EFFECT OF DIFFERENT MULCHES ON SOIL TEMPERATURE AND SOIL WATER RETENTION IN RELATION TO SEEDLING EMERGENCE AND CROP GROWTH

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DECLARATION

I hereby declare that this thesis entitled "Effect of different mulches on soil temperature and soil water retention in relation to seedling emergence and crop growth" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "Effect of different mulches on soil temperature and soil water retention in relation to seedling emergence and crop growth" is a record of research work done independently by Smt.P.Jayasree under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

1. INTRODUCTION

Uncertain water availability, unstable crop prices, environmental constraints and increase in the cost of energy and labour has overwhelmed the present day farmers to a great extent. Water has become such an important commodity and its management is the responsibility of the farmers, to provide the proper amount of water and air for his crops.

One important dimension of land quality is its capacity to hold the inputs that are applied and to ensure their use by the plant. In the case of water, this quality is called water holding capacity. To maintain favourable conditions for crop growth, management of physical conditions of soil is highly necessary. The factors to be considered are moisture, aeration, temperature and the resistance to root penetration to the depth, normally reached by the given crop.

Moisture stress in plants, is a resultant of combined effects of soil moisture stress in the root zone, resistance to water movement in the plant, stomatal control, and atmospheric evaporation demand (Sivakumar and Virmani, 1979). Soil water in the upper layers, more than any other factor, primarily determines seed germination and establishment of seedlings. Water absorption by seeds, is the first event in the process of seed germination. It is influenced by soil temperature through its effects on the viscosity of the water and permeability of seed coat (Chaudhary et al., 1971).

The moisture situation of the soil can be modified in a variety of ways. The methods used may be direct application or removal of water or through changes in structure and temperature of the soil. The quality of moisture available depends both on the amount and distribution of soil water and on the temperature.

The amount of water in the soil has an indirect effect on soil temperature which can be managed to some extent by using mulches. The soil temperature has great influence, right from seed germination to yielding stage of plants. Soil nutrients and plant uptake are also influenced by soil temperature. Soil temperature has a profound effect on the water supplying power of the soil. The free energy of water increases with temperature.

Under rainfed conditions, especially after the rainy season, excessive rate of water loss by evaporation should be minimised to increase the water availability and water use efficiency of crops. Mulches have an important role in influencing the above factors and also the physical and chemical properties of soil.

Evaporational losses of water from soil is considerably higher in semiarid regions than humid regions and constitute single largest loss of water from field. In higher moisture regimes, more water is used for evaporation rather than crop production, reducing water use efficiency (Selvaraj, 1976). Losses by evapotranspiration are irrecoverable and are usually considered the net water requirement.

Ways and means of cutting this waste had been the object of many investigations in the past. Many have tried in creating a soil mulch and spreading foreign materials over the soil surface with varying degrees of success. The economic aspect of the problems i.e., the possibility of growing crops in more areas with the same irrigation water is of vital importance. For most of the agricultural soils, the reduction in evaporation and temperature management can be brought about by some cultivation practices like mulching and tillage. A generous amount of residues placed in and above the soil can improve the soil conditions. Mulches have an important role in temperature management and water retention. Numerous types of mulches, from rocks and stones to slowly decomposing materials like wood shavings, sawdust and chips are tried (Lamb and Chapman, 1943).

Mulching protects the soil from rainfall impact, decreases evaporation and reduces the soil temperature fluctuations. Indirectly, mulching increases the moisture content of the soil, raises its heat capacity and helps in slower warming up of the soil in spring season.

It has been reported that the soil covering conserves soil moisture, keeps soil temperature higher than bare soil and decreases frost penetration.

The effect of a given mulch depends on its colour, and its perviousness to water. Crop residue mulches even in small quantities decrease evaporation in the initial stage but large amounts are required to obtain water saving over extented period (Prihar and Arora, 1980). Appreciable conservation of moisture could be achieved by concentrating on crop residue on a portion of soil surface as well as by larger application of water.

The comparative efficacy of these mulches may vary under different conditions depending on different aspects. Some mulches act as nutrient suppliers also. Paddy straw can provide about 0.05 to one per cent phosphorus. Certain mulches like rice hull act as reflectant preventing the heating up of soil by radiation.

Present study has been undertaken with the following objectives:

1. To study the effect of different mulches on the physico chemical properties of the soil.
2. To study the effect of mulches on soil temperature and seedling emergence.
3. To investigate the effect of mulches on soil moisture characteristic.
4. To study the interaction effects of soil temperature and soil water on plant growth and yield, using Bhindi (Abelmoschus esculentus) as test crop.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Several processes like water transportation, movement of nutrients and Nitrification are affected by soil temperature. Soil temperature has profound influence on seed germination, root growth, shoot growth, nutrient uptake and crop yield. Research informations from different studies, relating soil temperature and plant growth, mulch treatment effect on soil water and temperature, nutrient uptake and other parameters relating to plant growth and yield, are reviewed here; under different topics.

2.1. Effect of different mulches on soil physical properties, with emphasis on soil temperature and soil water.

2.2. Soil temperature - its influence on seedling emergence, plant growth; yield and nutrient uptake.

2.3. Soil moisture impacts on soil temperature and consequent effect on plant growth and yield.

2.4. Influence of soil moisture and soil temperature on root growth of plants.

2.1. Effect of different mulches on soil physical properties, with emphasis on soil temperature and soil water.

Mulches were applied to crops from the dawn of Agriculture; mainly with a view to conserve the soil moisture. Scientific investigations, on the use of mulches, was directed mainly to the soil conservation aspects, as well as the changes in soil structure and effect on soil temperature, increase in organic content of the soil, microbial activities and availability of nutrients.

2.1.1 Comparative effect of different mulching materials.

Numerous types of mulches have been tried from rocks and stones to slowly decomposing materials like saw dust, chips and wood shavings, alfalfa and bean straw, hay and manures (Lamb and Chapman, 1943).

Using dry leaves as mulch, the cost of irrigation and weeding can be reduced and soil structure can be improved (Rangacharylu and Nagabhushanam, 1960).

The economy in weed control using mulches had been proved by Green (1961) Haske and Slife (1962) and Sanjeevi (1963).

The greatest amount of research with mulches were with cheap and readily available crop residues and other plant waste products like straw, stover leaves, wood chops etc. and found to increase the rate of infiltration of water into the soil and retain soil moisture for longer periods (Horning and Overson, 1962, Prihar _et al_ 1968, Wiegard _et al_ 1968).

Trials conducted by Mohanty (1977) on ginger shows that dry leaf mulches are superior to grass or soil mulch which gave best result in rhizome yield; sprouting percentage suppression of weed and prevention of soil erosion.

Bhatacharjee _et al_ (1979) showed that by using straw mulch number of irrigations can be decreased by one to two.

Ross _et al_ (1985) proved that lighter coloured more reflective mulches are less efficient than darker ones. Detailed study conducted by him showed that medium and heavy mulches reduced the water loss over 6 days by 1.4 and 2.7 mm respectively.

Anon (1986) has observed that the rice hull act as the superior reflectant but appear to be the most difficult mulch to keep in position during heavy rains. In his opinion straw mulch is the most suitable mulch in South East Asia. It possesses no draw backs; except that the layer should be thin enough to permit the emerging plant to get through.

Mulches will hasten emergence and improve yield. This was proved by Vander Zaag et al (1986). They tried with different mulches in different seasons on potatoes. All mulches hastened the emergence rate and enhanced the yield.

2.1.2 Influence of mulches on soil temperature management.

The loss of heat energy from the soil is mainly by radiation, convection and evaporation of soil moisture. The mulches covering the soil protects the soil from nocturnal cooling and also prevents the evaporational loss during day time and keeps the soil cooler. Wadleigh and Gauch (1948) proved that as the soil temperature increases, the water stress also increases.

Records of soil temperature for five years kept by Kohnke (1963) at 1 to 4 and 10 inches depth in a silt loam, left bare or mulched with 1.5 t/acre straw showed that mulched soil was 1 to 2°F warmer in winter and 1 to 2°F or 3 to 4°F cooler in spring and summer than bare soil. Daily temperature fluctuations at 1 inch depth were twice as large.

An adverse effect of mulch is reported by Dorokhov (1969) that the mulching reduces the day time temperature and increases the night temperature of soil and also increased the possibility of plant injury by night frost.

The straw mulch considerably lowered the maximum soil temperature, especially when the prevailing temperature was high. The minimum temperature was only slightly affected by straw mulch (Bansal et al 1971 and Lal, 1972) mulching significantly reduced the maximum soil temperature measured at 5, 10 and 20 cm depths, where as maximum temperature was recorded by unmulched plot. Tripathi and Katiyar (1984) got the same trend in soil temperature under straw mulch which ranged from 19 - 28.7°C. Similar results were obtained by Moody et al (1965).

Observations made on soil temperature at one hour intervals by Lal (1972) indicated that there were phase differences of daily temperature fluctuations due to mulching. The maximum for unmulched plots at 5 cm depth occured at about 3 PM followed by a sharp decline; while the maximum for the mulched plots was around 4 PM with a gradual decline in the temperature.

Mehta and Prihar (1973) observed progressive decrease in maximum soil temperature with increasing rate of wheat straw mulch from 2 tonnes to 6 tonnes/ha and also the mulching reduced temperature by 7°C at a depth of 5 cm.

Venkatachalam (1976) in his experiment in soil temperature reveals that the rate of heat flow from the soil during night time is reduced considerably and heat is conserved in the soil. This is observed for higher temperatures during the morning hours in the mulched plots. Similar results have been reported by Gajendra Giri and Singh (1963).

Venkatachalam (1976) in his studies have also proved that the mulched plots recorded lower temperature during afternoon hours than bare soil. This can be attributed to the shading effect produced by the mulches, thus shutting out the soil from direct sun light and a slower rate of heating of soil due to higher moisture content of the soil under mulches.

Studies conducted by Chuman and Lal (1982) showed that the plastic mulches on a flat surface lowered the maximum temperature at the 1 cm depth by 5°C and rice straw mulch lowered by 15°C compared with the bare flat. These differences decreased with depth.

Radke (1982) opined that the mulches decreases day time soil temperature. Mandal and Ghosh (1983) working on mulching states that Paddy straw is more efficient in reducing soil temperature than paddy husk.

Detailed experiments conducted by Ross et al (1985) reveals that the mulches can reduce soil surface temperature upto 20°C by intercepting incoming radiation. It dessipiates this intercepted energy, quite efficiently by free convection without concomitant increase with temperature of the underlying soil surface. Mulch application prolongs the process of slow evaporation from the soil surface. The resulting soil water content also decreases soil surface temperature through its effects on soil thermal properties.

The mulches will reduce the soil temperature in hot conditions and in winter it will keep the soil temperature higher than surroundings (Vander Zaag et al 1986)

2.1.3 Soil physical properties as influenced by mulches.

The practice of soil mulching has considerable influence on soil properties such as bulk density, water holding capacity, soil aggregation, porosity, hydraulic conductivity, infiltration etc.

Duvelle and Mc Calla (1961) reported lower bulk density and higher waterstable aggregation in soil as a result of stubble mulch tillage than clean tillage.

Experiments conducted by Bunescu and Petrucha (1969) in a soil which had a pH of 7.4 to 7.6, a humus content of 3.75 to 3.9 % and field capacity of 24.8 % and an increase in temperature from 10 to 40°C increased the amount of resin extractable phosphorous by 50.6 %. Corresponding figures for an increase in bulk density from 1.0 to 1.4 g cm^{-3} and an increase in moisture from 11 to 31 % were 9.6 and 240.4 %.

Lal (1978) reported a higher bulk density in the unmulched plot. Again during 1980 he reported that the Bulk density of newly cleared tropical alfisols was decreased with increase in the mulch.

Kamalam and Kunju (1982) conducted experiment on the effect of mulching on bulk density. The effect on bulk density of the soil was found to be highly significant. Mulching in general decreased the bulk density. Minimum bulk density was obtained for treatments which received mulching.

Nathan et al (1984) observed insignificant influence of mulches on the bulk density of black soil.

The effect of soil aggregate size on sugar beet seedling emergence was examined by Hammoron (1961). He found that finer aggregates (1mm) have better moisture supplying capacity.

Aggregation increased porosity and oxygen availability which are important in seedling establishment (Anderson and Kemper, 1964). Unger (1969) noted higher water stabble aggregates under mulched conditions.

Kamalam and Kunju (1982) have also reported that the mulching the soil with leaves mught have improved the organic matter status of the soil which in turn might have increased the content of water stabble aggregates.

Soil temperature accelerates the infiltration rate. Infiltration studies conducted by Moore (1940) reveals that maximum water content in the wetted layer decreased while the infiltration rate increased with increasing soil temperature.

Lal et al (1980) reported that the hydraulic conductivity of the newly cleared tropical alfisols was improved by mulching. Mathan et al (1984) have also reported that the hydraulic conductivity was influenced by mulches. It was 6.0 cm/hr in control plot and it varied from 6.9 to 7.0 cm/hr in mulched plot. Among the mulches there was no significant differences.

Lal <u>et al</u> (1980) reported that the porosity of the newly cleared tropical alfisols was higher than the unmulched control. Watson <u>et al</u> (1974) reported that the total porosity was significantly influenced by mulches during the first crop, the increase was 16.6 %. The difference were not significant for next two crops. The decomposed organic matter below the mulches would have contributed for the above effect.

In the case of particle size distribution the percentage of coarse and medium sand fraction were not altered, though that of very coarse sand is increased with increasing mulch rate. Seolt et al (1985) have reported that the practice of soil mulching has considerable influence on soil properties and conditions.

2.1.4 Effect of Different mulches on soil water retention and release.

Mulches were applied for various crops even from very ancient days. The main intention behind mulching is to conserve moisture. Majority of writers conclude that mulches are useful in moisture conservation and tend to increase yields(Mielke <u>et al</u> 1978).

Desilva Asp (1957) has studied the various phases of mulching and concluded with benefits like conservation of moisture; prevention of erosion, increased thickness of aerable layer, elemination of weed competition and economy in its use were attributed to trash mulching.

Hanks and Woodruff (1958) found the primary effect of mulches as increasing the length of vapour path, and the energy absorbed by the mulch had little influence on the water loss.

Bavor (1960) was of the opinion that artificial mulches greatly retard evaporation and protect the soil from direct rays of the sun and wind current, consequently the soil was kept cool and the vapour pressure of the air in the mulch was more nearly the same as that within the soil air.

In contrast to the findings of the workers mentioned above, many do not corroborate the beneficial effect of mulching. Cahoon et al (1961) showed that the downward movement of water was not in any way different in the mulched plots than that in the unmulched.

Donald, L. Myhre and Joe, O. Senford (1970) in their studies proved that mulched rough soil surface help in minimizing soil water dificits and therefore reduce the risk when growing a crop without irrigation and he found that the straw mulch was effective in increasing yield.

Mulches are used for various reasons. However, water conservation and erosion control are the most important for agriculture in dry season (Unger 1971, Black and Siddoway 1979 and Subbiah et al 1979).

Lal (1972) in his experiment with mulches in tropical soil states that the water conservation characters of soil was improved by mulches and also the mulches reduced the weed growth. Observations made by them indicated that the mulched plot had a higher soil moisture content throughout the growing season than the unmulched plots for both 0-10 and 10-20 cm depth and he also noticed that the mulching indirectly influenced the water holding capacity and moisture release characters of soil.

Mulches had beneficial and favourable influence on soil temperature and reduced soil water loss through evaporation which resulted in more available soil moisture for a longer period which helped in improving the yield attributing characters and ultimately grain yield (Mandal and Ghosh 1983). The above result corroborated the findings of several workers (Bond and Willis 1969, Murty and Rao 1969, Lal 1974 and Mandal and Vamadevan 1975 Balyan and Malik 1980 and Gajendra Giri and Singh 1983). Mandal and Ghosh opined that the consumptive water use efficiency was lowest with straw mulch and highest with no mulch. The consumptive use efficiency was also influenced by irrigation levels and mulches.

Surface mulching is more beneficial in reducing evaporational loss of water than sub-surface mulching Abdullah Saadmodaihsh et al (1985).

2.1.5 Effect of different mulches on yield.

Significant increase in yield of potato and considerable decrease in weed growth had been reported by Saptarishi and Azariah (1954) when straw mulch was applied similar results were obtained to Fieldhouse et al (1966) in Asparagus.

Kemper (1961) worked on corn has found that the yield was approximately doubled by a 10°C rise in temperature above 20°C. In vegetable crops yield increase with use of mulches was reported by Patel (1965) and Saccogand Bianco (1967) so also Baxter (1970) and Maehara (1976) proved that the Autumn straw mulching increased the yield. They also proved that the peach trees grow better and produce more fruits on mulched soil.

Lal (1974) also proved that the higher grain yield can be achieved by mulching.

Studies on sandy loam soils at Ludhiana by Khera et al (1976) showed 13-26% increase in dry forage yield of summer maize with straw mulching. Donald L. Myhre and Joe O Sanford (1970) also got similar results.

Allan and Quisumbing (1977) showed that the mulching increases the plant growth parameters and rhizome yield and starch content in ginger. Coconut leaves were the best mulch followed by rice straw.

Mohey *et al* (1980) have carried out an experiment on turmeric with 3 levels of irrigation and 3 mulches. The result revealed that mulching affected growth and yield factors and economised the use of irrigation water.

Kumar *et al* (1983) showed an increased yield in straw berry by using cut grass as mulch.

A field experiment conducted at IARI by Krishna murari and Pandey (1983) revealed that the straw mulch improved harvest index (36.4%) than with out mulch (33.2%)

In tomatoes, the mulched plants grew taller and had more branches and a greater number and weight of fruits (Olasanten 1984).

Any type of mulch will increase yield (Vander Zaag 1986). Similar results obtained by Murty and Rao (1969) Black (1970).

2.2. Soil temperature - its influence on seedling emergence, plant growth, yield and nutrient uptake.

Soil temperature profoundly influences various stages of plant growth and soil conditions, from seed germination to yield. It influences uptake of plant nutrients and soil nutrient content.

2.2.1 Influence of soil temperatures on the seed germination.

Studies conducted by Woods (1960) showed that the germination was delayed at soil temperatures below 30°C and inhibited above 30°C, where as Segeta et al (1964) reported that different genotypes show genetic variations in minimum germination temperatures.

Relationship between temperature and seedling emergence in cotton seed was studied by Wanjura et al (1967). They affirmed that the emergence rate can be predicted by knowing the soil temperature; since the rate of emergence of crop is constant with various ranges of soil temperatures.

Black low (1972) and Miedema et al (1982) informed that the soil temperature restricted the germination by its effect on imbibition.

Increasing soil temperature reduced the period of time between sowing and emergence from 10 to 11 days (Saunders 1971).

Kailasanathan et al (1976) observed that in sorghum and cowpea, germination at 25°C was poor and at 40°C appeared lethal. High percentage of vigorous seedling growth was observed at 30 and 35°C.

Miedema et al (1982) studied the effect of constant temperature on imbibed seeds sown at a depth of 4 cm and showed that the time from sowing to emergence was 23 days at 10°C, 8 days at 15°C, 4 days at 21°C and 2 days at 32°C. In the case of elongation rate of primary roots show a linear relationship between 10 and 25°C. The minimum temperature was around 9°C, the optimum around 30°C Elongation rate ranged from 0.5 mm/hr at 10°C to 3 mm/hr at 30°C.

The optimum range of soil temperature for emergence of wheat was found to be 20-23°C (Pushkala and Nagaraja Rao 1983).

2.2.2 Soil temperature and plant growth.

Influence of soil temperature on plant growth are manifold with increased soil temperature emergence was hastened and earliness promoted in maize (Willis et al 1957). They also found a linear growth rate over a temperature range of 60 - 80°F.

Brouwer (1959) obtained better growth of peas at higher temperature in laboratory as well as field studies. Dry matter production also followed at same trend.

Burrows and Larson (1962) reported that growth rate of maize progressively retarded with decreasing soil temperature.

Research conducted by Chaudhury and Ghildyal (1970) on the shoot growth and yield response of rice variety I.R-1 to different soil temperature revealed that maximum yield obtained at 32/20°C resulted from higher shoot and root dry weight greaternumber of effective tillers and spikelets per panicle and lower spikelet sterility (Lindeman and Ham (1979) and Muncvar and Wollum II (1981) have reported a maximum plant height and dry weight at 25°C. Pushkala and Nagaraja Rao (1982) observed that the leaf area and plant height of soy bean was found to be maximum at a temperature range of 26-32°C.

2.2.3 Effect of soil temperature on nutrient uptake.

Soil temperature influence plant growth by affecting soil moisture, microbial activity, enzymatic activity etc., thereby affecting the nutrient uptake and low temperatures slow down the intake of water by roots and extreme heat makes plant life difficult. By mere raising or lowering the temperature, has pronounced effect on the decomposition of organic and mineral components of the soil resulting release of plant nutrient.

Vonder Honest and Hooymans (1955) determined the nitrate uptake at a temperature of 5-40°C. The uptake at 10°C was about 30% of that at 20°C. Shtrausberg (1958) reported that the uptake of P^{32} at 7°C was 32% of that at 21°C. So also the potassium content of roots at 10°C was about 40% of that at 20°C. This experiments show that the ion uptake is retarded by lowering the temperature. Not appreciable amounts of nitrate, phosphate and probably potassium are absorbed at around the minimum temperature for growth. The concentration of nitrogen, phosphorus, calcium, magnesium and minor elements was little affected by the root temperatures.

Simpson (1960), Dormaar and Ketcheson (1960) and Nielsen et al (1960), all of them have reported that increased growth rate were noticed with higher temperatures which were attributed with the increased uptake of nutrients by the crop plants.

Low root temperatures decreased the P_2O_5 and water content of the leaves and stems of tomato and snap beans, and the P_2O_5, K_2O, Na_2O, CaO and MgO content of cucumber plants (Mori et al, 1956).

Significant increase in the nutrient uptake with increase in temperature in case of nitrogen, potassium, manganese and copper by wheat have been reported by Whitfield and Smika (1971). Similar results were reported by Simpson 1960 in Soy bean for phosphorus, Ketcheson (1970) in corn for phosphorus and potasium.

The carbon mineralisation increased with raising temperature, but not linearly, (Cavor, 1960). At higher temperatures (35-40°C) shoot and root concentration of nitrogen, phosphorous, potassium and zinc decreased while that of Boron increased.

According to Cornillon (1980) the absorption of plant nutrients by tomato roots were not greatly influenced by temperature, the effect seems to be primarily on subsequent translocation.

2.3. Soil moisture impacts on soil temperature and consequent effect on plant growth and yield.

Soil moisture has an important role in deciding the physical and chemical properties of soil, fertility of soil and plant growth greatly depends on the moisture status of the soil. As the temperature increases the water stress also increases Wadleigh and Gouch (1948).

2.3.1 Soil water plant relationships.

The leaf area index will be minimum when the available soil moisture is less due to the fact that adequate water was not available for the full expression of crop growth. Similar result have obtained by Gerard and Cowley (1963), Lashin *et al* (1970).

Research carried out by Geiger (1950) shows that the specific heat of water being high, the rate of heating and cooling will be slowed down resulting in lower temperature in the afternoons and higher temperature during night.

For seed germination humid (over 98% R.H) environment is required, which is normally present in soils even when the soil moisture content approaches the permanent wilting percentage (Richards and Ogata, 1958).

Hanks (1960) proved that as the temperature increases the evaporational rate also increases resulting the soil drying which leads to the increased crust strength and decreased ability to crop growth.

In cold countries the mulches are used to increase the soil temperature. Works carried out by Clarkson (1960) and Bisorn J Van (1961) showed that soil covering, conserved moisture and kept soil temperature higher than that of bare soil and decreased frost penetration.

Parker and Taylor (1965) have reported that in grain sorghum seeds with the increase in soil moisture tension to 1 bar or more there was a decrease in the rate and amount of emergence and single grain weight was most affected by the moisture stress. So also the plant height was most reduced when moisture stress occured before ear emergence.

The experiment carried out on different water depletion studies (100, 80, 60 40 and 20% of available soil moisture) shows that more the quantity of water supplied, more would be the reduction in water use efficiency. In higher moisture regimes, more water is used for evaporation rather than production, thereby reducing the water use efficiency (Selva raj, 1976). This is in agreement with the findings of Grimes et al (1969).

2.3.2 Soil water and soil temperature in relation to plant growth.

Soil water is influenced by the soil temperature. The research conducted by Moore (1943) revealed that even though the maximum water content in the soil decreased by temperature, the infiltration rate increased with increasing soil temperature.

Moisture content is the most important factor which influences the emergence of seedlings. As the soil temperature increases, at first, the emergence rate increases. But after a level it decreases (Hughes et al 1966). Similar research conducted by spring field (1968) on seed germination at 6 levels of moisture stress in the range of 0-15 bar and at 5 temperatures revealed that germination decreased significantly as the moisture stress increased.

When the soil moisture is maintained at field capacity, the emergence and survival is adversely affected by soil temperature (Sosebee and Herbel, 1969) and when the soil moisture was only slightly above wilting point, the radicle was observed to extend into new soil, fastly to meet the moisture needs (Trouse, 1971).

As moisture tension and soil temperature increased, the rate of emergence and total emergence of all species declined (Weight et al 1978). Sarma (1979) showed that after germination the radicle must remain in a humid atmosphere to ensure development of the seedlings for emergence, which decreases with increasing temperature.

2.4. Influence of soil moisture and temperature on root growth of plants.

According to Russel (1961) the soil plant system primarily related through the root system and the rate of root growth. This in turn depends on the temperature, water and air supply in the soil, the amount of carbohydrates translocated to the root system and on the competetion they face from other roots. With the exception of the aquatic plants and a few epiphytes, plants absorb practically all their water through roots and the effectiveness of roots as absorbing surface, depends on this extent of the root system and on the efficiency of individual roots. The importance of root system; for proper maintainance of water balance in the plant and characteristics of "drought hard" varieties, was observed by Khanna and Raheja (1947) and Misra (1955).

2.4.1 Soil temperature and root growth.

High and low temperatures may limit root growth Arndt (1945) and Wilson (1981) found the optimum soil temperature for root elongation, between 33 and 36°C.

Nielson and Humphres (1966) investigated that each species of plant has a minimum soil temperature below which no elongation occures. Above the minimum temperature root elongation rate increased almost linearly with temperature ~~root elongation rate increased almost linearly~~ ~~with temperature~~ ~~almost linearly~~ to a maximum temperature, above which the elongation decreases rapidly (Choudhury and Ghildyal 1970).

Natr and Kura (1970) and Wilson (1961) in their experiment with plants under different root temperatures proved that the dry mater ratio of root and shoot increases with increase in soil temperature.

Research carried out by Pearson et al (1970) showed that the rate of root elongation gradually increased with increasing soil temperature up to 32°C and then sharply decreased with further temperature increase. The effect of temperature was most pronounced at high pH and at low levels of soil strength.

Allmaras and Neilson (1973) observed that the initiation of adventitious roots of corn in the 0 - 10 cm soil depth was dominently influenced by soil temperature.

The crops are highly sensitive to high soil temperature at the seedling stage Lal (1972) was of the opinion that during early stages, the root activity is confined to the upper few centimeters of soil and the growing point of crop remains below the soil surface during the first week. He also observed some chlorotic symptoms in maize and seedlings grown in unmulched plot. This may be due to the poor root development which restricted the nutrient up take.

Anon (1959) reported that at higher temperatures the root growth was restricted because of the higher ethylene concentration (> 1 ppm) in soil.

The response of maize roots to soil temperature was showed by Priher et al (1968). The alteration in soil temperature caused by straw mulch significantly increased rooting density in the upper 10 cm of the soil but decreased below 15 cm depth.

Korovin and Nanaev (1975) and Lahav et al (1982) conducted experiments on temperature and dry matter production of Avocado plants and found the dry matter production of roots as maximum at 30°C and minimum at 10°C. Above 35°C it suddenly decreased.

Moorby and Nye (1983) and were of the opinion that the root growth increases with increase in root temperature.

For a soil temperature range of 24 to 37°C, the root length and root distribution was found to decrease at higher and lower ranges of temperatures in soy bean (Pushkala and Nagaraja Rao, 1983). Macduff et al (1985) showed that root temperatures affect root extension, mean radius, root surface area, number and length of roothairs. Both lower and higher temperatures are harmful for root growth and development.

2.4.2 Soil moisture and root growth.

Soil moisture is the deciding factor of root growth and development. Extensive root system was shown to absorb water from greater volume of soil (Yalenov, 1926).

Bennet and Doss (1960) observed that the lower levels of moisture increased the root depth in plants where as found as the lower level of moisture increased the root weights. Increase in the number of roots per plant and more root hair under such conditions were observed by Mmock et al (1957).

Duncan (1941) found that the root growth in tree seedlings inversely proportional to the available soil moisture content. Cannon (1911) Weaver (1920) and Weaver and Crost (1922) found that the depth of penetration of root system depended on the depth to which the soil was wetted. But Shantz (1927) Breazale and Crider (1934) were of the opinion that roots of at least certain species would penetrate in to soil below permanent wilting point.

However Hendrickson and Veihmeyer (1937), Reed (1939) Kauffman (1945) and Muller (1946) considered such a possibility, most likely under field conditions.

Hunder and Kelley (1946) and Trouse (1971) stated that roots have a tendency to move from a moist area to dry soil and utilize moisture from that area. But at the same time they are unable to utilize the plant nutrients in the dry soil.

Gard (1959) conducted experiments on maize and found that as the soil moisture stress increased, maize roots extracted more water from lower depths. Another study carried out by Dargan _et al_ (1965) showed that by with holding irrigations for 6 to 7 weeks in the early stages, the root system developed better.

Root elongation was appreciably reduced by an increase in soil water suction and vice verse (Taylor _et al_, 1967). Soil temperature has both direct and indirect effect on water absorption by influencing the root growth and by influencing the synthetic activity of roots.

Selvaraj (1976) showed that root weight is directly proportional to the root length. Root weight decreased with the increase in the available moisture percentage of the soil. Mandal and Ghosh (1983) have opined that the increased water use efficiency with mulching and irrigation was probably due to increased root development, efficient moisture extraction and decreased consumptive use.

Root growth between germination and emergence for the corn hybrids was studied by Cutforth _et al_ (1986) and confirmed that the sensitivity to water content decreased with decreasing soil temperature and both this decreased the root growth rate.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The experiment was carried out as pot culture with Bhindi as test crop in the pot house at the College of Agriculture, Vellayani using the red loam garden soil, during May-August 1986.

3.1. Climatic conditions.

Vellayani is situated at a latitude of 8.5°N, longitude of 76.9°E and at an altitude of 29 meters M.S.L. During the period of investigation, there was an average rainfall of 154.6 mm. The average relative humidity maintained during the period was 75.5%. An average maximum day temperature of 30.05°C and minimum of 22.55°C was recorded during the period of investigation.

3.2. Preliminary studies on soil.

The initial analysis for the physico chemical properties of the soil were carried out and are given in table 1 to 5.

3.3. Pot culture Experiment.

11.6 kg air dry soil was filled in each pot. Pots were insulated from solar heating with thick coating of white paint on all exposed phases. Three seeds of Bhindi (Abelmoscus esculentus) variety selection-1 were sown in each pot. Fertilizers were added as recommended in the package of practices of Kerala Agricultural University (N:P:K at the rate of 125:50:50). Plant protection measures were taken whenever needed.

Table 1. Moisture Retention Characteristics.

Pressure applied in atmosphere	0.3	0.5	1.0	3.0	5.0	10.0	15.0
% of moisture	8.89	7.67	6.99	6.02	5.55	5.14	4.29

Table 2. Aggregate analysis (%).

Size of particles in mm	5.0	2.0	1.0	0.5	0.2	0.1	0.1
% of particles	20.20	8.77	15.00	10.80	19.47	15.45	7.24

Table 3. Textural analysis (%).

Coarse sand	Fine sand	Silt	Clay
55.28	11.45	30.20	3.07

Table 4. Physical constants.

Water holding capacity %	Bulk density $g\,cm^{-3}$	Particle density $g\,cm^{-3}$	Porosity %	Volume of expansion %
24.90	1.42	2.3	38.63	5.08

Table 5. Chemical analysis.

Available				Exchangeable		%
N kgh^{-}	P kgh^{-}	K kgh^{-}	SO_4 kgh^{-}	Ca kgh^{-}	Mg kgh^{-}	O.C*
64.96	94.08	306.88	450.2	1276.8	87.36	0.4385

*(O.C = Organic Carbon).

3.4.1 Design and treatments.

The experiment was conducted in a factorial completely randomised design with treatments of 4 mulches and two water levels. The treatment combinations were as follows.

1. Dry leaf mulch with 20% depletion of water from Field capacity
2. Dry leaf mulch with 40% depletion of water from Field capacity
3. Saw dust mulch with 20% depletion of water from Field capacity
4. Saw dust mulch with 40% depletion of water from Field capacity
5. Paddy husk mulch with 20% depletion of water from Field capacity
6. Paddy husk mulch with 40% depletion of water from Field capacity
7. Paddy straw mulch with 20% depletion of water from Field capacity
8. Paddy straw mulch with 40% depletion of water from Field capacity
9. No mulch

All the treatments were replicated five times. Altogether 45 pots were there. Pots were plugged using cement to prevent water loss. On the basis of water retention studies, water treatments were given, as and when the moisture reached 20% depletion of field capacity and 40% depletion of field capacity for the two water levels. These levels were fixed by calibrating the tensiometer readings, using corresponding gravimetric moisture content.

3.4.2 Installation of Tensiometer and Thermometers.

Manometric type tensiometers were fabricated in the laboratory and installed in the pots, with the cups buried at a depth of 15 cm from soil surface. Soil thermometers were also installed at a depth of 15 cm in each pot to note the soil temperature. The servicing of the tensiometers were done daily using air free distilled water. Plate-1 shows the installation of tensiometers and thermometers for the treatments.

3.4.3 Mulching and water levels.

Mulching was done on the third day after sowing. Uniformly measured quantity of mulches were applied in

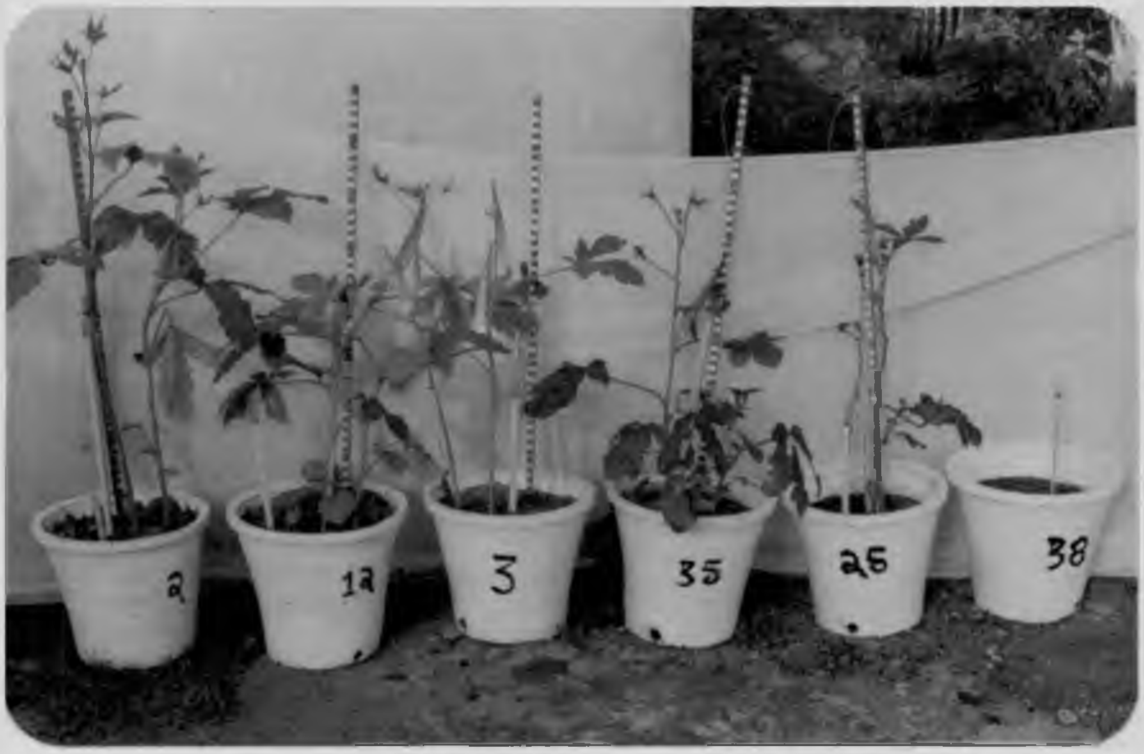


Plate-1- Installation of Tensiometer.

each pot to give a uniform thickness.

The treatments were named by the following symbols.

Mulches

M_1 - Dry leaf mulch

M_2 - Saw dust mulch

M_3 - Paddy husk mulch

M_4 - Paddy straw mulch

M_0 - No mulch

Irrigation levels

W_1 - 20% water depletion from Field capacity

W_2 - 40% water depletion from Field capacity

3.5. Observations.

3.5.1 Seedling emergence.

Seedlings emerged were counted each day after germination. The number of days taken for complete emergence and failure in emergence were recorded. The emergence in each treatment was evaluated using coefficient of velocity of emergence (Kotowiski, 1926) mean time of emergence and spread in emergence time (Orchard, 1977).

3.5.2 Physical properties.

1. Soil water status - Gravimetric soil water content was recorded by collecting soil samples from 15 cm depth, once in a week.

2. Tensiometer readings were recorded daily at 07.30 and 14.30 hours.

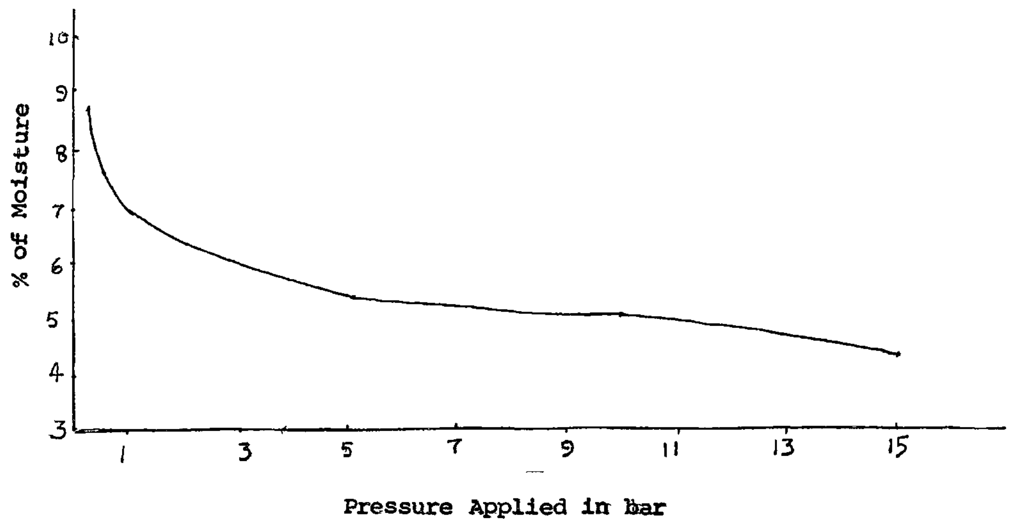
3. Soil Temperature - Soil temperature at 15 cm depth was recorded at 07.30 and 14.30 hours daily. Simultaneously, the maximum and minimum atmospheric temperatures were also recorded from the College Observatory.

The soil samples after harvest of the crops were analysed for the following physical properties.

1. Gravimetric moisture content-oven dry weight of moisture was determined and expressed on percentage basis.

2. Moisture retention characteristics:- The water retained at a suction of 0.5, 1,3,5,7,10,13 and and 15 bar were determined using core samples

Fig-1- Moisture Retention Capacity of initial Soil.



from 15 cm depth. This was done using the pressure plate apparatus (Richards, 1948).

3. Textural analysis: Mechanical separates were analysed by Bouyoucos hydrometer method (Gupta and Dakshinamurthy, 1980).

4. Physical constants: Bulk density water holding capacity volume of expansion and porosity were determined using the Keen Raczkowski's method. Particle density was measured using specific gravity bottle (Gupta and Dakshinamurthy, 1980).

5. Aggregate analysis: Aggregate analysis was carried out by Yoder's wet sieving method (Yoder, 1937) as described by Gupta and Dakshinamurthy, (1980). The samples were wetted slowly and using the set of sieves water stable aggregates were determined. Mean weight diameter was used as structural index (Van Bavel, 1949).

6. Hydraulic Conductivity: Using the Jodpur constant head permeameter, hydraulic conductivity for samples from each treatment was determined (Gupta and Dakshinamurthy, 1980). Core samples were

equilibrated with water, over night and constant head were maintained using the permeameter. Quantity of water collected for 10 minutes were noted until concurrent values obtained. Hydraulic conductivity 'K' was calculated using the Darcy's equation.

$$K = \frac{QL}{\Delta HAt}$$

where K = Hydraulic conductivity (cm hr^{-1})

t = time in hour (10 minutes)

Q = Amount of water collected in time 't' (-cm^3)

L = Length of the soil column (cm)

A = Area of cross section of core (cm^2)

H = Effective hydraulic head (Height from base of soil column to the top of the water level(-cm)

3.5.3 Chemical analysis.

Chemical analyses were done for all the soil samples and plant samples.

I. Analysis of soil sample:

1. Organic Carbon was determined by Walkley and Black's rapid titration method (Jackson, 1973).

2. Available nitrogen was estimated using the permanganate titration method by Subbiah and Asija (1956).

3. Available phosphorus was estimated by Dickman and Bray's molybdenum blue method (Jackson, 1973).

4. Available potassium present in soil sample was read in flame photometer using neutral normal ammonium acetate extract (Jackson, 1973).

5. Exchangeable Calcium and Magnesium were estimated using Atomic Absorption Spectrophotometer from the ammonium acetate extract.

6. Sulphate Sulphur: Sulphate form of sulphur present in soil sample was estimated by Turbidimetry method (Piper, 1966).

II. Analysis of plant sample.

1. Plant Nitrogen was estimated by micro kjeldhal's method using sulphuric acid extract (Piper, 1966).

2. Phosphorus in plant sample was estimated by vanado molybdic phosphoric yellow colour method (Piper, 1966)

3. Potassium in plant was read in flamephotometer using tripple acid extract (Piper, 1966).

4. Calcium and Magnesium: Both the elements were estimated in Atomic absorption spectrophotometer using tripple acid extract.

3.5.4 Biometric observations.

Internodal length, plant height, leaf area, root length (Newman, 1966) and root weight were measured and recorded at harvest time. Root length was determined by the following method.

Root length: For root length measurement, the entire soil containing the roots was removed from each pot and the roots were separated carefully. The total root length in each pot was obtained by using the following equation (Newman, 1966).

$$R = \pi AN/2H$$

where 'R' is the total root length in a field area of 'A' and 'N' is the number of intersections between the roots and random straight lines of total length 'H'.

After these length measurement the roots were dried at 70°C in an air oven and dry weights were recorded.

Yield per plant was also recorded from the first harvest onwards.

RESULTS

4. RESULTS

The results obtained during the present investigations for different treatments of mulches and water levels are presented in different readings with the aid of tables and figures.

4.1. Studies on seedling emergence.

4.1.1 Evaluation of seedling emergence.

Seedling emergence is evaluated using the indices: coefficient of velocity of emergence (Kotowski, 1926), mean time of emergence and spread in emergence time (Orchard, 1977).

Coefficient of velocity of emergence 'cv' is calculated from the observations using the formula.

$$'cv' = \frac{F1 + F2 + F3 + \ldots\ldots Fn \times 100}{F1T1 + F_2T_2 + F_3T_3 \ldots\ldots Fn\ Tn}$$

where Fn = Frequency of seedling emergence at any particular time Tn

Tn = time in days up to n^{th} observation

Table 6. Effect of different treatments on seedling emergence as evaluated by 'cv' '$\bar{T}$' and 'σ'.

Treatments	cv	$\bar{T}$	σ
M_1 W_1	14.29	7.01	1.549
M_1 W_2	10.71	9.33	0.815
M_2 W_1	13.13	7.60	2.249
M_2 W_2	12.63	7.92	1.129
M_3 W_1	12.74	7.85	2.050
M_3 W_2	10.61	9.43	1.954
M_4 W_1	12.17	8.21	1.711
M_4 W_2	11.54	8.67	3.660
Control	11.63	8.60	—

cv = Coefficient of velocity of emergence

$\bar{T}$ = Mean time of emergence

σ = Spread in emergence time

Mean time of emergence ($\bar{T}$) which is the arithmetic mean of time (expressed as number of days), taken for emergence of all emerged seedlings, based on grouped data and is calculated as $\bar{T} = \frac{\sum fT}{\sum f}$ where 'f' is the frequency of emergence at any time 'T' (in days).

The index spread in emergence time "σ" is a parameter associated with mean time of emergence. This is found out as follows:

$$\sigma = \left[\sum f \, (T - \bar{T})^2 / (\sum f - 1) \right]^{\frac{1}{2}}$$

4.1.2 Seedling emergence evaluation for different treatments.

The seedling emergence evaluated for different treatments are given in table 6 and figures 2 and 3. It is observed there the coefficient of velocity of emergence increased and mean time of emergence decreased. The observations were taken up to 12 days, thereafter there was no emergence in any treatments.

Irrespective of the mulches, lower values of mean time of emergence are obtained for higher water levels i.e. at 20% depletion of water from field capacity.

Among the mulches the influence of dry leaf and saw dust mulch on seedling emergence is almost the same. In comparison with M_3 and M_4 both M_1 and M_2 show higher values of 'cv' and lower values of '$\bar{T}$'. Highest 'cv' (14.297) and lowest '$\bar{T}$' (7.01) being obtained for dry leaf mulch treatment. Dry leaf treatment influenced seedling emergence significantly and 100% emergence observed only for this treatment.

At lower water level (40% depletion from field capacity) with Paddy husk mulch has the least influence on seedling emergence, which gave a 'cv' of 10.61 and $\bar{T}$ of 9.43.

The highest 'σ' value is obtained for paddy straw mulch with 40% water depletion (3.66) confirming its least influence on emergence (Fig.2 and 3). Least value of 'σ' obtained for dry leaves with 40% water depletion shows that this treatment is better comparatively.

Fig.2 shows clearly the influence of mulches and water levels on 'cv' and Fig.3 on '$\bar{T}$'. At lower water level, seedling emergence is influenced more by saw dust

Fig - 2 Effect of Different Treatments on Coeficient of Velocity of Emergence

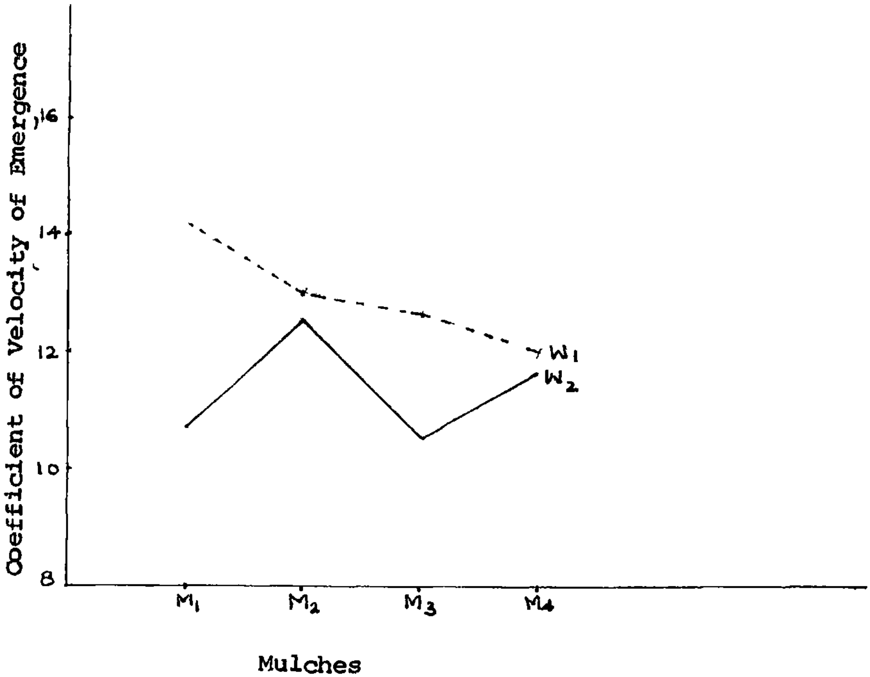
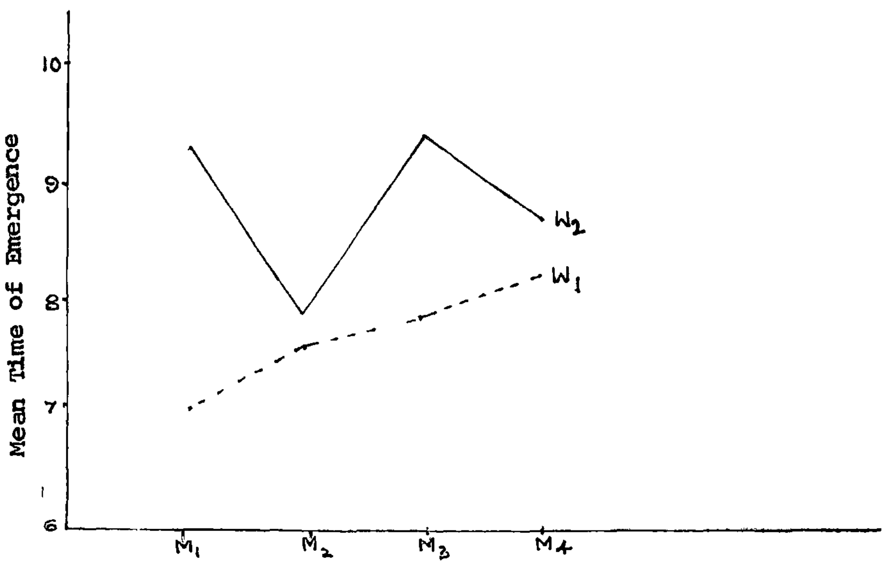


Fig - 3- Difference in mean time of emergence under different treatments



mulch and least by paddy husk, which shows a 'cv' of 10.61 and 'F' of 9.43. Here the time of emergence is comparable for M_1 and M_3.

Considering the whole table, it is difficult to establish any relationship between spread in emergence time and the different mulch treatments. But lower values of 'σ' are obtained for lower water levels in most of the treatments.

4.2. Biometric characters.

Important biometric characters studied are plant height, internodal length, leaf area, root weight and root length. The results obtained in the trial are statistically analysed and are presented in table 7 to 11 and figures 4 to 7.

4.2.1. Plant Heights.

4.2.1.1. Effect of different mulches.

The mean plant height obtained for different mulches are presented in table 7 and Fig.4. The plant

Table 7. Effect of treatments on plant height (cm).

Treatment	W_1 (20% water depletion)	W_2 (40% water depletion)	Mean (M)
Dry leaves (M_1)	129.8	128.8	129.3
Cow dust (M_2)	113.8	84.4	99.1
Paddy husk (M_3)	79.2	64.0	71.6
Paddy straw (M_4)	34.8	23.6	29.2
Control	—	—	21.8
Mean (W)	89.4	75.2	—

CD at 5% level for mulches = 21.13

CD at 5% level for water level = 14.94

CD at 5% level for interaction = 29.88

SE of means = 10.41

height shown by the plants grown in dry leaf mulching (109.3 cm) is found to be significantly superior over all other treatments. The influence of M_2 (saw dust) on plant height is superior than that of M_3 and M_4 (Paddy husk and paddy straw).

4.2.1.2. Effect of water levels on plant height.

The plant height obtained for 20% water depletion has got no statistical significance over the plant height obtained for 40% water depletion treatment, even though it is higher for higher water levels (Fig.4).

4.2.1.3. Interaction effect.

The interaction of treatment combinations are given in the table 7. Maximum plant height is obtained for M_1W_1 (129.8 cm) and lowest for M_4W_2 (83.6 cm) (Paddy straw with 40% water depletion). For M_1W_1 eventhough the plant height is more, it is not statistically significant over M_1W_2 and M_2W_1. These treatments are on par. All the other treatments are significantly lower than those treatments.

Fig.- 4 Difference in plant Height under different treatments

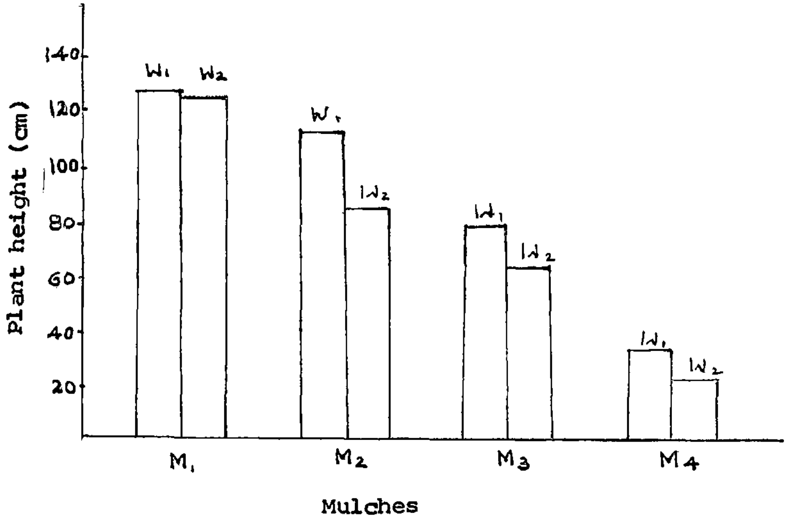
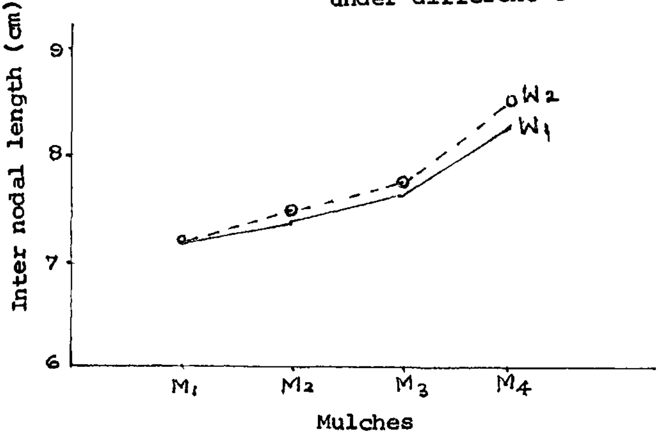


Fig. - 5 - Difference in internodal length under different treatments



4.2.2. Inter nodal length.

Mean inter nodal length for different treatments are given in table 6 and presented in fig.5.

4.2.2.1. Effect of different mulches.

Paddy straw mulched plant (M_4) show maximum internodal length (8.78 cm) followed by the plants grown with mulches of paddy husk, saw dust, and dry leaves. The minimum internodal length observed in the dry leaf mulched plants (7.21 cm). It is in the order of $M_4 > M_3 > M_2 > M_1$. The highest internodal length is obtained for control (5.6 cm).

4.2.2.2. Effect of water levels.

Comparing the two water treatments the mean obtained for 20% water depletion (W_1) is lower (7.6 cm) than that for 40% water depletion treatment (7.75 cm). The two water levels have significant effect on internodal length (Fig.5).

4.2.2.3. Interaction effect.

Interaction of mulches and water levels are given in table 6. The highest internodal length obtained for M_4W_1

Table 8. Effect of treatments on internodal length (cm)

Treatment	W_1	W_2	Mean (M)
M_1	7.20	7.22	7.21
M_2	7.40	7.54	7.47
M_3	7.68	7.74	7.71
M_4	8.32	7.52	8.42
Control	—	—	9.60
Mean (W)	7.66	7.75	

CD at 5% level for mulches = 0.240

CD at 5% level for water level = 0.169

CD at 5% level for interaction = 0.339

SE of means = 0.118

(Paddy straw with 20% water depletion) and lowest internodal length showed by M_1W_1 (dry leaves with 20% water depletion)

4.2.3. Leaf area.

Mean values of leaf area for different treatments are presented in table 9 and Fig.6.

4.2.3.1. Effect of different mulches.

Comparing the leaf area obtained for different mulches (Table 9) the dry leaf mulched plants have got higher leaf area (358 cm^2). There is no significant difference between M_1 and M_2. The lowest leaf area is obtained for straw mulch treatment (128 cm^2) which is higher than that for control (77 cm^2).

4.2.3.2. Effect of water levels.

Comparing the leaf area obtained for two water levels the 20% water depletion has got significantly higher value than W_2. For W_1 there is no difference in leaf area for plants which were grown in dry leaf and saw dust mulches (Fig.6).

Fig - 6 - Effect of Different Treatments on Leaf area.

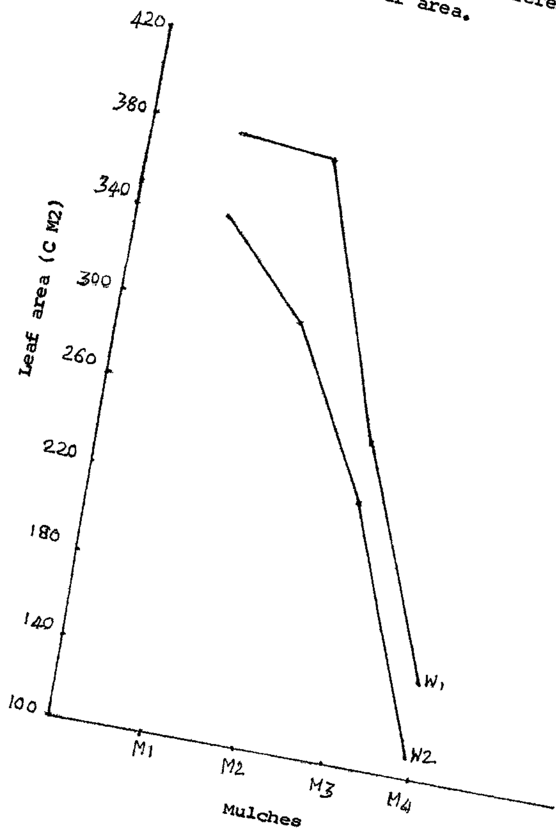


Table 9. Effect of treatments on leaf area (cm^2).

Treatment	W_1	W_2	Mean (M)
M_1	376	340	358
M_2	372	298	335
M_3	247	221	234
M_4	147	110	128
Control	--	--	77.6
Mean (W)	285	242	

CD at 5% level for mulches = 29.93

CD at 5% level for water levels = 21.16

CD at 5% level for interaction = 42.32

SE of means = 14.74

4.2.3.3. Interaction effect.

The interaction of mulches and water treatments on leaf area is given in the table 9. Among the treatment combinations, the M_1W_1 (dry leaves with 20% water depletion) has got the highest leaf area (376 cm^2). The lowest for M_4W_2 (paddy straw with 40% water depletion) (110 cm^2). M_1W_1 is on par with M_2W_1 and M_1W_2. Both M_1W_1 and M_2W_1 influenced leaf area to the same extent.

4.2.4. Root length and root weight.

The root length was measured by Newman's method (1966) (3.5.4.). Mean root length and root weight are given in tables 10 and 11 respectively and root length is presented graphically in Fig.7.

4.2.4.1. Effect of mulches.

Highest root length and root weight obtained for plants grown in dry leaf mulch (1641 cm and 870 g respectively).

Table 10. Effect of treatments on root length (cm).

Treatment	W_1	W_2	Mean (M)
M_1	1967.86	1182	1575
M_2	2541.48	740	1641
M_3	1333.00	357	845
M_4	813.57	477	645
Control	—	—	580
Mean (W)	1663	689	

CD at 5% level for mulches = 764

CD at 5% level for water level = 554

CD at 5% level for interaction = 1109

SE of means = 386

fig-7 - effect of different treatments on root length.

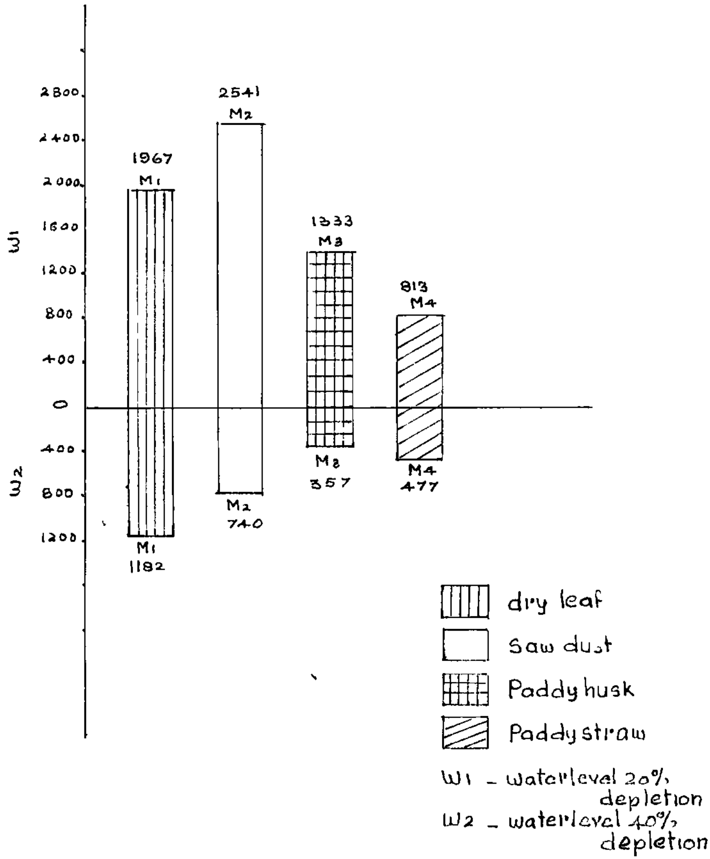


Table 11. Effect of treatments on root weight (g).

Treatments	W_1	W_2	Mean (M)
M_1	614	201	407
M_2	1205	535	870
M_3	667	105	385
M_4	256	136	196
Control	—	—	36
Mean ( )	685	244	

CD at 5% level for mulches = 490

CD at 5% level for water level = 347

CD at 5% level for interaction = 694

SE of means = 241

Minimum value of root length and root weight are obtained for straw mulch. Saw dust and dry leaves are on par and they are significantly different from M_3 and M_4.

4.2.4.2. Effect of water levels.

In the case of water treatments both root length and root weight obtained for 20% water depletion are statistically significant over those obtained for 40% depletion i.e., the crop which received more water have got higher root length and root weight.

4.2.4.3. Interaction effect.

By studying the interaction between the mulches and water treatments, the highest root length and root weight are obtained for M_2W_1 (saw dust with 20% water depletion) which is statistically superior over all the other treatments. So also the lowest value for both observations are obtained for M_3W_2 (paddy husk with 40% depletion of water).

4.3. Physical properties.

4.3.1 Effect of treatments on soil moisture characters.

Important observations made under this are volume of expansion; hydraulic conductivity; water holding capacity, moisture retained at field capacity and permanent wilting point. The results are given in tables 12 to 16.

4.3.1.1 Volume of expansion.

In the case of volume of expansion the highest value obtained for M_4 (straw mulch) among different mulches (Table 12). The values are in the order of $M_4 > M_2 > M_1 > M_3$. When comparing the water levels 40% depletion from field capacity gives relatively higher values (5.036%) for volume of expansion than for W_1 (4.603%).

Considering the combined effect of mulches and water levels $M_4 W_2$ has significantly higher values (5.292%). The minimum value is obtained for $M_3 W_1$ (4.072).

Table 12. Effect of treatments on volume of expansion(%).

Treatments	W_1	W_2	Mean (M)
M_1	4.94	4.87	4.90
M_2	4.95	5.11	5.03
M_3	4.67	4.86	4.76
M_4	4.87	5.29	5.08
Control	--	--	4.09
Mean (W)	4.86	5.03	

CD at 5% level for mulches = 0.671

CD at 5% level for water level = 0.352

CD at 5% level for interaction = 0.705

SE of means = 0.249

4.3.1.2. Hydraulic Conductivity.

Table 13 gives an idea of hydraulic conductivity for different treatments. The hydraulic conductivity obtained for the soil taken from dry leaf mulched pots are significantly superior over hydraulic conductivity of other mulch treated soils. It is in the order of $M_1 > M_2 > M_4 > M_3$. The hydraulic conductivity obtained for M_3 was lowest (13.1 cm hr^{-1}). Between the two water levels, the hydraulic conductivity obtained from W_1 (20% water depletion from field capacity) is significantly superior (27.3 cm hr^{-1}) than the hydraulic conductivity obtained from W_2 (40 depletion from field capacity).

For different treatment combinations the M_1W_2 (dry leaf mulch with 40 water depletion) has got highest hydraulic conductivity (43.1 cm hr^{-1}) and the lowest value obtained for M_3W_2 (7.9 cm hr^{-1}). The hydraulic conductivity is in the following order.

$$M_1W_2 > M_1W_1 > M_2W_1 > M_4W_1 > M_2W_2 > M_3W_1 > M_4W_2 > M_3W_2.$$

Paddy husk mulch had no influence on hydraulic conductivity.

Table 15. Effect of treatments on Hydraulic conductivity (cm hr^{-1}).

Treatment	W_1	W_2	Mean (M)
M_1	39.63	43.04	41.34
M_2	28.42	20.06	24.24
M_3	18.25	7.93	13.09
M_4	22.72	14.04	18.38
Control	—	—	10.91
Mean (W)	27.26	21.27	

CD at 5% level for mulches = 3.172

CD at 5% level for water level = 2.2[illegible]3

CD at 5% level for interaction = 4.485

SE of means = 1.565

4.3.1.3. Water Holding Capacity.

Values are given in the table 14. Statistically there is no significant difference between the water levels and among different mulches. Water holding capacity for sawdust mulched soil showed maximum value (25.41%) followed by paddy husk.

There is no significant difference between the water holding capacity of 20% and 40% water depletion treatments.

The interaction effect among different treatment combinations show that the water holding capacity of M_2W_1 is highest followed by M_2W_2 (sawdust with 20% and 40% water depletion). These are superior over all the other treatment combinations revealing that the water holding capacity of saw dust is best mulch for conserving soil moisture.

4.3.1.4. Water retention at field capacity and permanent wilting point.

Results obtained for moisture retention characteristic studies using pressure plate apparatus are given in

Table 14. Effect of treatments on water holding capacity (%).

Treatment	W_1	W_2	Mean (M)
M_1	24.78	24.81	24.79
M_2	25.92	24.89	25.41
M_3	25.21	24.73	24.97
M_4	24.70	23.82	24.26
Control	--	--	22.60
Mean (W)	25.15	24.56	

CD at 5% level for mulches = 0.975

CD at 5% level for water level = 0.689

CD at 5% level for interaction = 1.379

SE of means = 0.489

table 15 and 16 and Fig.8 to 11. From this it can be observed that the soils with saw dust mulch stands first in moisture retention capacity at 1/3rd and 15 bar suction (Field capacity and permanent wilting point) followed by soils with M_4 (straw mulch), M_1 (dry leaves) and M_3 (Paddy husk) treatments.

All the mulch treatments as well as water treatments differ significantly.

While comparing the treatment combinations, the moisture retention capacity is found to be more in the case of M_2W_1, in the 20% depletion water level as well as M_2W_2 in the case of 40% water depletion study.

At permanent wilting point i.e., at 15 atmosphere suction, effect of mulches is same as in the case of 1/3rd atmosphere. Between the water levels higher water level gave higher value for moisture retention (6.60%).

4.3.2. Effect of treatments on structural attributes.

Effect of different mulches and water levels on structural characters like bulk density particle density, porosity and mean weight diameter are depicted in tables 17 to 20.

Fig.3 Moisture retained by paddy husk mulched Soil

Under Two Water levels

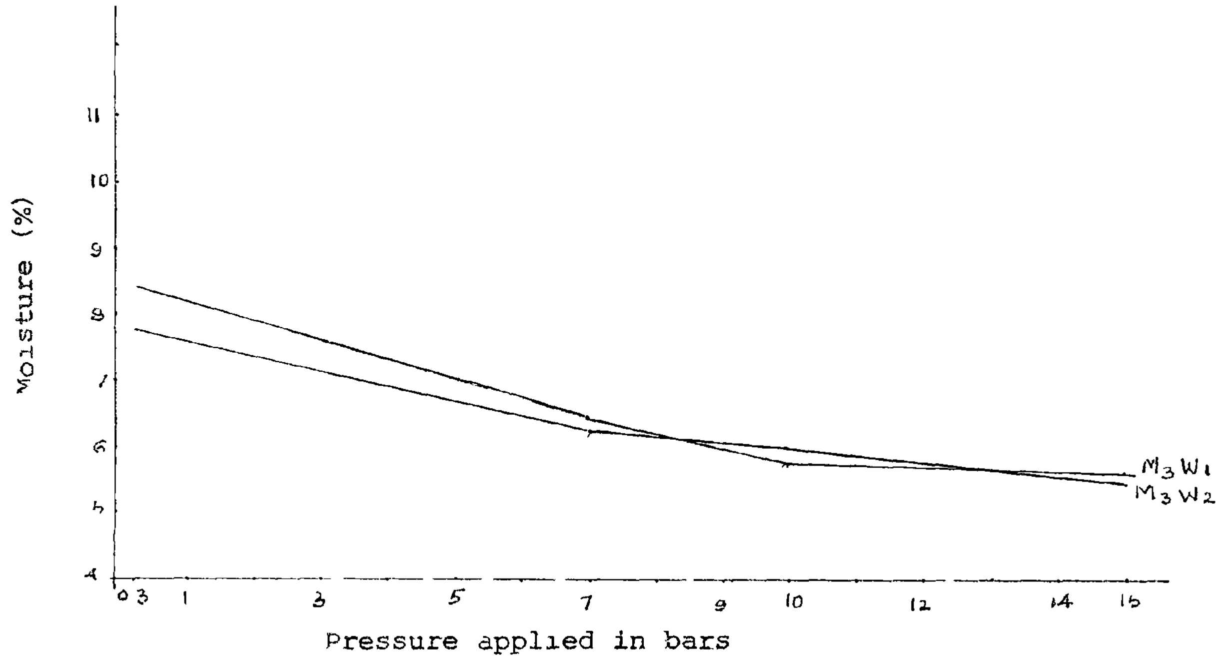


Fig: 9. Moisture retained by Paddy straw Mulched Soil

Under two water levels.

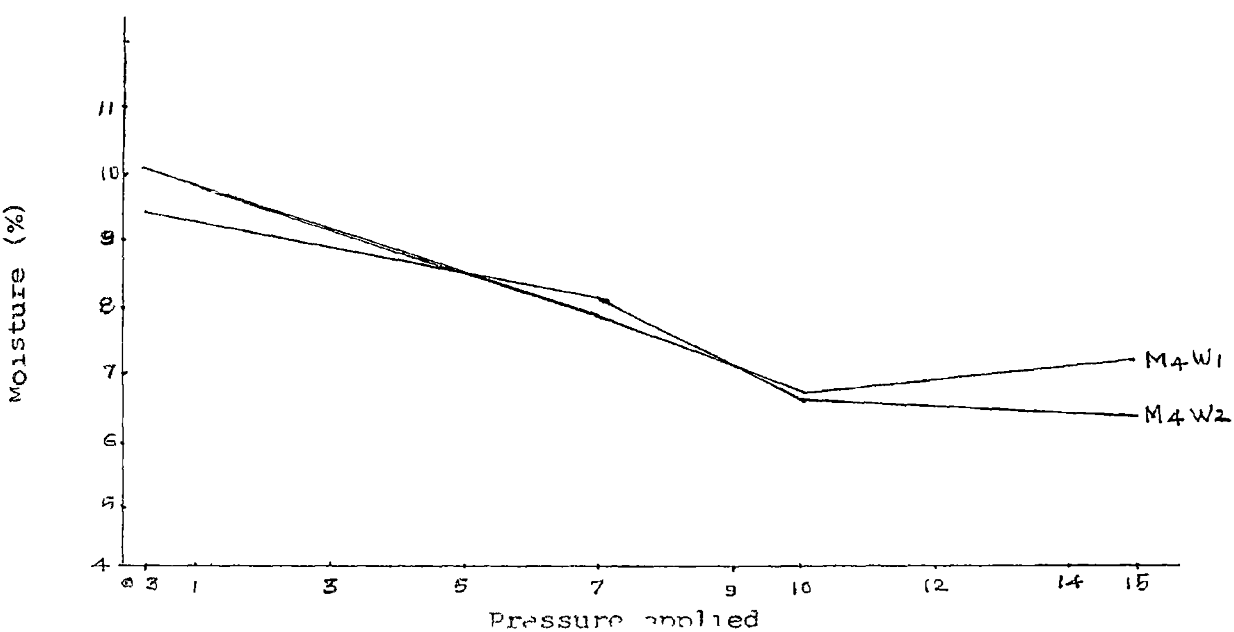


Fig - 10 - Moisture Retained by Sawdust Mulched Soil under Two Water Levels

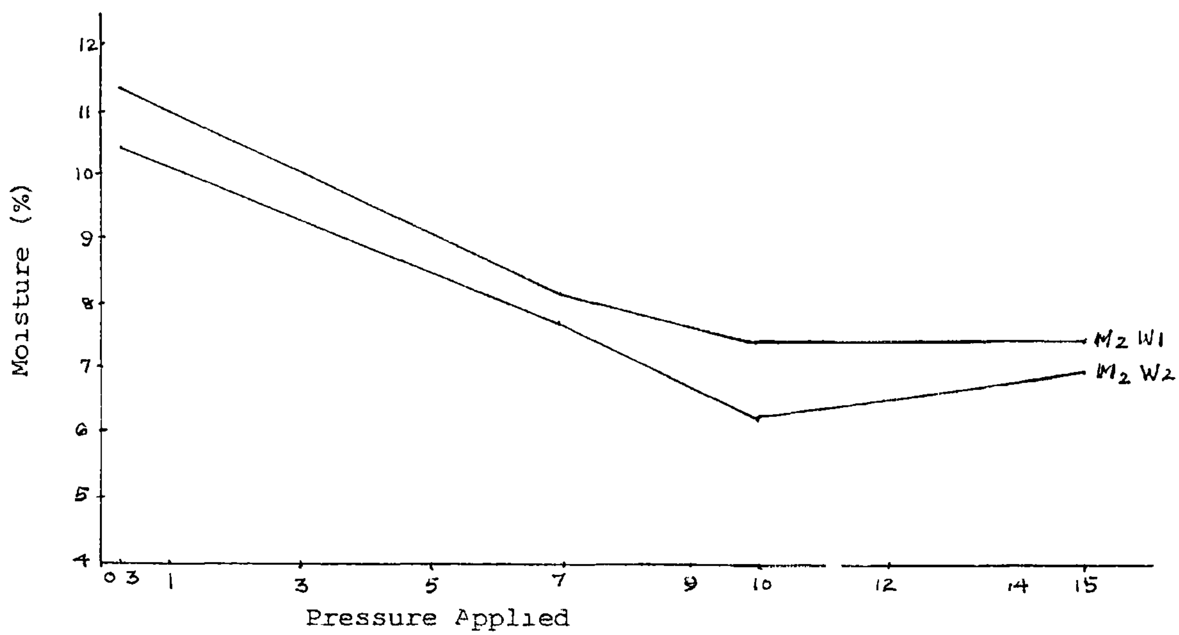


Fig - 1 - Moisture Retained by Dryleaf Mulched Soil Under Two Water Levels.

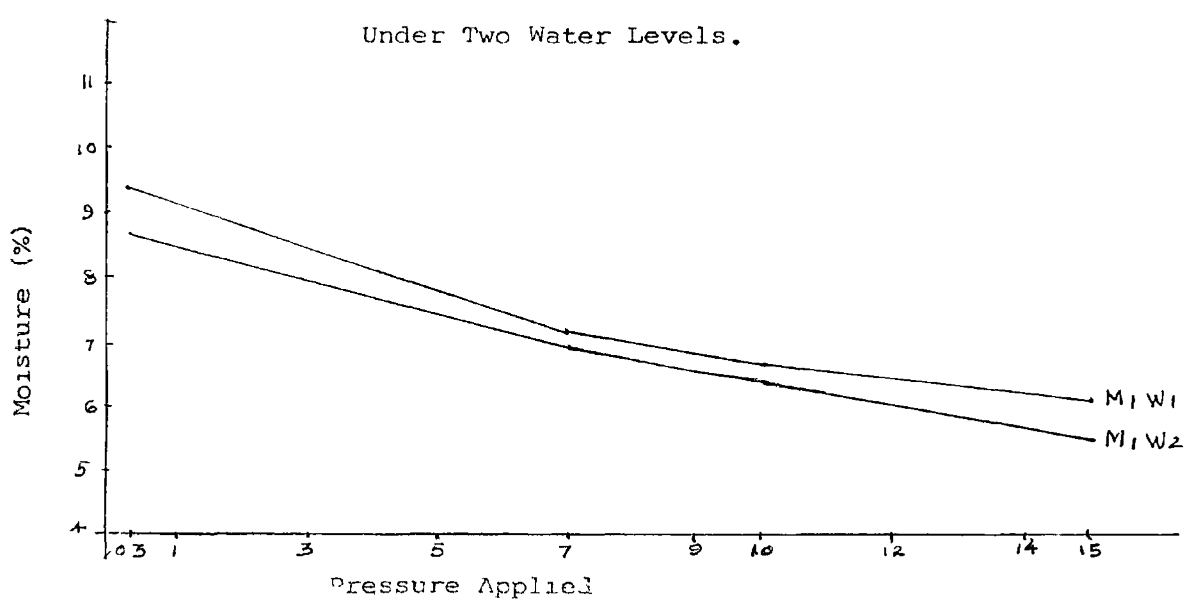


Table 15. Effect of treatments on water retention at field capacity (%).

Treatment	W_1	W_2	Mean (%)
M_1	9.40	8.74	9.07
M_2	11.42	10.38	10.90
M_3	8.38	7.75	8.06
M_4	10.05	9.40	9.72
Control	-	-	7.27
Mean (%)	9.81	9.07	

CD at 5% level for mulches = 0.439

CD at 5% level for water level = 0.310

CD at 5% level for interaction = 0.621

SE of means = 0.216

Table 16. Effect of treatments on water retention at wilting point (%).

Treatment	W_1	W_2	Mean (M)
M_1	6.12	5.57	5.84
M_2	7.40	6.93	7.17
M_3	5.66	5.90	5.78
M_4	7.22	6.34	6.78
Control	-	-	4.85
Mean (W)	6.60	6.09	

CD at 5% level for mulches = 0.269

CD at 5% level for water level = 0.190

CD for 5% level for interaction = 0.381

SE of means = 0.133

4.3.2.1. Bulk density.

Bulk density has not been influenced by any of the mulches (Table 17). But these values are lower than that obtained for control (1.46 g cm^{-3}). Water treatments also do not affect bulk density.

Considering the combined effect, straw mulch with higher value for bulk density than the other combinations.

4.3.2.2. Particle Density.

From Table 18 it is clear that particle density is also not much affected by any of the mulches. Straw mulch shows the lowest value (2.298 g cm^{-3}). The two water levels also have no significant influence on particle density.

The lowest value is obtained for M_4W_1 using paddy husk at 20% water depletion (2.28 g cm^{-3}).

4.3.2.3. Porosity.

The porosity of the soil taken from the field before planting was 38.63%. The soil after harvest do not show

Table 17. Effect of treatments on bulk density ($g\,cm^{-3}$).

Treatment	W_1	W_2	Mean (M)
M_1	1.392	1.382	1.337
M_2	1.398	1.390	1.394
M_3	1.402	1.404	1.403
M_4	1.406	1.404	1.405
Control	-	-	1.462
Mean (W)	1.399	1.395	

CD at 5% level for M = 0.156

CD at 5% level for W = 0.011

CD at 5% level for interaction = 0.022

SE of means = 7.727

Table 18. Effect of treatments on particle density (gcm^{-3}).

Treatments	M_1	M_2	Mean (N)
N_1	2.394	2.290	2.342
N_2	2.436	2.260	2.362
N_3	2.280	2.372	2.326
N_4	2.282	2.314	2.298
Control	-	-	2.356
Mean (M)	2.348	2.316	

CD at 5% level for N = 0.128

CD at 5% level for M = 0.090

CD at 5% level for interaction = 0.181

CV of means = 6.339

any appreciable change with the mulch treatment (Table 19). The highest porosity is obtained for M_4W_1, i.e., 50.3% (straw mulch with 20 water depletion) where the lowest value 37.24% is obtained for M_3W_1 (Paddy husk with 20% water depletion).

4.3.2.4. Mean Weight Diameter.

The result of the analysis of the mean weight diameter of soil obtained from M_4 (Paddy straw) treatment is significantly higher than M_2 (saw dust) and M_3 (Paddy husk).

In examining the water treatment studies, the mean weight diameter obtained for 40% water depletion treatment was higher than that of 20% water depletion. But there was no statistical significance between treatments. The paddy straw combined with 40% depletion of water treatment (M_4W_2) has significantly higher value than all other treatments. But in all the other treatments there is no significant difference. The mean weight diameter of control is 0.8496. Higher mean weight diameter affects the plant growth adversely.

Table 19. Effect of treatments on porosity (%).

Treatment	W_1	W_2	Mean (M)
M_1	38.04%	38.25%	38.14%
M_2	37.86%	37.35%	37.61%
M_3	37.24%	38.09%	37.67%
M_4	38.33%	37.53%	37.93%
Control	-	-	37.39
Mean (W)	37.87%	37.81%	

CD at 5% level for M = 1.59

CD at 5% level for W = 1.08

CD at 5% level for interaction = 2.16

SE of means = 0.75

Table 20. Effect of treatments on mean weight Diameter.

Treatments	W_1	W_2	Mean (M)
M_1	0.8122	0.7916	0.8019
M_2	0.8150	0.7704	0.7927
M_3	0.7762	0.7202	0.7482
M_4	0.7660	0.9334	0.8497
Control	-	-	0.849
Mean (W)	0.7924	0.8039	

CD at 5% level for M = 0.0546

CD at 5% level for W = 0.0386

CD at 5% level for interaction = 0.0773

SE of means = 0.0269

4.4. Plant Nutrients.

The effect of mulches, water levels and their interaction on mean values of plant content of nitrogen, phosphorus, potassium, calcium and magnesium are given in table 21-23.

4.4.1. Effect of mulches on plant nutrients.

The plant analysis (Table 21) show that the nitrogen, phosphorus and potassium content of plants which grown in paddy husk is superior over the other mulches. The minimum values for nitrogen (0.988%) and potassium (0.14%) is obtained for straw mulch and minimum value of phosphorus obtained for saw dust mulch (0.201%).

Plant content of calcium and magnesium are maximum for dry leaf mulched plants (1.253%) and 0.605%) and least for M_2 and M_3 treatment respectively.

4.4.2. Effect of water levels on plant nutrients.

The effect of water levels on plant nutrients are given in table 22.

Table 21. Effect of mulches on plant nutrients (%).

Treatment	N	P	K	Ca	Mg
M_1	1.138	0.272	0.21	1.253	0.605
M_2	1.378	0.201	0.15	0.885	0.569
M_3	1.395	0.299	0.24	0.967	0.379
M_4	0.988	0.286	0.14	0.959	0.539
Control	0.502	0.210	0.11	0.710	0.396
CD at 5% level	0.124	0.061	0.12	0.068	0.031
SE of means	0.061	0.030	0.05	0.033	0.015

Table 22. Effect of water levels on plant nutrients (%).

Treatment	N	P	K	Ca	Mg
W_1	1.543	0.283	0.18	1.168	0.528
W_2	0.906	0.246	0.18	0.863	0.518
CD at 5% level	0.088	0.043	0.08	0.048	0.021
SE of means	0.061	0.030	0.05	0.033	0.015

Table 23. Interaction of treatments on plant nutrients(%).

Mulches	Water level	N	P	K	Ca	Mg
M_1	W_1	1.398	0.364	0.23	1.659	0.593
	W_2	0.878	0.181	0.18	0.846	0.617
M_2	W_1	1.832	0.163	0.17	0.933	0.571
	W_2	0.923	0.239	0.14	0.836	0.568
M_3	W_1	1.742	0.262	0.18	1.111	0.355
	W_2	1.047	0.336	0.30	0.823	0.404
M_4	W_1	1.200	0.343	0.16	0.970	0.592
	W_2	0.776	0.229	0.11	0.948	0.487
MO	-	0.502	0.210	0.11	0.710	0.396
CD at 5% level		0.1760	0.0863	0.167	0.0962	0.0436
SE of means		0.0614	0.0300	0.058	0.0335	0.0157

Between the water levels the 20% depletion from field capacity has got higher values for all the plant nutrients. In the case of Nitrogen and calcium, the values are significantly higher for W_1 than for W_2 (40% depletion).

4.4.3. Interaction effect.

The interaction effect of mulches are given in the table 23. When we consider the interaction, the plants which are grown under dry leaf mulching with 20% water depletion show higher values of plant nutrients M_4W_2 straw mulch with 40% water depletion is found to have less influence on plant nutrient content as far as nitrogen, phosphorus, potassium calcium and magnesium are concerned.

4.5. <u>Soil nutrients.</u>

Treatment effects on soil nutrient such as nitrogen, phosphorus, potassium, calcium, magnesium, sulphate sulphur and organic carbon are presented in table 24-25.

4.5.1. Effect of mulches on soil nutrients.

Result of soil analysis conducted before the experiment is given in table 5. soil nitrogen after experiment is more in dry leaf mulched treatment. Dry leaf mulch has great influence on soil nitrogen which is higher than the values for other treatments. Soil phosphorus content is much influenced by Paddy husk mulch treatment (206.08). In the saw dust mulched soil the Phosphorus content was very much reduced (51.52 kg/h).

The potassium content of soils do not differ significantly in most of the treatments except for M_4. The potassium is in the range of 206 kg^{-h} to 358.4 kg^{-h}. Maximum value is obtained for M_4 and minimum for M_3.

Calcium content of the soils do not seem to be influenced by any of the treatments.

The magnesium content in M_2 (saw dust) treatment is higher when compared with the values obtained for other treatments. Sulphur content of soil after treatment is significantly lower than the sulphur content of initial soil (450.24 kg^{-h}). This may be due to the highly mobile

Table 24. Effect of mulches on soil nutrients.

Mulch Treatment	N Kg/h	P Kg/h	K Kg/h	Ca Kg/h	Mg Kg/h	SO_4 Kg/h	O.C%
M_1	71.68	112.00	262.08	934.08	116.72	62.72	0.395
M_2	66.97	51.52	202.24	1120.0	197.12	62.72	0.298
M_3	66.75	206.08	206.61	1330.5	109.76	51.52	0.290
M_4	66.75	179.20	390.40	954.24	50.44	105.28	0.301
M_0	53.76	41.88	259.84	1456.0	56.00	40.32	0.230
CD at 5% level	6.49	79.92	76.16	426.04	33.62	26.88	0.0617
SE of means	3.135	36.75	35.84	209.88	16.57	13.44	0.0304

nature of the sulphur which might have leached down. Among different mulches, soil mulches M_4 (straw mulch) has got highest sulphur content. The treatments in general have reduced the sulphate sulphur content of the soil.

The organic carbon obtained for mulch treatment has got higher value than the control. Organic carbon followed the same trend as soil Nitrogen.

4.5.2. Effect of water levels on soil nutrients.

For higher water levels content of nitrogen, phosphorus, potassium, calcium and organic carbon are found to be significantly higher than the lower water level, as evident from table 25. Sulphur content is not influenced by water levels but magnesium is slightly lower at the higher water levels.

4.5.3. Interaction effect.

Higher water level with dry leaf mulch show higher content of soil nitrogen i.e., 73.92 kg ha^{-1} (interaction table 26) and minimum value 62.72 kg ha^{-1} is obtained for M_4W_2 (Paddy straw with 40% water depletion).

Paddy husk with 20% water depletion shows higher values of phosphorus which is higher than the phosphorus content in the initial soil sample. The lowest value obtained for M_2W_2 (Saw dust with 40% water depletion). Phosphorus status of the treatment combinations are in the order of M_3W_1 M_4W_1 M_3W_2 M_1W_1 M_4W_2 M_2W_1 M_1W_2 M_2W_2.

Soil potassium percentage is in the order of M_4W_1 M_4W_2 M_3W_2 M_2W_1 M_1W_1 M_3W_1 M_2W_2 M_1W_2.

In the case of soil calcium content higher value is obtained for M_3W_1 (table 26) and for soil magnesium; the highest value obtained for M_2W_2. The lowest value for both calcium and magnesium are given by M_4W_2 (Paddy straw with 40% water depletion).

In contrast to the general trend, M_4W_2 (straw mulch with lower water level) has got highest value (114.24 kg/ha for soil sulphur while the lowest is 49.20 kg ha^{-1} obtained for M_1W_2, M_2W_1 and M_3W_2.

Table 25. Effect of water levels on soil nutrients.

Treatment	N kgh^{-}	P kgh^{-}	K kgh^{-}	Ca kgh^{-}	Mg kgh^{-}	SO_4 kgh^{-}	O.C %
W_1	69.44	170.24	315.84	1238.72	118.72	71.68	0.335
W_2	64.96	105.28	266.72	931.84	129.92	71.60	0.3064
W_0	53.76	41.68	253.84	1456.00	50.00	40.32	0.233
CD at 5% level	4.704	55.32	54.21	300.16	23.14	19.46	0.083
SE of means	31.36	38.75	37.63	209.88	16.57	26.80	0.0304

Table 25. Interaction of treatments on soil nutrients.

Mulches	Water levels	N kg/h	P kg/h	K kg/h	Ca kg/h	Mg kg/h	SO_4 kg/h	O.C %
M_1	W_1	75.92	168.00	266.72	1646.32	98.56	60.64	0.440
	W_2	67.2	58.24	239.68	879.34	141.12	49.28	0.349
M_2	W_1	69.44	60.48	313.6	1290.24	195.64	49.28	0.313
	W_2	64.96	44.80	253.36	949.76	203.84	78.4	0.284
M_3	W_1	67.2	362.88	275.52	1500.00	109.76	56.24	0.310
	W_2	67.2	188.16	322.56	1160.32	112.00	49.28	0.270
M_4	W_1	71.68	226.24	392.00	1111.04	73.92	98.56	0.260
	W_2	62.72	134.40	327.04	797.44	67.2	114.24	0.322
CD at 5% level		9.184	110.68	96.32	602.56	47.71	39.21	0.087
SE of Means		3.20	38.53	37.65	209.68	16.57	13.66	0.0304

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4.6. Effect of treatments on Gravimetric moisture content.

Mean values of weekly soil moisture (on gravimetric basis) for different treatments at 15 cm depth are given in table 27 and Fig.12. Soils of saw dust mulch treatment show maximum value of gravimetric moisture percentage i.e., 9.1% and among mulches the lowest value 8.03% is obtained for paddy straw mulch. The least value 5.58% is obtained for control.

Between the water levels, 20% water depletion from field capacity gives higher value of gravimetric moisture content (6.75%).

Among the treatment combinations M_2I_1 has influenced water content than any other treatment. It is on par with M_3I_1. Even at lowest water level M_2 is superior over paddy husk and paddy straw.

4.7. Effect of treatments on soil temperature.

Effect of different mulches and water levels on soil temperature at 15 cm depth are given in table 28 and

Table 27. Effect of treatments on soil moisture content (%).

Treatment	N_1	N_2	Mean (M)
M_1	8.54	8.44	8.49
M_2	9.21	8.79	9.00
M_3	8.92	8.08	8.50
M_4	8.36	7.70	8.03
Control	5.98		
Mean (N)	8.75	8.25	

fig-12 - Soil moisture under different multches and water level

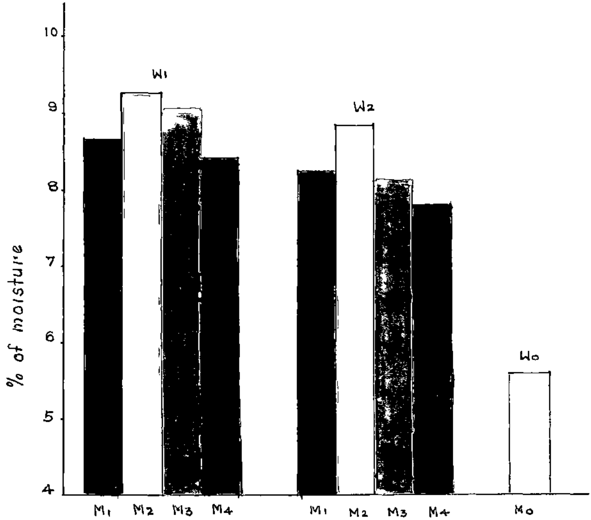
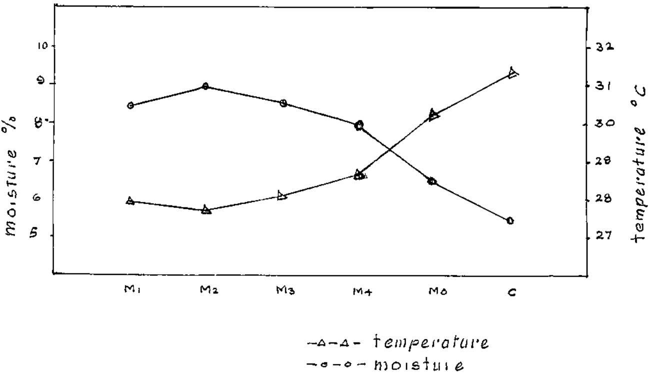


Table 28. Effect of treatments on soil temperature(C°).

Treatment	W_1	W_2	Mean(M)
M_1	27.9	28.0	27.9
M_2	27.6	27.8	27.7
M_3	27.9	28.3	26.2
M_4	28.4	29.0	28.7
Control	31.41%		
Mean (W)	27.9	28.2	

fig-13. mean soil moisture and temperature under different mulches.



Mean Monthly Soil Temperature - Under defferent Mulches

Fig. - 14 - 20% Water Depletion

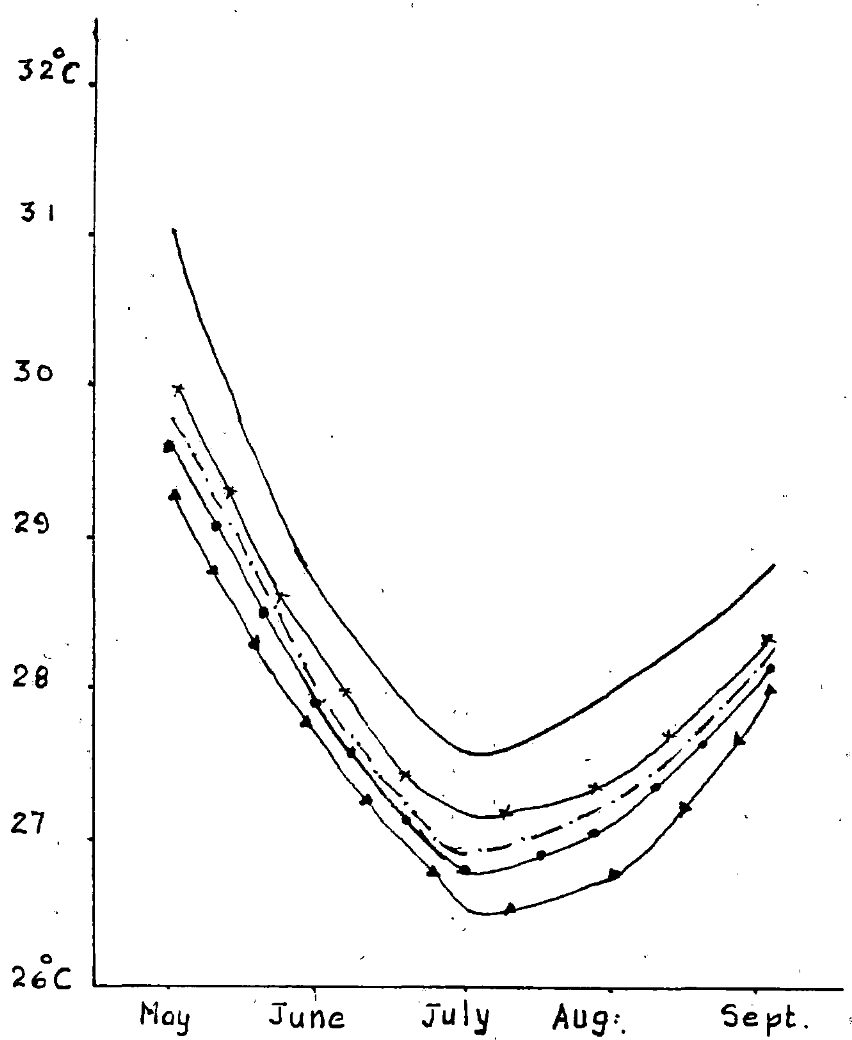


Fig. - 15 - 40% Water Depletion

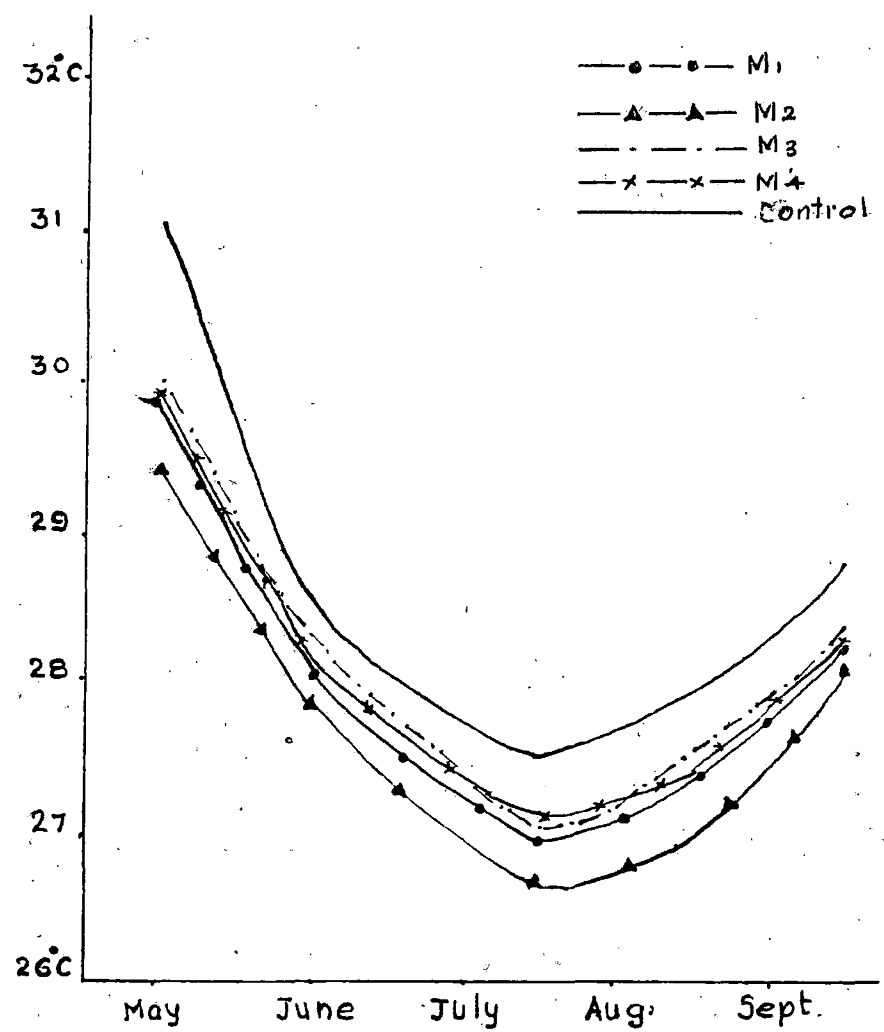


Fig.13, 14 and 15. The control with no mulch and no water treatment showed the highest value of 31.4°C. Next higher value for soil temperature was recorded by paddy straw (28.7°C). The increasing soil temperature is in the order of $M_2 > M_1 > M_3 > M_4$ control.

Between the water levels, higher water levels shows lower values of soil temperature (27.97°C). Treatment combinations of saw dust with higher water content ($M_2 W_1$) shows the minimum soil temperature (27.6°C). Straw mulch with lower water levels gives the maximum value for soil temperature (29°C).

4.8. Yield.

Yield data obtained from periodical harvest from each pot (for each plant) is statistically analysed and given in table 29 and Fig.16.

4.8.1. Effect of mulch treatment.

The yield obtained for M_1 (dry leaf) and M_2 (saw dust) mulched plants are on par and are significantly higher than the yield values for M_3 and M_4 (table 29).

Table 29. Effect of different treatments on yield g plant^{-1}.

Treatment	W_1	W_2	Mean(M)
M_1	492.0	388.2	440.1
M_2	410.8	355.6	383.2
M_3	282.4	252.2	267.3
M_4	234.2	205.4	219.8
Control	-	-	193.4
Mean (W)	354.9	300.0	

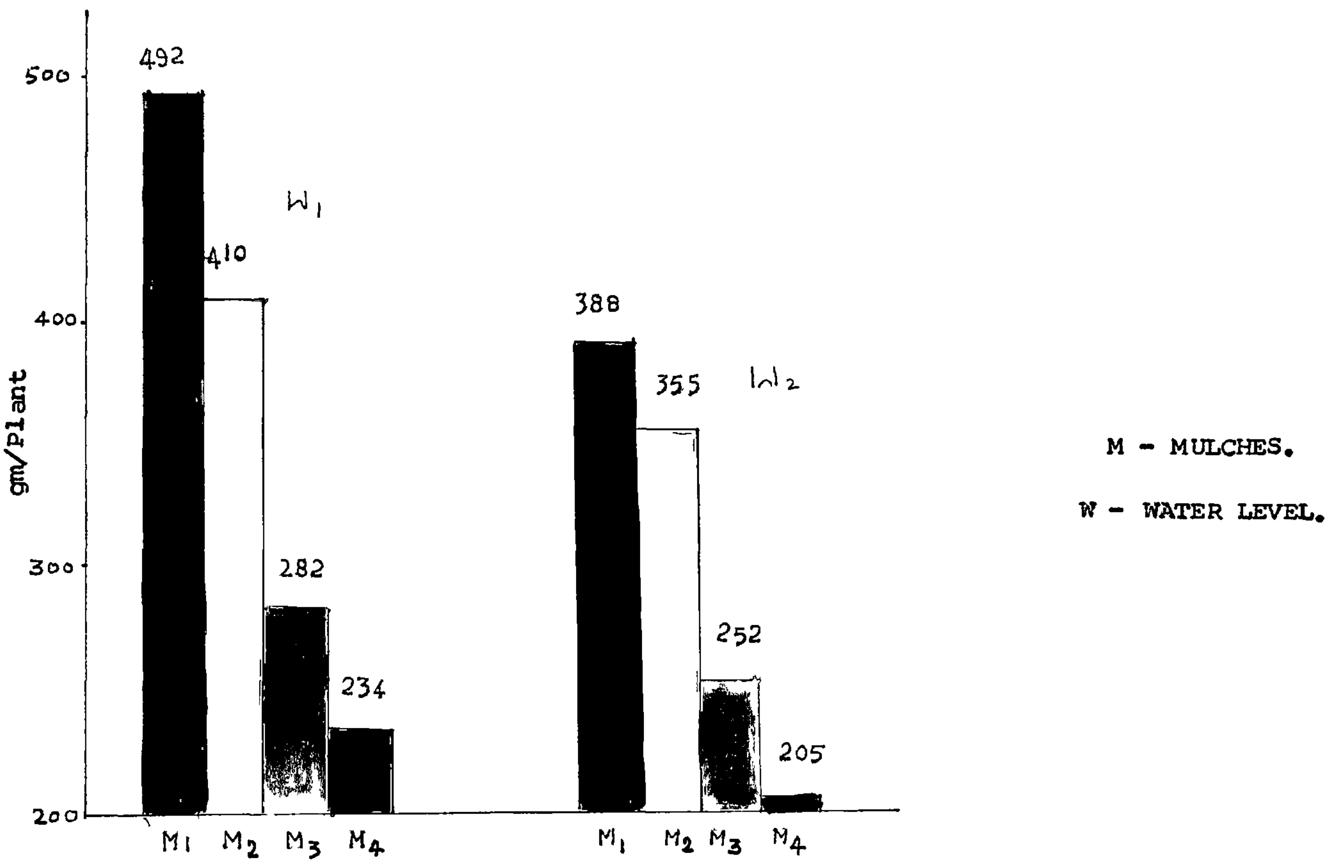
CD at 5% level for mulch = 72.95

CD at 5% level for water level = 51.58

CD at 5% level for interaction =103.17

SE of means = 35.950

Fig. 16 - EFFECT OF TREATMENTS ON YIELD



4.8.2. Effect of water levels on yield.

High water levels give significantly higher yield than lower water level.

4.8.3. Interaction of mulches and water levels on yield.

Treatment combinations of M_1W_1 (492 g) is significantly superior over all other treatment combinations.

In general plants grown under higher water level with dry leaf mulch show the maximum yield value i.e., 492 g followed by $M_2W_1 > M_1W_2 > M_2W_2 > M_3W_1 > M_3W_2 > M_4W_1 > M_4W_2$ control. The lowest yield obtained for the control (193.4 g).

Table 30. Correlation between different factors.

Factors	Plant height	Leaf area	Root length	Root weight	Internodal length	M.W.D.	Hydraulic conductivity	Bulk density	Yield
Soil Nitrogen	0.3224**	0.2654**	0.1724	0.1771	-0.2702*	-0.2293	0.1657	-0.2731*	0.2529*
Soil sulfur	-0.207	-0.2700	0.0249	0.0365	0.2543*	0.329**	-0.0924	-0.0359**	-0.2367
Organic Carbon	0.2698*	0.3809**	0.0026	-0.2724*	-0.30	-0.053	0.4612**	-0.218	0.3862**
Soil Calcium	-0.159	-0.2224	-0.035	0.0765	0.2527*	-0.1592	-0.1431	0.325**	-0.1236
Soil Magnesium	0.4231**	0.497**	0.0715	0.1599	-.4172**	-0.1767	0.22	-.1647	0.2952**
Plant Nitrogen	0.4145**	0.5406**	0.5155**	0.4651**	-0.5395**	-0.2517*	0.1822	-0.3235**	0.4401**
Plant Calcium	0.4096**	0.4369**	0.3575**	0.1728	-0.406**	-0.0268	0.448**	-0.25*	0.4556**
Plant Magnesium	0.4263**	0.4999**	0.2364	0.068	-0.468**	-0.016	0.6540**	-0.469**	0.5031**
Bulk Density	-0.4917**	-0.562**	-0.1812	-0.152	0.6917**	0.1057	-0.2816**	1	-0.4079**
Hydraulic conductivity	0.655**	0.6194**	0.3982**	0.1445	-0.4502**	0.0236	1	-0.2616**	0.592**
Mean weight diameter	-0.1411	-0.3116	0.153	0.1546	0.236	1	0.0236	0.1057	-0.1383
Porosity	0.134	0.2149	0.065	-0.036	-0.2059	-0.3042**	0.1041	-0.2877**	0.073
Volume of expansion	-0.0136**	-0.078**	-0.122	-0.093	0.1268	0.3737**	-0.0927	0.1731	-0.1412
Yield	0.670	0.7606	0.4696**	0.3654**	-0.6963**	-0.1303	0.592**	-0.4079**	1

CD at 5% level = 0.2813
CD at 1% level = 0.2379

* - Significant at 1% level
** - Significant at 5% and 1% levels.

DISCUSSION

5. DISCUSSION

The present investigation is carried out as pot culture experiment to study the role of different types of mulches on soil plant characteristics, soil temperature management and water use efficiency. Disease resistant (yellow vein mosaic) variety of Bhindi (*Abelmoschus esculentus*) is used as the test crop for the study.

Four type of mulches and two different water levels are used in the investigation. Direct effects and interaction effects of the water levels and different mulches are studied and analysed statistically.

Daily soil temperature at 7.30 and 14.30 hours are recorded. From this the average daily temperature and monthly temperature for crop period are calculated and presented in table 31 and fig. 14 and 15. The average monthly tensiometer readings and the corresponding gravimetric moisture content are calculated from the daily observations and are given in table 32 and fig.12.

Table 31. Mean monthly soil temperature (C°).

Temperature	May	June	July	August	September
M_1W_1	29.59	27.80	26.71	27.13	28.16
M_1W_2	29.90	28.05	26.94	27.39	28.32
M_2W_1	29.24	27.61	26.48	26.72	28.02
M_2W_2	29.42	27.79	26.66	26.99	28.16
M_3W_1	29.75	27.89	26.93	27.25	28.39
M_3W_2	30.01	28.36	27.09	27.56	28.38
M_4W_1	29.94	28.16	27.13	27.40	28.44
M_4W_2	30.13	28.70	27.31	27.68	28.55
M_0W_1	30.37	28.40	27.37	27.69	28.61
M_0W_2	30.56	28.85	27.31	27.89	28.75
Bare(Control)	31.07	28.59	27.50	28.02	28.79
Mean monthly air temperature.	28.43	27.09	27.13	26.33	26.58

Table 32. Mean monthly Tensiometer reading (cm).

Treatment	May	June	July	August	September
M_1W_1	28.76	24.97	24.02	24.27	25.47
M_1W_2	29.42	25.10	24.37	24.39	25.62
M_2W_1	27.20	24.37	23.95	24.10	25.42
M_2W_2	28.15	24.75	24.43	24.25	25.35
M_3W_1	27.37	24.57	24.47	24.52	25.82
M_3W_2	29.10	35.32	24.77	24.77	26.12
M_4W_1	30.35	25.60	24.76	24.80	26.15
M_4W_2	30.45	26.05	25.07	25.00	26.40
M_0W_1	31.50	26.02	25.10	25.20	26.50
M_0W_2	35.75	26.50	25.32	25.34	26.75
Bare (Control)	38.52	26.80	25.50	25.55	27.06

Atmospheric temperature during the crop growth is also recorded daily and the average monthly temperature is plotted in fig.14 and 15 for comparison with soil temperature and water levels.

5.1. Seedling Emergence.

Maximum coefficient of velocity of emergence and minimum mean time of emergence are obtained for dry leaf mulch with higher water level treatment combinations (table 6).

Between the two water levels seedling emergence is influenced by the higher water level i.e. at 20% water depletion from field capacity for all the mulches tried. This shows the importance of water in seedling emergence. Imbibition of water by seed is the first process of germination. This process is also influenced by soil temperature through its effect on viscosity of water and permeability of seed coat. Supporting this view Parker and Taylor (1965) have also reported that in grain sorghum seeds with the increase in soil moisture tension to one bar or more there was a decrease in the rate and amount of emergence.

Pushkala and Nagaraja Rao (1983) have also studied the effect of different water levels on seedling emergence of wheat and soybean and have reported that as the moisture content increased from 7.5 to 15%, higher value of co-efficient of velocity of emergence and lower value of mean time of emergence are obtained for soybean.

Higher coefficient of velocity of emergence and lower mean time of emergence are noticed with the pots which received dry leaf and saw dust mulches. This may be due to the fact that these soils could retain higher water content and showed lower soil temperature compared to paddy husk and paddy straw mulches.

Blacklow (1972) and Wiedema et al (1982) have reported that the soil temperature restricted the germination by its effect on imbibition. Mulching significantly reduced the soil temperature measured at 5, 10 and 20 cm depths (Lal, 1974). He has also showed that with mulches in tropical soil water conservation characters of soil can be improved. Observations by Mehta and Prihar, 1973 also support this view. In the present study unmulched pots showed least values of co-efficient of velocity of emergence which lead to the failure of emergence in these pots. The low values of coefficient of velocity of emergences obtained for straw mulch indicate that the seeds have not obtained enough water because of high rate of evaporation from the soil surface resulting in lower water content. Supporting this, high soil temperature (28.70°C) also is recorded in these pots.

In general as the moisture tension and soil temperature increased the rate of emergence and total emergence of all species declined (Wright et al, 1978).

5.2. Biometric characters.

Moisture regimes and the mulches have a positive influence on a good number of plant characters. The interaction effect however did not come out as significant in most of the characters studied.

5.2.1 Plant Height.

The mulches tried have significant influence on plant height. The plant height obtained for dry leaf treatment is the highest. The high organic matter content in dry leaves, which is easily decomposible might have contributed for the plant growth. This may be due to the increased supply of nitrogen during vegetative growth (Table 26).

From the very first event that is seedling emergence, dry leaf treatment showed great influence which is reflected in the later stages also. Mulched plants are significantly superior over unmulched plants.

Moisture stress in the plants is a result of the combined effect of lack of soil moisture at the root zone, resistance to water movement in the plant; stomatal control and atmospheric evaporation demand (Sivakumar and Virmani, 1979).

The height of the plants is influenced by the two moisture regimes, though the difference is not significant (Fig.4).

In dry leaf mulching there is no significant difference between the plant heights obtained for the two water levels. This may be due to the higher nutrient content of dry leaf mulch and also the high water retention capacity in this treatment. Rangacharylu and Raghbhushanam (1960) have reported that using dry leaves as mulch the cost of irrigation can be reduced by increasing the retention.

The result shows that at higher water levels the plant growth rate is more. Water deficit may cause decrease or cessation of elongation of stems which depends on the turgid conditions of the cell. Heyns (1946), Kroyer (1950) and Cleland and Bonner (1956) also have obtained similar results.

5.2.2 Internodal length.

Highest value for internodal length was obtained for paddy straw mulch. As the inter nodal length increases the yield will decrease because the flower buds arises from this point. The dry leaf mulched plant has lowest internodal length. The soil temperature under straw mulch is comparitively higher than the soils under other mulching materials. This might have increased the vertical elongation rate of cells combined with other adverse effects, such as deficiencies of nutrients and water. Higher soil temperature reduces soil moisture percentage due to increased evaporation which is higher in the case of straw mulched pots. Similar results were obtained by Simpson (1960) and Dormer and Ketcheson (1960).

Higher values for internodal length was observed in the lower water treatment. This itself shows that the lower moisture percentage in soil adversely affect the healthy growth of plant. Healthy plants will have shorter internodal length .

5.2.3 Leaf area.

Leaf area is an important factor which is easily affected by the moisture and temperature. The leaf area is directly related to the photosynthetic activity of the crop. This growth component is influenced by different mulches and water levels (Table 9, Fig.6). The plants grown in dry leaf mulching have the highest leaf area and which grown in straw mulch showed the least leaf area. As per Abraham Jacob (1963) the leaf area is independent of the influence of mulches and moisture regimes. In contrast to the findings of Abraham Jacob the present result may be due to the difference in moisture with dry leaf mulched soil. The increased uptake of nitrogen by the plants also might have influenced the leaf area.

Pushkala (1982) also have obtained higher leaf area in case of wheat for higher moisture treatments during the vegetative growth. Similar results were obtained by Watson (1947) Wadleigh and Gouch (1948), Samiev et al (1971) and Selvaraj (1976).

5.2.4 Root growth.

The present investigations on the effect of different mulches and two water levels on root length and root weight show that mulched plants have higher values for both. The root length and root weight are more in the case of saw dust mulched plants. This may be due to the low temperature and higher water availability in soils under saw dust. These conditions have enhanced the root growth. The soil temperature in straw mulched pot is comparatively high. Singh et al (1976) reported the response of maize roots to soil temperature alterations caused by straw mulch and plastic mulch, where straw mulch increased rooting density in the upper 10 cm of soil, but decreased it below 15 cm depth as obtained in the present study.

This denser rooting in the top layer with mulching was attributed to the lower and more favourable soil temperature and the reduced mechanical impedance due to greater moisture conservation. In the present study the lowest soil temperature (27.72°C) and maximum gravimetric moisture content (9.01%) was recorded in the saw dust mulched pots. The plants grown in these pots showed maximum values for root length and root weight.

The root length of maize, ground nut and wheat were increased slightly by the incorporation of paddy husk @ 50 q/ha; powdered ground nut shell at the rate of 50 q/ha (Anon, 1984). Wong et al (1971) showed that high root temperature beyond certain limit could account for the loss of roots. Anon, (1959) reported that at high temperature the root growth was restricted because of the higher ethylene concentration (>1 ppm in soil).

Between the water levels, the water stressed plants showed less root length and weight. Taylor et al (1967) also reported that root elongation appreciably reduced by an increase in soil water suction and vice versa. Chaudhury and Bhatnagar (1980) found a close correlation between wheat root distribution and extraction pattern.

Prihar et al (1975) observed deeper rooting and greater depletion of water in soils with higher seeding time moisture. Water stress in the early stages prevents the plants to develop an adequate root system to extract water from deeper layers. In the present study also the plants which experienced water stress from the early stages showed less root weight and root length. In contrast to this study more root length and root weight observed in stressed conditions by Gard (1959) Dergen et al (1965) Dennet and Doss (1960) and Puchkala and Nagaraja rao (1965). The result obtained for the present study may be attributed to the fact that the plants are grown in pots where the plant roots are restricted to grow more and more in search of water.

All the biometric characters except internodal length are positively correlated with yield (Table 50). The internodal length is negatively correlated. When we consider the biometric factors, nutrient uptake and soil nutrient are concerned, the plant nitrogen content is positively correlated with plant height, root length, root weight and leaf area. The internodal length is negatively correlated. So also almost all the nutrients are positively correlated with major plant characters especially magnesium content of soil and plant highly influenced the plant height and leaf area.

In the present study, higher values of Hydraulic conductivity is obtained for dry leaves with higher level of water treatment (Table 12). Among the mulches the differences are highly significant. The hydraulic conductivity of control is 10.09 cm^{-hr} and that of dry leaf mulched soil is 41.342 cm^{-hr}. The hydraulic conductivity was improved by mulching.

Subramanyam and Kar (1976) observed a curvilinear relationship between initial moisture content and infiltration rate for a lateritic sandy loam soil. A linear relationship obtained between 6% and 20% moisture treatments which experienced low soil temperature showed high values of hydraulic conductivity.

Lal et al (1980) & Mathan et al (1984) have also reported a significant increase in hydraulic conductivity by the application of mulches; but there was no significant difference among different mulches Sandhu and Bhumble (1967) observed that non capillary porosity and the hydraulic conductivity of silty loam could be improved by adding sugarcane trash.

retention of soil moisture for longer periods Horning and Overson (1962); Prihar et al (1968); Koshi and Fryrear (1971) and Lal (1972) also observed a higher soil moisture content under mulched conditions through out the growing season than unmulched plots.

Hydraulic conductivity is positively correlated with organic carbon. The potassium seems to decrease Hydraulic conductivity. It can be attributed to the soil matrix interaction in the presence of salts. Calcium and Magnesium uptake by plants are positively correlated with Hydraulic conductivity. So also the hydraulic conductivity is positively correlated with plant height, leaf area and root length. Increased hydraulic conductivity always helps in root absorption. The water holding capacity has no significant correlation with any of the factors studied except plant uptake of nitrogen and particle density whereas it is negatively correlated with mean weight diameter (Table 30).

When the soil is compacted or as the bulk density is increased water holding capacity also increases. But when the structural stability decreases water holding capacity also decreases with higher values of mean weight diameter.

5.3.2 Structural characters.

Soil mulching in general has considerable influence on bulk density of soil. The initial soil had a bulk density of 1.42 g cm^{-3}. But after the mulch treatment considerable reduction in all treatments can be seen (Table 17) especially for dry leaf mulching. It has been reduced to 1.387 gcm^{-3}. This may be due to the added organic matter content to the upper layers of soil by decomposed dry leaves. Organic matter reduces the bulk density of soil. Supporting this it has been observed that chiselling the field along with incorporation of bulky organic materials like wheat stubbles, rice husk powdered ground nut shell, at the rate of 100-250 q ha^{-1} re duced the bulk density of alluvial sandy loam, red sandy loam soil and black clay soil (Mallick and Nageraja rao (1979). Increase in bulk density decreases the hydraulic conductivity of soil Khanna et al (1973) also have reported lower hydraulic conductivity for increased bulk density.

The particle density of initial soil sample was 2.3 gcm^{-3}. A negligible increase of particle density is noticed in saw dust mulched soil. This may be due to the mixing up of decomposed fine particles of saw dust in higher irrigation levels. All other treatments are on par.

There is no such difference between the initial values of porosity and the mulch treated values. But slight decrease in porosity is noticed with the soil tested after mulching. Similar result was obtained by Lal et al (1980) where the porosity of the newly cleared tropical alfisol was slightly higher than the unmulched control. Nathan et al (1984) also reported that the total porosity was significantly influenced by mulches. This may be due to the decomposed organic matter at the lower layers of mulches. The increase in bulk density from 1.5 gcm^{-3} to 1.8 gcm^{-3} of lateritic sandy loam at Kharagpur reduced the aeration porosity from 10% to 4% and capillary porosity from 36% to 29%. For porosity significant correlation is noted with any of the factors studied.

The structural index, mean weight diameter of initial soil sample was 0.795. Improvement in soil aggregation in lateritic sandy soil is not because of increase in organic matter, but due to the cementing materials produced during crop growth (Ghildyal, 1969).

Among the treatments there is no significant difference in the value of Mean Weight Diameter. This shows that in the case of red loam soils, which is well aggregated otherwise, we can not expect much changes in the structural attributed.

When we consider the correlation effect as given in table 30 between bulk density and other factors, the bulk density is negatively correlated with uptake of magnesium, calcium and nitrogen and soil nitrogen. Plant characters such as leaf area and plant height and soil characters such as porosity and hydraulic conductivity are also negatively correlated with bulk density. As all these main characters are negatively correlated, the yield is also negatively correlated where as the internodal length is positively correlated with bulk density. Similar correlation was noted for nitrogen, potassium and calcium uptake by sun flower and lady's finger by increasing the bulk density from 1.55 gcm^{-3} to 1.7 gcm^{-3} of red sandy loam at Coimbatore (Anon, 1984). A negative correlation exist with hydraulic conductivity which is supported by the results obtained for lateritic sandy loam where hydraulic conductivity decreased to one eighth from 3 $cm\ h^{-1}$ when the bulk density of 1.40 gcm^{-3} increased to 1.7 $g\ cm^{-3}$.

Physical properties like volume of expansion, porosity and water holding capacity are significantly and negatively correlated with mean weight diameter. Decrease in water holding capacity and porosity; adversely affected plant growth. All the other characters are not significantly correlated (Table 30).

5.4. Plant nutrient uptake and soil nutrients.

Soil nutrient movement and nutrient uptake by plants greatly controlled by soil temperature, which can be managed to some extent by mulching. In the present study nitrogen, potassium and phosphorus uptake by plants are higher and calcium and magnesium are lower in paddy husk mulched pots though it is not significant statistically, over other treatments. Among the treatments paddy husk mulched soil shows comparatively higher soil temperature than dry leaves and saw dust. This higher temperature might have increased NPK uptake. Similar study conducted by Chaudhary and Childyal (1970) have also reported same results. From many studies, it has been observed that by increasing the bulk density, the nutrient uptake like N, P and K increased significantly. In the paddy straw and husk mulched pots, the soil shows the higher values of bulk density which might have contributed for the comparatively larger uptake of nutrients by the plants (Table 17).

In a study at Hissar with alluvial sandy loam soil, for an increase in bulk density from 1.40 to 1.6 gcm^{-3}, the P uptake increased but the magnesium, calcium and sodium uptake decreased with the increase in bulk density to 1.6 gcm^{-3} (Anon, 1984). This report supports the present observations on the nutrient uptake.

Irrespective of mulches, the higher water levels increased the nutrient uptake. For the dissolution and movement of nutrients, water is necessary (Table 22). If it is inadequate nutrient uptake by plant is adversely affected.

As far as the soil nutrients are concerned (Table 24 and 25) Nitrogen content is higher in dry leaf mulched soil and P in paddy husk mulched soil, and K in straw mulched one. The nitrogen supply from dry leaf decomposition might have contributed for the increased soil nitrogen and the fact that rice bran contains more phosphorous, which might have increased P in these pots. Any how, there was no significant difference in soil nutrients for different mulch treatments and water levels.

Soil nitrogen is positively correlated with plant nitrogen; plant calcium, plant P, plant height, root characters, and also with leaf area. The soil P is negatively correlated with soil and plant Magnesium.

Soil P is positively correlated with the mean weight diameter and internodal length and negatively correlated with soil Magnesium and leaf area, plant calcium and magnesium. Leaf area and hydraulic conductivity are positively correlated with organic carbon (Table 30).

A positive correlation exist between plant nitrogen and plant height, root length, root weight, leaf area, water holding capacity of soil, soil nitrogen and yield. The internodal length is negatively correlated with almost all the factors.

Nutrient uptake by plant and soil nutrients are influenced by the soil temperature and moisture status. As the root temperature increases, the nutrient uptake increases. In higher air temperatures, the transpirational rate will be more, resulting in higher uptake of water and nutrients. In such cases, in mulched soils the higher moisture status will help in more uptake of water as well as nutrients which may increase the yield attributing characters.

Vander Honest and Hooymans (1955) showed that the nitrate uptake is more in higher temperatures, so also in this study the nitrogen uptake with paddy husk is more than dry leaves and saw dust in which the temperature is less than paddy husk. Bever (1960) proved that at higher root temperature shoot and root concentration of N, P and K decreased while Cornillon (1974) was of the opinion that the absorption of nutrients by tomato roots was not greately incluenced by temperature.

5.5. Gravimetric Moisture content and water retention.

When irrigation water is limited, the aim is to get the maximum production per unit of water applied. In the present investigation, effect of different types of mulches on water content shows that mulches definitely play a role in conserving soil water. The soil water content in unmulched pots are far below (5.5%) than the mulched pots (fig.12). Mulches greately retard evaporation and protect the soil from direct rays of sun and wind current, consequently the soil is kept cool and retain more water. Among the mulches, saw dust increased the soil water content to the maximum (9%) as given in table 27. This may be due to the high compactness created by saw dust on the soil surface, there by reducing evaporational loss. Paddy straw shows minimum soil water content.

Any kind of soil coverage may reduce evaporational loss as well as it will conserve moisture by increasing the infiltration of water into the soil and retain soil moisture for longer time. The present result is in consonance with the findings of Horning and Overson (1962), Prihar *et al* (1968), Greb *et al* (1970) and Fochi and Fryrear (1971). Studies carried out by Lal (1972) showed that mulched plots had high soil moisture content. In agreement to the present investigation Rangacharylu and Nagabhushanam (1960) showed that; using dry leaves as mulch, the cost of irrigation can be saved.

Contrast results were obtained by Cahoon *et al* (1961). They showed that down ward movement of water was not in any way different in the mulched plots than in unmulched.

Between the two water levels even at lower water level, the saw dust mulch could increase the soil water content than other mulches at higher water level (Table 27).

For treatments which received higher water level, the soil water content is more irrespective of mulches tried. The saw dust mulch showed a significantly higher water retention at field capacity and permanent wilting point (11.43% and 7.40% respectively) so the water use effeciency can be increased by using saw dust as a mulch.

The moisture retention characters of different mulched soils estimated using pressure plate apparatus are presented graphically in fig.8 to 11 and Table 32. The moisture retained at field capacity for the initial soil sample was 8.89% (Table 1 and Fig.1). After the treatments the moisture retention character of all the mulch treated soil have been improved in all the tensions. So that any kind of soil cover can improve the water retention characters of soil.

The effectiveness of the mulches on moisture conservation and evaporation control has long been a controversial issue. This is because of the fact that the influence of mulch in controlling evaporation depends not only on the water retention and transmitting characteristics of the soil, but also on the prevailing evaporative demand of the atmosphere and the frequency of rains (Bond and Willis 1969, Laver 1960).

5.6. Soil temperature.

Soil temperature is an important property of soil which affect plant growth directly and indirectly. Soil temperature has a substantial influence on the dynamic process of vegetation production and also an important role ~~i~~in soil plant atmospheric balance.

Effect of different mulches on soil temperature is studied in the present trial. Mulches had beneficial and favourable influence on soil temperature and reduced soil water loss through evaporation which resulted in more available soil moisture for a longer period which helped in improving yield attributing characters and ultimately in yield (Mandal and Ghosh, 1983). This result corroborate with the findings of the present study. Soil temperature recorded at 15 cm depth as an average of the weekly temperature are given in table 28 and fig.13, 14 and 15. Highest value of soil temperature was obtained for control and lowest for saw dust mulch. Saw dust is found to be effective in keeping the soil more cool even at lower water levels. This may be due to the non conducting nature of saw dust. Besides this the higher water content in saw dust treatment helped in reducing the soil temperature. Research conducted by Krishnamurari and Pandey (1983) and Mandal and Ghosh (1983) showed that the straw mulch was more efficient in reducing soil temperature when compared with polythene mulches.

Between the two water levels, higher level reduced soil temperature. Straw mulch with lower water levels gave the maximum value for soil temperature (29°C) (Table 28 and fig.14). The effect of irrigation on soil temperature depends upon the relative temperatures of soil and irrigation water, the atmospheric conditions, the type of mulch and the nature and extent of crop cover. The moderating effect of irrigation have been reported also by Bhool et al (1964) Khera et al (1976) and Sandhu et al (1980).

As the temperature increases the moisture status of soil decreases (Fig.13). The work of Wadleigh and Gouch (1948) and subsequent studies made by various scientist prove this to be correct.

5.7. Yield.

Highest yield is obtained for dry leaf mulched plant in both water levels. The yield obtained for dry leaf and saw dust mulch are almost same. Among the mulches the lowest yield obtained for straw mulched plants (219.69). The yield increase is noted with all the mulches. This may be due to the high water use efficiency under mulch. Same result was obtained ~~to~~ by Krishna murari and Pandey (1983) Mandal and Ghosh (1983) Murty and Rao (1969) Lal (1974) Mandal and Vasudevan (1975) Bansal et al (1971).

Significant increase in yield under dry leaf mulch (440 g per plant) when compared with the yield under other mulches indicate that the easy decomposition of dry leaves might have contributed for the nutritional status of soil which in turn might have influenced the growth rate and yield. Lal (1972) had opined that the mulched plots had a higher soil moisture content. Increase in grain yield by mulching was attributed primarily to a decrease in soil temperature and partly to improved soil moisture regime.

Yield is positively correlated with many factors. Plant characters such as plant height, leaf area, root length, root weight, hydraulic conductivity and nutrients such as organic carbon, nitrogen and magnesium. It is negatively correlated with internodal length and bulk density (Table 30).

In this study the increase in yield may be attributed to a decrease in soil temperature, soil moisture conditions and a variety of resultant chemical and biochemical factors associated with mulching.

SUMMARY AND CONCLUSION

6. SUMMARY AND CONCLUSION

In the present study investigations have been carried out mainly to study the effect of different mulches on soil temperature and soil water retention in relation to seedling emergence and crop growth. Studies were carried out as pot culture experiment in the pot house at College of Agriculture, Vellayani. The pots were insulated with a thick coating of white paint. Four mulches and two water levels were tried. The mulches used were dry leaves, saw dust, paddy husk and paddy straw. The two water levels tried were 20% depletion and 40% depletion of water from field capacity. Direct effect and interaction effects of water levels and mulches were studied. Bhindi crop was selected as test crop. Manometer type tensiometers were fabricated in the laboratory and installed in the pots to assess the daily soil moisture of soil. Daily soil temperature at 7.30 and 14.30 hours was recorded at 15 cm depth. Based on tensiometer readings moisture percentage was calculated and irrigations were given at 20% and 40% water depletion from field capacity (8.66%). Mulches were applied uniformly (by volume) in all pots except for control. The seedling emergence count was taken daily.

Initial analysis of soil samples were conducted for nutrient status such as nitrogen, phosphorus, potassium, calcium, magnesium, sulphur and organic carbon, physical constants, aggregate analysis, textural analysis and moisture retention characteristics. Biometric observations such as plant height internodal length, leaf area, root length and root weight and yield were observed and tabulated. Daily atmospheric temperature also recorded and compared with soil temperature and water levels.

From these observations following conclusions have been made.

1. In the case of seedling emergence maximum coefficient of velocity of emergence and minimum mean time of emergence values were obtained for dry leaf mulch with higher water levels. As a general trend lower spread in emergence time (σ) were obtained for lower water levels in most of the treatments seedling emergence was more influenced by higher water levels and mulches especially for dry leaves and saw dust.

2. High values of plant height and leaf area have been recorded for (Table 30) dry leaf mulch, with higher water levels. Straw mulch recorded maximum internodal length at lower water level leading to minimum yield.

3. Both root length and root weight were maximum for saw dust mulched plants with high water level. All biometric parameters except internodal length was influenced by dry leaf mulch and higher water level.

4. Among the physical characteristics soil bulk density was lowered by 20% in dry leaf mulched soils from the value obtained for initial analysis thereby increasing plant growth and development in these pots. Dry leaves and saw dust can reduce the bulk density to some extent. Bulk density was negatively correlated with almost all the factors except internodal length (Table 30).

Higher values of mean weight diameter, obtained for straw mulch (0.849) shows that this mulch is less recommendable compared to others so far as the soil structural character is concerned.

5. Dry leaf mulch profoundly influenced hydraulic conductivity giving a value of 41.3 cm^{-hr} while water holding capacity (25.4%), moisture retention at $1/3^{rd}$ (10.9%), and 15 bar (7.17%), were influenced by saw dust mulch. As moisture characters were concerned the dry leaves and saw dust were on par in their roles.

6. From the average values obtained for gravimetric moisture content; it is evident that saw dust is a better mulch to conserve soil moisture which could save 28% moisture over control; while straw mulch was giving only 19% over control. Dry leaves also can be used as a mulch to increase water use efficiency since it could give an increase of 23% moisture over control with no mulch.

7. Soil temperature can be lowered by 1.8 to 2°C by using either dry leaves or saw dust as mulch. This in turn increases the water retention.

8. As far as nutrients are concerned, the soil nitrogen content and organic carbon contents were observed to be higher in dry leaf treatments, which was reflected

in plant uptake also. Since paddy husk contains more phosphorus than other mulches, the soil phosphorus content as well as uptake by plants were more in this treatment.

From the observations, the maximum value for magnesium uptake was obtained for dry leaf treatment (0.605%) which in turn had influenced the leaf area, plant growth and yield.

9. Generally it can be concluded that dry leaf and saw dust are found favourable for plant growth, soil moisture retention, temperature management, nutrient uptake and finally the yield.

10. Using saw dust as mulch the water supply can be limited to even 4.5% i.e., near to permanent wilting point for red loams, without much reduction in yield.

11. Since the study is conducted in pots, the water retention and root absorption is not fully covered, so this has to be extended as a field trial.

12. Since 20% depletion from field capacity water level (6.6%) has given a satisfactory result, water levels, less than this i.e., between 1/3 and 15 atmospheres can be taken up in future research programmes.

Dry leaves mulching is the best among the mulches tried. Though saw dust is on par with dry leaf, it is costly, when dry leaves are available on plenty in our surroundings free of cost. The cost of saw dust varies from Rs.20 to 25/50 kg and also not easily available as dry leaves.

The results of the present study thus bring out the importance of simple methods, such as mulching, on moisture conservation. These methods are becoming more relevant to Kerala in the last few years; due to failure of both the monsoons and prolonged periods of drought between November and April. It is prior to the onset of the drought period, around October-November, that mulching should be resorted to.

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EFFECT OF DIFFERENT MULCHES ON SOIL TEMPERATURE AND SOIL WATER RETENTION IN RELATION TO SEEDLING EMERGENCE AND CROP GROWTH

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ABSTRACT

Plant life depends mainly on climatic conditions such as temperature rainfall, humidity etc. Both air and soil temperatures are limiting factors for plant growth. Several processes like seed germination nutrient availability, water movement, root and shoot growth, yield etc. are influenced by soil temperature.

The present investigation has been undertaken to study the comparitive effect of different mulches on soil temperature and soil water retention in relation to seedling emergence and crop growth. Studies are carried out as pot culture experiment. Bhindi (Abelmoschus esculentus) is taken as test crop which is raised in pots which were insulated with white paints to avoid external heat. The moisture status and temperature of the soil were assessed daily using tensiometers and soil thermometers. Based on this irrigations were given at 20% and 40% depletion from field capacity values. Four mulches are used viz., dry leaves, saw dust, paddy husk and paddy straw. These four mulches and two water levels were compared with control. Single effect and interaction effects were studied.

The result of all observations show that at lower water levels, the seedling emergence was influenced greatly by saw dust mulch and least by paddy husk. Under dry leaf mulching, the plants grew faster and healthier and higher yield were obtained. Where as the straw mulch was comparatively poor in all aspects. But even at lower yield the performance of straw mulch was better than control which show that any type of mulching materials can reduced the evaporational loss of water and thus increase the yield.

Observations made on the plants kept in two water levels showed that the higher water levels gave better performance. The saw dust can hold comparatively higher moisture percentage than the other mulches. So the yield obtained for the plants grown in saw dust is not far behind to the plants grown in dry leaf mulch.

The soil temperature recorded in saw dust mulched soil was lowest than the other soils. Water retention also was high with this mulch.

Influence of dry leaves on various factors is on par with that of saw dust treatment. Irrespective of water levels, saw dust mulch could increase yield and yield