showed an increasing trend with each increment dose of mulch.

In sub plot , $T_2$ ( 150:100:100 kg $ha^{-1}$) treatment recorded the highest leaf area duration on all periods of observation and was significantly different from other treatment .

Among the interaction mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:10:100 kg $ha^{-1}$ ($m_1t_2$) recorded highest leaf area duration on all periods of observation .

Treatment effects varied significantly with both control $C_1$ and $C_2$. A significant difference was noticed between the control $C_1$ as well as $C_2$ . Leaf area duration is a measure of green leaf retention over time and it takes into account both the duration and extend of photosynthesis tissue of the crop canopy. The higher LAD of $M_1$ , $T_2$ and $m_1t_2$ shows they have potential for improving radiation use efficiency as observed by ( Reynolds and Pfeiffer ,2000). The higher LAD might be due to higher chlorophyll content per leaf area unit in these treatments ( Hunkova *et al.*, 2009) .

### 5.6.7 Bulking rate

The bulking rate recorded significant variation among main plot treatments on $6^{th}$ to $8^{th}$ month of observation. (Table 25)

Highest bulking rate was recorded due to mulching 30 t ha $^{-1}$ during this period (0.237 g plant $^{-1}$day$^{-1}$). This might be due to the increased availability of nutrients at higher levels of mulch. Babu (1993) reported a positive correlation of increased levels of mulch ( 22.5 t ha$^{-1}$) on bulking rate in ginger .

In sub plot, double the dose of recommended fertilizers was significantly higher in all periods of observation while in $4^{th}$ to $6^{th}$ month . An increased bulking rate with fertilizer levels were observed in ginger ( Joseph, 1992). Mridula (1997) reported that an increase in bulking rate was observed with higher levels of nutrients( 45:45 kg ha$^{-1}$ of N , $P_2O_5$ ) in mango ginger

Interaction was significant and treatment combination mulches @30 t ha$^{-1}$ and fertilizer dose of 150:100:100 kg ha$^{-1}$ noted highest bulking rate in $4^{th}$ to $6^{th}$ months.

A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ and $C_2$ also showed a significant difference between them. This might be due to the better translocation of photosynthates to economic part by increase in fertilizer levels.

### 5.6.8 Chlorophyll content

Significant differences in chlorophyll content among mulch treatments was observed throughout the crop growth period. (Table 26)

Plants that received 30 t ha$^{-1}$ of mulch ($M_1$) resulted in maximum chlorophyll content in all growth periods. At 8 months chlorophyll content of 1.33 mg g$^{-1}$ was recorded from $M_1$ . The positive influence of mulch on chlorophyll content may be due to enhanced soil physical condition caused by the mulch treatment.

Sub plot treatment of 150:100:100 kg $ha^{-1}$ ( $T_2$ ) recorded the highest chlorophyll content on $4^{th}$ and $6^{th}$ months of observation. while in 8 months chlorophyll content of 1.24 mg $g^{-1}$ was recorded for 150:100:100 kg $ha^{-1}$ ($T_2$) and 100:75:75 kg $ha^{-1}$ + foliar application of 19:19:19 @ 0.5% ($T_4$). Nitrogen is an integral part of chlorophyll molecule, thus its supply at higher amount would have favoured the production of chlorophyll which in turn increased photosynthetic efficiency of plant and thus yield. Higher nutrient levels were adequate for the production of good amount of chlorophyll.

The interaction between mulching and fertilizers , was significant throughout the periods of observation and combination of mulches @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ resulted in maximum chlorophyll content.

A significant difference in chlorophyll content in all periods of growth was recorded between treatment and control. The control $C_1$ and $C_2$ varied significantly from treatments in all periods. Chlorophyll content recorded between controls also varied significantly. Mridula (1997) reported that in mango ginger a positive correlation was observed with chlorophyll content and yield.

## 5.7 WEED COUNT AND DRY WEIGHT PER UNIT AREA

### 5.7.1 Weed count

Weed count differed significantly between all periods of observation and interaction effect is presented in Fig 17

The lowest weed count was recorded from plastic mulch on $45^{th}$ and $90^{th}$ days of observation .Weed count of 9.21 was obtained in the $120^{th}$ day of observation and the highest weed count was observed in mulching @ 7.5t $ha^{-1}$ and recorded 43.31 in $120^{th}$ days of observation. Mohanty *et al.* (1991) reported that application of mulch delayed the emergence of weeds and would have also had a smothering effect on them. This quick and better establishment of the plants along with reduced competition by weeds had a favourable effect on all growth parameters of turmeric. Chandra and Govind (2001) reported that application of mulch enhanced the sprouting of ginger rhizomes and minimized weeds and total weed biomass production was highest in unmulched plots compared to mulched plots. The heavily mulched plot ($M_1$) had reduced weed count, however it was higher than the plastic mulched plot. Weed population was very low in plastic mulches only a few weeds emerged from the plastic mulch due to increased size of holes.

In sub plot, ($T_1$) 75:50:50 kg $ha^{-1}$ recorded the least weed count on all periods of observation and was significantly different from other treatments. Weed count of 29.75 was obtained in the $120^{th}$ day from $T_1$.

Among the interaction mulching with plastic mulch and fertilizer dose of 75:50:50 kg $ha^{-1}$ ($m_4t_1$) recorded the lowest weed count on $45^{th}$ and $90^{th}$ days of observation.

Treatment effects varied significantly with both control . A significant difference was noticed between the control $C_1$ and $C_2$. Manhas *et al.* (2011) reported that weed population were significantly lower with 6.25 t $ha^{-1}$ mulch than with no mulch in turmeric.

**5.7.2 Dry weight per unit area**

A significant variation in dry weight of weed per unit area was observed among the different mulch, fertilizer and their interaction. (Table 28)

The mulch treatment of plastic mulch recorded lowest dry weight of weed of 32.72 g $m^{-2}$ in $120^{th}$ day . Manhas *et al.* (2011) reported that weed dry matter were significantly lower with 6.25 t $ha^{-1}$ mulch than with no mulch in turmeric . Kaur and Brar (2016) reported that weed dry matter was also significantly reduced in mulched plots as compared to no mulch. Weed dry matter was 81.5 % and 163.5 % less in mulch plots as compared to no-mulch plots at 45 and 90 days after planting respectively. The effect of different organic mulches and plastic mulches on weed suppression and yield of ginger revealed that application of paddy straw @ 6 t $ha^{-1}$ along with green leaf mulch of 7.5 t $ha^{-1}$ at 45 and 90 days after planting and application of dried coconut leaves at the time of planting @ 5.4 t $ha^{-1}$ recorded higher weed control efficiency, higher economic returns compared to application of *Glycosmis pentaphylla* leaf mulch in ginger( Thankamani *et al.*, 2016)

In subplots, double the dose of recommended fertilizers ($T_1$) resulted in the lowest dry weight of weed all periods of observation . Lower level of fertilizer resulted in decrease in weed dry matter production compared to other treatments.

Among the combination, mulching with plastic mulch and fertilizer dose of 75:50:50 kg $ha^{-1}$($m_4t_1$ ) recorded lowest dry weight of weed on all periods. The combination of lower level of nutrients along with plastic mulch had resulted in lower dry weight of weeds.

Treatment effects varied significantly from both controls. A significant difference was noticed between the controls.

5.8 AGRONOMIC INDICES

**5.8. 1 Agronomic efficiency**

Mulch treatments , fertilizer dose and their combination significantly influenced agronomic efficiency of N, P and K in all periods of growth in ginger are presented in Table 29

The highest agronomic efficiency of N, P and K was recorded in mulching @ 30 t ha $^{-1}$ ($M_1$) . The agronomic efficiency of N,P and K recorded in main plot treatment ($M_1$) was 20.18, 28.34 and 28.34 kg yield kg$^{-1}$ of N,P and K respectively . The values of agronomic efficiency of N were the lowest in heavy and mixed mulching treatment and higher level of N increased agronomic efficiency in rice (Cho and Korean, 1999) . Efficient fertilizer use can be defined as maximum returns per unit of fertilizer applied (Mortvedt *et al.*, 2001) .Higher agronomic efficiency of N noticed under $M_1$ was due to the higher uptake ultimately improving the growth and yield. Mavarkar ( 2016) reported that in baby corn agronomic efficiency was higher in treatments with fertilizer dose of 135:65:45 kg NPK ha$^{-1}$.

In sub plot, 150:100:100 kg ha$^{-1}$ ($T_2$) treatment showed significant higher agronomic efficiency of N, P and K . The treatment , $T_2$ resulted in agronomic efficiency of 18.58, 32.13 and 32.13 kg$^{-1}$ of N , P and K respectively. Jagadeeshwaran (2004) reported that in turmeric agronomic efficiency varied from 18.8 kg dry rhizome per kg of N applied with NPK level at 75% to 29.2 kg dry rhizome kg$^{-1}$ of N applied with 100% NPK level. The agronomic efficiency was maximum with 100% NPK level. Agronomic efficiency varied from 47.1 kg dry rhizome kg$^{-1}$ of $P_2O_5$ applied with 75% NPK level to 73.1kg dry rhizome kg$^{-1}$ of $P_2O_5$ applied at 100% NPK level. In potassium use efficiency agronomic effiency varied from 26.2kg with 75% NPK level to 40.6 kg at 100% NPK level. Dobermann (2007) reported that agronomic efficiency of N for cereals in developing countries ranged between 10 and

30 kg $kg^{-1}$. Zhang *et al* . (2007) reported that the capability of yield increase per kg pure N declined remarkably with increasing N application in rice. Szmigiel *et al.* (2016) reported that the highest N agronomic efficiency, of 32.7 kg kg-1 was observed for the rate of 60 kg N $ha^{-1}$ in wheat . The application of double the recommended dose of fertilizers increased the agronomic efficiency of N produced 18.5 kg dry rhizome per kg of N applied , 32.13 kg dry rhizome $kg^{-1}$ of $P_2O_5$ applied and 32.13 kg of dry rhizome $kg^{-1}$ of $K_2O$ applied.

Interaction effect on agronomic efficiency of N, P and K was significant and treatment combination $m_1t_2$ ( mulches @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$) noted highest agronomic efficiency for N , P and K in all periods of observation. A significant difference in agronomic efficiency of N,P and K was observed between the treatments and the control, $C_1$ on all periods of growth. The higher mulch along with higher fertilizer dose produced higher agronomic efficiency suggesting that higher mulch might have influenced the fertilizer use efficiency and the requirement of N,P,K nutrients for ginger might have been high. These higher agronomic efficiency showed positive relationship.

**5.8. 2 Partial factor productivity**

Plants that received $M_1$ (30 t $ha^{-1}$ ) as main plot resulted in maximum partial factor productivity of nitrogen , phosphorus and potassium (Table 30).The partial factor productivity of N,P and K recorded from main plot treatment $M_1$ was 36.75, 51.94 kg $kg^{-1}$ respectively.

Sub plot treatment $T_1$ ( 75:50:50 kg $ha^{-1}$) recorded the highest partial factor productivity of nitrogen , phosphorus and potassium of 44.26,66.39 and 66.39 respectively . Increase in fertilizer level from 75:50:50 kg $ha^{-1}$($T_1$) to 150:100:100 kg $ha^{-1}$($T_2$) declined the partial factor productivity of N,P and K at the rate of 41%. In the interaction between main plot and sub plot, significant variation in partial factor productivity of N, P and K was noticed and treatments $m_1t_1$ resulted in maximum partial factor productivity of nitrogen , phosphorus and potassium of 48.54, 72.81 and 72.81 kg $kg^{-1}$ respectively . Mavarkar ( 2016) reported that in baby corn treatments with NPK dose of 135:65:45 kg $ha^{-1}$ recorded higher PFP for potassium and lowest value was recorded by 100:40:60 kg NPK $ha^{-1}$

A significant difference in partial factor productivity of N,P,K was recorded between treatment and control. The partial factor productivity of N,P and K for control $C_1$ was 46.30,69.46 and 69.46 kg $kg^{-1}$ respectively. The reduction of values for the partial factor N,P,K index to higher nutrient rates may be due to the fact that a unit of imported nutrient formed lower production compared to the lower rates.

**5.8. 3 Physiological efficiency**

Physiological efficiency of nitrogen, phosphorus and potassium showed significant variation among mulches, fertilizers and interaction as presented in table 31

Mulching @30 t $ha^{-1}$ of mulch recorded the highest physiological efficiency of nitrogen, phosphorus and potassium of 45.37 , 708.83 and 36.58 kg $kg^{-1}$ .

In sub plot, fertilizer treatment of double the recommended dose recorded the highest physiological efficiency of nitrogen, phosphorus and potassium. In rice, yield increase $Kg^{-1}$ of N accumulated in rice plant was decreased with increasing N application Quanbao *et al.* (2007).

Among the interactions mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ ($m_1t_2$) recorded the highest physiological efficiency of nitrogen, phosphorus and potassium and it was on par with $m_1t_4$, $m_4t_2$, $m_4t_4$ and physiological efficiency of N and K . The physiological efficiency of phosphorus of the treatment combination $m_1t_2$ was on par with $m_3t_1$. Mavarkar ( 2016) reported that in baby corn treatments with NPK dose of 135:65:45 kg $ha^{-1}$ recorded higher physiological efficiency of phosphorus and least was observed with NPK dose of 100:40:60 kg $ha^{-1}$)

## 5.9 SOIL CHEMICAL ANALYSIS

Soils of the experimental plots before the experiment were in medium range of nitrogen and remained in medium range even after the experiment ( Table 32). The available soil N content ranged from 367.41 kg $ha^{-1}$ to 400.4 kg $ha^{-1}$ before the experiment and after the experiment the available soil N ranged from 410 to 484 kg $ha^{-1}$. Soil Phosphorus in the experimental plots were in medium range before and after the experiment. The available soil P content before the experiment ranged from 16.32 to 21.75 kg $ha^{-1}$ while it increased to the range of 73.2 to 115.1 in treated plots. The appreciable bulid up of available P after the experiment might be attributed to the influence of organic and inorganic nutrients in increasing the liable P in soil through complexing of cations like $Ca^{2+}$, $Mg^{2+}$ and the additional nutrients applied through organic and inorganic fertilizers. Potassium content of the soils were in low range and after the experiment only a slight increase in soil potassium content was noticed . The potassium content of the experimental site from before and after the experiment ranged from 105.86 to 120.35 kg $ha^{-1}$ and after the experiment it increased to the range of 130 to 156 kg $ha^{-1}$ . Mohankumar *et al.* (1973) reported that green leaf mulch was found to be efficient in increasing the contents of soil nutrients and the increased availability of NPK content for leaf mulch over other mulch materials was due to the nutrient addition by decomposition of leaf mulch.

## 5.10 PLANT NPK UPTAKE

Interaction of mulch and nutrients on uptake of N,P,K are presented in Fig 18

The plant NPK uptake differed significantly and mulching treatment of 30 t $ha^{-1}$ recorded the highest uptake of NPK on all periods. Priya and Shashidhara (2016) reported that nitrogen uptake was significantly influenced by mulching in maize and wheat( 0.5 kg $m^{-2}$ and 0.8 kg $m^{-2}$ respectively). Application of mulch during both kharif and rabi recorded significantly higher nitrogen, phosphorous and potassium uptake at harvest stage as compared to control . This was due to higher yield and higher soil nutrient status and also of higher biomass and decomposition of residue which resulted in higher availability of NPK and subsequently increased uptake of nutrients.

In sub plot , $T_2$ (150:100:100 kg $ha^{-1}$) treatment recorded the highest uptake of nitrogen, phosphorus and potassium and was significantly different from other treatments . Ajithkumar and Jayachandran (2001) reported that uptake of nitrogen, phosphorus and potassium were significantly increased with higher rate of application and higher uptake of nutrients under N 150 : 100: 100 kg $ha^{-1}$ of NPK was attributed to better availability of nutrients which reflected in better growth and rhizome yield. Singh and Singh (2007) have shown increased uptake of nutrients in ginger crop under Nagaland conditions with combined application of organic manures and inorganic fertilizers. Shaikh *et al.* (2010) reported that uptake of nitrogen, phosphorous and potassium was the highest with 75:50:50 kg $ha^{-1}$ + 25 t FYM $ha^{-1}$ followed by application of 50 % N through 75:50:50 kg/ha + 50 % N through poultry manure in ginger.

Among the interactions, mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ recorded the highest uptake of nitrogen, phosphorus and potassium. Treatment effects varied significantly with both control $C_1$ as well as $C_2$. For ginger crop, Nitrogen is the most critical among the major nutrients. Gowda *et al.,* (1998) reported that the yield could be increased by application 150:75:50 NPK kg $ha^{-1}$ under Bangalore conditions. The uptake of N,P and K in the leaf and pseudostem progressively increased upto 180$^{th}$ day and then decreased while the uptake in rhizome steadily increased until harvest. The higher application of mulch and double the dose of fertilizer recommendation (150:100:100 kg $ha^{-1}$) had increased the shoot

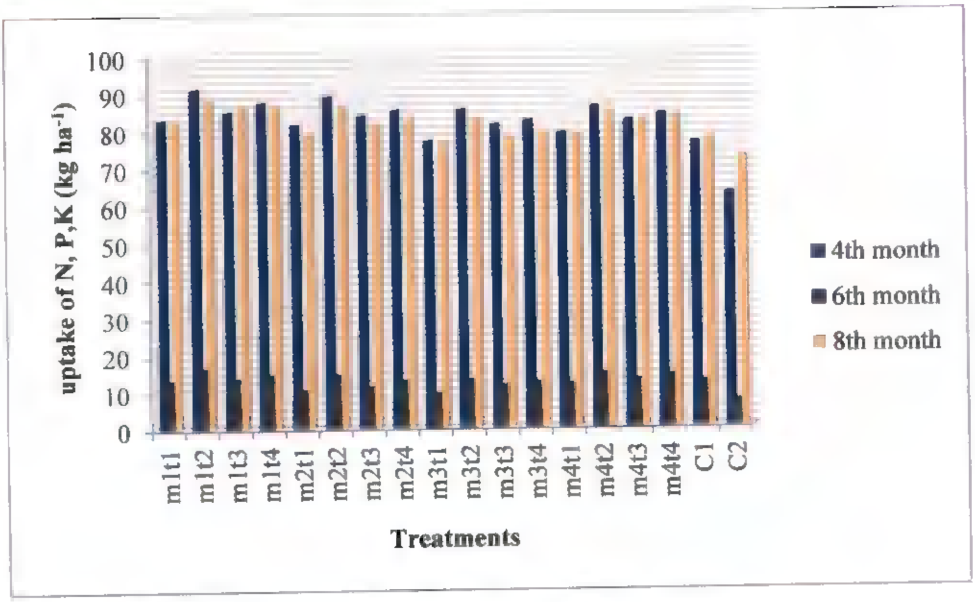


Fig 18 : Interaction effect of mulch and nutrients on uptake of N, P, K weight and rhizome weight due to the promoting effect of increased uptake of N,P and K. N supply increase the number of meristamatic cells and their growth leading to the formation of tillers in addition to leaf expansion and number (Lawlor, 2002). It also act as a key component of various amino acids, chlorophyll, coenzyme , enzymes, proteins, purines and pyrimidines (Lea and Guadry, 2001 ; Marschner, 2002) . N application is known to increase level of cytokinin which affects cell wall extensibility (Arnold *et al.*, 2006). The benefical effect of soil applied N as inorganic fertilizer corroborates with the findings of Haque *et al.*(2007) in ginger crop. In the present study the higher uptake of P and K apart from N might be due to the more availability occurred. The release of P and K as well as the higher addition might have helped on increasing uptake. The uptake of K by ginger ranged between 80 to 153 kg $ha^{-1}$ for varied rates of K application in Bangladesh and the optimum dose for maximizing ginger was found as 122 kg $ha^{-1}$. (Akhter *et al.*, 2013)

## 5.12 NUTRIENT BALANCE SHEET FOR NPK

The nutrient balance sheet for nitrogen revealed a higher uptake in the combination of mulches @ 30 t $ha^{-1}$ and double the dose of fertilizer ( Table 35) . The net loss of nitrogen was comparatively higher for all the combinations of 30 t $ha^{-1}$ ,while in the all fertilizer plots treated with plastic mulch a reduction in the net loss of nitrogen was observed . The maximum residual status of available nitrogen and potassium was observed in application of 100 per cent 120:60:60 kg NPK followed 50 per cent 120:60:60 kg NPK and lowest nutrient balance of nitrogen and potassium were in control treatment for sorghum (Gawai and Pawar, 2007).

The nutrient balance sheet prepared for phosphorus revealed that net loss was less for treatments with plastic mulches (Table 36). The net loss of P was minimum for absolute control. Among the treatments least net loss of P was for treatment combination plastic mulch and recommended dose of fertilizer as per KAU POP ($m_4t_1$).

The nutrient balance sheet prepared for potassium revealed that the net loss was less for combination of plastic mulch ( Table 37). The K added ranged from 230 kg ha-1 to 406 kg $ha^{-1}$ . Noor *et al.* ( 2014) reported an annual removal of 180 kg K $ha^{-1}$ in turmeric through harvested produce at the highest rate of K application of 160 kg K $ha^{-1}$ and also a negative K balance was observed even with balanced fertilization, implying the importance of K management in achieving sustainable yields and maintaining soil health. The nitrogen addition had increased the available N status of soil after the experiment. However, loss in Nitrogen was also noted .Nitrogen loss occur as ammonia ( $NH_3$) , nitrous oxide ($N_2O$) , dinitrogen ($N_2$) or in the form of nitrate ($NO_3$) leaching and run off .

In the case of Phosophorus , only a small proportion of the applied P is removed by the crop (Datta *et al* 1990). The initial soil Phosphorus ranged from 17.84 to 21.88 kg $ha^{-1}$ and the addition ranged from 173kg $ha^{-1}$ to 115.10 kg $ha^{-1}$ in the treatments thus showing that increasing levels of fertilizer application increased the available Phosphorus content of soils.

The potassium content in the soil is of low status and ranged from 106.89 to 115.20 kg $ha^{-1}$ while K addition ranged from 230 to 406 kg $ha^{-1}$ . The uptake of treatments ranged from 76.22 to 88.33 kg $ha^{-1}$ .The net loss was noticed in the soil and the magnitude of negative K balance ranged from 140.43 to 271.88 kg $ha^{-1}$. Considering the treatment with least loss of N,P and K , combinations of plastic mulch with treatments can be considered an alternative for ginger cultivation.

5.13 BENEFIT COST ANALYSIS

The treatment of 30 t $ha^{-1}$ of mulches applied in two split doses with a fertiliser dose of 150: 100: 100 kg of NPK $ha^{-1}$ ($m_1t_2$) along with 30 t $ha^{-1}$ of FYM generated a higher net profit compared to all other treatment and had a BC ratio of 1.87 ( Table 38) . The cost of cultivation was more for all the combinations ($m_4t_1$, $m_4t_2$, $m_4t_3$,$m_4t_4$)

which used plastic mulch. All the treatment combinations except the combination of plastic mulch and fertilizer dose of 75:50:50 kg ha$^{-1}$ ($m_1t_1$) resulted in higher BC ratio than control $C_1$ which the crop was raised as direct sowing of rhizomes and nutrients applied as per recommended package of practises of KAU. Nath and Karla (2000) calculated economics of ginger and found maximum net profit and cost benefit ratio of ginger with application of 100:50:50 kg ha$^{-1}$ NPK along with biofertilizers. There was a significant increase in net return and B: C ratio with each increase in mulch level and the maximum net return and B: C ratio were obtained with 9.38 t ha$^{-1}$ mulch, significantly higher than mulch application at 6.25 t ha$^{-1}$ and no mulch (Manhas,2011). The economic evaluation of different treatments showed that cost of cultivation was maximum with polyethylene mulch whereas highest total income, net return and input : output ratio were obtained with application of *palas* leaves and concluded that use of mulching material in ginger is beneficial with regard to yield as well as economics as compared to no mulch (Kushwah *et al* .,2013) . In a study on traditional ecological knowledge adaption practice in ginger, bio mulching using oak leaves increases yield by 43% and net returns by 61% compared to no mulching as reported by Singh *et al.* (2014). As revealed from the present study raising ginger plants in portray and transplanting with the application of 30 t of FYM ha$^{-1}$ and 30 t ha$^{-1}$ of mulch with the fertilizer dose of 150:100:100 kg ha$^{-1}$ increased net returns to nearly 36.67% over the conventional method of raising ginger plants with the recommended package of practice of KAU.

# *SUMMARY*

# 6. SUMMARY

An experiment was undertaken at the Instructional Farm, College of Agriculture, Vellayani during April 2016 to January 2017. The ginger variety used for the study was Karthika. Field experiment was laid out in split plot design with four levels of mulches ($M_1$, $M_2$, $M_3$, $M_4$) in main plots and fertilizer levels in sub plots with four replication. The levels of mulches included organic mulches @ 30, 15, and 7.5 t ha $^{-1}$ ($M_1$ , $M_2$, $M_3$ respectively ) and plastic mulch ( $M_4$). For $M_1$ and $M_2$, half the quantity of organic mulch was applied at the time of transplanting and the remaining at two months after transplanting (MAT). For $M_3$, full quantity of mulch was applied at the time of transplanting. The sub plot treatments were $T_1$ (75:50:50 kg of NPK ha$^{-1}$) ,$T_2$ (150: 100: 100 kg ha$^{-1}$) ,$T_3$ ($T_1$ + foliar application of 19:19:19 @ 0.5% applied at 1, 3, 4 MAT and $T_4$ (100:75:75 kg ha$^{-1}$ + foliar application of 19:19:19 @ 0.5% applied at 1, 3, 4 MAT). For all treatments except $C_2$ , half N, full P and half K were applied at the time of transplanting and remaining half N, half K applied at two MAT . Two control plots, one with ginger rhizomes planted with recommended nutrient level as per KAU POP ($C_1$) and other absolute control ($C_2$) was also included. Except for the treatment $C_1$ for all other treatments two noded rhizome bits of ginger cultivar was raised in protrays filled with *Trichoderma* enriched coir pith compost and FYM in the ratio 2:1 and were transplanted at 1 ½ - 2 months age in beds taken in the interspaces of coconut. FYM @ 30 t ha$^{-1}$ was applied uniformly to all plots except absolute control. The study was planned to evaluate the efficacy of different levels of mulch and nutrients on the growth, yield, quality and profitability of ginger transplants intercropped in coconut garden. The salient findings are summarised below:-

Plants that received 30 t ha$^{-1}$ of mulch resulted in significantly superior parameters like plant height, number of leaves per plant , number of tillers per plant, shoot weight in all growth periods . Double the recommended dose of fertilizer (150:100:100 kg ha $^{-1}$ ) produced significantly higher plant height, number of leaves per plant , number of tillers per plant, shoot weight compared to other fertilizer levels on all periods of observation . Combination of mulches @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg /ha resulted in producing significantly higher plant height, number of leaves per plant , number of tillers per plant, shoot weight compared to other fertilizer levels on all periods of observation Significant difference was noticed between treatment and controls ($C_1$ & $C_2$) in all periods of growth and also observed significant difference between the controls.

Root characters like root length, root weight and root volume differed significantly between mulches on all periods of observation. Root length of 32.24 cm, root dry weight of 1.17 g $plant^{-1}$ and root volume of 114.20 $cm^3$ $plant^{-1}$ was recorded at 8 month of planting from the plants treated with 30 t $ha^{-1}$ of mulch. Double dose of recommended fertilizer as per KAU POP ($T_2$) recorded highest root characters on all periods of observation. In interaction, combination of mulches @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ resulted in significantly higher root length, root weight and root volume on all periods of observation except for root weight at 6th month and root volume at 8th month where it was on par with $m_1t_4$. The treatments were significantly different from both the controls and there was significant difference between the controls as well. The root shoot ratio was significantly affected by mulch on 4th and 6th months while at different fertilizer levels influenced the root shoot ratio only at 6th. However the interaction of mulches and fertilizers significantly affected root shoot ratio on all periods of observation.

Mulching @ 30 t $ha^{-1}$ recorded highest fresh yield on all periods and obtained 18093.53 kg $ha^{-1}$ at final harvest. Second best treatment was obtained from plots treated with plastic mulch which recorded 17567.25 kg $ha^{-1}$. In subplot, treatments were significant throughout the periods of observation and treatment ($T_2$) 150:100:100 kg $ha^{-1}$ recorded highest fresh yield on all periods and obtained 17855.03 kg $ha^{-1}$ and lowest in 75:50:50 kg $ha^{-1}$ ($T_1$) (16746.15 kg $ha^{-1}$) .Combination of mulches @ 30 t $ha^{-1}$ and double the recommended dose of fertilizer as per KAU POP

($m_1t_2$) resulted in significantly higher yield on all periods of observation and recorded 18644.40 kg $ha^{-1}$ followed by mulching @ 30 t $ha^{-1}$ and fertilizer dose of 100:75:75 kg ha $^{-1}$ and foliar application of 19:19:19 @ 0.5% (18138.60 kg $ha^{-1}$) which was on par with combination of plastic mulch and double the dose of fertilizer (18135.30 kg $ha^{-1}$). A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ and $C_2$ also showed a significant difference between them.

Significant difference in dry yield of ginger was noted due to different mulches, fertilizers and their interactions. The treatment of mulching @ 30 t $ha^{-1}$ recorded highest dry yield on all periods and obtained 3828.15 kg $ha^{-1}$ in harvest followed by plots treated with plastic mulch (3564.38t $ha^{-1}$). In subplot, treatments showed significant difference throughout the periods of observation and treatment $T_2$ (150:100:100 kg $ha^{-1}$) recorded highest dry yield on all periods and obtained 3911.10 kg $ha^{-1}$ on harvest . Combination of mulches @ 30 t $ha^{-1}$ and double the recommended dose of fertilizer as per KAU POP resulted in significantly higher dry yield on all periods of observation and recorded 4316.10 kg $ha^{-1}$ at harvest followed by mulching @30 t $ha^{-1}$ and fertilizer dose of 100:75:75 kg ha $^{-1}$ and foliar application of 19:19:19 @ 0.5% ( 3842.10 kg $ha^{-1}$ ) which was on par with plastic mulch and fertilizer treatment 150:100:100 kg $ha^{-1}$ (3881.80 kg $ha^{-1}$). A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ and $C_2$ showed a significant difference between them.

Harvest index and dry recovery was significantly influenced by main plots, sub plots and their interaction on all periods of observation. Plots treated with 30 t $ha^{-1}$ of mulch retained significantly higher harvest index and dry recovery in all periods. Fertilizer treatment of ($T_2$) 150:100:100 kg $ha^{-1}$ recorded highest harvest index and dry recovery . The combination of mulches @ 30 t ha $^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ resulted in superior harvest index and dry recovery in all periods of observation . The dry recovery recorded by the treatment varied significantly from the control on all periods of growth . The comparison of $C_1$ as well as $C_2$ with the treatments also indicated significant difference in the harvest index and dry recovery at all periods of growth. A significant difference was noticed between the control $C_1$ as well as $C_2$ .

Rhizome characters like rhizome thickness and rhizome spread were significantly influenced by different mulches, fertilizers and their interaction at $4^{th}$ , $6^{th}$ and at harvest. Mulching @ 30 t $ha^{-1}$ recorded highest rhizome thickness of 1.69 cm and rhizome spread 13.31cm for rhizome spread at harvest. Fertilizer treatment $T_2$ recorded highest rhizome characters on all periods of observation and was significantly different from other treatments throughout the periods of observation. In interaction the combination of mulches @ 30 t $ha^{-1}$ and double the recommended dose of fertilizer as per package of practices of KAU resulted in significantly higher rhizome thickness (1.79 cm) and was on par with $m_1t_4$. The rhizome spread of $m_1t_2$ was on par with $m_1t_3$ at harvest and were 14.30 cm and 14.23 cm respectively. The treatments were significantly different from both the controls and there was significant difference between the control as well.

Quality parameters like starch, fibre, oil and non volatile oil were significantly influenced by mulches, fertilizer levels and their interaction at $4^{th}$ month $6^{th}$ month and at harvest. Mulching with 30 t $ha^{-1}$ resulted in significantly higher starch , fibre, oil and NVEE at harvest while starch content at harvest was on par with plastic mulch. Fertilizer treatment of 150:100:100 kg $ha^{-1}$ produced significantly higher starch, fibre, NVEE and oil in all periods of observation while oil was on par with $T_4$ at harvest. Combination of mulches @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ resulted in significantly higher starch, fibre, oil and NVEE in all periods of observation. A significant difference was observed between the treatments and the control with respect to quality on all periods of growth. The comparison of $C_1$ and $C_2$ also showed a significant difference in the quality parameters.

Physiological parameters like dry matter production, net assimilation rate and leaf area index , leaf area duration and RGR were significantly affected by mulches, fertilizers and their interaction on all periods of observation. Crop growth rate, bulking rate and relative growth rate was significantly affected by mulches during the period from $6^{th}$ to $8^{th}$ month, fertilizer levels significantly influenced the CGR at $4^{th}$ to $6^{th}$ month while RGR at $6^{th}$ to $8^{th}$ month . The interaction significantly influenced the RGR and bulking rate at both periods of observation. Treatment 150:100:100 kg $ha^{-1}$ recorded highest dry matter production, net assimilation rate, leaf area index, leaf area duration, chlorophyll content on all periods . Among interaction combination of mulches @ 30 t $ha^{-1}$ and double the recommended dose of fertilizer as per package of practices of KAU obtained highest dry matter production net assimilation rate, leaf area index, leaf area duration, chlorophyll content , relative growth rate and bulking rate on all periods of observation . A significant difference was observed between the treatments and the control for DMP, LAI and LAD on all periods of observation while NAR, CGR,RGR and bulking rate were significant at both levels.

Weed count and dry weight of weed recorded at $45^{th}$ , $90^{th}$ day and $120^{th}$ day showed significant variation with respect to mulches, fertilizers and their interaction. Mulching @ 7.5 t $ha^{-1}$ produced highest weed count and dry weight of weed in all periods of observation . Fertilizer treatment of 150:100:100 kg $ha^{-1}$ was significantly higher for weed count and dry weight of weed in all periods of observation . Combination of mulches @ 7.5 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ resulted in highest weed count and dry weight of weed in all periods of observation. A significant difference was observed between the treatments and the control on all periods of growth. The comparison of $C_1$ and $C_2$ also showed a significant difference between them.

Agronomic efficiency, Physiological efficiency and Partial factor productivity of Nitrogen, Phosphorus, Potassium were significantly influenced by mulches, fertilizers and their interaction. Significantly higher agronomic efficiency, partial factor productivity and physiological efficiency of N,P and K was recorded with application of mulches @ 30 t $ha^{-1}$. Double the recommended dose of fertilizer resulted in significantly higher agronomic efficiency and physiological efficiency of Nitrogen, Phosphorus and Potassium. Partial factor productivity of N,P and K was significantly higher for fertilizer application of 75:50:50 kg $ha^{-1}$. Treatment combination mulches @30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ noted significantly higher agronomic efficiency and physiological efficiency for Nitrogen, Phosphorus and Potassium . A significant difference in agronomic efficiency, partial factor productivity and physiological efficiency of N, P and K was observed between the treatments and the control, $C_1$ .

Soils of the experimental plots before the experiment were in medium range of nitrogen and remains in medium range even after the experiment . Phosphorus range of soils in the experimental plots were in medium range and after the experiment, there was increase in phosphorus content of the soil. Potassium content of the soils were in low range and after the experiment only a slight increase in soil potassium content was noticed . The NPK content of organic mulch used was 0.5 %, 0.4% and 0.42 % respectively. The FYM applied contained 0.5% N, 0.4% P and 0.64% K.

The uptake of N,P and K was significantly influenced by mulches , fertilizer levels and their interaction. Mulches @ 30 t $ha^{-1}$ significantly increased the uptake of N,P and K compared to other mulches. Double the dose of recommended fertilizer treatment recorded highest uptake of nitrogen, phosphorus and potassium and was significantly different from other treatments. Among the interaction mulching @ 30 t $ha^{-1}$ and fertilizer dose of 150:100:100 kg $ha^{-1}$ recorded significantly higher uptake of nitrogen, phosphorus and potassium. Treatment effects varied significantly from control $C_1$ as well as $C_2$. A significant difference in the uptake of N, P and K was noticed between the control $C_1$ and $C_2$ as well .

The nutrient balance sheet analyzed revealed a higher uptake for $m_1t_2$ followed by $m_2t_2$ however the net loss of nitrogen was comparatively higher for all the combinations of $m_1$, while in the all fertilizer plots treated with plastic mulch a reduction in the net loss of nitrogen was observed. The nutrient balance sheet prepared for phosphorus revealed that net loss was less for treatments with plastic mulches. The net loss of P was minimum for absolute control. The combination of plastic mulch with fertilizer dose of 75:50:50 kg ha $^{-1}$ recorded least net loss of P (-110.03kg ha$^{-1}$) .The nutrient balance sheet prepared for potassium revealed that net loss was less for combination of plastic mulch . The K added ranged from 230 kg ha-1 to 406 kg ha$^{-1}$ . The plant uptake of K ranged from 62.25 in absolute control to 88.33kg ha-1 in combination of mulches @30 t ha$^{-1}$ and fertilizer dose of 150:100:100 kg ha$^{-1}$.

There was no pest incidence in the field however leaf spot was noticed in few plants one month after transplanting which could be controlled by a single dose of mancozeb @ 0.3 per cent.

The treatment of 30 t ha$^{-1}$ of mulches applied in two split doses with a fertiliser dose of 150: 100: 100 kg of NPK per hectare along with 30 t ha$^{-1}$ of FYM generated a higher net profit compared to all other treatment . The cost of cultivation was more for all the combinations where plastic mulch was used.

From the present study , it was observed that mulching @ 30 t ha$^{-1}$ a fertilizer dose of 150: 100: 100 kg ha$^{-1}$ was found to be superior in improving yield and quality parameters of ginger transplants intercropped in coconut garden and thus improve economic returns.

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# STANDARDISATION OF AGRO TECHNIQUES FOR TRANSPLANTED GINGER ( *Zingiber officinale* Rosc.)

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**ABSTRACT**

The efficacy of different levels of mulch and nutrients on the growth, yield, quality and profitability of ginger transplants intercropped in coconut garden was evaluated at the Instructional Farm, College of Agriculture, Vellayani during April 2016 to January 2017 . The ginger variety used was Karthika. Field experiment was laid out in split plot design with four levels of mulches ($M_1$, $M_2$, $M_3$, $M_4$ ) in main plots and fertilizer levels in sub plots with four replication. The levels of mulches included organic mulches @ 30, 15, and 7.5 t ha $^{-1}$ ( $M_1$ ,$M_2$, $M_3$ respectively ) and plastic mulch ( $M_4$). For $M_1$ and $M_2$, half the quantity of organic mulch was applied at the time of transplanting and the remaining at two months after transplanting (MAT). For $M_3$, full quantity of mulch was applied at the time of transplanting .The sub plot treatments were $T_1$ (75:50:50 kg of NPK ha$^{-1}$) ,$T_2$ (150: 100: 100 kg ha$^{-1}$) ,$T_3$ ($T_1$ + foliar application of 19:19:19 @ 0.5% applied at 1, 3, 4 MAT and $T_4$ (100:75:75 kg ha$^{-1}$ + foliar application of 19:19:19 @ 0.5% applied at 1, 3, 4 MAT). For all treatments except $C_2$ , half N, full P and half K were applied at the time of transplanting and remaining half N, half K applied at two MAT . Two control plots, one with ginger rhizomes planted with recommended nutrient level as per KAU POP ($C_1$) and other absolute control ($C_2$) was also included.

Two nodded rhizome bits of ginger cultivar was raised in protrays filled with *Trichoderma* enriched coir pith compost and FYM in the ratio 2:1 for treatments except $C_1$, and were transplanted at 1 ½ - 2 months age in beds taken in the interspaces of coconut. FYM @ 30 t ha$^{-1}$ was applied uniformly to all plots except absolute control. The result revealed that growth parameters like plant height, number of leaves per plant , shoot weight, dry matter production , net assimilation rate , leaf area index, leaf area duration were significantly higher for mulch, $M_1$ ( 30t ha$^{-1}$ ) and fertilizer dose , $T_2$ ( 150: 100: 100 kg ha$^{-1}$ NPK ) . The yield attributes like fresh yield , dry yield , harvest index, dry recovery, rhizome thickness, rhizome spread were significantly higher for $M_1$ and $T_2$. Considering the treatment interaction

increased growth , yield character , uptake of N,P,K , agronomic efficiency of N,P,K were observed with mulching @ 30 t $ha^{-1}$ along with a fertilizer dose of 150: 100: 100 kg $ha^{-1}$ NPK ($m_1t_2$).

The quality parameters of ginger rhizome at harvest viz., starch, oil, fibre, Non Volatile Ether Extract (NVEE) were higher for $M_1$ while for starch and NVEE it was on par with $M_4$. Starch, volatile oil, NVEE and fibre were more for $T_2$ while the volatile oil content in $T_2$ was on par with $T_4$ at the time of harvest . Among combinations $m_1t_2$ (mulching @ 30 t $ha^{-1}$ with 150: 100: 100 kg $ha^{-1}$ NPK) significantly increased starch, fibre, oil and NVEE on all stages of observation.

The weed count and weed dry weight were significantly low in treatments with plastic mulch . Nutrient balance sheet studies revealed the significance of plastic mulch in reducing the net loss of nutrients . The treatment combination, $m_1t_2$ registered higher net profit and B:C ratio.

The results of the study indicated that of ginger transplants intercropped in coconut garden, that mulching @ 30 t $ha^{-1}$( half at transplanting and half 2 MAT) along with 150:100:100 kg NPK $ha^{-1}$ and basal application of 30 t $ha^{-1}$ of farm yard manure could be recommended for higher yield, quality and profit. It also resulted in 24 per cent increase in dry ginger yield over the conventional method of planting and nutrient application .

# *APPENDICES*

## APPENDIX I

Average input cost and market price of produce

| SL No. | Items | Cost |
|---|---|---|
| | INPUTS | |
| **A.** | **Labour charge** | |
| 1. | Men and women | Rs 650/- |
| **B.** | **Cost of seeds** | |
| 1. | Seed ginger | Rs 100 per kg |
| **C.** | **Cost of manures and fertilizers** | |
| 1. | Farm yard manure | Rs 5 per kg |
| 2. | Leaves | Rs 1 per kg |
| 3. | *Trichoderma* | Rs 80 per kg |
| 4. | *Pseuodomonas* | Rs 100 per kg |
| 5. | Urea | Rs 7 per kg |
| 6. | Rock phosphate | Rs 14 per kg |
| 7. | Murate of potash | Rs 15 Per kg |
| 8. | 19:19:19 | Rs 20 per kg |
| **D.** | **Cost of other items** | |
| 1. | Protrays | Rs 30 per tray |
| 2. | Coirpith block | Rs 12 per block |
| 3. | Plastic sheet for mulching | Rs 12 per $m^2$ |
| | **OUTPUT** | |
| | Market price for fesh ginger | Rs 50 per kg of fresh ginger |