MULCHING FOR SOIL QUALITY, CLIMATE STRESS MITIGATION AND CROP PRODUCTIVITY IN OKRA

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THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Mulching for soil quality, climate stress mitigation and crop productivity in Okra"**is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed for the award to me any degree, diploma, fellowship or other similar title, of any other University or Society.

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2

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3

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Dedicated to my beloved guide & my family

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CONTENTS

9

LIST OF TABLES

10

LIST OF FIGURES

12

LIST OF PLATES

LIST OF APPENDICES

13

LIST OF ABBREVIATIONS

%	- Percent
@	- At the rate of
°C	- Degree Celsius
B: C	- Benefit cost ratio
Cfu	- Colony forming unit
DAS	- Days after sowing
dSm^{-1}	- Deci siemen per meter
EC	- Electrical conductivity
FYM	- Farm Yard Manure
et al	- And others
i.e	- That is
IPCC	- Inter-governmental Panel on Climate Change
K	- Potassium
kg	- Kilogram
kg ha^{-1}	- Kilogram per hectare
N	- Nitrogen
P	- Phosphorus
RBD	- Randomized Block Design
SOC	- Soil Organic Carbon
SOM	- Soil Organic Matter
WAS	- Weeks After Sowing
WMO	- World Meteorological Organization

15

INTRODUCTION

CHAPTER 1

INTRODUCTION

Global warming and climate change is the major concern of mankind in the 21st century. Under changing climatic scenarios crop failures, reduction in yields, reduction in quality and increasing pest and disease problems are common and they render the cultivation unprofitable. Global simulation studies indicated that between 2080 and 2100, temperature increase may lead to 10-40% loss in crop production in India (IPCC, 2007).

The increased atmospheric concentration of carbon dioxide will influence the soil temperature, pattern of precipitation and evaporation and will make resultant changes in the physiochemical and biological properties of soil. The direct effect of increased levels of carbon dioxide is generally beneficial to vegetation though there may have a range of negative or positive impacts depending on complex interactions among managed and un managed systems (Long *et al.*, 2006).

Mulching is one of the management practices to conserve soil moisture, prevent soil degradation, and protect crops from heavy rains, high temperatures and flooding. Plastic sheets, crop residues, newspaper, coir pith etc. are common mulching materials used to reduce evaporation and to moderate wide fluctuations in diurnal soil temperature, especially in the root zone environment. Mulching helps to increase the soil moisture status, regulate the temperature in the upper layer of soil, suppress the growth of weeds and pathogens which in turn will improve the growth and yield of crops (Solaiappan *et al.*, 1999). This will also help to save 20-25% of irrigation water.

Use of organic materials as mulch can improve the soil properties and thereby fertility. Rice straw, which is abundant in rice growing areas of the tropics, is generally recommended for summer crops. Mulching improved the growth of eggplant, okra, bottle gourd, ridge gourd and sponge gourd compared to 16 the non-mulched plots under diverse climatic conditions of India (Pandita and Singh, 1992).

Okra [*Abelmoschus esculentus* (L.) Moench] is an annual vegetable crop in the tropical and sub-tropical parts of the world. It is one of the important nutritious vegetable crops grown round the year. Dried fruit contains 12 to 22% edible oil and 20 to 22% protein and is used for refined edible oil. It is widely cultivated and used in Kerala. The study on weed management in okra revealed that organic mulches viz. mango leaves and newspaper were effective for managing weeds (Faras, 2015). Very few studies have been conducted regarding the effect of mulching on soil quality and crop productivity.

Hence the study on "Mulching for soil quality, climate stress mitigation and crop productivity in okra" was undertaken to evaluate the effect of different mulches on soil characters, soil micro climate and crop productivity in Okra.

17

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITREATURE

The review of literature pertaining to the study on “Mulching for soil quality, climate stress mitigation and crop productivity in okra” is presented below.

2.1Effect of climate change on vegetable production

Climate change is predicted to cause an increase in average air temperature of between 1.4°C and 5.8°C, increase in atmospheric CO_2 concentration, and significant changes in rainfall pattern (Houghton *et al.*, 2001).Globally averaged surface temperature is expected to rise by 1.1°C - 6.4°C by the last decade of the 21st century (Minaxi *et al.*, 2011).

The mean annual temperature of India is increased by 0.46°C over a period of last 111 years since 1901 (24.23°C) to 2012 (24.69°C) (Data Portal India, 2013). Global combined surface temperatures over land and sea have been increased from13.68°C in 1881-90 to 14.47°C in 2001-10 (WMO, 2013).

Vegetables are high value crops in terms of total calorific production, nutritional security, export market and food consumption. The reduction in economic yield of vegetables has been reported to be 59-90 per cent in okra, 60-70 percent in chilli, 42-71 per cent in tomato, 60-82 per cent in potato, 70-80 per cent in carrot, 67 per cent in onion, 61 per cent in cauliflower, 60 per cent in cabbage, 70 per cent in sugar beet, 43 per cent in cucumber, 60 per cent in garlic, 70 per cent in french-bean, 30-95 per cent in beet root and 40 to 70 per cent in peas (Singh *et al.*, 1978; Singh *et al.*, 1982; Sharma *et al.*, 1983; Singh *et al.*, 1984; Singh, 2002; Rana *et al.*, 2011).

The prevalence of drought conditions adversely affects the germination of seeds in vegetable crops like onion and okra and sprouting of tubers in potato

(Arora *et al.*, 1987).In okra, high temperature causes poor germination of seeds during spring and summer seasons. Flower drop in okra is recorded at higher temperature above 42°C (Dhankhar and Mishra, 2001) whereas flower abscission and ovule abortion in french bean occurs at temperature above 35°C (Prabhakara *et al.*, 2001). Flynn *et al.*(2002) found higher seed germination percentage (90%) in chilli at 20°C and complete inhibition at 10°C indicating that fall in minimum temperature affects the seed germination in chilli.

Warm humid climate increases the vegetative growth and results in poor production of female flowers in cucurbitaceous vegetables like ash gourd, bottle gourd and pumpkin which causes low yield (Singh, 2010).The temperature fluctuations delay the ripening of fruits and reduce the sweetness in melons. Low moisture content in the soil affects the fruit quality and development of fruits in melons and gourds (Arora *et al.*, 1987).

Environmental stress is the primary cause of crop losses worldwide reducing the average yields of major crops by more than 50% (Bray *et al.,* 2000).In pepper, exposure to high temperature at post-pollination stage inhibits fruit set(Erickson and Markhart, 2002).

Climate change can affect the yield of crops through weather induced changes in incidence of pests (Cammel and Knight, 1992), diseases (Fand *et al.*, 2012) and requirement of water and nutrients (Panda *et al.*, 2003).

Yamamura and Kiritani (1998) found that the activity and population of sucking pests such as aphids, white flies and thrips increases with increase in temperature. Relative humidity and CO_2 can potentially affect the pest and disease occurrence (Hamilton *et al.*, 2005). According to Das *et al.*(2011),elevated CO_2 may increase the canopy size and density in C_3 plants, resulting in a greater biomass with a much higher microclimate.

According to Schneider *et al.,* (2001), vulnerability of any system to climate change is the degree to which these systems are susceptible and unable to survive with the adverse impacts of climate change. Climate change affects the water storage and availability of water for irrigation. Since the availability of water is limited, drought will become the major stress factor to vegetable production, further stressing farming systems (Verchot *et al.*, 2007).

2.2 Climate change vs soil properties

According to Piment (2006), climate change has the potential to threaten food security through its effects on soil properties and processes (Brevik, 2013).Carney *et al.* (2007) observed that soil organic C levels were declining under increased atmospheric CO_2 levels due to increased microbial activity. Therefore, elevated CO_2 levels will not necessarily lead to increased soil C sequestration, but may instead result in more C turn over (Eglin *et al.*, 2011).

Global climate change may induce accelerated soil organic matter decomposition through increased soil temperature and other important changes, which collectively influence the C balance in soils. Soil C decomposition is sensitive to changes in temperature, and even small increase in temperature may prompt large releases of C from soils (Conant *et al.*, 2008).

Garcia-Fayos and Bochet (2009), found strong correlations between climate change and soil erosion and negative impacts on aggregate stability, bulk density, water holding capacity, pH, organic matter content, total N, and soluble P in the soil, all properties important for good crop growth . Therefore, it can be stated that if climate change increases soil erosion, it will also damage soil properties that are important in the production of food and fiber resources needed for human beings. Li *et al.* (2010) found that elevated atmospheric CO_2 concentrations may lead to increased uptake of Cd in rice.

21

2.3 Mulching

According to Jacks *et al.* (1955), the word 'mulch' is believed to be derived from the German word "molsch", meaning soft to decay, apparently referring to the use of straw and leaves by gardeners as a spread over the ground.

Olasantan (1985) observed that mulching significantly increased vegetative growth and yield components of tomato plants. Zaag *et al.*, (1986) noticed reduction of weed seed germination, weed growth and overall control of weeds due to mulching. Mulched plants grew taller and had more branches and a greater number and weight of fruits (Kundu *et al.*,2006). Goswami and Saha (2006) opined that mulched crops recorded better yield than un- mulched crops.

Derwerken and Wilcox (1988) opined that mulching can effectively minimize water vapour loss, soil erosion, weed problems and nutrient loss. When mulches were applied to the crops, the weed growth was checked and the soil moisture loss through evaporation was arrested (Liu *et al.*, 1989).

Kumar *et al.* (1990) found that mulching reduced the deterioration of soil by way of preventing runoff and soil loss, minimized weed infestation and reduced evaporation. Thus it facilitated more retention of soil moisture and helped to control the temperature fluctuations, improved physical, chemical and biological properties of soil and ultimately enhanced the growth and yield of crops.

According to Pramanik *et al.*, (2002), mulching could increase 65.7 per cent water use efficiency in okra. Sunilkumar and Jaikumaran (2002) observed that mulching in okra recorded higher fruit set and yield over unmulched crop.

Mulches modified the micro environment of crop depending on the type of mulch, management practices and environmental conditions; however in general, organic mulches resulted in higher moisture retention than bare soil (Munn,1992; Johnson *et al.*, 2004).

2.3.1 Organic mulching

Gupta and Gupta (1987), reported that light and frequent irrigation to sandy loam soil, along with straw mulch reduced the soil temperature by 2 - 7°C and increased the availability of water and nitrogen. Mulching with wheat and oats straw was efficient in controlling weeds in cucurbits and improve crop quality (Sheriff *et al.*, 1998).

In ragi, coir pith mulch @ 10 t ha^{-1} and sugar cane trash mulch @ 12 t ha^{-1} was applied to the soil surface to form a layer of 2 cm thickness of coir pith and 10 cm thickness of sugarcane trash. It significantly increased the water use efficiency, plant height and dry matter production (Nagarajan and Wahab, 2001).

Sannigrahi and Borah (2002), noticed 67% increase in yield and yield attributes by mulching with water hyacinth. According to Uwah *et al.*, (2012) organic mulches @ 4 t/ha with poultry manure @ 10 t/ha increased the fresh pod yield of okra. Olabode *et al.*, (2007) observed that mulching with *Panicum maximum* in okra contributed larger leaves and stems as well as higher number of leaves. Yield by grass mulching was about 6.7 t/ha and the plants were significantly taller.

Straw mulching increased the soil organic carbon and decreased the bulk density (Mupangwa *et al.*, 2013). The presence of straw mulch on the soil surface reduced the maximum temperature and increased the minimum diurnal soil temperature. Mulching with straw increased the concentration of available nitrogen and phosphorus in soil surface and improved the water use efficiency in alfalfa (Jun *et al.*, 2014).

2.3.2 Paper mulching

According to Smith (1931), paper mulches have been used for fruit and vegetable production. Asphalt-impregnated paper mulches were efficiently used in pineapple fields in 1920s for increasing the yield and quality. Kostewicz and

Stephens (1994), reported that mulching with newspaper gave larger sized heads in cabbage compared to hand weeded plots.

Runham *et al.*, (2000) observed higher moisture content under rainfed conditions where paper mulch was incorporated in soil after the harvest of crop. Application of pesticide along with biodegradable paper mulch resulted better control of soil nematodes and fungi in okra compared to pesticide application alone (Johnson *et al.*, 1997).

Shogren (2000), investigated that newspaper mulches represent an easily available and cost effective resource and it has added advantages over plastic mulches as it is bio degradable. Mulching with paper eliminates disposal concerns associated with plastic mulches (Brault *et al.*, 2002). Compared to straw, paper mulch is free of weeds (Munn, 1992).According to USDA (2007), newspaper and other papers were used in organic production excluding sheets with glossy or coloured inks. This will help to limit the amount of paper deposited in landfills (Anderson *et al.*, 1995).

2.3.3 Plastic mulching

Aranjo De *et al.*, (1992) observed that mulching with red or black polythene sheet has extended the harvesting of cucumber by seven days. Plastic mulching increased the total yield of water melon (Jimenez *et al.*, 2006).

According to Hemphill (1993) the disposal options of plastic mulches are limited. Plastic mulches are illegally disposed, burnt or used for land-filling. Since plastic mulching increases soil temperature, it cannot be used in high temperature regions.

The benefits of plastic mulches include higher yield, early harvest, improved weed control and increased water and fertilizer use efficiency (Lamont,1993). Incalcattera and Vetrane (2000) reported that mulching with polythene sheet had significant positive effects on soil temperature, seed germination, fruit production and plant growth pattern.

Black or non light transmitting plastic is preferred for the elimination of light requirement necessary for weed germination and growth. Black pigments in mulches reduce light transmission, restricting photosynthesis and hence the weed growth. Recommended thickness for plastic mulches for seasonal crops is 20 – 25 micron (NCPAH, 2011).Weed growth has been significantly controlled by plastic mulching. But many of the monocotyledonous plants in the field grew in soil under clear plastic (Beckford *et al*., 1997).

Ali *et al*. (2001) found that incidence of mosaic disease in okra was reduced and quality and yield of fruit were increased by the application of plastic mulch. Higher yield attributing characters and weed control (83.5%) were also reported in okra and tomato with black polythene mulch (Sannigrahi and Borah, 2002; Birbal *et al*., 2013).

According to Mahadeen (2004), polythene mulch had significant positive effect on yield of okra. Saikia *et al*., (1997) noticed that black low density polythene film enhanced the growth, weed control efficiency and yield (22.3 t/ha) compared to unmulched control (3.1 t/ha). These sheets maintained higher moisture and temperature regimes in the soil. Mulching with black polythene film increased the plant height and pod yield by 29.65% over unmulched control (Patel and Patel, 2011).

According to Gopalakrishnan (2007), mulching with black polythene sheet is very effective in controlling weed growth in vegetables. Effective weed suppression in pumpkin and guard was obtained by the adoption of plastic mulching (Kelley and Mcdonald, 2008).

At present, in arid and semi arid regions, application of black plastic mulch film is becoming popular and very good results have been achieved (Bhardwaj *et al*., 2011). Polythene mulches are widely used for vegetable production as they improve earliness and crop yield through increased temperature, reduced evaporation from soil, reduced weed population and improved produce quality (Lamont, 2005).

2.4 Effect of mulches on physiological properties

Grzeszkiewicz (1978), studied the effect of using composted pine bark for mulching on growth and flowering of gladiolus. He found no difference in corm quality or yield between mulched and control plots. Cormlet production was higher in plots mulched with peat moss and composted bark. Mulching with composted bark resulted in longer flower spikes and improved growth.

Younyol *et al.,* (2000) observed the influence of mulching materials on yield and quality of cut rose in soil cultivation and found, in transparent polyethylene (PE) film daily average soil temperatures was high, followed by black PE film, black/white PE film, reflex film and straw mulch.

Murugan and Gopinath (2001) studied the influence of organic and inorganic mulches on the growth and flowering of crossandra (*C. undulaefolia* [*C. infundibuliformis*]) cv. Soundarya. The quality and flowering attributes viz., lengths of spike at first and last flower opening stages, number of flowers per spike, number of spikes per plant and yield of flowers per plant were significantly influenced by mulching. Black polyethylene mulching resulted in the longest spike at first and last flower opening stages, more number of flowers per spike and spikes per plant.

Patra *et al.*, (2003) studied the effects of mulching with dry leaves, paddy straw black polyethylene, saw dust, cover crop or bare soil on the flowering and yield of guava. Mulching with saw dust resulted the earliest flowering and the highest number of flowers per plant followed by paddy straw and black polyethylene mulch. 26

Dehkaei (2004) conducted an experiment on the effect of tea wastes on composting of shredded and non-shredded tree bark and the effects of mixes on the growth of French marigold (*T. patula* L.) and found that the tea wastes in 50 and 70% ratio accelerated the composting of shredded and non-shredded tree bark and tea wastes reduced the C:N ratio of tree bark. The mixes also showed significant effect on the top fresh and dry weights, plant height, number of lateral shoots and number of open flowers.

Gavhane *et al.*, (2004) evaluated the effect of graded doses of fertilizers and polythene mulch on the growth, flower quality and yield of marigold. They found that growth, flower quality and yield parameters are significantly increased in all the treatments. 300:150:150 kg NPK/ha + black polythene mulching recorded the highest plant height(137.46 cm), number of branches per plant (33.33), flower diameter (9.20 cm), flower stalk length (21.02 cm), number of flowers per plant (62.80), flower yield per plant (841.52 g) and per hectare (415.55 q/ha).

Younis *et al.*, (2012) studied the effect of different mulching materials such as transparent plastic sheet, rice straw and black plastic sheet on growth and flowering of Freesia. In freesia plants, the time taken for germination was reduced and the percentage of germination was significantly improved by black mulch as compared to control. Maximum flower diameter was also observed in black polythene mulch.

Ahsan *et al.*, (2013) studied the effects of different techniques to improve plant growth characteristics and to create earliness in tuberose (*Polianthes tuberosa* L.). Micronutrient application in combination with mulching was the best for improving all vegetative and reproductive growth and quality characteristics.

Sarmah *et al.*, (2014) observed the effect of mulching on growth and flowering of gerbera under Assam condition. They concluded that the black polythene triggered plant growth and development and also encouraged flower production both quantitatively or qualitatively. The plant had produced tallest plant with maximum number of leaves per plant and number of suckers per clump, earlier flower bud visibility, maximum flower size, and highest length of flower stalk.

Tegen *et al.,*(2014) conducted an experiment to study the effect of different types of mulches (black and white plastic mulch as well as grass mulch) on early yield of tomato varieties (Miya and Cochoro) under polyhouse condition and they found that white plastic mulch resulted in early flowering, fruit setting and fruit maturity compared to other mulching materials.

2.5 Effect of mulching on chemical properties of soil

2.5.1 pH

Long term effect of organic manures brought about a significant variation in soil pH. Continuous application of chemical fertilizers for seven years lowered the soil pH by 0.1 to 0.2 units, while an increase of 0.1 to 0.7 units over initial value was observed in manured treatments (Grewal *et al.,* 1981).

Srivastava *et al.,* (1988) stated that the soil reaction is one of the indices of soil fertility status which was considerably improved by continuous use of FYM either alone or in combination with fertilizer. Mulch induced pH reduction resulted from the addition or retention of organic matter and organic acids produced from decomposition of plant derived materials accumulating or leaching in to the soil (Himelick and Watson, 1990).

A field experiment was conducted to study the direct and residual effect of vermi compost and inorganic fertilizers on soil chemical properties (Srikanth *et al.,* 1999). The pH of soil was maintained at neutral condition in the treatment receiving vermi compost and crop residue as mulch. 28

2.5.2 Soil Organic Carbon

Larson *et al.*, (1972) indicated that seven years of residue application had a positive effect on SOC content in the 0-10 cm layer of the soil. Hulugalle *et al.*, (1986) reported that mulch treatments have dramatic effects on soil organic matter, microbial activity and nitrogen cycling that was readily apparent after only one season. The mulches increased the organic matter content of soil, with the yard waste mulch having the most substantial effect, increasing organic matter content by nearly 40 per cent.

Lamers and Feli (1993) reported that the crop residue application as surface mulch can play an important role in the maintenance SOC levels and productivity through increasing recycling of mineral nutrients, increasing fertilizer use efficiency and improving soil physical and chemical properties and decreasing soil erosion.

Giller *et al.*, (1997) reported that the legume residue as mulching practices that retain organic matter and the embodied nutrients in situ are required to maximize the beneficial effects of improved fallows. Such alternatives to legume removal may include mulching or legume residue incorporation in to the soil. Paustian *et al.,* (1997) reported that the crop residue returned to the land increase or maintain SOC content.

Rasse *et al.*, (2000) reported that the application of organic residues increases the SOM (Soil Organic Matter) content and can affect soil physical properties. Effect of cropping systems on soil chemical properties are often related to increases in soil organic matter.

2.5.3 Available Nitrogen

According to Wade and Sanchez (1983) composted yard wastes and ground wood mulches had widely differing effects on nitrogen cycling. Total N was highest in the yard waste treatment, while the ground wood mulch had no effect on total N. This is not surprising since yard waste mulch has a relatively high concentration of N (1.91%) while the ground wood contains very little (0.65%).

Hulugalle *et al.*, (1986) reported that the total nitrogen content of the fallow and cropped soils was increased by mulching. The ammoniacal and nitrate nitrogen of the fallow as well as cropped soil were augmented due to mulch at all the intervals. The favourable influence of mulching in enhancing the production of nitrate particularly in the uncropped soils was noted. It seems that mulching was favourably influenced the nitrifying bacteria.

2.5.4 Available Phosphorus

The organic acids produced during the decomposition of organic mulches influenced by soil pH, form stable complexes or chelates with cations which are responsible for P fixation and thus increasing the availability (Tiwari *et al.*, 1980). Hundal *et al.*, (1998) reported that the incorporation of crop residues such as green manure increased the availability of added and native P.

Suresh and Gowda (1994) found that there was high available phosphorus due to the solubilisation of inorganic phosphorus in to soluble phosphorus by the enhanced bacterial activity due to the application of organic mulch. Addition of organics is expected to increase the availability of phosphorus in the soil (Duraisami and Mani, 2000).

2.5.5 Available Pottassium

Prasad and Sing (1980) reported that continous application of composted residues had resulted in a build up of available K in sandy loam soil. Recycling of organic wastes like maize straw and crop residues were reported to be useful in increasing the organic carbon and other plant nutrients in the soil (Ravi Kumar and Krishnamoorthy, 1983).

Moldenhauer *et al.*, (1994) found that crop residue mulching altering nutrient availability and fertilizer use efficiency. The retention of the crop residues as mulch affects the release, immobilization and loss of nutrients. Suresh *et al.*, (1995) observed that an increase in soil available K due to application of organic manure along with biofertilizers.

2.6 Effect of mulching on weed management

Mudalagiriyappa *et al.*, (2001) reported that crop residue application (Pongamia and Gliricidia) and soil solarization with transparent polyethylene resulted in maximum weed reduction in ground nut-French bean cropping system.

Patel *et al.*, (2004) observed that three hand weedings gave the highest net profit and followed by pre-plant application of pendimethalin supplemented with one hand weeding in transplanted chilli.

In a study by Mohtisham *et al.*, (2013) straw mulch reduced the number of germinating weeds by half compared to an unmulched control. Similarly, in a study by Radics and Bognar (2004), mulching with straw and grass significantly limited weed germination compared to plots without mulch.

According to Kexin *et al.*, (2014) surface tillage with straw mulching for maize in cold and arid regions of North China, had significant advantages in growth of root formation, yield increase and water availability.

2.7 Effect of mulching on microclimate

Mulches are known to increase the soil temperature since the sun's energy passes through the mulch and heats the air and soil beneath the mulch directly and then the heat is trapped by the "greenhouse effect" (Hu *et al.*, 1995).

Chen and Katan (1980) observed that in plastic mulching practices the soil temperature has been increased by 0.9 to $4.3^{\circ}C$ at seedling stage, 1.6 to $2.3^{\circ}C$at the bud initiation stage and 0.8 to $1.9^{\circ}C$ at the flowering stage. Mulching by pearl millet straw with light and frequent irrigations decreased soil temperature and evaporation and increased the soil moisture content in soil and the yield of tomato and okra in the summer season (Gupta, 1985).

Mean maximum temperature has been decreased by about 6°C by permanent mulching with *Imperata cylindrica* compared to that of unmulched plots. Also the mean emergence time of okra and castor has been decreased between 2 and 8 days (Fasheun, 1988).

The practice of mulching has been widely used as a management tool in many parts of the world. It dampens the influence of environmental factors on soil by increasing soil temperature controlling diurnal/seasonal fluctuations in soil temperature (Bristow and Abrecht, 1989; Bragagnolo and Mielniczuk, 1990; Stratton and Rechcigl, 1998; Lalitha *et al.*, 2001).

The surface mulch favourably influences the soil moisture regime by controlling evaporation from the soil surface (Jalota and Prihar, 1990; Prihar *et al.*, 1996; Ji *et al.*, 2001; Pawar *et al.*, 2004), improves infiltration, soil water retention, decreases bulk density (Kladivko and Unger, 1994) and facilitates condensation of soil water at night due to temperature reversals (Tisdall *et al.*, 1991).

Mulching can influence the microclimate by way of regulating soil temperature, soil moisture, humidity and wind speed. Ham *et al.* (1993) observed that the highest mid day temperature is beneath the plastic mulch and it was due to the high transmittance of short wave radiation along with long wave radiation.

Soil temperature can be higher up to 7°C under clear mulch compared to bare soil (Lamont, 1993). Park *et al.*, (1996) observed an increase of 2.4°C in average soil temperature at 15 cm depth under transparent film and an increase of 0.8°C under black film. 32

According to Incalcaterra and Vetrano (2000) under the transparent polyethylene mulch film, the average soil temperatures at 5 cm depth recorded at 08.00 and 12.00 h were 1.7 and 2.7°C higher than unmulched plots of okra.

According to Murthy and Rao (2000) the knowledge on the effect of weather parameters on crop production helps in the adoption of suitable agronomic practices to reduce yield losses.

Mulches also promote crop development and early harvest, and increase the yield. Very little weed growth occurs under the mulch as the mulches prevent penetration of light or exclude certain wavelengths of light that are needed for the weed seedlings to grow (Ossom *et al.*, 2001).

Aswathi *et al.*, (2006) observed that compared to unmulched plots, mulching with local grass straws and leaves in brinjal showed higher moisture content in the range of 33 to 100 percent under hot arid conditions. Soil temperature, soil moisture and evaporation can be modified by mulching which will enhance the yield of tomato(Gandhi and Bains, 2006).

Proper irrigation scheduling and grass straw mulching improved water storage in soil and increased the yield of okra (Adekalu, 2008). Mulching with dried weeds and grasses resulted in higher soil moisture conservation. Subrahmanian *et al.*, (2008) reported that higher root temperatures enhanced the root functions that supply water and nutrients to the shoot and favouring the biomass partitioning to shoots.

Subrahmanian *et al.*, (2008) observed that in black polyethylene mulch films the rate of growing degree days and heat thermal units were lower compared to non mulched control. In peak winter season mulching with wheat straw could increase the soil temperature by 2 to 3°C (Sarolia and Bhardwaj, 2012).

2.8 Effect of mulching on soil microflora

Hankin *et al.*, (1982) found that integrated effect of mulching and soil microbial activity had improved the yield of vegetables. Singh et al., (1986) reported the beneficial effects of sawdust mulching in reducing the populations of nematodes and pathogenic fungi in soil due to the production of phenols during the process of decomposition of saw dust.

Vethamani (1988) has noticed that mulching with sugarcane trash in okra improved the microbial population in soil. According to Wardle *et al.*, (1993) weed management strategies like mulching influenced the soil moisture content and was likely to induce the most significant responses by the soil microflora.

Cong *et al.*, (2006) conducted an experiment to examine the microbial biomass and activity, and nutrient availability under four management regimes with different organic inputs. Microbial biomass and microbial activity were higher in organically managed soils. Addition of composted cotton gin trash and mulching with straw increased the soil microbial biomass and potential N availability. The microbial properties and nitrogen availability for plants differed under different organic inputs.

Soil microorganisms respond directly to environmental changes and they are able to grow very fast if the conditions are appropriate (Xu *et al.*, 2009). However, the increase in soil moisture and temperature due to plastic film mulching can change the biological characteristics of the soil and may have a negative impact on soil quality (Li *et al.*, 1999).

Soil microorganisms and the processes they govern are essential for long-term fertility of soil. Soil microbes have the potential as early and sensitive indicators of soil stress or productivity changes, and there is considerable evidence that they can be used to evaluate the influence of management and land use of soils (Jinbo *et al.*, 2007).

34

Microbial activity, which relies on the availability of decomposable material, plays an important role in regulating soil fertility and transforming organic matter (Marinari *et al.*, 2007).

Neumeister (2010) reviewed that temperature, rainfall, humidity, radiation or dew can affect the growth and spread of fungi and bacteria. Other important factors influencing plant diseases are air pollution, particularly ozone and UV-B radiation as well as nutrient availability.

Lijing *et al.*, (2013) reported that straw residues returned to paddy field enhanced the microbial population and microbial diversity. Corn straw application in maize growing fields improved soil properties and soil microbial communities (Ping *et al.*, 2015). According to Pal *et al.*, (2013) population of actinomycetes in soil increased towards crop maturity due to the increased availability of carbon at that stage due to mulches.

2.9 Economics of mulching

Trials conducted in okra with black polythene, water hyacinth (*Eichornia crassipes*) @ 9 t/ha, paddy husk at 2.5 t/ha showed that the most economical mulch was paddy husk with a cost: benefit ratio of 1: 4.6 (Prasad and Mohan, 1993). Sutagundi (2000) reported that the treatment receiving straw mulch recorded significantly higher net returns (Rs. 30,894/ha) and benefit: cost ratio (1:1.80) compared to control in chilli. Rautaray (2005) observed higher profits in rice-tomato, rice-potato and rice-radish cropping systems due to utilization of straw as mulch in Assam.

Green leaves of *Antigonon leptopus* served better as organic mulch in a field experiment conducted during the kharif season and found that green leaf mulching is cheaper than polythene mulching for okra. Higher pod yield (17.1 t/ha), cost: benefit ratio (4.86) and growth attributing characters were observed under mulching with green leaves (Bandyopadhyay *et al.*, 2001).

According to Goswami and Saha (2006), organic mulches such as water hyacinth and paddy straw recorded the highest benefit: cost ratio of 3.12-3.38 for elephant-foot yam compared to polythene mulches (1.8-2.09). Sugarcane trash @ 10 t/ha as mulch resulted in higher net returns and benefit: cost ratio for cotton (Ghadage *et al.*, 2005).

36

37

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

The present study entitled "Mulching for soil quality, climate stress mitigation and crop productivity in okra" was carried out at the Academy of Climate Change Education and Research, Kerala Agricultural University, Vellanikkara, Thrissur during 2015-2016. The materials used and the methodology adopted for the study are described in this chapter.

3.1 General Details

3.1.1 Location

The experiment was conducted in the Water Technology Centre of Department of Agricultural Engineering, College of Horticulture, Vellanikkara, Thrissur, Kerala. Geographically the area is situated at 10°31′ N latitude and 76°13′E longitude, at an altitude of 22.25 m above mean sea level.

3.1.2 Time of experiment

The experiment was conducted from 22nd March to 13th July 2016.

3.1.3 Climate and weather conditions

The area enjoys a typical warm humid climate and receives average annual rainfall of 2663 mm. The mean weekly averages of important meteorological parameters were observed during the experimental period (Appendix I).

3.2 Methods

3.2.1 Crop and variety

Okra (Variety ArkaAnamika) was used for the experiment. Plants are tall and well branched. Purple colour pigment is present on the petal base. Fruits are green, tender and long.

3.2.2 Technical Programme

Treatments - 9

Design - RBD

Replications - 3

Spacing - 60 cm × 30 cm

Plot size - 3 m × 1.5 m

Treatments

T_1 - Mulching with leaf litter @ 5 t/ha

T_2 - Mulching with paddy straw @ 5 t/ha

T_3 - Mulching with coir pith @ 5 t/ha

T_4 - Mulching with black and white embossed sheet (30 guage)

T_5 - Mulching with black and silver embossed sheet (30 guage)

T_6 - Mulching with newspaper (2 layer)

T_7 - Mulching with coir chips @ 5 t/ha

T_8 - Control (No mulching)

T_9 – Live mulching with cowpea

Layout

Fig. 1. Layout plan of the experimental field

N

T_2	T_4	T_8	T_7	T_6	T_8	T_2	T_9	T_7
T_7	T_1	T_9	T_3	T_1	T_5	T_6	T_8	T_1
T_3	T_5	T_6	T_4	T_9	T_2	T_4	T_3	T_5
R_1			R_2			R_3		

3.2.3 Cultural operations

The experimental site was ploughed, levelled and raised beds of 3m length and 1.5m width were taken. Mulching materials were spread uniformly in each plot as per the technical programme. Sowing was done on 22-03-2016. Presoaked seeds were dibbled at a spacing of 60 cm × 30 cm @2 seeds/hole. Planting in polythene and newspaper mulched plots were done by making circular holes of 5cm diameter.

3.2.3.1 Manures and Fertilizers

Manures and fertilizers were applied as per the Package of practices recommendations (Adhoc) for organic farming : crops.

40

Plate 1.Field view

3.2.3.2 Irrigation

Drip irrigation was given at the discharge rate of 3.25 litres per hour.

3.2.3.3 Weed management

Hand weeding was done at 25 days interval starting from 30 days after sowing.

3.3 Observations recorded

Nine plants per replication were selected from each treatment for taking observations. The following parameters were recorded and the means were worked out for analysis.

3.3.1 Plant characters

1. Time taken for germination

The number of days taken for germination was noted.

2. Germination percentage

The percentage of germination was recorded at 3 and 6 DAS.

3. Height of plants

The height of plants was measured at 30, 60 and 90 DAS.

4. Number of leaves per plant

The number of leaves was counted at 30, 60 and 90 DAS.

5. Days to first flowering

The number of days taken for the opening of the flowers was recorded. 42

6. Number of flowers per plant

The number of flowers per plant was counted and recorded for each treatment.

7. Days to first harvest

The number of days from sowing to the date of first harvest of the fruits was noted.

8. Crop duration

The number of days taken from the sowing to the last harvest of crops was recorded.

9. Fruit yield

Fruits harvested separately from each plot periodically were, weighed and the total yield (t/ha) was worked out.

3.3.2 Soil characters

Soil characters before the experiment were estimated using appropriate methods (Appendix II). Soil samples were collected separately from each experimental plot at the end of the experiment and analyzed for physical and chemical characteristics. Observations on pH, electrical conductivity, organic carbon and content of major nutrients (N,P and K) in soil were taken for each treatment.

3.3.3 Soil microflora

Total microbial population (bacteria, fungi and actinomycetes) were estimated before and after the experiment. Enumeration of total microbial count was carried out using appropriate media as detailed in Appendix III. The method used for the evaluation was serial dilution as described by Agarwal and Hasija (1986). Ten grams of soil was added to 90 ml sterile water and agitated for 20 minutes. One ml of the solution was transferred to a test tube containing 9 ml of sterile water to get 10^{-2} dilution and similarly 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6} dilutions were also prepared.

Plates were incubated at 28±2°C. Observations were taken as and when the colonies appeared (bacteria- 2-3 days, fungi- 5-7 days and actinomycetes- 3-14 days).

3.3.4 Micro climate

3.3.4.1 Soil temperature

Soil temperature at surface, 15cm and 30cm was recorded at weekly intervals using thermometer (EMCON Soil thermometer) and the mean was worked out.

3.3.4.2 Soil moisture content

Soil moisture content at surface, 15cm and 30cm was recorded at fortnightly intervals by the gravimetric method using the formula

$$Pw = \frac{Wm - Wd}{Wd} \times 100$$

where,

Pw = Percentage of soil moisture by weight   Wm = Weight of moist sample

Wd = Weight of oven dry sample

3.3.5 Incidence of pests and diseases

The incidence of pests and diseases was observed and recorded.

44

3.4. B: C Ratio

The Benefit: Cost ratio was worked out using the formula as given below.

$$\text{BCR} = \frac{\text{Gross return}}{\text{Cost of cultivation}}$$

3.5. Statistical Analysis

The data recorded from the field experiment were tabulated and subjected to statistical analysis by applying the technique of analysis of variance using OP-STAT package. Correlation analysis was done by using SPSS.

RESULTS

CHAPTER 4

RESULTS

The results pertaining to the experiment on "Mulching for soil quality, climate stress mitigation and crop productivity in Okra" are furnished in this chapter.

4.1 Biometric and Phenological observations

4.1.1 Germination percentage

The germination percentage at 3 and 6 DAS is presented in Table 1. Highest early germination was observed in plots mulched with black and white embossed sheet (T_4) followed by black and silver embossed sheet (T_5) and mulching with leaf litter (T_1) among the nine treatments. Plots mulched with black and white embossed sheet (T_4) recorded the highest germination of 86.67% on 3rd day followed by T_5 (black and silver embossed sheet) and T_1 (mulching with leaf litter). T_9 (live mulching) and T_8 (unmulched control) had the minimum germination percentage.

On 6th day, the plots mulched with black and white embossed sheet (T_4) recorded the maximum germination (100%). It was at par with T_1, T_2, T_5, T_6 and T_7. The plots mulched with live mulch (T_9) recorded the lowest value of 72.98%.

4.1.2 Plant Height

Plant height was recorded at three stages of crop growth at 30, 60 and 90 DAS (Table2). The highest plant height recorded at all these stages were under mulching with black and silver embossed sheet (T_5) with 54.63cm, 106.7cm and 119.53cm respectively and was statistically superior to all other treatments. Mulching enhanced the height of plants in all the treatments at all the stages of crop growth. Control plots recorded significantly lowest height at all the stages of crop growth.

Table 1. Germination percentage as influenced by the treatments

Treatments	3DAS	6DAS
T_1 Mulching with leaf litter @ 5 t/ha	80.00	97.00
T_2 Mulching with paddy straw @ 5 t/ha	76.67	96.66
T_3 Mulching with coir pith @ 5 t/ha	63.33	90.00
T_4 Mulching with black and white embossed sheet (30 gauge)	86.67	100.00
T_5 Mulching with black and silver embossed sheet (30 gauge)	80.00	97.83
T_6 Mulching with newspaper (2 layers)	66.67	93.33
T_7 Mulching with coir chips @ 5 t/ha	70.00	96.74
T_8 Unmulched control	63.87	88.46
T_9 Live mulching with cow pea	50.00	72.98
C.D (0.05)	11.27	9.63

Table 2. Height of plants at 30, 60 and 90 DAS as influenced by the treatments

Treatments	Plant Height		
	30 DAS	60 DAS	90 DAS
T_1 Mulching with leaf litter @ 5 t/ha	36.27	81.60	95.60
T_2 Mulching with paddy straw @ 5 t/ha	44.40	87.80	98.23
T_3 Mulching with coir pith @ 5 t/ha	36.33	82.97	95.67
T_4 Mulching with black and white embossed sheet (30 gauge)	45.00	91.93	103.47
T_5 Mulching with black and silver embossed sheet (30 gauge)	54.63	106.67	119.53
T_6 Mulching with newspaper (2 layers)	28.97	69.27	81.70
T_7 Mulching with coir chips @ 5 t/ha	34.50	81.47	95.17
T_8 Unmulched control	22.50	57.70	70.97
T_9 Live mulching with cow pea	32.43	61.60	72.80
C.D (0.05)	4.77	6.90	5.30

49

4.1.3 Number of leaves per plant

Number of leaves was recorded at30, 60 and 90 DAS (Table 3). The highest number of leaves was in plots mulched with black and silver embossed sheet (T_5) at all the growth stages and was significantly superior to all other treatments. Second best treatment was T_4 followed by T_2. At 30 DAS the number of leaves in plots mulched with coir pith (T_3) and paddy straw (T_2) were statistically on par. Plots mulched with newspaper (T_6), live mulch (T_9) and unmulched control (T_8) gave lower values. In general, mulching with plastic sheets recorded more number of leaves compared to other mulching practices and control.

4.1.4 Days to first flowering

Days taken for first flowering varied significantly among the treatments, as shown in Table 4. Mulching with paddy straw (T_2) flowered earlier (38.33 DAS) which was statistically superior. The treatments mulched with leaf litter (T_1), coir pith (T_3), black and white embossed sheet (T_4), black and silver embossed sheet (T_5) and newspaper (T_6) were on par. Flowering was delayed by 15 days in unmulched control (T_8) compared to T_2. The plants under live mulching (T_9) were the last to flower (81.67 DAS).

4.1.5 Number of flowers per plant

Total number of flowers produced per plant varied significantly among the treatments (Table 4). The plots mulched with black and silver embossed sheet (T_5) recorded the highest value of 24.48. Plots mulched with black and white embossed sheets (T_4) were the second with 21.96 numbers. The traditional method of mulching with leaf litter (T_1) ranked third regarding this parameter. Number of flowers per plant in control (T_8) was 14.67 and the lowest number of flowers (3.69) was recorded in T_9 (live mulching).

4.1.6 Days to first harvest

Days taken for first harvest furnished in Table 5 showed that there is significant difference among the treatments. In general, mulching with plastic sheets (T_4 & T_5) recorded early harvesting (59 DAS). Live mulching (T_9) took maximum days of 76.67 days to harvest.

4.1.7 Crop Duration

The data on duration of crop are furnished in Table 5. T_4 (black and white embossed sheet) recorded the longest duration (109.67 days) followed by T_5 (black and silver embossed sheet). The shortest crop duration (85.33) was noticed in T_9 (live mulching).

Table 3. Number of leaves at 30, 60 and 90 DAS as influenced by the treatments

Treatments	Number of leaves		
	30 DAS	60 DAS	90 DAS
T_1 Mulching with leaf litter @ 5 t/ha	26.60	55.33	63.70
T_2 Mulching with paddy straw @ 5 t/ha	27.40	58.80	73.53
T_3 Mulching with coir pith @ 5 t/ha	27.73	49.63	64.43
T_4 Mulching with black and white embossed sheet (30 gauge)	25.40	61.20	74.87
T_5 Mulching with black and silver embossed sheet (30 gauge)	35.20	68.23	82.70
T_6 Mulching with newspaper (2 layers)	21.90	48.13	62.67
T_7 Mulching with coir chips @ 5 t/ha	26.43	50.47	64.77
T_8 Unmulched control	24.00	55.67	69.00
T_9 Live mulching with cow pea	24.00	34.20	39.00
C.D (0.05)	3.10	8.44	7.65

Table 4. Effect of the treatments on days to first flowering and number of flowers per plant

Treatments	Days to first flowering	Number of flowers per plant
T_1 Mulching with leaf litter @ 5 t/ha	43.33	19.85
T_2 Mulching with paddy straw @ 5 t/ha	38.33	20.01
T_3 Mulching with coir pith @ 5 t/ha	42.00	14.40
T_4 Mulching with black and white embossed sheet (30 gauge)	41.33	21.96
T_5 Mulching with black and silver embossed sheet (30 gauge)	43.67	24.48
T_6 Mulching with newspaper (2 layers)	41.67	17.43
T_7 Mulching with coir chips @ 5 t/ha	47.33	16.48
T_8 Unmulched control	53.33	14.67
T_9 Live mulching with cow pea	81.67	3.69
C.D (0.05)	2.83	0.92

53

4. 1.8 Yield

The data on total yield (Table 5) showed that there was significant difference among the treatments. The highest yield of 14.41 t ha^{-1} was recorded in mulching with black and silver embossed sheet (T_5) which was statistically superior to all other treatments. T_4 (mulching with black and white embossed sheet) ranked second with a value of 11.66 t ha^{-1}.T_4 was significantly superior to all other treatments except T_5. But T_4 was significantly inferior to T_5. The lowest yield of 1.08 t ha^{-1} observed in T_9 (live mulching) was significantly inferior to all other treatments.

4.2 Weed population

Observations on weed population at 30, 60 and 90 DAS are given in Table 6. Broad leaved and grassy weeds were counted separately. At 30 DAS, the highest weed count of broad leaved weeds was observed in unmulched control (T_8). The lowest weed count (6.67) was seen in T_5 (mulching with black and silver embossed sheet) followed by T_4 (mulching with black and white embossed sheet). The same trend was observed in the case of grassy weeds also. Mulching with sheets reduced the occurrence of grassy weeds whereas the count was highest in control plots.

At 60 DAS the highest weed count of broad leaved weeds were observed in plots mulched with paddy straw (T_2) followed by live mulching (T_9). Broad leaved weed count in T_2 was significantly higher than that in control plots (T_8). The lowest count was recorded under plots mulched with black and silver embossed sheet (T_5). T_5 and T_4 were at par. In the case of grassy weeds, the highest weed population was observed in T_2 (mulching with paddy straw) and was statistically superior to all other treatments. The lowest count was observed in plots mulched with plastic sheets (T_4 and T_5).

At 90 DAS, the similar trend was observed in the case of broad leaved weeds as was at 60 DAS. Grassy weeds were the highest in control plots (T_8)

followed by T_2 (mulching with paddy straw). The lowest count was observed when mulched with plastic sheets (T_4 and T_5).

4.3 Incidence of pests and diseases

No severe attack of pest and diseases was observed during the experimental period. Shoot and fruit borer incidence was observed in all the treatments. During the initial stages of crop growth attack of mealy bugs was noticed in few plants irrespective of treatments. Attack of termites was observed in T_6 (mulching with newspaper) and T_3 (mulching with coir pith). During the final stages of crop growth, few plants showed symptoms of yellow vein mosaic disease in all the treatments. Beauveria, Lecanicillium, neem soap and tobacco decoction were sprayed for controlling the pests whereas the termites were controlled by metarhizium.

Table 5. Effect of the treatments on days to first harvest, crop duration and crop yield

Treatments	Days to first harvest	Crop duration	Yield (t/ha)
T_1 Mulching with leaf litter @ 5 t/ha	60.33	104.33	10.05
T_2 Mulching with paddy straw @ 5 t/ha	60.33	104.67	10.20
T_3 Mulching with coir pith @ 5 t/ha	66.33	101.33	7.71
T_4 Mulching with black and white embossed sheet (30 gauge)	59.00	109.67	11.66
T_5 Mulching with black and silver embossed sheet (30 gauge)	59.00	108.67	14.41
T_6 Mulching with newspaper (2 layers)	63.33	100.00	8.38
T_7 Mulching with coir chips @ 5 t/ha	63.33	104.67	8.91
T_8 Unmulched control	70.49	95.33	7.43
T_9 Live mulching with cow pea	76.67	85.33	1.08
C.D (0.05)	6.12	8.05	1.02

Table 6. Effect of the treatments on weed population at 30, 60 and 90 DAS

Treatments	Broad leaved weeds/m^2			Grassy weeds/m^2		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
T_1 Mulching with leaf litter @ 5 t/ha	87.00 (8.84)	119.67 (10.82)	135.00 (11.66)	4.33 (2.16)	4.00 (2.23)	5.33 (2.49)
T_2 Mulching with paddy straw @ 5 t/ha	209.00 (13.98)	303.67 (17.41)	364.33 (19.11)	40.67 (6.39)	43.00 (6.63)	36.67 (6.12)
T_3 Mulching with coir pith @ 5 t/ha	51.33 (7.23)	57.00 (7.62)	69.67 (8.40)	4.67 (2.22)	5.33 (2.51)	4.00 (2.23)
T_4 Mulching with black and white embossed sheet (30 gauge)	10.33 (3.36)	13.67 (3.83)	20.33 (4.61)	2.00 (1.73)	2.00 (1.72)	1.33 (1.52)
T_5 Mulching with black and silver embossed sheet (30 gauge)	6.67 (2.72)	6.00 (2.63)	5.33 (2.51)	1.00 (1.33)	1.67 (1.61)	2.00 (1.69)
T_6 Mulching with newspaper (2 layers)	30.67 (5.60)	41.33 (6.50)	48.00 (6.99)	4.00 (2.19)	4.33 (2.29)	6.00 (2.61)
T_7 Mulching with coir chips @ 5 t/ha	83.00 (8.92)	116.67 (10.84)	147.33 (12.15)	6.33 (2.68)	5.33 (2.51)	10.67 (3.39)
T_8 Unmulched control	225.67 (14.86)	243.00 (15.61)	269.00 (16.43)	37.33 (6.18)	33.33 (5.85)	39.33 (6.31)
T_9 Live mulching with cow pea	185.33 (13.31)	281.33 (16.80)	271.67 (16.50)	7.67 (2.90)	7.67 (2.94)	9.67 (3.26)
C.D (0.05)	128.73	49.34	24.54	9.56	4.54	7.60

57

4.4 SOIL ANALYSIS

4.4.1 pH

The pH of soil before and after the experiment is furnished in Table 7. The initial pH of the soil was 5.37. All the treatments significantly increased soil pH. Mulching with paddy straw (T_2) contributed the highest pH (6.74) after the experiment. The lowest value of pH was observed in control plots (5.90).

4.4.2 EC

The EC of the soil before and after the experiment presented in Table 7 revealed the significant difference among the treatments. The initial EC of the soil was 0.04 dS m^{-1}. After the experiment, T_9 (live mulch) recorded the highest EC (0.103 dS m^{-1}), followed by mulching with leaf litter (T_1). The plots mulched with coir chips (T_7) recorded the lowest value (0.023 dS m^{-1}) of EC.

4.4.3 Organic carbon

The organic carbon content of soil before and after the experiment is furnished in Table 8. It shows that there was significant difference in the soil organic carbon content after the experiment. The initial organic carbon content of soil was 0.54 %. After the experiment, the highest percentage of organic carbon was recorded in the plots mulched with coir chips (0.81 %) which were on par with live mulching. These treatments were significantly superior to other treatments. The lowest value of organic carbon (0.48 %) was observed in plots mulched with black and silver embossed sheets (T_5) and control plots. T_5 was at par with control plots (T_8).

4.4.4 Available N, P and K

The data pertaining to the effect of treatments on available status of major nutrients in soil is given in Table 8. The available nitrogen content of the soil before and after the experiment revealed that the treatments had significant difference on soil available nitrogen. The initial value of nitrogen content was 62.63 kg/ha. There was significant increase in available nitrogen in soil in all treatments over the control. The highest content of available nitrogen was recorded in T_6 (mulching with newspaper) with a value of 159.03 kg ha^{-1} followed by 102.03 kg ha^{-1} in T_5 (mulching with black and silver embossed sheet). T_6 (Mulching with newspaper) was significantly superior to all other treatments. The lowest value of nitrogen content was observed in T_4 (mulching with black and white embossed sheet.

The data given in (Table 8) clearly shows the significant influence of treatments on available phosphorus content in soil after the trial. The initial value of P content in soil was 9.41 kg ha^{-1}. As in the case of available nitrogen, available P also increased significantly in all the treatments except control. Mulching with coir pith showed the highest percent of 31.16 kg ha^{-1} which was on par with plots mulched with plastic sheets. These three treatments were significantly superior to all other treatments. The lowest content of P was recorded in T_6 (mulching with newspaper) with a value of 14.75 kg ha^{-1}.

The treatments significantly influenced the available potassium content of the soil after the experiment. Initial K content of the soil was 17.28 kg ha^{-1}. There was significant increase in available K in all the treatments except T_5 and control. T_7 was significantly superior to all other treatments. There was significant increase in available potassium in soil after the trial over the control in all treatments except T_5. T_7 (mulching with coir chips) recorded the highest potassium content of 92.70 kg ha^{-1} followed by T_3 (coir pith) with a value of 84.46 kg ha^{-1}. T_7 was significantly superior to all the other treatments. The lowest K content (17.5 kg ha^{-1}) was observed in T_5 (mulching with black and silver embossed sheet).

59

4.5 TOTAL MICROBIAL POPULATION IN SOIL

The data on microbial population in soil (Table 9) showed that there was significant difference in the microbial population among the treatments before and after the experiment.

The initial population of bacteria in soil was 6.00 × 10^6cfu g^{-1}. After the experiment, the highest population of bacteria (52.33 × 10^6cfu g^{-1}) was observed in T_2 (mulching with paddy straw) followed by mulching with coir chips (24.00 × 10^6cfu g^{-1}). T_2 was significantly superior to all other treatments. The lowest population was observed in T_6 (mulching with newspaper) with a value of 7.00 × 10^6cfu g^{-1}.

The initial population of fungi in soil was 8.67 × 10^4 cfu g^{-1}. The highest population of fungi (22.67 × 10^4cfu g^{-1}) was observed in T_1 (mulching with leaf litter) followed by T_2 (mulching with paddy straw) and T_7 (mulching with coir chips). T_1 was significantly superior to all the other treatments. The lowest value of 6.67 × 10^4cfu g^{-1} was observed in T_6 (mulching with newspaper).

The initial population of actinomycetes in soil was 7.89 × 10^5 cfu g^{-1}. The highest population of actinomycetes (171.00 × 10^5cfu g^{-1}) was recorded in T_2 (mulching with paddy straw). The increase in actinomycetes population in T_2 was tremendous and significantly superior to all the other treatments. Mulching with leaf litter (T_1) was ranked second with a population of 65.33 × 10^5cfu g^{-1}. The lowest value was observed when mulched with newspaper (8.67 × 10^5cfu g^{-1}).

Table 7. Effect of the treatments on soil pH and EC

Treatments	pH	EC (dSm^{-1})
T_1 Mulching with leaf litter @ 5 t/ha	6.42	0.07
T_2 Mulching with paddy straw @ 5 t/ha	6.74	0.04
T_3 Mulching with coir pith @ 5 t/ha	6.61	0.03
T_4 Mulching with black and white embossed sheet (30 gauge)	6.6	0.06
T_5 Mulching with black and silver embossed sheet (30 gauge)	6.40	0.03
T_6 Mulching with newspaper (2 layers)	6.35	0.05
T_7 Mulching with coir chips @ 5 t/ha	6.63	0.02
T_8 Unmulched control	5.90	0.04
T_9 Live mulching with cow pea	6.31	0.10
C.D (0.05)	0.29	0.02
Initial Value	5.37	0.04

61

Table 8. Effect of the treatments on organic carbon, nitrogen, phosphorus and potassium content in the soil

Treatments	OC (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)
T_1 Mulching with leaf litter @ 5 t/ha	0.75	82.53	17.73	32.10
T_2 Mulching with paddy straw @ 5 t/ha	0.64	77.03	24.69	38.10
T_3 Mulching with coir pith @ 5 t/ha	0.64	79.36	31.15	84.46
T_4 Mulching with black and white embossed sheet (30 gauge)	0.70	71.86	28.30	27.23
T_5 Mulching with black and silver embossed sheet (30 gauge)	0.48	102.03	30.32	17.54
T_6 Mulching with newspaper (2 layers)	0.62	159.03	14.75	21.78
T_7 Mulching with coir chips @ 5 t/ha	0.81	79.43	19.81	92.70
T_8 Unmulched control	0.49	73.66	23.04	20.51
T_9 Live mulching with cow pea	0.77	75.46	18.92	21.65
C.D (0.05)	0.07	3.79	2.99	3.65
Initial Value	0.54	62.63	9.41	17.28

62

4.6 Microclimate

4.6.1 Minimum soil temperature

4.6.1.1 Minimum soil temperature at surface

The data pertaining to weekly minimum soil temperature at surface is presented in Table 10. All mulches except live mulching with cowpea increased the minimum soil temperature at surface. The lowest minimum temperature was recorded in unmulched control (T_8) followed by T_9 (live mulching) during the entire crop period. Mulching with black and silver embossed sheet (T_5) showed the peak value of soil minimum temperature at surface. All organic mulching treatments maintained higher minimum temperature at surface than control, but were inferior to T_5.

4.6.1.2 Minimum soil temperature at 15cm depth

Table 11, clearly shows that the lowest minimum temperature at 15 cm depth was observed in unmulched plots (T_8) throughout the crop period. The highest value of soil minimum temperature was noticed in T_5 (Mulching with black and silver embossed sheet) followed by T_4 (mulching with black and white embossed sheet). Compared to unmulched control (T_8) and live mulching (T_9), all other treatments maintained a higher minimum soil temperature at 15 cm depth. Polythene mulching maintained more minimum temperature at 15 cm depth than organic mulches.

4.6.1.3 Minimum soil temperature at 30cm depth

The data on weekly variation in minimum soil temperature at 30cm depth is presented in Table12. The lowest value of soil minimum temperature is observed under plots with unmulched control (T_8) compared to all other treatments. In general the peak value of soil minimum temperature was observed under plots mulched with black and silver embossed plastic sheet. All organic mulches except T_8 maintained higher minimum temperature than control throughout the period of observation. When depth of the soil profile increased the minimum soil temperature was found to be increasing.

4.6.2. Maximum soil temperature

4.6.2.1 Maximum soil temperature at surface

Maximum soil temperature at surface at weekly intervals is presented in Table 13. The highest temperature at soil surface was observed under plots mulched with black and silver embossed sheet (T_5) followed by mulching with newspaper (T_6) and unmulched control (T_8). The lowest value of maximum soil temperature at surface was observed under plots mulched with paddy straw (T_2).

4.6.2.2 Maximum soil temperature at 15cm depth

The weekly variation of maximum soil temperature at 15cm depth is furnished in Table 14. Soil temperature at 15cm depth observed was higher under plots mulched with newspaper (T_6), black and silver embossed sheet (T_5) and mulching with black and white embossed sheet (T_4). Mulching with coir pith (T_3) and coir chips (T_7) also showed higher values. The lowest value was recorded under plots mulched with paddy straw (T_2) during the entire crop period.

4.6.2.3 Maximum soil temperature at 30cm depth

Maximum soil temperature at 30 cm depth at weekly interval is presented in Table 14. Mulching with black and silver embossed sheet recorded higher values of maximum soil temperature during the entire crop period and the highest value of 40.5°C was observed at 5 WAS. T_5 was followed by T_6 and T_4. Lower values of maximum soil temperature were noticed under plots mulched with paddy straw during the entire crop period. Maximum temperature at 30 cm depth was comparatively lesser in plots mulched with organic wastes.

The maximum soil temperature was found to be decreasing with increase in the depth of soil.

Table 9. Effects of the treatments on total microbial population

Treatments	Total microbial population		
	Bacteria (× 10^6cfu g^{-1})	**Fungi (× 10^4cfu g^{-1})**	**Actinomycetes (× 10^5cfu g^{-1})**
T_1 Mulching with leaf litter @ 5 t/ha	8.33	22.67	65.33
T_2 Mulching with paddy straw @ 5 t/ha	52.33	14.67	171.00
T_3 Mulching with coir pith @ 5 t/ha	18.67	8.00	44.67
T_4 Mulching with black and white embossed sheet (30 gauge)	8.00	8.67	14.33
T_5 Mulching with black and silver embossed sheet (30 gauge)	11.67	9.00	9.33
T_6 Mulching with newspaper (2 layers)	7.00	6.67	8.67
T_7 Mulching with coir chips @ 5 t/ha	24.00	14.33	14.67
T_8 Unmulched control	8.00	13.00	9.33
T_9 Live mulching with cow pea	10.33	10.67	25.67
C.D (0.05)	4.19	2.87	5.37
Initial Value	6.00	8.67	7.89

Plate2. Intial microbial population in soil

Bacteria

Fungi

Actinomycetes

Plate 3.Soil microbial population after the experiment

Bacteria

Fungi

Actinomycetes

Table 10. Effect of treatments on minimum soil temperature at surface

Treatments	Minimum soil temperature at surface (^0C)										
	4WAS	5WAS	6WAS	7WAS	8WAS	9WAS	10WAS	11WAS	12WAS	13WAS	14WAS
T_1 Mulching with leaf litter @ 5 t/ha	34.8	33.5	33.5	33	32.4	32.4	32.5	32.4	32.9	32.5	32.4
T_2 Mulching with paddy straw @ 5 t/ha	33.6	32.9	32.9	32.9	32.3	32.5	32.9	32.7	32.8	33.8	33.9
T_3 Mulching with coir pith @ 5 t/ha	34.3	33.3	33.3	32.7	32.7	32.7	33.3	32.9	33.7	32.7	32.7
T_4 Mulching with black and white embossed sheet (30 gauge)	34.1	33.1	33.1	33.2	32.5	33.5	31.1	33.5	35.7	34.6	34.5
T_5 Mulching with black and silver embossed sheet (30 gauge)	35	34	34	34.4	33.6	33.6	34	34.2	36.2	35	34.9
T_6 Mulching with newspaper (2 layers)	33.7	32.1	32.1	32.6	32.3	32.8	32.1	32.3	35.9	34	34
T_7 Mulching with coir chips @ 5 t/ha	34.8	33.1	32.3	33.5	32.8	33.0	33.1	31.7	33.5	32.9	32.3
T_8 Unmulched control	32.6	31.8	31.8	31.8	31.8	32	31.9	32	31.9	31.9	31.9
T_9 Live mulching with cow pea	32.9	32.2	32.1	31.5	31.7	32.4	32.2	31.8	32.4	31.7	31.5
C.D (0.05)	0.344	0.389	0.359	0.35	0.356	0.325	0.403	0.426	0.337	0.364	0.396

*WAS – Weeks After Sowing

Table 11. Effect of treatments on minimum soil temperature at 15cm depth

Treatments	Minimum soil temperature at 15 cm depth (^0C)										
	4WAS	5WAS	6WAS	7WAS	8WAS	9WAS	10WAS	11WAS	12WAS	13WAS	14WAS
T_1 Mulching with leaf litter @ 5 t/ha	35.4	34.5	34.9	33.8	33.3	34.6	33.8	34.0	33.5	33.9	34.0
T_2 Mulching with paddy straw @ 5 t/ha	34.4	33.2	33.5	33.6	33.0	34.8	33.7	33.9	33.4	34.8	34.4
T_3 Mulching with coir pith @ 5 t/ha	35.0	34.3	34.8	33.3	33.5	34.5	34.3	33.6	34.4	34.0	33.9
T_4 Mulching with black and white embossed sheet (30 gauge)	34.7	34.1	34.0	34.0	33.6	35.4	33.0	34.4	36.9	35.9	35.4
T_5 Mulching with black and silver embossed sheet (30 gauge)	35.4	34.8	34.6	35.1	34.7	35.9	34.3	35.1	37.8	35.6	35.8
T_6 Mulching with newspaper (2 layers)	34.4	32.9	32.9	33.4	34.0	35.0	33.4	33.0	36.5	35.0	34.7
T_7 Mulching with coir chips @ 5 t/ha	35.2	33.8	33.1	34.3	33.8	34.5	34.5	32.6	35.0	33.8	34.0
T_8 Unmulched control	33.1	33.1	33.1	33.1	33.1	33.2	33.1	33.1	33.1	33.1	33.1
T_9 Live mulching with cow pea	33.4	33.1	33.0	33.3	32.8	34.9	33.8	32.9	34.0	33.1	32.7
C.D (0.05)	0.34	0.38	0.35	0.35	0.35	0.32	0.40	0.42	0.33	0.36	0.39

*WAS –Weeks After Sowing

69

Table 12. Effect of treatments on minimum soil temperature at 30 cm depth

Treatments	Minimum soil temperature at 30 cm depth (^0C)										
	4WAS	5WAS	6WAS	7WAS	8WAS	9WAS	10WAS	11WAS	12WAS	13WAS	14WAS
T_1 Mulching with leaf litter @ 5 t/ha	38.0	37.5	38.4	38.0	37.9	37.4	37.7	37.7	37.0	37.7	37.4
T_2 Mulching with paddy straw @ 5 t/ha	37.8	37.1	37.8	37.1	36.6	37.8	38.2	37.9	36.7	38.6	38.8
T_3 Mulching with coir pith @ 5 t/ha	37.9	37.6	38.0	37.4	37.6	38.1	37.7	38.1	38.6	38.0	37.6
T_4 Mulching with black and white embossed sheet (30 gauge)	38.3	37.0	36.7	36.7	37.8	38.8	36.9	38.6	39.7	39.5	39.6
T_5 Mulching with black and silver embossed sheet (30 gauge)	38.8	38.2	38.5	38.5	38.2	39.2	37.6	38.8	40.3	39.3	40.1
T_6 Mulching with newspaper (2 layers)	36.7	36.6	37.0	37.7	36.8	38.1	37.1	36.7	39.5	38.8	39.6
T_7 Mulching with coir chips @ 5 t/ha	37.1	36.7	36.9	38.1	37.1	37.2	37.9	37.0	38.5	37.5	38.2
T_8 Unmulched control	36.8	36.9	36.8	36.9	36.9	37.0	36.9	36.9	36.8	36.8	36.9
T_9 Live mulching with cow pea	36.9	36.0	36.8	36.5	36.6	37.5	37.5	37.2	36.9	37.0	36.8
C.D (0.05)	0.34	0.38	0.35	0.35	0.35	0.32	0.40	0.42	0.33	0.36	0.39

*WAS – Weeks After Sowing

70

Table 13. Effect of treatments on maximum soil temperature at surface

Treatments	Maximum soil temperature at surface (^0C)										
	4WAS	5WAS	6WAS	7WAS	8WAS	9WAS	10WAS	11WAS	12WAS	13WAS	14WAS
T_1 Mulching with leaf litter @ 5 t/ha	42.8	41.8	41.8	39.0	41.3	41.4	41.8	41.3	40.5	40.5	41.5
T_2 Mulching with paddy straw @ 5 t/ha	38.3	39.2	39.2	40.2	40.8	40.8	39.2	41.8	39.0	41.7	42.6
T_3 Mulching with coir pith @ 5 t/ha	42.0	40.9	40.9	39.0	40.4	40.4	40.9	41.4	40.7	41.3	41.5
T_4 Mulching with black and white embossed sheet (30 gauge)	43.8	42.7	42.7	40.5	43.6	44.2	42.7	43.7	43.6	43.5	43.0
T_5 Mulching with black and silver embossed sheet (30 gauge)	44.4	44.6	43.7	42.3	43.7	44.5	44.6	44.5	44.1	43.9	44.2
T_6 Mulching with newspaper (2 layers)	44.6	44.2	44.2	43.6	44.0	43.8	44.2	43.3	43.4	44.1	42.5
T_7 Mulching with coir chips @ 5 t/ha	41.6	40.2	41.2	39.4	40.6	41.5	40.6	40.3	41.7	41.5	41.2
T_8 Unmulched control	44.4	43.3	43.3	43.3	43.3	43.4	43.2	43.2	43.3	43.3	43.3
T_9 Live mulching with cow pea	43.5	43.0	43.2	43.1	43.1	43.2	43.5	42.9	43.0	42.5	42.8
C.D (0.05)	0.34	0.38	0.35	0.35	0.35	0.32	0.40	0.42	0.33	0.36	0.39

*WAS – Weeks After Sowing

71

Table 14. Effect of treatments on maximum soil temperature at 15 cm depth

Treatments	Maximum soil temperature at 15 cm depth (^0C)										
	4WAS	5WAS	6WAS	7WAS	8WAS	9WAS	10WAS	11WAS	12WAS	13WAS	14WAS
T_1 Mulching with leaf litter @ 5 t/ha	38.3	38.0	37.3	35.6	37.7	36.7	35.4	36.0	36.1	34.6	36.7
T_2 Mulching with paddy straw @ 5 t/ha	36.3	36.5	35.4	36.5	36.2	35.6	34.6	35.9	35.3	35.4	37.3
T_3 Mulching with coir pith @ 5 t/ha	39.3	37.2	36.5	36.0	36.0	35.4	35.1	36.5	36.5	35.1	36.4
T_4 Mulching with black and white embossed sheet (30 gauge)	41.3	39.4	38.1	35.7	38.2	38.	37.1	37.9	39.5	38.5	38.2
T_5 Mulching with black and silver embossed sheet (30 gauge)	41.6	40.1	39.4	38.1	38.4	39.6	38.7	38.2	39.9	38.6	38.8
T_6 Mulching with newspaper (2 layers)	42.3	40.5	39.9	39.1	39.2	39.2	38.4	38.5	38.9	39.0	37.1
T_7 Mulching with coir chips @ 5 t/ha	39.5	36.6	36.7	35.0	35.7	37.1	37.0	35.6	35.9	35.2	36.7
T_8 Unmulched control	38.4	38.0	38.0	38.0	38.0	38.2	38.0	38.0	37.9	37.8	38.0
T_9 Live mulching with cow pea	38.7	39.	38.2	38.2	38.0	38.3	38.2	38.3	38.5	36.5	37.2
C.D (0.05)	0.34	0.38	0.35	0.35	0.35	0.32	0.40	0.42	0.33	0.36	0.39

*WAS – Weeks After Sowing

Table 15. Effect of treatments on maximum soil temperature at 30 cm depth

Treatments	Maximum soil temperature at 30 cm depth (^0C)										
	4WAS	5WAS	6WAS	7WAS	8WAS	9WAS	10WAS	11WAS	12WAS	13WAS	14WAS
T_1 Mulching with leaf litter @ 5 t/ha	35.4	37.2	36.1	34.0	36.0	35.8	34.5	35.1	35.5	33.4	35.0
T_2 Mulching with paddy straw @ 5 t/ha	33.4	35.1	34.5	35.5	35.2	34.8	33.3	35.4	33.9	34.4	36.5
T_3 Mulching with coir pith @ 5 t/ha	35.4	36.5	35.4	35.4	35.1	34.9	34.5	35.1	35.5	34.6	34.8
T_4 Mulching with black and white embossed sheet (30 gauge)	38.0	38.1	37.1	34.0	36.9	37.3	36.4	37.3	38.0	37.1	37.2
T_5 Mulching with black and silver embossed sheet (30 gauge)	39.3	40.5	38.1	37.5	37.3	38.4	37.2	36.8	39.0	37.2	37.9
T_6 Mulching with newspaper (2 layers)	38.3	38.8	38.9	38.3	37.8	38.9	37.0	37.3	38.3	38.6	36.1
T_7 Mulching with coir chips @ 5 t/ha	37.1	35.2	34.9	34.4	34.0	36.6	36.1	34.6	35.0	34.0	35.4
T_8 Unmulched control	36.6	36.9	36.9	36.9	36.9	37.2	36.7	38.1	36.8	36.9	36.8
T_9 Live mulching with cow pea	36.0	37.9	37.0	37.0	37.5	37.7	37.0	37.5	37.2	35.5	36.3
C.D (0.05)	0.34	0.38	0.35	0.35	0.35	0.32	0.40	0.42	0.33	0.36	0.39

*WAS – Weeks After Sowing

4.6.3 Soil moisture content content

4.6.3.1 Soil moisture content at surface

Soil moisture content at surface at fortnightly interval is presented in Table 16. All the mulches except newspaper and live mulching increased soil moisture at surface over the control. Organic mulches were superior to plastic mulches. Higher moisture content at surface was recorded under plots mulched with paddy straw (T_2) throughout the crop period. The highest value of 36.3 % was observed at 12 WAS. Treatments T_3 and T_7 also maintained higher moisture content at surface. The lowest value of soil moisture content was observed under plots with unmulched control (T_8) and mulching with newspaper (T_6). The least value of 20.7% was observed at 6 WAS in plots mulched with newspaper (T_6).

4.6.3.2 Soil moisture content at 15cm depth

Soil moisture content at 15cm depth at fortnightly interval is furnished Table 17. All the mulches except newspaper and live mulch increased soil moisture at 15 cm depth. Higher soil moisture content at 15cm depth was recorded under plots mulched with coir chips (T_7) with a value of 36.6% at 12 WAS and paddy straw (T_2) with a value of 37.7% at 12 WAS. The lowest value of soil moisture content at 15cm depth was observed in treatments T_8 (control), T_6 (newspaper) and T_9 (live mulching). Organic mulches were superior to plastic mulches.

4.6.3.3 Soil moisture content at 30cm depth

The data pertaining to fortnightly soil moisture at 30cm depth are presented in Table 18. As in the case of soil moisture recorded at surface and 15cm depth, all the mulches except newspaper and live mulch retained more moisture than the control. Organic mulches except newspaper and live mulch was superior to plastic mulches. Higher values of soil moisture content were observed under plots mulched with coir chips (T_7), paddy straw (T_2) and coir pith (T_3). The lowest value for soil moisture content was observed under plots mulched with T_6(newspaper), T_9 (live mulch) and T_8 (Unmulched control).

75

Table 16. Effect of treatments on soil moisture content at surface

Treatments	Soil moisture content at surface (%)						
	2WAS	4WAS	6WAS	8WAS	10WAS	12WAS	14WAS
T_1 Mulching with leaf litter @ 5 t/ha	23.6	26.4	21.5	31.3	29.6	33.3	30.2
T_2 Mulching with paddy straw @ 5 t/ha	26.7	28.8	24.5	34.6	32.4	36.3	33.4
T_3 Mulching with coir pith @ 5 t/ha	26.6	27.4	26.8	33.6	31.6	35.6	32.5
T_4 Mulching with black and white embossed sheet (30 gauge)	25.2	26.6	24.0	32.4	30.1	34.6	31.6
T_5 Mulching with black and silver embossed sheet (30 gauge)	22.6	26.6	20.8	32.3	30.3	34.4	31.4
T_6 Mulching with newspaper (2 layers)	22.6	25.2	20.7	29.6	27.5	32.6	28.8
T_7 Mulching with coir chips @ 5 t/ha	27.7	27.7	27.4	33.9	31.6	35.7	32.7
T_8 Unmulched control	22.4	25.3	20.8	29.5	27.4	32.6	28.5
T_9 Live mulching with cow pea	23.5	25.5	21.3	30.2	28.9	33.4	29.3
C.D (0.05)	0.59	0.31	0.38	0.26	0.28	0.27	0.24

*WAS – Weeks After Sowing

76

Table 17. Effect of the treatments on soil moisture content variation at 15 cm depth

Treatments	Soil moisture content variation at 15 cm depth (%)						
	2WAS	4WAS	6WAS	8WAS	10WAS	12WAS	14WAS
T_1 Mulching with leaf litter @ 5 t/ha	24.6	27.3	23.1	32.5	30.4	34.4	31.3
T_2 Mulching with paddy straw @ 5 t/ha	27.5	29.4	25.5	35.5	33.5	37.7	34.6
T_3 Mulching with coir pith @ 5 t/ha	28.6	28.6	28.1	34.7	32.5	36.5	33.6
T_4 Mulching with black and white embossed sheet (30 gauge)	25.7	27.4	25.8	33.2	31.2	35.6	32.4
T_5 Mulching with black and silver embossed sheet (30 gauge)	23.2	27.7	21.8	33.7	31.4	35.5	32.5
T_6 Mulching with newspaper (2 layers)	23.8	26.5	21.4	30.7	28.6	33.5	29.5
T_7 Mulching with coir chips @ 5 t/ha	28.8	28.5	28.9	34.6	32.7	36.6	33.4
T_8 Unmulched control	23.6	26.5	21.8	30.4	28.6	33.5	29.4
T_9 Live mulching with cow pea	24.7	26.4	22.4	31.3	29.4	34.4	30.4
C.D (0.05)	0.59	0.31	0.38	0.26	0.28	0.27	0.24

*WAS – Weeks After Sowing

77

Table18. Effect of the treatments on soil moisture content variation at 30 cm depth

Treatments	Soil moisture variation at 30cm depth (%)						
	2WAS	4WAS	6WAS	8WAS	10WAS	12WAS	14WAS
T_1 Mulching with leaf litter @ 5 t/ha	25.5	28.7	23.9	33.6	31.2	35.5	32.6
T_2 Mulching with paddy straw @ 5 t/ha	28.8	30.1	26.9	36.6	34.5	38.5	35.4
T_3 Mulching with coir pith @ 5 t/ha	29.7	29.3	29.2	35.6	33.6	37.4	34.4
T_4 Mulching with black and white embossed sheet (30 gauge)	26.7	28.7	27.4	34.6	32.4	36.4	33.5
T_5 Mulching with black and silver embossed sheet (30 gauge)	24.2	28.3	23.4	34.4	32.7	36.7	33.6
T_6 Mulching with newspaper (2 layers)	26.0	27.5	23.2	31.3	29.6	34.5	30.7
T_7 Mulching with coir chips @ 5 t/ha	30.1	29.4	30.1	35.8	33.5	37.4	34.5
T_8 Unmulched control	24.9	27.8	23.4	31.3	29.5	34.5	30.7
T_9 Live mulching with cow pea	25.6	27.4	23.6	32.2	28.5	35.5	31.2
C.D (0.05)	0.59	0.31	0.38	0.26	0.28	0.27	0.24

*WAS – Weeks After Sowing

4.7 CROP WEATHER RELATIONSHIPS

4.7.1 Soil temperature and different growth parameters

4.7.1.1 Soil temperature and plant height

The correlation between minimum soil temperature at different depths and plant height at monthly interval was found out and is presented in Table 19. Plant height at all the stages (30, 60 and 90 DAS) of crop showed significant positive correlation with minimum soil temperature. Minimum soil temperature at surface exhibited a significant positive correlation with plant height (0.610, 0.735 and 0.738) during the entire crop period. Similar relation was observed in minimum soil temperature at 15 cm depth and 30 cm depth.

4.7.1.2 Soil temperature and number of leaves per plant

Number of leaves per plant had a significant positive correlation with minimum soil temperature (Table 20). Number of leaves at 30, 60 and 90 DAS showed significant positive correlation with minimum soil temperature at surface, 15 cm depth and 30 cm depth. Minimum soil temperature at 15 cm depth has no significant correlation during the final stages of crop growth.

4.7.1.3 Soil temperature and yield

From Table 21, it is observed that minimum soil temperature had significant positive correlation with yield at fruiting and harvesting stage. There was no significant correlation during the initial stages of crop growth.

4.7.2 Soil moisture and different growth parameters

4.7.2.1 Soil moisture and plant height

The correlation between soil moisture at different depths and plant height at monthly interval was found out and is presented in Table 22. At all the stages of 79 crop growth plant height showed a significant positive correlation with soil moisture.

4.7.2.2 Soil moisture and number of leaves per plant

Number of leaves per plant had a significant positive correlation with soil moisture (Table 23). Number of leaves at 30, 60 and 90 DAS showed significant positive correlation with soil moisture at surface. Soil moisture at 15 cm depth and 30 cm depth had no significant correlation with the number of leaves per plant.

4.7.2.3 Soil moisture and yield

From Table 24, it is observed that soil moisture had significant positive correlation with yield at fruiting stage. There was no significant correlation during the initial and final stages of crop growth.

4.7.3 Phenological observations and weather parameters

The correlation between different phenological observations and different weather parameters was found out and is presented in Table 25.

Days to first flowering showed significant negative correlation with sunshine hours (-0.452) and evaporation (-0.841). Also, days to first flowering showed strong significant negative correlation with minimum soil temperature and soil moisture. Days to first flowering showed a significant positive correlation with maximum soil temperature at surface.

Days to first harvest showed significant positive correlation with mean relative humidity (0.838) and rainfall (0.743), whereas sunshine hours (-0.464) and evaporation (-0.789) showed significant negative correlation. Days to first harvest had no significant correlation with minimum soil temperature and maximum soil temperature. Soil moisture at 15 cm and 30 cm depth showed significant negative correlation.

4.8 Economics

The data regarding B: C ratio is presented in Table 26. The different treatments contributed significant variation in benefit to cost ratio. The highest B: C ratio of 2.24:1 was obtained in mulching with mulching with black and silver embossed sheet (T_5) followed by plots mulched with black and white embossed sheet (T_4). Among organic mulches plots mulched with paddy straw recorded the highest B: C ratio of 1.71:1. The least B: C ratio of 0.21:1 was observed in live mulch (T_9).

81

Table.19. Correlation between minimum soil temperature and plant height at monthly intervals

	Plant height		
Depth	**30 DAS**	**60 DAS**	**90 DAS**
Surface	0.610	0.735	0.738
15 cm depth	0.596	0.779	0.718
30 cm depth	0.843	0.786	0.726

Table.20. Correlation between minimum soil temperature and number of leaves at monthly intervals

	No. of leaves		
Depth	**30 DAS**	**60 DAS**	**90 DAS**
Surface	0.593	0.513	0.458
15 cm depth	0.548	0.465	NS
30 cm depth	0.736	0.521	0.391

Table.21. Correlation between minimum soil temperature and yield at monthly intervals

	Yield		
Depth	**30 DAS**	**60 DAS**	**90 DAS**
Surface	NS	0.599	0.779
15 cm depth	NS	0.611	0.529
30 cm depth	NS	0.518	0.689

82

Table.22. Correlation between soil moisture and plant height at monthly intervals

	Plant height		
Depth	**30 DAS**	**60 DAS**	**90 DAS**
Surface	0.510	0.574	0.580
15 cm depth	0.563	0.637	0.617
30 cm depth	0.556	0.640	0.607

Table.23. Correlation between soil moisture and number of leaves at monthly intervals

	Number of leaves		
Depth	**30 DAS**	**60 DAS**	**90 DAS**
Surface	0.401	0.445	0.462
15 cm depth	NS	NS	NS
30 cm depth	NS	NS	NS

Table.24. Correlation between soil moisture and yield at monthly intervals

	Yield		
Depth	**30 DAS**	**60 DAS**	**90 DAS**
Surface	NS	0.393	NS
15 cm depth	NS	0.391	NS
30 cm depth	NS	0.598	NS

Table 25. Correlation between phonological observations and weather parameters

	Maximum Temperature	Minimum Temperature	Mean Relative Humidity	Sun Shine hours	Rainfall	Evaporation	Minimum soil temperature			Maximum soil temperature			Soil Moisture		
							surface	15cm	30cm	surface	15cm	30cm	Surface	15cm	30cm
*DFF	NS	NS	NS	-0.452	.790	-0.841	-0.62	-0.515	-0.418	0.448	NS	NS	-0.471	-.519	-.579
*DFH	NS	NS	0.838	-0.464	0.743	-0.789	NS	NS	NS	NS	NS	NS	NS	-0.444	-0.665

*DFF- Days to First Flowering

*DFH- Days to First Harvest

84

Table 26. Effect of the treatments on Benefit: Cost ratio

Treatments	Total cost of cultivation (Rs.)	Gross returns (Rs.)	Net returns (Rs.)	B:C ratio
T_1 Mulching with leaf litter @ 5 t/ha	169226.34	251250.00	82023.66	1.48
T_2 Mulching with paddy straw @ 5 t/ha	149144.03	255175.00	106030.97	1.71
T_3 Mulching with coir pith @ 5 t/ha	210378.60	192825.00	-17553.60	0.92
T_4 Mulching with black and white embossed sheet (30 gauge)	152765.43	291575.00	138809.57	1.91
T_5 Mulching with black and silver embossed sheet (30 gauge)	160995.88	360425.00	199429.12	2.24
T_6 Mulching with newspaper (2 layers)	128074.07	209500.00	81425.93	1.64
T_7 Mulching with coir chips @ 5 t/ha	321489.71	222825.00	-98664.71	0.69
T_8 Unmulched control	128074.07	186075.00	58000.93	1.45
T_9 Live mulching with cow pea	129884.77	27175.00	-102709.77	0.21

85

DISCUSSION

CHAPTER 5

DISCUSSION

The experiment entitled "Mulching for soil quality, climate stress mitigation and crop productivity in okra" was conducted during 2015-2016 in Academy of Climate Change Education and Research, Vellanikkara. The results pertaining to the study are discussed below.

5.1 Effect of mulching on soil characters

A general increase in soil pH was observed after the cropping period (Fig.1). The initial pH of the soil was 5.37. Plots mulched with paddy straw (T_2) recorded the highest pH (6.74) after the experiment and the lowest value of was observed in control plots (5.90). Salau *et al.*, (1992) also reported increased soil pH in banana plots due to mulching. Use of lime and organic manures has contributed to an increase in soil pH after the experiment. Mulches have further reduced the soil acidity.

The initial EC of the soil was 0.04 dS m^{-1}(Fig.2). After the experiment, T_9 (live mulching) recorded the highest EC (0.103 dS m^{-1}) followed by T_1 (mulching with leaf litter). This may be due to the release of phytochemicals by the living roots of cowpea.

The initial content of organic carbon was 0.54%. After the experiment, the value ranged from 0.48% in T_4 (black and white embossed sheet) to 0.81% in T_7 (coir chips) as depicted in Fig.3. The increase in organic carbon content of soil under organic mulches is quite obvious since the carbonaceous materials after decomposition contributed organic carbon to the soil. The same trend was observed by Dahiya *et al.*, (2007) due to organic mulching.

The nutrient status of soil was improved by mulching. There was significant improvement in soil available N, P and K status compared to pre experiment status (Fig.4) due to the mineralization of high doses of organic manures used for the trial. The highest available nitrogen content was recorded in 87

T_6 (newspaper) with a value of 159.03 kg ha^{-1} which was significantly superior to all other treatments. Sarma and Baruah (1997), found a significant positive influence on soil chemical properties Mulching increased the soil pH, organic carbon, available nitrogen and potassium contents compared to unmulched plots. Mulching with coir pith recorded the maximum P content followed by plastic mulching. These treatments would have contributed to the maximum mineralization of P. T_7 (Mulching with coir chips) recorded the highest potassium content of 92.70 kg/ha followed by T_3 (Coir pith) with a value of 84.46 kg/ha. Savithri *et al.*, (1993) also noticed that coir pith is rich in potassium and being acidic, its application can enhance the release of mineral potassium in soil and hence the quantity of potassium fertilizers can be reduced in agriculture.

88

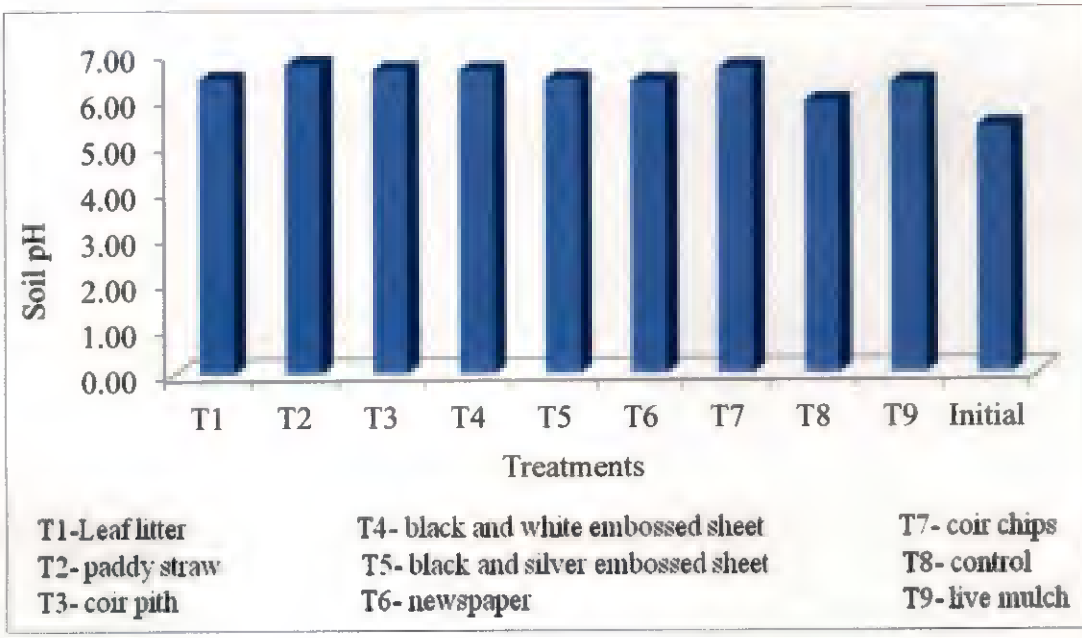

Fig.1. Soil pH as influenced by the treatments

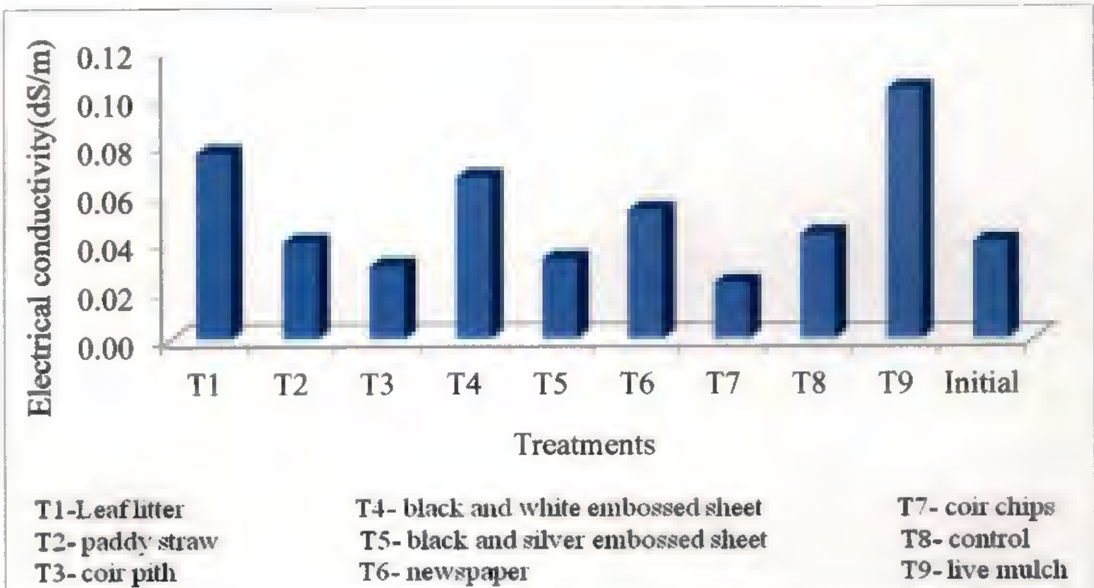

Fig.2. Soil electrical conductivity as influenced by the treatments

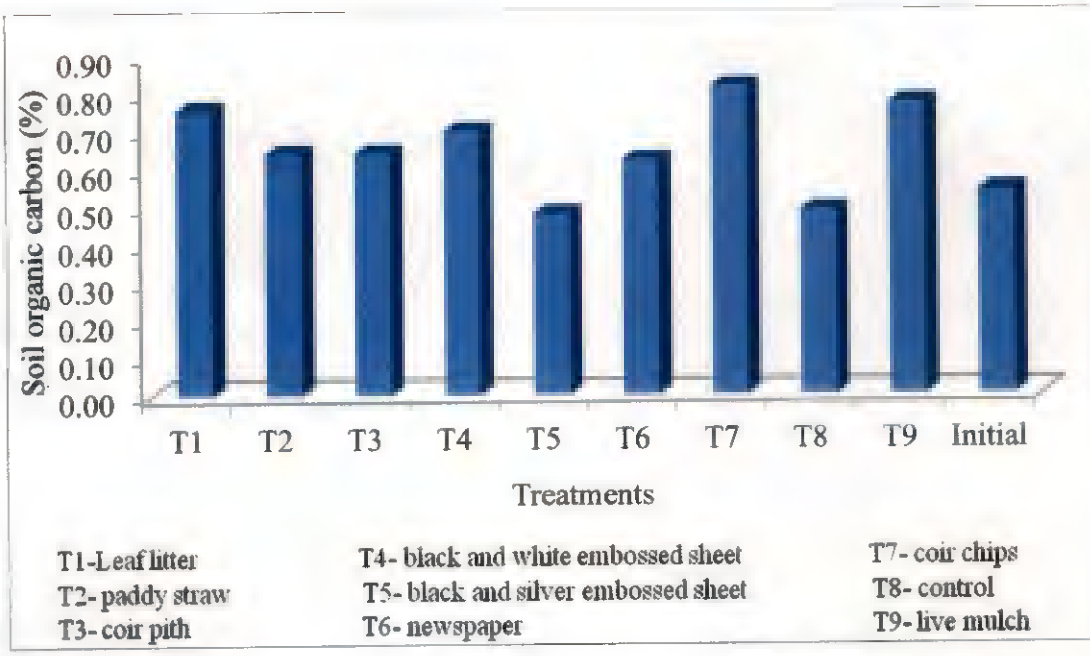

Fig.3. Soil organic carbon as influenced by the treatments

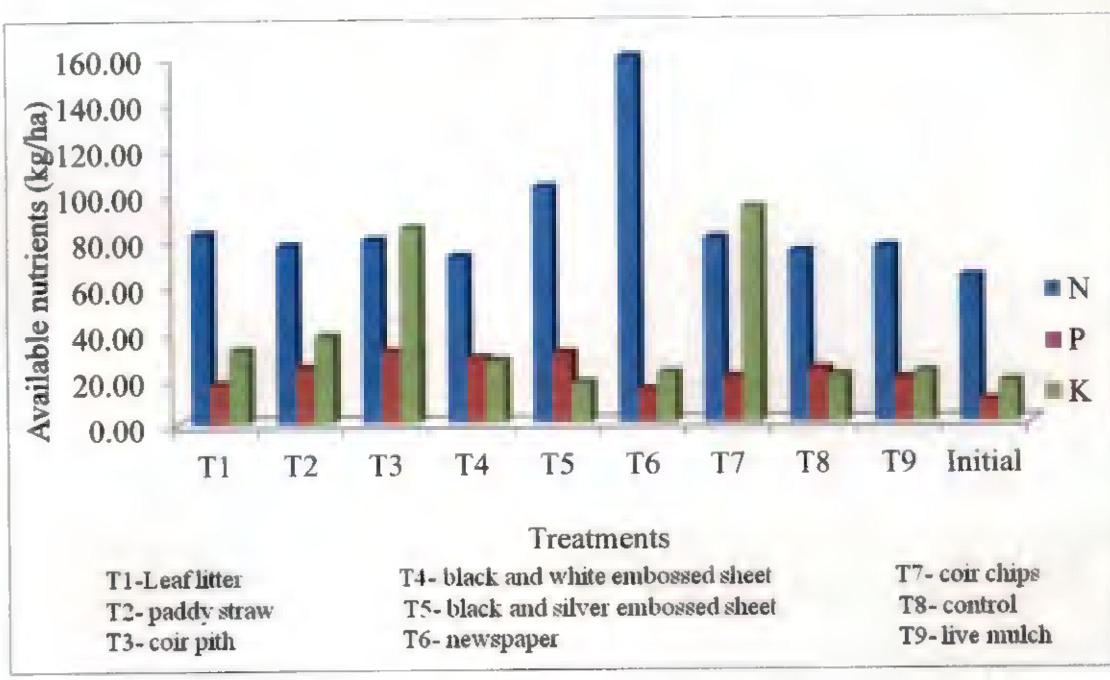

Fig.4. Available soil N, P and K as influenced by the treatments

90

5.2 Effect of mulching on soil microbial population

Different mulching treatments significantly increased the microbial population (bacteria, fungi and actinomycetes) in soil (Fig.5). Microbial activity, which relies on the availability of decomposable material, plays an important role in regulating soil fertility and transforming organic matter (Marinari *et al.*, 2007).

The initial population of bacteria, fungi and actinomycetes were 6 cfu g^{-1}, 8.67 cfu g^{-1} and 7.89 cfu g^{-1}, respectively. After the experiment, the highest population of bacteria (52.33×10^6cfu g^{-1}) and actinomycetes (171.0×10^5cfu g^{-1}) were observed in T_2 (mulching with paddy straw). According to Chen *et al.* (2010), rice straw mulching increased the number of Pseudomonas colony forming units in wheat rhizosphere and bulk soils. The favourable effect of paddy straw as increasing the bacterial and actinomycetes population is evident from the study. The same treatment also could increase the population of fungi after the trial. Mulching with plastic sheet and newspaper could not significantly alter the microbial populations. Live mulch of cowpea could bring about a significant increase in actinomycetes population after the trial. Yadav and Yadav(2013) reported that the soil microbial population is dependent on soil temperature, air temperature and relative humidity. The highest population of fungi (22.67×10^4cfu g^{-1}) was observed in T_1 (mulching with leaf litter) followed by T_2 (mulching with paddy straw) and T_7 (mulching with coir chips).

The different mulching treatments significantly influenced the population of bacteria, fungi and actinomycetes. In general, plots mulched with paddy straw favoured the microbial population. Organic mulching materials might have provided the energy and favourable condition for the growth of microbes which in turn have increased their population.

91

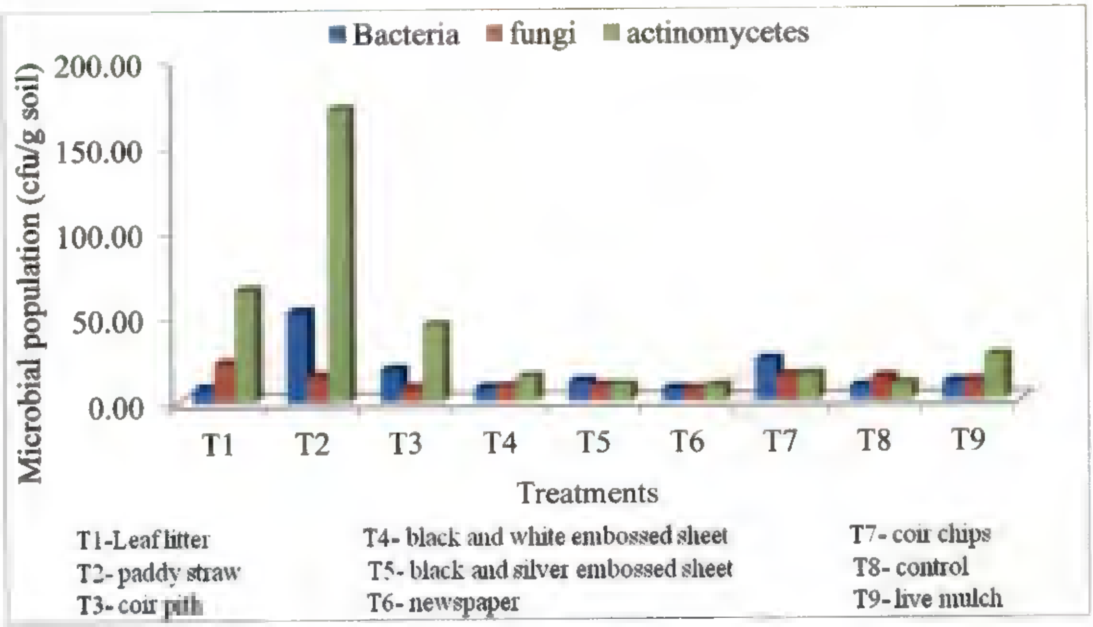

Fig.5. Soil microbial population as influenced by the treatments

91

5.3 Effect of mulching on soil microclimate

5.3.1 Minimum soil temperature

The minimum soil temperature at surface, 15 cm and 30 cm depth were significantly influenced by the treatments as depicted in Fig.6,7,8. The lowest minimum temperature was recorded in unmulched plots (T_8) followed by T_9 (live mulch) during the entire crop period. Mulching with black and silver embossed sheet (T_5) showed the peak value of soil minimum temperature at surface. According to Incalcaterra and Vetrano (2000), under the transparent polyethylene mulch film , the average soil temperatures at 5 cm depth recorded at 08.00 and 12.00 h were 1.7 and 2.7°C higher than unmulched plots of okra. Compared to the unmulched plots and organic mulches, polythene sheets recorded higher values of soil minimum temperature. Low soil temperature under organic mulches is due to high moisture holding capacity of organic materials as reported by Wooldridge and Harris (1991).

5.3.2 Maximum soil temperature

The maximum soil temperature at surface, 15 cm and 30 cm depth was significantly influenced by the different mulching treatments as shown in Fig.9,10,11. In general, the maximum soil temperature was observed under plots mulched with black and silver embossed sheet (T_5) followed by mulching with black and white embossed sheet (T_4) and mulching with newspaper. Soil temperature was 7°C higher under mulch compared to bare soil as observed by Lamont (1993). Park *et al*., (1996) observed an increase of 2.4°C in average soil temperature at 15 cm depth under transparent film and an increase of 0.8°C under black film. Throughout the experimental period, mulching with organic wastes like leaf litter, paddy straw, coir pith and coir chips maintained significantly lower maximum temperature at surface, 15 cm depth and 30 cm depth. Thus, the effect of organic mulching on reduction in maximum temperature is evident from the study. This may be due to moisture conservation.

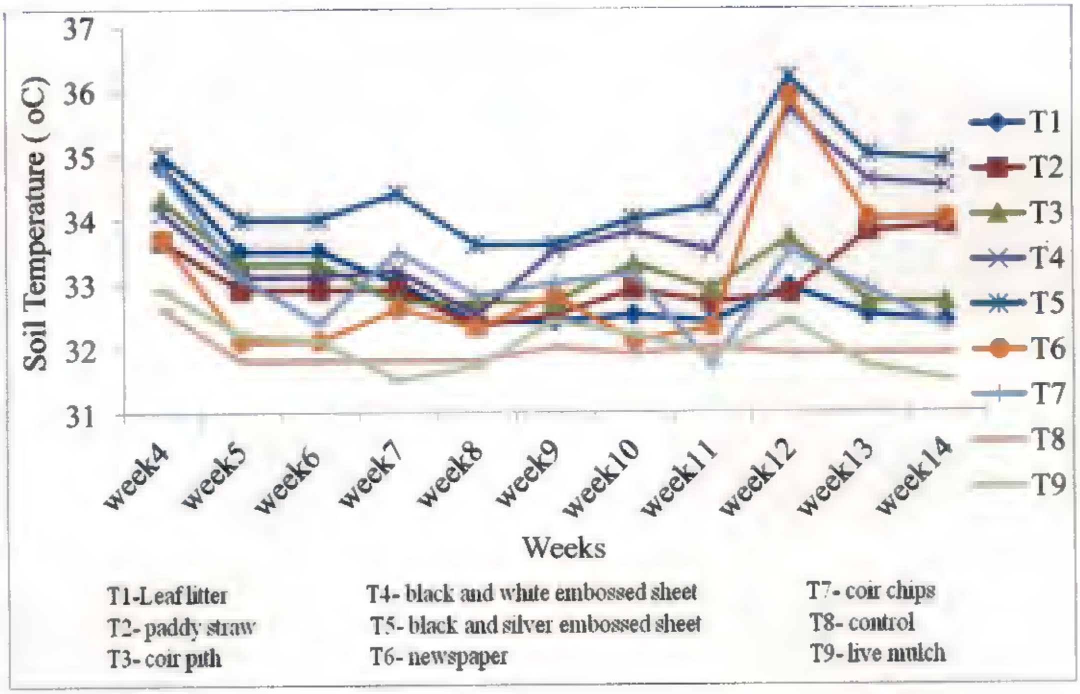

Fig.6. Minimum soil temperature at surface as influenced by the treatments

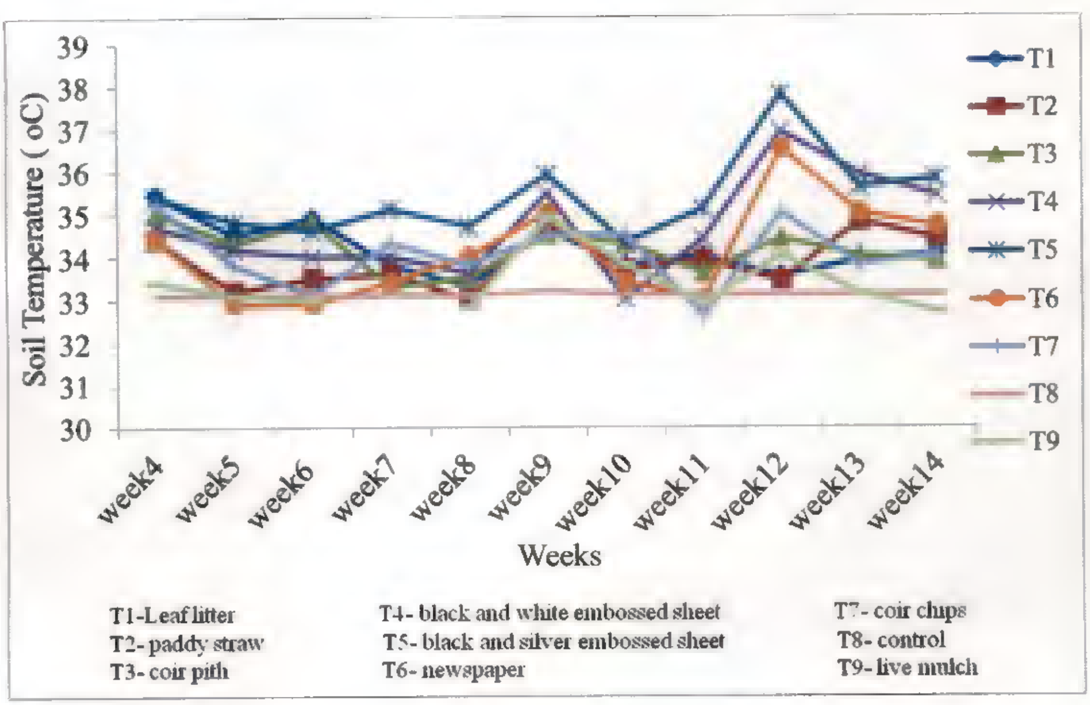

Fig.7. Minimum soil temperature at 15 cm depth as influenced by the treatments

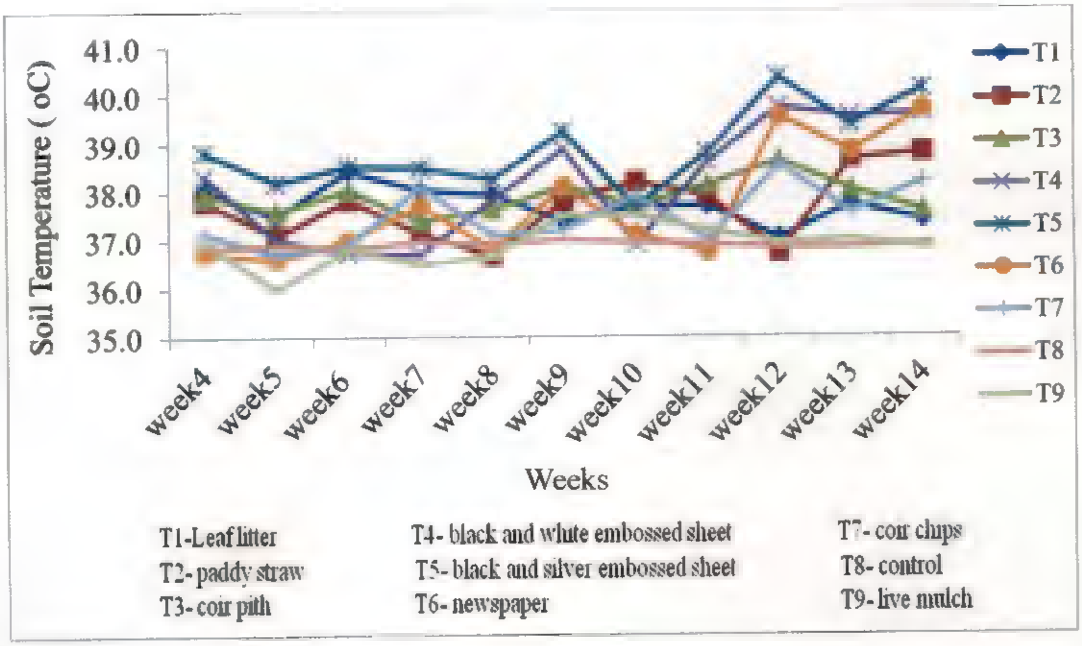

Fig.8. Minimum soil temperature at 30 cm depth as influenced by the treatments

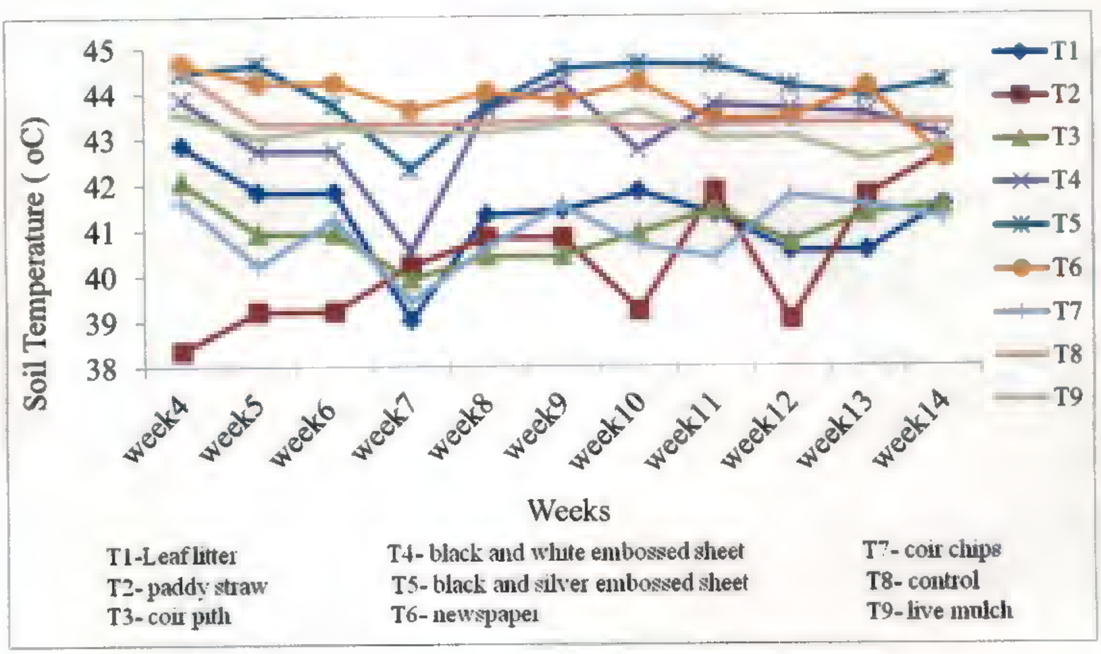

Fig.9. Maximum soil temperature at surface as influenced by the treatments

94

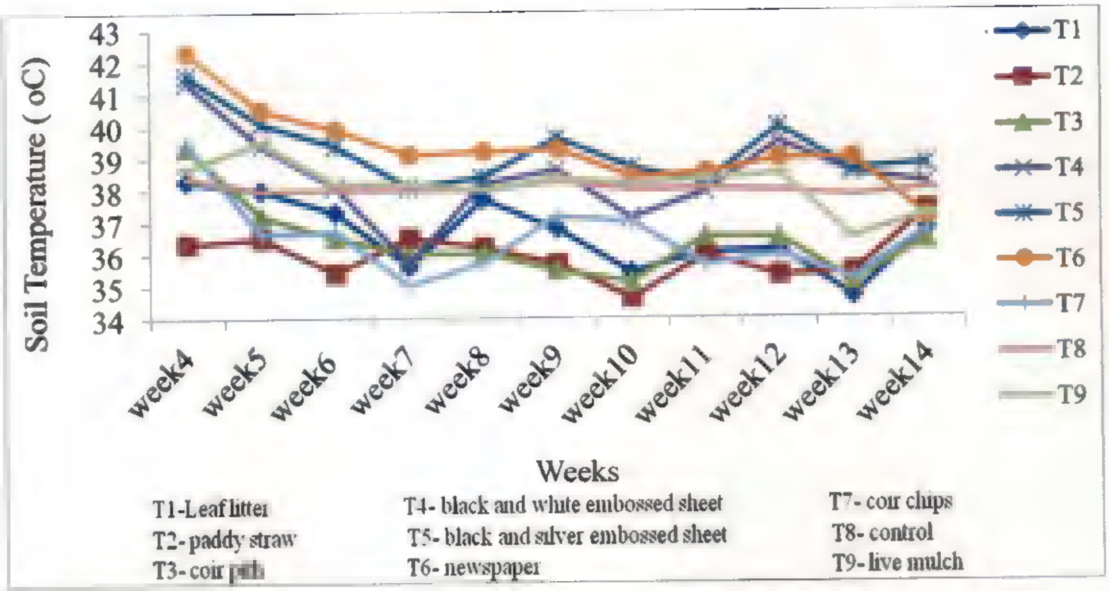

Fig.10. Maximum soil temperature at 15cm depth as influenced by the treatments

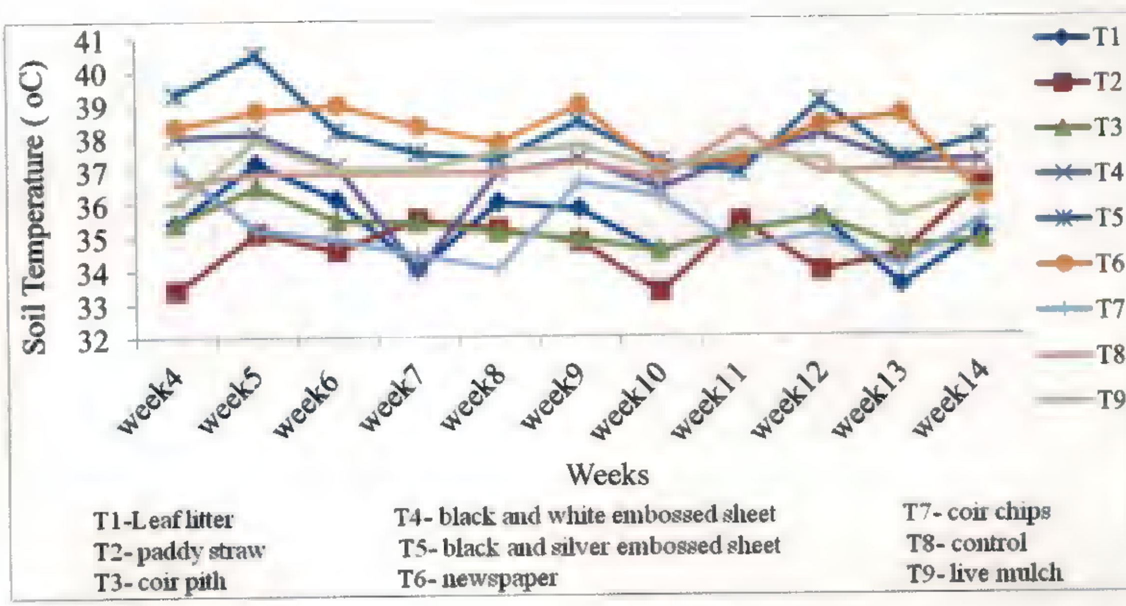

Fig.11. Maximum soil temperature at 30 cm depth as influenced by the treatments

5.3.3 Soil moisture content

Soil moisture content varied significantly based on the type of mulching materials used (Fig.12,13,14).Higher moisture content at surface was recorded under plots mulched with paddy straw (T_2) throughout the crop period. Aswathy *et al*. (2006) also reported higher moisture content in the range of 33 to 100 per cent by mulching with paddy straw and green leaves compared to unmulched plots. Mulching with coir pith (T_3) and coir chips (T_7) also maintained a higher moisture content at surface. All mulches except newspaper and live mulching increased soil moisture content over control at different depths. Organic mulches were superior to plastic mulches. The surface mulch favourably influenced the soil moisture regime by controlling evaporation from the soil surface (Jalota and Prihar, 1990; Prihar *et al*., 1996; Ji *et al*., 2001; Pawar *et al*., 2004), increasing infiltration and soil water retention, decreasing bulk density (Kladivko and Unger, 1994) and facilitating condensation of soil water at night due to temperature reversals (Tisdall *et al*., 1991).

96

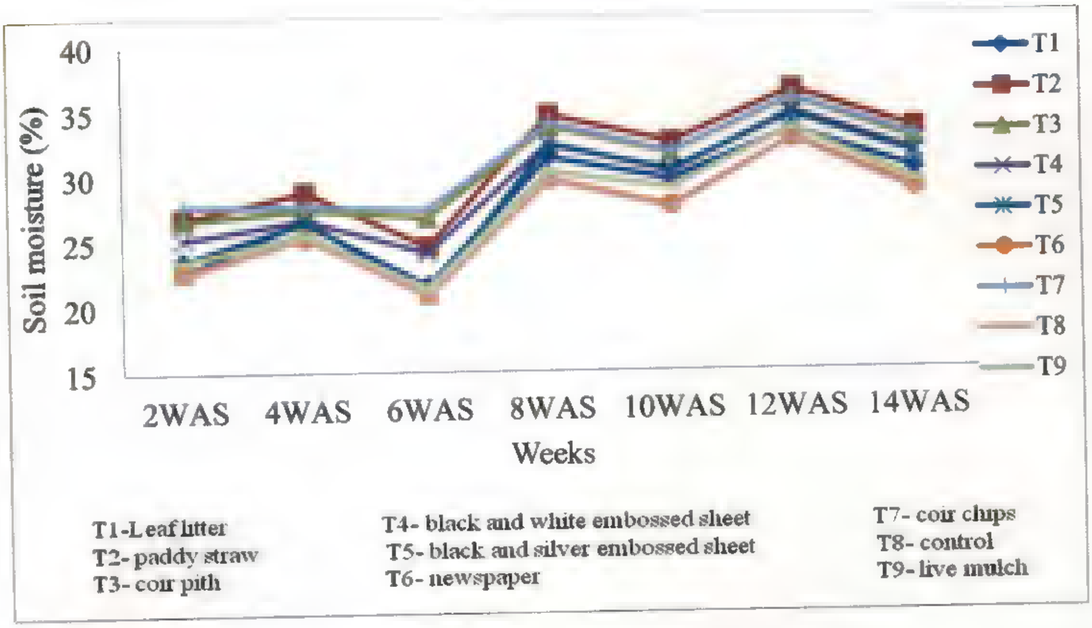

Fig.12. Soil moisture at surface as influenced by the treatments

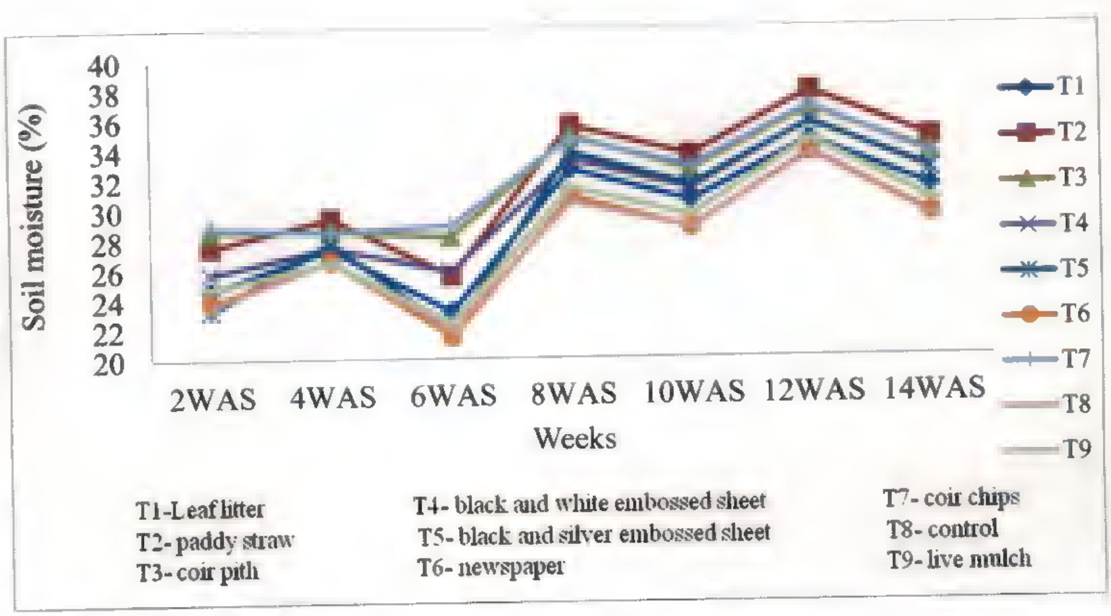

Fig.13. Soil moisture at 15 cm depth as influenced by treatments

97

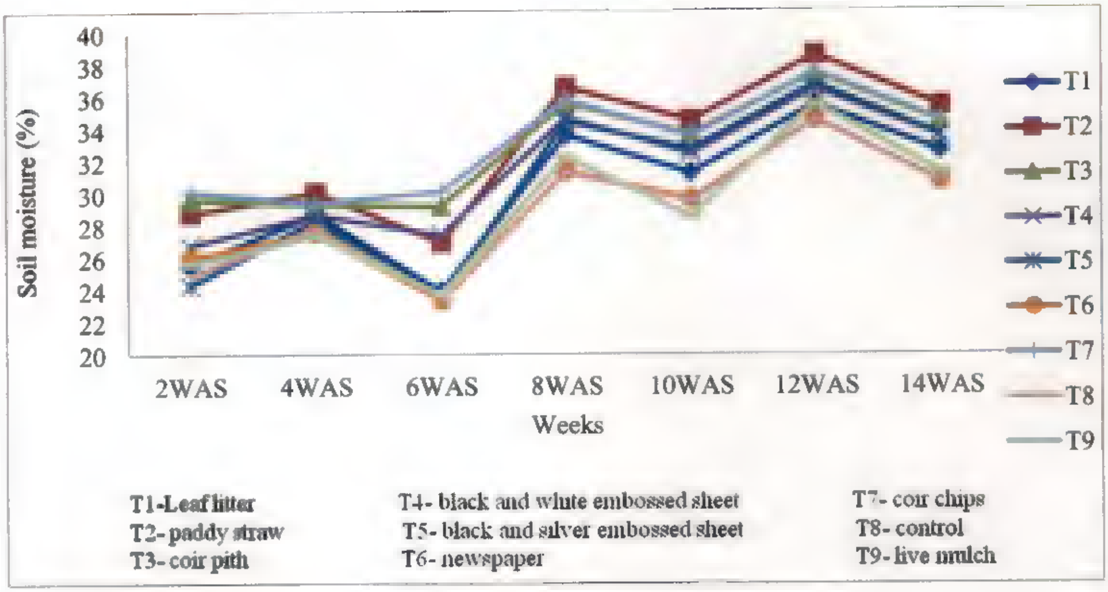

Fig.14. Soil moisture at 30 cm depth as influenced by treatments

98

5.4 Crop weather relationships

The minimum soil temperature and soil moisture showed significant positive correlation with different plant growth parameters like plant height and number of leaves. Higher soil moisture content and optimum soil temperature under mulches improved the plant microclimate leading to early growth and development, which advanced the flowering. Similar observations with respect to plant growth parameters were also reported by Igbal *et al.*, (2009) in hot pepper and Singh and Kamal (2012) in tomato. Parmar *et al.*, (2013) reported that the increase in growth parameters of watermelon is attributed to sufficient soil moisture near root zone and minimized the evaporation loss due to mulching. The extended retention of moisture and availability of moisture also lead to higher uptake of nutrients for proper growth and development, of plants compared to that in bare soil.

Crop yield shows highly positive correlation with soil temperature and moisture. Higher yield resulted from the application of polyethylene plastic mulch might be due to optimum soil temperature and sufficient soil moisture near the root zone that ensured better plant growth expressed as vigorous plant growth during early and mid season. Wang *et al.*, (2009) also found that plants under polyethylene mulch produced larger fruits and had higher fruit yield per plant because of the better plant growth due to favourable hydro-thermal regime of soil and complete weed free environment.

Days to first flowering showed a significant negative correlation with sunshine hours and evaporation. Days to first harvest showed significant positive correlation with mean relative humidity and rainfall.

5.4 Effect of mulching on weed population

Typical upland weeds were observed in the experimental field. Predominant broad leaved weeds were *Euphorbia geniculata*, *Borreria hispida* and *Centrosema pubescens*. The predominant grassy weeds seen in the plots were *Panicum maximum* and *Digitaria ciliaris*.

Observations on weed population at 30, 60 and 90 DAS are given in Fig.15. The highest count of broad leaved weeds was observed in unmulched control (T_8). The lowest weed count (6.67) was seen in T_5 (Mulching with black and silver embossed sheet) followed by T_4 (mulching with black and white embossed sheet). The same trend was observed in the case of grassy weeds also (Fig.16). Mulching with sheets reduced the occurrence of grassy weeds. Ashworth and Harrison (1983) also noticed that the use of polythene mulches were efficient for reducing the problems related to weed growth in vegetable plots.

5.5 Effect of mulching on plant growth and yield

Mulching with black and white embossed sheet recorded early germination and the highest germination percentage followed by black and silver embossed sheet as depicted in Fig.17. This could be explained in view of soil temperature and moisture. Mulching with plastic sheets significantly increased the soil temperature and conserved soil moisture. The best germination temperature for okra was reported to be 30°C (GTZ, 1992).

Height of the plants ranged from 22.50 cm to 54.63 cm, 57.70 cm to 106.67 cm and 70.97 cm to 119.53 cm at 30, 60 and 90 DAS respectively (Fig. 18). Mulching with black and silver embossed sheet (T_5) and mulching with black and white embossed sheet (T_4) contributed the highest plant height throughout the crop growth period. Compared to unmulched plots, mulched plots contributed more plant height. Among the organic mulches, paddy straw (T_2), coir pith (T_3) and coir chips (T_7) were better. Compared to leaf litter (T_1) and newspaper (T_6), unmulched control plots and plots under live mulch recorded lower plant height throughout the crop period. Usman *et al*., (2005) also reported reduction in plant height of okra due to crop weed competition in unmulched plots.

Mulching registered significant variation in the number of leaves (Fig.19). More number of leaves were observed in plots mulched with black and silver embossed sheet (T_5) followed by those mulched with black and white embossed sheet (T_4).The same trend was reported by Goswami and Saha (2006) in elephant foot yam. Lower number of leaves were noticed in plots under live mulch (T_9) and unmulched control (T_8).

Plots mulched with paddy straw (T_2) flowered earlier (38.33 days) while live mulching (T_9) recorded late flowering (81.67 days) as depicted in Fig.20. The earliness in flowering may be due to high heat unit efficiency of paddy straw (Aswathi *et al.*, 2009). Plots mulched with black and white embossed sheet (T_4) also recorded early flowering (41.33 days) compared to the rest of the treatments. Subrahmaniyan *et al.*, (2008) also reported that groundnut flowered five days earlier when raised under plastic mulch compared to control.

Plastic film sheets greatly influenced the number of flowers per plant compared to other treatments and unmulched control (Fig.21). The highest number of flowers (24.49) was observed in plots mulched with black and silver embossed sheet (T_5) followed by black and white embossed sheet (21.96), leaf litter (T_1) and paddy straw (T_2). Number of flowers in unmulched control (T_8) was 14.67. The lowest number of flowers (3.69) was observed with live mulching (T_9). The beneficial effect of intercropping with a pulse crop on the main crop of bhindi could not be observed in the trial. Singh (2005) reported the failure of organic mulches in enhancing the production of flowers in tomato compared to polythene mulches.

Figure 22.shows that plots mulched with plastic sheets recorded early harvesting (59 DAS) and the highest crop duration (109.67 days). Ibarra *et al.* (2001) also observed the same trend that plastic mulching recorded earlier harvests than bare soil and this can be attributed to soil temperature and moisture differences under plastic mulches.

The yield of okra was significantly influenced by different treatments as evident from Fig.23. The plots mulched with black and silver embossed sheet (T_5) recorded the highest yield of 14.42 t ha^{-1} followed by 11.66 t ha^{-1} in the plots mulched with black and white embossed sheet (T_4). Thus the positive effect of plastic mulching with black and silver embossed sheet is evident from the improvement in productivity of the crop. It is due to the overall effect of this mulch on the conservation of soil moisture, maintaining favourable ranges of soil temperature, favourable effect on soil microorganisms and other physical and chemical properties of the soil. Mahadeen (2014) reported the positive effects of black polythene sheet mulching on yield of okra. Olabode *et al.*, (2007) also reported that the more favourable soil environment under the polythene, during the early part of the growing season, resulted in increased number of fruits per plant, average fruit weight and fruit yield/ha. Among organic mulching treatments, paddy straw and leaf litter gave better yield of 10.21 t ha^{-1} and 10.05 t ha^{-1} respectively. Mulching with newspaper and coir pith did not favour a higher yield in bhindi. This result agrees with the findings of Lal (1994) who reported higher yields of okra by mulching. Organic mulches helped to maintain the soil moisture for longer period than the bare soil. Ghosh *et al.*, (2006) found more moisture content in soil mulched with wheat straw than that of without mulch under field condition while observing the growth and yield response of ground nut.

102

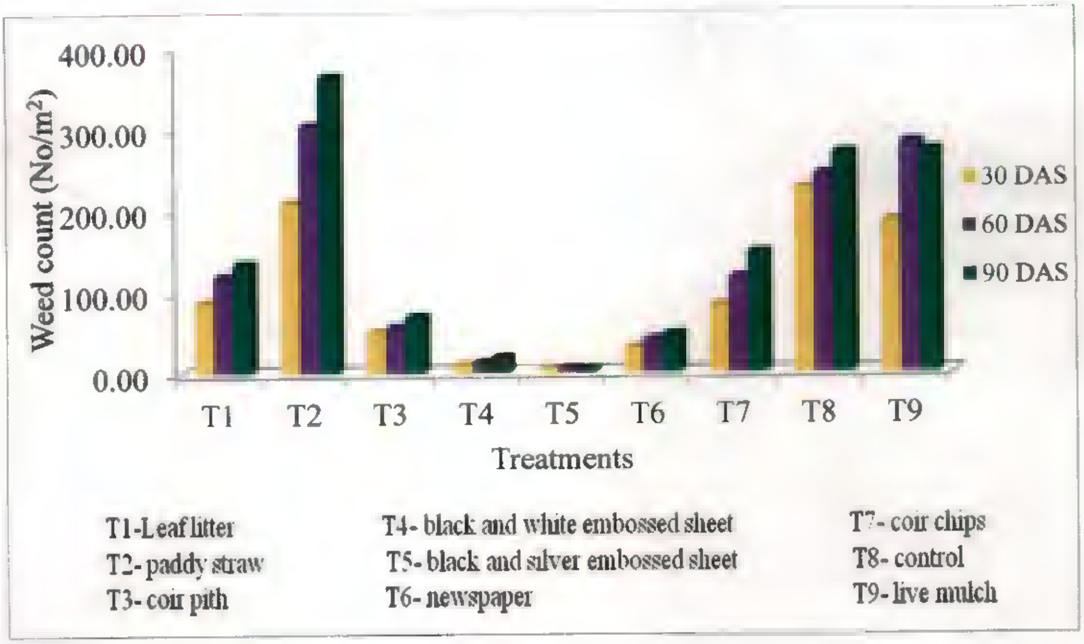

Fig.15.Broad leaved weeds as influenced by the treatments

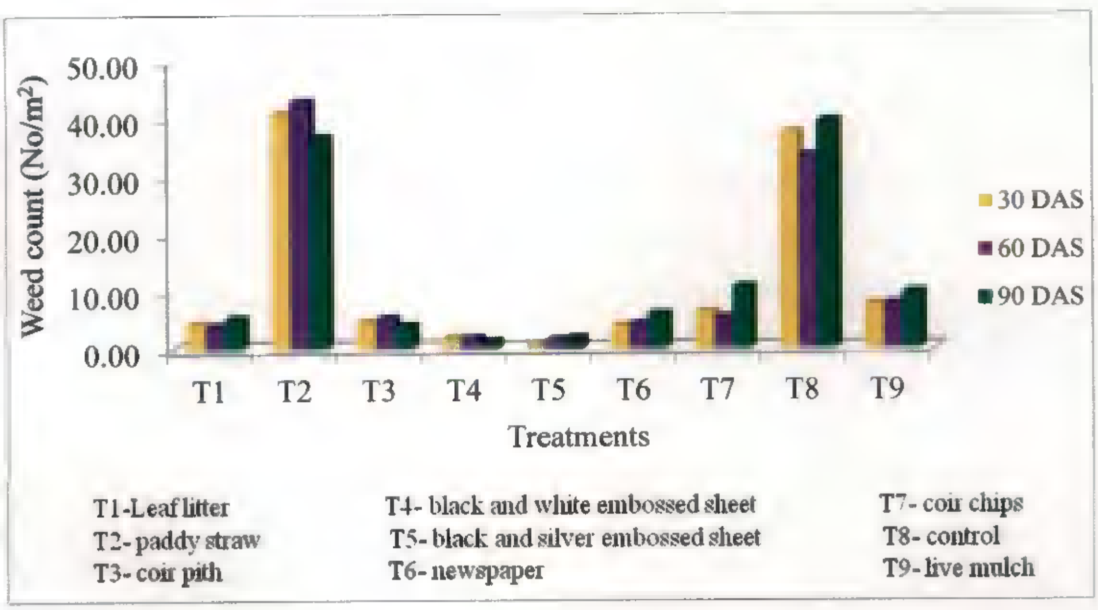

Fig.16. Grassy weeds as influenced by the treatments

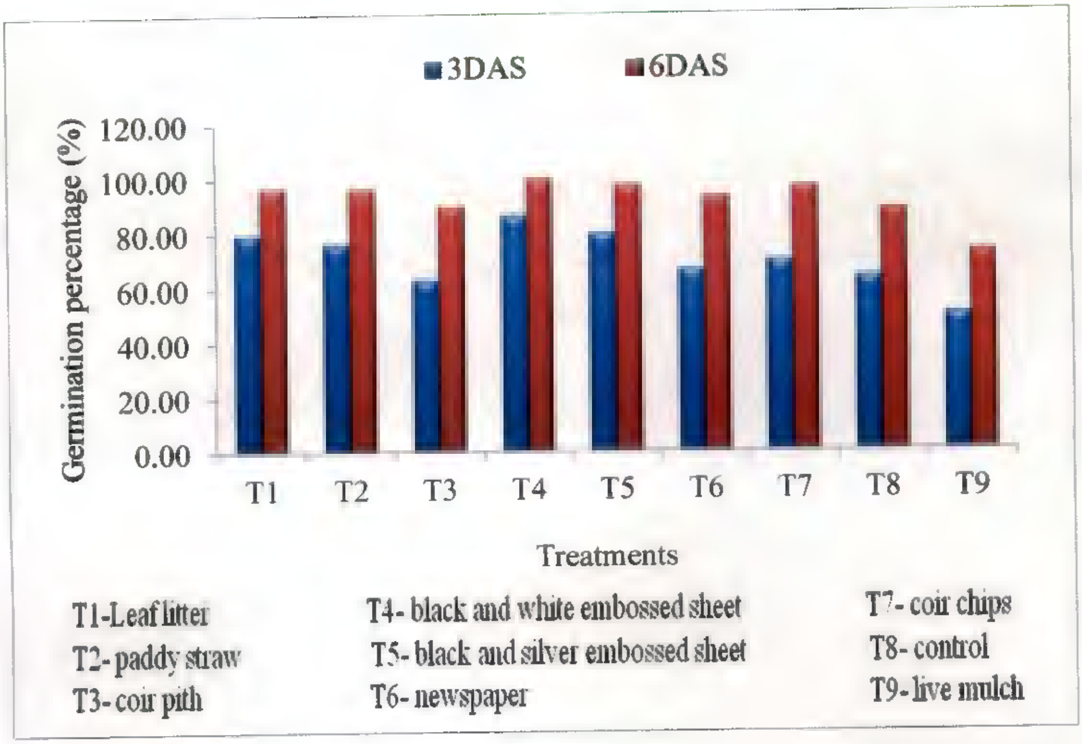

Fig.17. Germination percentage as influenced by the treatments at 3 and 6 DAS

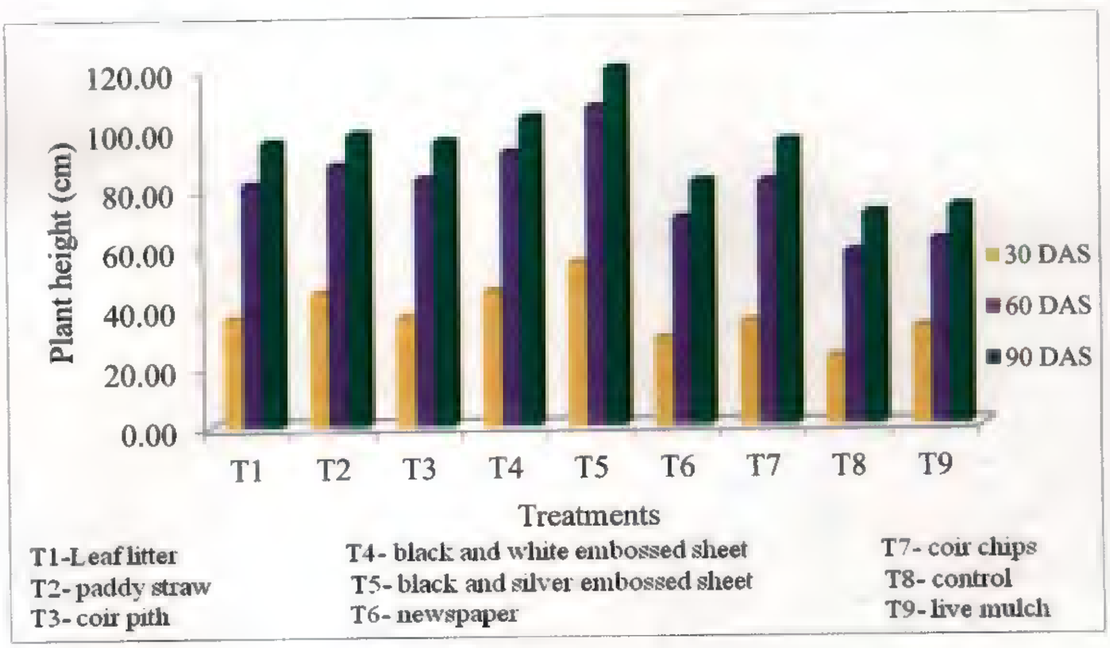

Fig.18. Plant height as influenced by the treatments

104

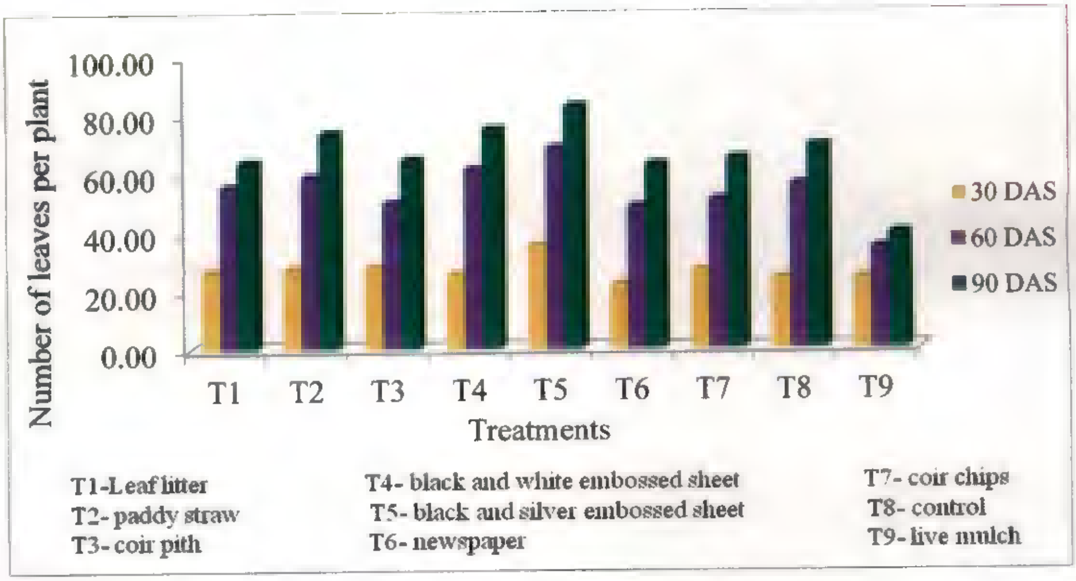

Fig.19. Number of leaves as influenced by the treatments

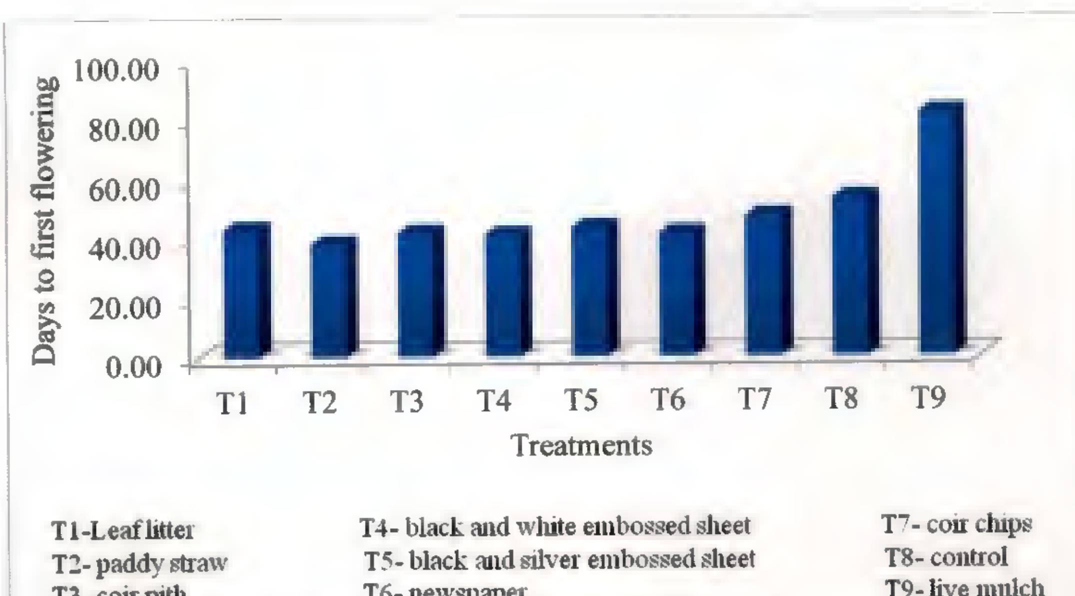

Fig.20. Days to first flowering as influenced by the treatments

105

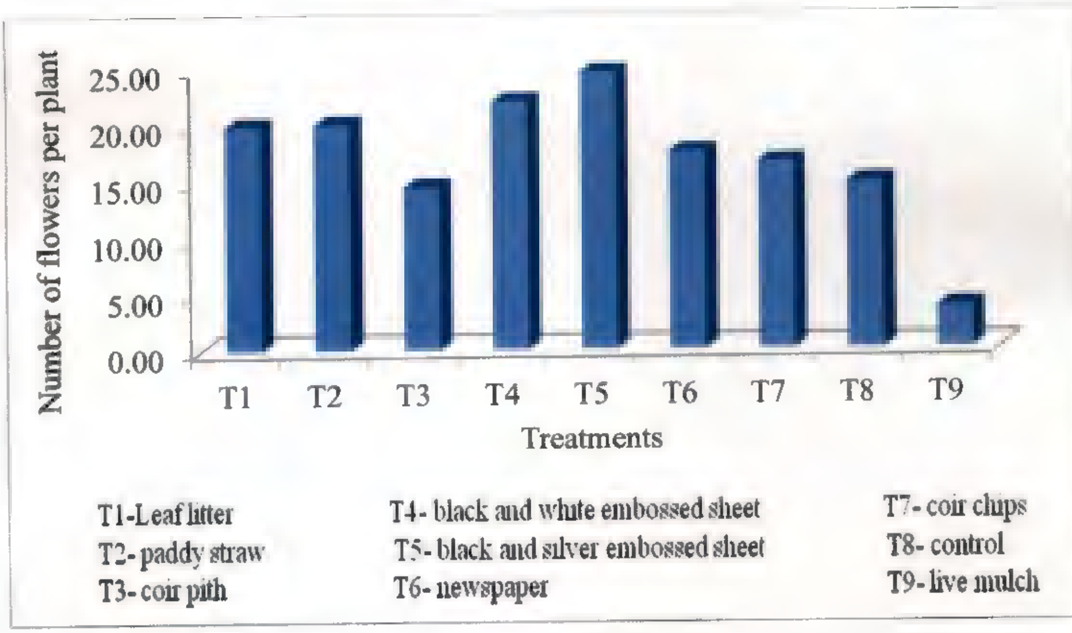

Fig.21. Number of flowers per plant as influenced by the treatments

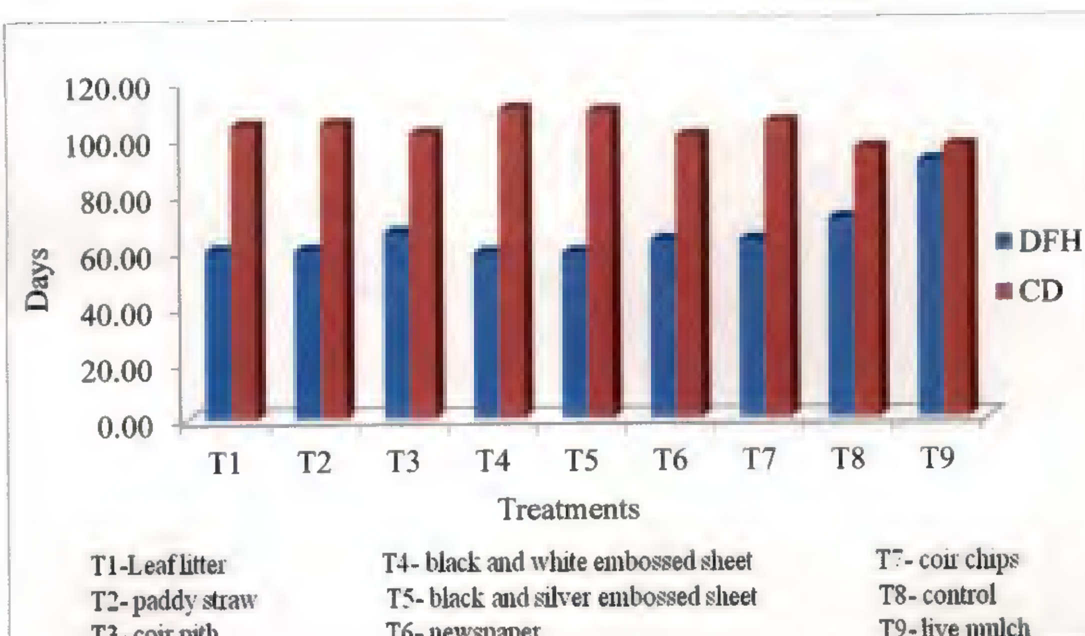

Fig.22. Days to first harvest and crop duration as influenced by the treatments

106

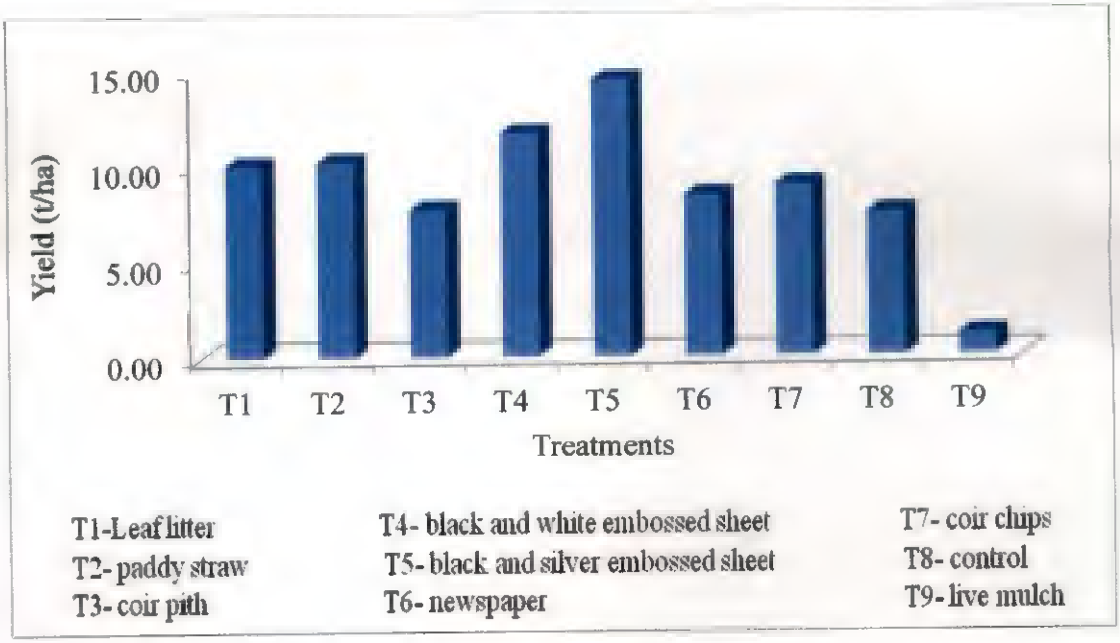

Fig.23. Yield as influenced by the treatments

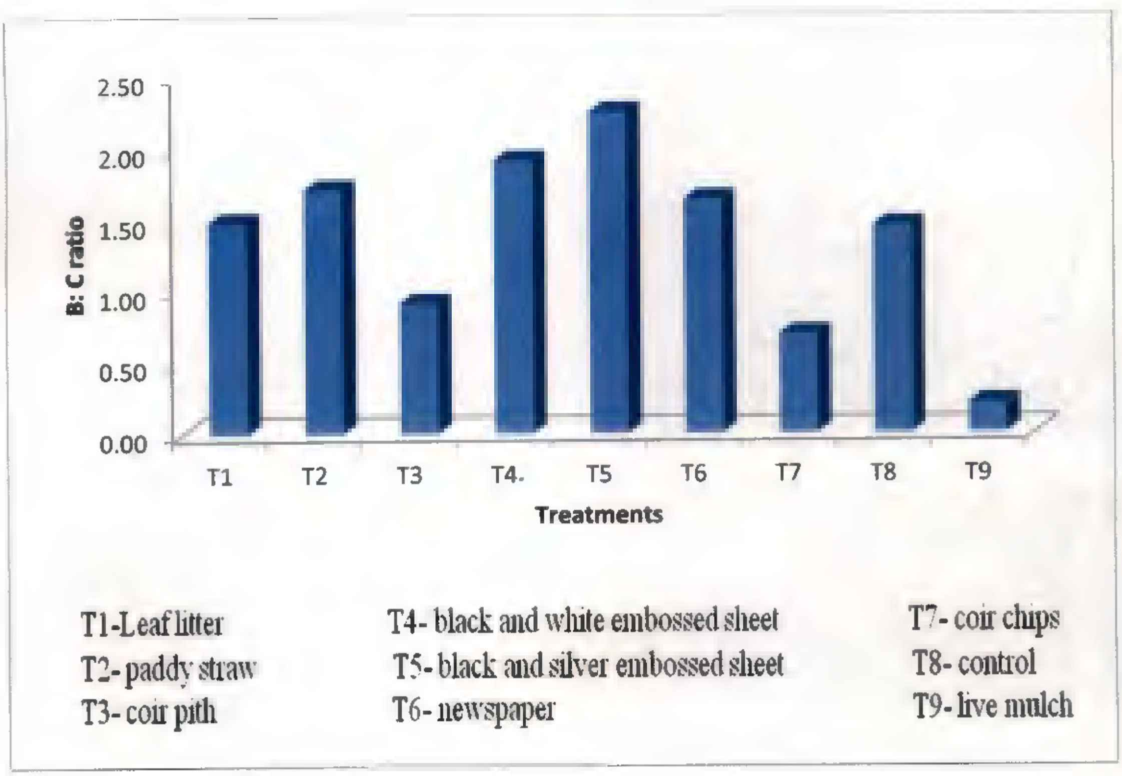

Fig.24. B: C ratio as influenced by the treatments

107

5.6 Economics

The different treatments contributed significant variation in benefit to cost ratio (Fig. 24). The highest B: C ratio of 2.24 was obtained in mulching with black and silver embossed sheet (T_5). Among the organic mulches paddy straw recorded the highest B: C ratio of 1.71. Because of the higher material cost, plots mulched with coir pith (T_3) and coir chips (T_7) recorded lower values of B: C ratio. The lowest B: C ratio of 0.21:1 was observed with live mulch (T_9).

CONCLUSION

The study on "Mulching for soil quality and climate stress mitigation and crop productivity in okra" revealed that mulching had significant influence on soil physical, chemical and biological properties. Mulching with black and silver embossed sheet identified as the best mulching practice in view of soil characters, soil micro climate and yield of okra. The B: C ratio of 2.24 was obtained in mulching with black and silver embossed sheet (T_5). Mulching was found to be a potential method to maintain soil quality and microclimate which in turn has improved the crop productivity in okra.

109

SUMMARY

CHAPTER 6

SUMMARY

The present study on "Mulching for soil quality, climate stress mitigation and crop productivity in okra" was carried out in Academy of Climate Change Education and Research, Kerala Agricultural University, Vellanikkara, Thrissur during 2015-2016. The trial was laid out in randomized block design with three replications. The treatments included mulching with leaf litter, paddy straw, coir pith, black and white embossed sheet, black and silver embossed sheet, newspaper, coir chips, live mulching (cow pea) and unmulched control. The variety Arka Anamika was used in trial. The summary of salient findings is presented below.

- The plots mulched with plastic sheets showed early germination and higher germination percentage.
- The highest plant height and number of leaves were recorded in plots mulched with black and silver embossed sheet.
- Plants mulched with paddy straw flowered earlier (38.33 DAS) while the highest number of flowers (25.66) were recorded in plots mulched with black and silver embossed sheet.
- In general mulching with plastic sheets recorded early harvesting and the highest crop duration.
- The highest yield (14.41 t ha^{-1}) was observed in plots mulched with black and silver embossed sheet.
- Mulching with paddy straw recorded the highest pH (6.74) and live mulching (cow pea) recorded the highest EC (0.103 dS m^{-1}) for the soil.
- The highest percentage of organic carbon was recorded in plots mulched with coir chips (0.81 %).
- The highest content of available N was recorded in plots mulched with newspaper (159.03 kg/ha) and plots mulched with coir pith and coir chips showed the highest content of P and K respectively.

- The highest population of bacteria (52.33×10^6cfu g^{-1}) and actinomycetes (171.00×10^5cfu g^{-1}) were observed in plots mulched with paddy straw whereas, the highest population of fungi (22.67×10^4cfu g^{-1}) was observed in plots mulched with leaf litter.
- Minimum soil temperature and soil moisture at different depths showed a positive correlation with different growth parameters of okra.
- Soil temperature and moisture showed a negative correlation with phenological parameters.
- Weather parameters like sun shine hours and evaporation showed a negative correlation with phenological parameters while rainfall showed positive correlation.

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130

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131

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133

APPENDICES

134

Appendix I. Meteorological data during the crop growing period

Standard Weeks	Temperature (°C)		Mean RH (%)	Wind Speed (Km/hr)	Mean Sunshine hrs	Rainfall (mm)	evaporation (mm)	Minimum soil temperature (°C)			Maximum soil temperature (°C)		
	Minimum	Maximum						5cm	15cm	30cm	5cm	15cm	30cm
12	25.4	36.4	69.7	5.2	9.8	9.8	7.7	30.8	32.6	36.0	43.2	38.1	37.7
13	26.0	36.3	71.2	2.7	7.6	0.0	5.5	32.2	33.6	37.0	44.3	38.8	37.5
14	25.4	35.5	71.3	2.9	7.8	23.6	6.3	31.4	32.7	36.8	42.1	37.4	36.6
15	28.5	36.7	72.2	2.6	6.6	2.2	4.8	32.5	32.9	36.6	44.1	38.6	36.9
16	26.3	36.2	69.2	2.1	9.2	0.0	4.1	31.7	32.9	36.6	43.4	38.2	37.2
17	26.3	36.2	69.1	2.4	9.2	0.0	4.5	31.7	32.9	36.6	43.4	38.2	37.2
18	26.3	36.2	69.9	2.1	8.1	1.2	3.9	31.7	32.9	36.6	43.4	38.2	37.2
19	26.3	36.2	79.9	2.4	8.6	170.6	4.1	31.7	32.9	36.6	43.4	38.2	37.2
20	26.5	36.2	81.9	2.1	9.6	33.3	2.5	31.9	33.0	36.7	43.5	38.2	37.1
21	26.5	36.2	82.1	3.2	6.8	59.8	3.8	31.8	32.9	36.6	43.3	38.2	37.0
22	26.7	36.3	88.4	2.4	8.2	228.4	3.3	31.9	32.9	36.6	43.5	38.3	37.1
23	26.4	36.2	93.2	2.3	8.6	190.5	3.5	31.8	32.9	36.6	43.4	38.2	37.1
24	26.4	36.2	83.0	2.1	7.3	45.7	3.5	31.8	32.9	36.6	43.4	38.2	37.1
25	26.5	36.2	89.5	2.3	9.5	92.9	3.1	31.8	32.9	36.6	43.4	38.2	37.1
26	26.4	36.2	93.0	2.1	8.8	124.6	2.6	31.8	32.9	36.6	43.4	38.2	37.1

Appendix II. Physio-chemical properties of soil

Particulars	Content	Method used
1.Physical properties Particle size composition		
Coarse sand (%)	31.90	Robinson international pipette method (Piper, 1942)
Fine sand (%)	27.30	
Silt (%)	18.64	
Clay (%)	22.16	
2. Chemical properties		
1.pH	5.37	1:2.5 soil water ratio Beckman glass electrode (Jackson,1973)
2. EC (dS/m)	0.04	Conductometric method (Jackson,1973)
3. Organic Carbon (%)	0.54	Walkley and Black method (Jackson, 1973)
4. Available N (kg/ha)	62.63	Alkaline permanganate method (Subbiah and Asijah, 1956)
5. Available P (kg/ha)	9.41	Ascorbic acid reduced molybdophosphoric blue colour method (Watnabe and Olsen, 1965)
6. Available K (kg/ha)	17.28	Neutral normal ammonium acetate extractant flame photometry (Jackson, 1973)

136

Appendix III. Media used for enumeration of micro organisms in soil

SI No.	Microbes	Medium	Reference
1	Bacteria	Nutrient agar	Agarwal and Hasija, 1986
2	Fungi	Martin's Rose Bengal Agar	
3	Actinomycetes	Kenknight's Agar	

137

MULCHING FOR SOIL QUALITY, CLIMATE STRESS MITIGATION AND CROP PRODUCTIVITY IN OKRA

By
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(2011-20-112)

ABSTRACT OF THE THESIS

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ABSTRACT

Global warming and climate change is the greatest concern of mankind in 21st century. Under changing climatic scenarios crop failures, reduction in yields, reduction in quality and increasing pest and disease problems are common and they render the vegetable cultivation unprofitable. Various crop management practices such as mulching and the use of shelters and raised beds help to conserve soil moisture, prevent soil degradation, and protect vegetables from heavy rains, high temperatures and flooding. These protective coverings reduce evaporation, moderate the soil temperature and reduce soil run-off and erosion.

A study entitled "Mulching for soil quality, climate stress mitigation and crop productivity in okra" was carried out at the Academy of Climate Change Education and Research, Kerala Agricultural University, Vellanikkara, Thrissur during 2015-2016. The experiment consisted of 9 treatments. Mulching with leaf litter, paddy straw, coir pith, black and white embossed sheet, black and silver embossed sheet, newspaper, coir chips, un mulched control and live mulch (cow pea).

The biometric and phenological parameters were significantly influenced by the treatments. The plots mulched with plastic sheets showed early germination and higher germination percentage. The highest plant height and maximum number of leaves recorded were in plots mulched with black and silver embossed sheet. Plants mulched with paddy straw flowered earlier (38.33 DAS) and the highest number of flowers (25.66) was recorded in plots mulched with black and silver embossed sheet. In general, mulching with plastic sheets promoted early harvesting and highest crop duration. The highest yield (14.41 t/ha) was observed in plots mulched with black and silver embossed sheet.

The soil microbial count was significantly influenced by the treatments. The highest population of bacteria (52.33×10^6cfu g^{-1}) and actinomycetes (171.00×10^5cfu g^{-1}) were observed in plots mulched with paddy straw whereas, the 139