A STUDY ON MICROCLIMATE MODIFICATION OF SUMMER MOONG (*Vigna radiata* L.) WITH THE USE OF MULCHES

By

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DEDICATED

TO MY GRANDFATHER

LATE CH. SUKH RAM SAHARAN

CONTENTS

CERTIFICATE I

This is to certify that the thesis entitled, "A study on micro-climate modification of summer moong (Vigna radiata (L) with the use of mulches", submitted for the degree of M.Sc. in the subject of Agricultural Meteorology of the Haryana Agricultural University, is a bonafide research work carried out by Shri Vinod Saharan under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE II

This is to certify that the thesis entitled, "A study on microclimate modification of summer moong (Vigna radiata (L.) with the use of mulches", submitted by Shri Vinod Saharan to the Haryana Agricultural University, in partial fulfilment of the requirements for the degree of Master of Science in the subject of Agricultural Meteorology has been approved by the student's Advisory Committee after an oral examination on the same in collaboration with an External Examiner.

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HISAR (VINOD SAHARAN)

CHAPTER I

INTRODUCTION

Pulses on account of their special properties of high protein content and soil fertility restoration have been considered to be the back bone of Indian agriculture with predominantly vegetarian population. Pulses are generally grown under unirrigated conditions. Green gram or moong (Vigna radiata (L) ranks third in the area and production among pulses in India. Besides its production in the main kharif season, the possibilities of extending the practice of summer moong cultivation are existing in the irrigated areas of North India. Moong, due to its wider adaptability in various agro-climatic regions, has been adapted as a summer crop in two, three or four crop rotations in Punjab, Haryana ,U.P., M.P. and Gujrat.

In Haryana pulses occupy an area of 830 thousand hectares and 66.7 thousand tonnes of pulses are produced annualy. Moong alone occupies an area of 77.9 thousand hectares and produce 5.8 thousand tonnes of seeds with an average of 745 kg seed yield per hectare (Agricultural situation in India, 1986). With the introduction of high yielding varieties, increased use of fertilizers, better irrigation facilities and improved agricultural technology, green revolution has resulted in multifold increase in the yield of cereals. But there has not been any significant improvement in production technology of pulses.

In summer moong soil moisture stress and excess thermal regime are two most important factors which adversely affect the crop production. These adverse effects may be due to high temperature and increased evaporation. Efforts have been made to reduce the crop losses by adopting various techniques. Among these techniques the use of mulches and application of irrigation have been widely tried for modification of micro climate in different crops. The use of mulches have been reported to result in lower evaporation losses, reduced soil temperature fluctuations by favourable modification of soil hydrothermal regimes.

Mulching effects on soil temperature and moisture conservation varies with the type of mulch, its rate and time of application season and weather conditions, moisture status and type of soil. In tropical and subtropical regions application of crop residue mulches and plastic film mulches during hot summer periods has been found beneficial for summer crops. Mulches plays an important role in checking evaporation. Polyethylene has been found to be most effective followed by organic and stubble mulches in conserving soil moisture. Reports on effect of mulches on weed growth and rhizobium population have been found in literature. Mulching can help us in modifying the soil hydrothermal regime favourably these resulting in better crop production. Microclimatic modifications can be of great importance for avoiding stress conditions in summer.

Similarly irrigation have also been reported to moderate the soil temperature by increasing evaporative cooling, soil specific heat and heat flow into soil due to enhanced thermal conductivity. The extent and duration of this effect, however depends on solar radiation flux, nature and extent of vegetative cover, thermal properties of soil and the amount and temperature of irrigation water applied.

Much work has been done on effect of environment on yield and interaction of genetic constitution and environment, but work on the modification of microclimate and its effect on yield of moong is still lacking.

Therefore, this experimental study was planned and undertaken to evaluate the role of mulching and irrigation in avoiding the adverse microclimatic stress and for providing a favourable environment for crop growth with the following objectives :

i) To evaluate crop growth and microclimatic environment interaction for summer moong.

ii) To test different methods for modification of microclimate and evaluate the sensitivity of the crop to stress conditions.

iii) To determine suitable agrometeorological conditions for summer moong and effectivity of the micro-environment modification technique.

iv) To study the effect of modified microclimate parameter on the yield of summer moong and yield attributing parameters.

CHAPTER II

REVIEW OF LITERATURE

The literature available on the subject is reviewed under the following heads :

2.1 Effect of mulches on soil thermal environment.

2.2 Effect of mulches on soil moisture conservation and water use efficiency.

2.3 Effect of mulches and irrigation on crop growth and development.

2.4 Effect of irrigation and mulches on water stress.

2.5 Effect of mulches on microclimatic modification.

2.6 Effect of mulches on yield and yield attributes.

2.1 Effect of mulches on soil thermal environment

Mulching offers an effective means of altering the soil thermal regime. However, the effect of mulching on soil temperature varies with the type of mulch, its rate and time of applications, season and weather conditions, moisture status, type of soil and nature and extent of crop cover. Depending upon the prevailing conditions therefore, a mulch can cool or warm the soil (Jacks et al., 1955) and may accelrate or depress the plant growth. Pusztai (1963) reported that the colour of plastic film mulches greatly affect on the soil temperature. The white or reflective plastic decreased the soil temperature. Adams (1962) stated that clear plastics result in higher temperature because the soil directly absorbs most of the energy from the incoming solar radiation, whereas with black plastic film the soil received only a portion of the incoming energy major amount being absorbed by the black film. Apparently, degree of contact between soil and black plastic influences the extent of temperature increase under a black plastic. White and reflective plastics resulted in lowering of the temperature because they did not absorb the incoming radiation. The maximum difference usually occurred during the hotest part of the day. At night the mulches had slight or no effect on soil temperature (Takatori et al., 1964, 1971). Evenson and Rum baugh (1972) reported that soil temperature were as much as 9°C lower in mulched as compared to unmulched plots. The average soil temperature at various soil depths under black polyethylene mulch were usually higher 1 to 5°F than that at comparative soil depths under non-mulched conditions. There was considerable variation in the weekly maximum and minimum soil temperature. The soil temperatures at 2 inches were 5 to 20°F higher when a mulch was used by Clarkson (1960).

Mulches of plant materials (straw, leaves etc.) reduced the soil temperature (Adams, 1965; Allmaras et al., 1964; Bansal et al., 1971; Bond and Willis, 1971). Burrows and Larson (1962) reported that the smaller the amount of soil cover greater is the amount of heat absorbed in the soil during the growing season. In this experiment each ton of mulch applied over the range from 0 to 4 tons/acre reduced the average soil temperature during May and June at the 4.0 inch depth by about 0.7 °F. In another field study Chaudhary and Prihar (1974) used four cultural treatments (i) control (ii) 5 cm deep post planting cultivation (iii) 2 cm thick straw mulch and (iv) inter-row compaction on sandy loam and loamy soil during 1970 and 1971. At the 5 cm depth straw mulch reduced the soil temperature most effectively and it was of the tune of 2.6°C in 1970 and 2.3 to 6.3°C in 1971.

An experiment conducted at Punjab Agricultural University, Ludhiana by Khera et al. (1986) showed that mulching with wheat straw or polythene sheet decreased the soil temperature by 8-10°C over without mulch in summer season. Mulches like mat (Typha sp.) and bajra stalks lowered the soil temperature maxima at a depth of 10 cm by 1.5°C during autumn and by 3.5°C during spring season as compared with bare soil plots. Polythene mulch increased soil temperature minima by 1.4°C and 2.2°C during autumn and spring season, respectively in potato crop. Under the climatic conditions of North India reported by Grewal and Singh (1974).

Daulay et al. (1979) reported that the mulches were found effective in modifying thermal regimes in arid and semi-arid region of Rajasthan. Gupta (1985) reported that mulching reduces the soil temperature of root zone at 10 cm depth by 2 to 7°C in kharif and 5 to 12°C in summer seasons over bare soil.

Soil temperatures reduction in straw mulched soil was associated with the corresponding reduction in net radiation (Hanks et al., 1961). In a study on soybeans, Mehta and Prihar (1973) found that the straw mulch lowered the maximum but increased the minimum soil temperatures in the seed zone and enhanced the rate of final count of seedling emergence.

In a similar study, Khera et al. (1976) found that maximum soil temperatures in the nonmulched soil was excessively high in the root zone of maize. Further they reported that the straw mulching reduced the maximum temperature at 10 cm depth by 5-9°C and maintained higher soil water content in upper soil layers. Gaur and Mukherjee (1980) while studying the effect of mulching in moong reported that soil temperatures ranged between 29.0 to 32.0°C in mulched crop and between 31.8 to 35.0°C in unmulched crop.

Straw mulching in sugarcane during pre-monsoon summer period caused 5-10°C reduction in maximum soil temperature at 10 cm depth (Sandhu et al., 1980). Gurnah and Mutea (1982) studied the effect of mulching on soil temperature and reported that soil temperature under coffee mulched with grass, clear, black and white polythene were recorded at different depths and it was found that grass mulch lowered the soil temperature, white polythene mulch either slightly raised the soil temperature or lowered it, while black and clear polythene greatly increased the soil temperature with the clear polythene giving the highest temperatures.

Hundal and Datta (1982) compared straw mulch with bare soil under fallow conditions and reported that lowest maximum as well as minimum soil temperatures at 10 cm depth for the straw mulch plants. Mean daily soil temperatures was less by about 3.0°C under straw mulch compared to bare soil. Further, they concluded that covering the soil with a straw mulch reduces the daily fluctuations in soil temperature. Also, straw mulch reduces the gain of heat during day and the loss of heat at night.

The application of grass mulch at the rate of 6 t/ha decreased maximum temperature of the soil by 1.0 to 9.0°C during the hot month of June (Gupta and Gupta, 1985). Whereas during kharif (July to September) the magnitude of temperature reduction however, narrowed down to 1-6°C, on the other hand, polythene mulch raised it by 1 to 3°C.

Preplanting mulching of moist soils with black and transparent polythene films for six weeks raised soil temperature 3-11°C over uncovered control soil (Stapleton and Garza-Lopez, 1988). Kalaghatagi et al. (1988) have reported that straw mulched treatments recorded lower minimum and maximum soil temperatures at 0-15 and 15-30 cm depths (10.8, 26.2, 11.5 and 25.3°C respectively). When compared with un mulched control treatments, polythene mulch recorded higher minimum and maximum soil temperature at 0-15 and 15-30 cm depths 16.0, 29.0, 16.5 and 27.9, respectively compared to straw mulched.

2.2 Effect of mulches on soil moisture conservation and water use efficiency

By their very nature, dry regions generally receive inadequate precipitation for good crop production. Further much of the precipitation that is received is lost by runoff and evaporation. Numerous studies have been conducted to determine the influence of mulches on soil water storage, content and evaporation. In Europe Linden (1963), Manescu and Ciofu (1970) and Pusztai (1963) reported increases ranging upto 32 per cent. In North America plastic films resulted in higher water contents than bare soil in most cases (Army and Hudspeth, 1960; Lippert et al., 1964; Liptay and Tiessen, 1970).

Increases in soil water due to plastic films have also been reported by Bansal et al. (1971) and Baumer (1964). The higher water contents resulted from reduced evaporation, induced infiltration, reduced transpiration by weeds or a combination of these factors (Austin, 1964, Hanks et al., 1961, Linden, 1963, Lippert et al., 1964, Liptay and Tiessen, 1970, Willis et al., 1963). The studies of Bond and Willis (1969, 1970, 1971) although conducted under laboratory conditions with soil columns initially wetted to a given level suggest that water storage can be increased where residue levels are adequate to reduce initial evaporation and thus permit water from precipitation to penetrate to greater depths. However, large amount of surface residues are required to obtain water saving over an extended period.

Olson and Horton (1975) found no significant difference in moisture content of top 45 cm soil profile between the straw mulched and unmulched plots. Singh and Sandhu (1979) found that with IW/CPE of 0.6 the soil moisture storage in the root zone under no mulch and straw mulch were comparable, whereas under a combination of transparent polythene and straw mulch it was 3 to 5 cm higher. In a 3-year field experiment with cane during early summer, moisture storage in the 0-180 cm soil was 1.0 to 6.5 cm more in the mulched than the non mulched plots (Sandhu et al., 1980). In a field study on dry season soil moisture conservation, Hundal and Datta (1982) found that the straw mulched soil lost water at 1.0 mm/day compared to 1.2 mm/day for the bare plots. Soil moisture content of mulched plots was more than the unmulched plots in both summer and rainy seasons. Soil moisture in the 1st, 2nd and 3rd sampling was 13.5, 10.6 and 18.7 per cent in the mulched plots against 4.0, 4.8 and 11.5 per cent in the unmulched plots, respectively as reported by Gaur and Mukherjee (1980).

The irrigation level ID/CPE of 0.40 recorded the highest water use efficiency while mulching did not seem to affect this attribute (Balyan and Malik, 1981). The inter-row mulching had favourable effects on water use efficiency of Bengal gram, moong and soybean where water use decreased upto 24.2, 42.2 and 40.0 per cent in these crops, respectively. The water use efficiency increased upto 83.8, 85.8 and 74.9 per cent in the respective crops due to mulch treatment over control. The effect of mulches on water use efficiency was in the order white polythene > Black polythene > Straw mulch > Control reported by Ghosh et al. (1983).

Kalaghatagi et al. (1988) found that mulches showed water economy. Consumptive use of water was significantly lowered (462.50 mm) with black polythene mulch compared to recommended practice (610.90 mm) and significatnly higher water was utilized in a control plot. These findings are in agreement with findings of Bansal et al. (1971) who reported lower consumptive use with polythene mulch in maize by about 40 mm.

Surface applied mulches are known to conserve soil moisture. According to Daisley et al. (1988) the mulched soil conserves more moisture within the profile than unmulched soil, perticular in the surface soil. The higher water content of surface soil had a positive effect on germination of cowpea seeds. This study indicated that the optimal mulch rate for soil water retention, seedling emergence, weed control and yield of crop was 4 t/ha dried guinea grass under Antigua conditions.

2.3 Effect of mulches and irrigation on crop growth and development

The effects of mulches on plants are operative through the effects of mulches on soil water, temperature. One of the most critical periods in the life cycle of a plant is the period of germination, emergence and seedling establishment. After germination the seedlings must emerge and become established. Due to their small size and tenderness, seedlings can easily be adversely affected by an unfavourable environment. Mulches can affect germination, emergence and seedling growth by moderating or improving the soil and aerial environment to which the seeds and seedlings are subjected.

Higher soil water contents and reduced evaporation were major reason for improved germination, emergence and seedling growth due to mulches (Army et al., 1961, Kowsar et al., 1969, Sale, 1966a, b, Takatori et al., 1971, Wann, 1969). Straw, petroleum gravel, stones and plastic films increased germination and early growth, but the plastic films had to be removed for continued growth. Higher soil temperatures due to mulches also improved germination, emergence and seedling growth (Adams, 1962, Dhesi et al., 1964, Miller and Bunger, 1963). The higher temperatures either alone or in combination with higher water contents were also effective for promoting later plant growth and hastening plant maturity (Bowers, 1968, Linden, 1963, Miller, 1968).

Early seedling of sweet corn, made possible by using a clear polythene plastic mulch resulted in the corn being ready for harvest 2 weeks before corn seeded in bare soil (Miller and Bunger, 1963). However, later growth sometimes was better on mulched than on bare soil due to improved water condition under mulch (Moody et al., 1963). Mulches influence the plant growth primarily by altering the soil temperature and moisture regime in the root zone. Application of crop residue mulches during hot summer periods has generally been found beneficial for summer crops. Lal (1974) and Olson and Horton (1975) reported significantly higher growth rate and vigour as well as increase in yield of maize by mulching the crop with straw. Burrows and Larson (1962) reported that as the amount of mulch is increased corn growth in term of plant height and dry matter production is decreased. Daisley et al. (1988) reported that in mulched soil, the higher water content of surface soil had a positive effect on germination. Gupta (1985) reported that due to high soil temperature the seedling emergence reduces to 50 per cent with mulching however this reduction was only 10-20%.

Chaudhary and Prihar (1974) reported that the root growth and lateral spread was higher in the mulched plot and due to reduction in maximum temperature and soil moisture losses because of mulching, it resulted in better plant growth and higher yield.

2.4 Effect of irrigation and mulch on water stress

Water is an essential requirement for plants. Irrigation is a measure to increase the water availability to plant and reduce adverse effects of water deficits to crop.

Huang and Ketring (1985) reported that pod filled and percentage of mature kernels were significantly reduced under rainfed conditions. Yield reductions due to water stress under rainfed conditions were 82.5 and 96.6 per cent in 1983 and 1984 respectively. In the water stressed conditions, the nodulation, nitrogen content, dry weight and plant biomass was reduced. Due to drought there was decrease in the yield of peanut. The reduction in peanut pod yields due to water stress during pegging or pod development period was significantly greater than that when stress was imposed during the vegetative growth (Kulkarni et al., 1988, Stansell et al., 1985, Polara et al., 1984). The increasing frequency of irrigation based on IW/CPE ratio of 0.5, 0.65, 0.8 and 0.95 increased the dry matter accumulation and yield of wheat, sorghum, maize and groundnut and also increased their consumptive use of water. In groundnut with increase of irrigation frequency there was an increase in plant height, dry matter accumulation, leaf area index and pod yield. In groundnut with increase in ratio of IW/CPE there was increase in pod yield but with increase in irrigation frequency there was decrease in water use efficiency (Burhanuddin and Reddy, 1985, Babalad and Kulkarni, 1988, Karte et al., 1988, and Chavan et al., 1988). Sarma et al. (1987) reported that seeds taken from plants with moisture stress during emergence to initiation of pegs, gave higher field emergence better seedling vigour and resulted in increased pod and seed yields over other treatments. The irrigation at an IW/CPE ratio of 0.7 during sowing to flowering and 0.9 during pegging to pod formation and pod development to maturation gave the highest pod yield of groundnut (Pahalwan and Tripathi, 1985).

Choudhary et al. (1985) reported that a significant increase in root density in the soil layer down to 30 cm occurred in both 1977 and 1978 in under straw mulch and only in 1977 under straw mulch. Leaf water potential measured before irrigation on May 18 was lowest under no mulch and highest under mulch (polythene + straw) followed by mulch straw and mulch polythene. Mulching resulted in a significant increase in grain yield.

Moisture was lost quickly from the upper 5 cm of the soil in the soil mulch more moisture was received between 5 and 45 cm depth throughout the cropping season. It was observed that water intake rate, pore space and moisture storage had increased by 30.0, 21.7 and 26.5 per cent respectively, under the soil mulch as compared to the control (no mulch). The increase in seed yield with mulching throughout the crop season was more than mulching until seedling emergence in groundnut (Subbareddy, 1986, Ye et al., 1986).

Joshi et al. (1987) reported that straw mulch + kaolin foliar spraying registered significantly higher yield of pods, foliage, kernel and oil/ha over no mulch. By preventing water loss through evapotranspiration and thus maintaining favourable water balance in the soil and plant, it was possible to increase the yield of groundnut by mulch and kaolin coating to the time of 25 per cent over no mulch.

2.5 Effect of mulches on microclimatic modifications

Excess thermal regimes is most important factor which adversely effect on crop production. With the help of mulches we can modify favourable soil hydro-thermal regime for better crop production.

Watersl et al. (1980) reported that mulching with rice hulls to a depth 4.0 cm reduced the afternoon soil temperature and reduced fluctuation and rate of soil moisture loss.

Chakravarty and Sastry (1983) observed a linear relationship between biomass production and evaporation beyond a threshold value of 126 mm and with accumulated temperatures beyond a threshold of 550 degree days in moong crop mulched with wheat straw. The 6 t/ha straw mulch and polythene mulch can be used to manipulate the soil environment for increasing crop production under arid conditions as per the report of Gupta and Gupta (1985). Field experiment conducted to study the influence of environmental conditions on biomass production and seed yield in two *Vigna radiata* Cvs. grown in the summer season on a sandy loam soil by Chakravarty et al. (1986) and found that modification of the microenvironment by applying wheat straw mulch 6 t/ha immediately after the 1st irrigation at 20 days after sowing increased the above ground biomass by 30-36 per cent.

In a study on turmeric crop, Mahey et al. (1986) concluded that mulches affected growth, yield contributing characters and yield favourably. The mulch changed the microclimate by conserving more moisture, modifying soil temperature, controlling weeds and thus economise the use of irrigation water. Gupta (1985) reported that mulching reduces the evaporation rate by cutting off the radiation falling on the surface of the soil. Mulching reducesthe maximum soil temperature of root zone at 10 cm depth by 2 to 7°C in kharif and 5 to 12°C in summer season. Prihar et al. (1975) reported that the straw mulching was not only a good substitute for promoting growth of maize by creating a more favourable temperature regime. Clarkson (1960) reported the average soil temperature at various soil depths under a black polythene mulch were usually higher 1 to 5°F than at comparative. Soil depths under non mulched conditions. As the soil depth increase the amount and temperature fluctuation and the difference between mulched and nonmulched soil temperatures decreased.

Examination of the daily variation of microclimate, surface and sub surface temperature shows that minimum surface temperature were consistently lower when a black polythene mulch was used and that microclimate and sub surface temperature were normally higher. This would indicate that re-radiation of heat from the soil was being partially blocked by the plastic film.

Daulay et al. (1979) reported that the mulches were found effective in modifying thermal and moisture regimes condusive to growth and development of pearl millet. When rainfall distribution was uniform, mulches did not show any advantage. Mulches like mat (Typha sp.) and bajra stalks lowered the soil temperature at a depth of 10 cm by 1.5°C during autumn and by 3.5°C during spring season as compare with bare soil plots. Polythene mulch increased the soil temperature maxima by 1.4°C and 2.2°C during autumn and spring season, respectively and minima by 2.4°C during both the season. The results of the study conducted by Grewal and Singh (1974) point out to the possibility of manipulating soil temperature in order to improve quality and yield of potato crop under the climatic conditions of north India.

2.6 Effect of mulches on yield and yield attributes

A majority of the reports indicated higher yields when crops were grown with mulches rather than without mulches with most materials being effective for increasing yields (Adams, 1970, Austin, 1964, Bansal et al., 1971, Dixit and Agarwal, 1971). The yield increases generally were moderate. In some cases very substantial increases were reported (Moody et al., 1963, Pusztai, 1963, Zakharov and Semikina, 1964) ranging from about 50 to 300 per cent. Yield response due to mulches, although primarily related to soil water and temperature was also affected by better plant populations (Sale, 1966 a, b, Takatori et al., 1971), reduced root rot (Lavee, 1963). Undoubtedly, mulch effects on soil structure, nutrients microbial activity, root distributions etc, also played an important role in the higher yields.

Reduced crop yields due to mulches have related to some specific conditions, generally soil temperature, corn apparently is very sensitive to low temperatures under a straw mulch early in the season. When temperatures normally limit plant growth (Allmaras et al., 1964, Burrows and Larson, 1962, Moody et al., 1963). The adverse effects of low temperatures were reflected in lower yields in more northern regions (Allmaras et al., 1964, Burrows and Larson, 1962).

With blacktar mulch corn yields were increased in Quebec (Canada) apparently due to higher soil temperatures (MacMillan and Millette, 1971). A straw mulch in Alberta (Canada) however, delayed maturity and reduced wheat yields due to lower soil temperatures and increased soil shading and occasionally due to lower nitrate production (Anderson and Russell, 1964).

At the drier locations, wheat yield increases due to stubble mulch tillage resulted from greater soil water content at seedling (Johnson and Davis, 1972).

The residues, when maintained as a mulch on the surface resulted in increased water storage during fallow when weeds and volunteer crop plants were controlled with herbicides (Musick et al., 1973, Unger et al., 1971, Unger and Parker, 1974). The addition stored water was effective for reducing preplant or seasonal irrigations for subsequent irrigated crops (Musick et al., 1973, Unger et al., 1971) or for increasing yields of subsequent dry land crops (Unger and Parker, 1974).

The mulching with plastic film increased silage and grain yield of maize by 2.2, 12.4 and 0.9, 2.7 t/ha, respectively and caused earlier ripening. It was considered that the yield increase would only cover the cost of the film at sites marginal for moong growing (Kromer and Freese, 1980). The inter-row mulching had favourable effects on yield of Bengal gram, moong and soybean. Grain yield increased upto 38.7, 8.5 and 5.0 per cent in gram, moong and soybean with mulching than without it as reported by Ghosh et al. (1983).

The application of 4 t/ha straw mulch significantly increased the yield (Singh et al., 1984). The mulches supressed weed growth, improved moisture status of the soil and thus increased production of the pearl millet and okra. With increase in the application rate of grass mulch, there was also reduction in the water status of the soil and plant and improvement in the root growth and nodulation. Mulch application 6 t/ha led to 40 per cent increased production of the green gram over control (Gupta and Gupta, 1985). Fernando (1981) reported that straw mulching increased the yield of moong and cowpea and decreased weed growth, population. Likewise, live leguminous mulches showed promise for good crop performance and weed control. The mulching increased maize dry matter yield by upto 6 t/ha and grain yield by upto 3.06 and 2.25 t/ha at the early sowing date (19 April and 30 April, respectively) as reported by Delahaie and Lechat (1986). The seed pod yield of sesame was increased upto 97 per cent and dry seed upto 72 per cent over control soil after mulching. Black film mulching was as effective as solarization for increasing yield of sesame (Stapleton and Garza-Lopez, 1988). The mulch supressed weed growth with in both cowpeas and egg plants, yield of both crops in terms of accumulation of dry matter is positively effected by mulching (Daisley et al., 1988). There was significant response of mulch regarding all the yield component of barley and lentil and number of capsules of linseed (Mandal et al., 1989). The dry forage yield of maize was increased by 13-15 per cent with application of straw mulch (Singh and Sandhu, 1979). The cane yield with mulch was 13.8 per cent higher than that with no mulch reported by Sandhu et al. (1980). The mulching significantly increased the grain and biomass yield of green gram. The grain and stover yield of green gram was increased by 31.6 and 26.2 per cent, respectively over the control (Gaur and Mukherjee, 1980). Gupta and Rao (1989) reported that mulching increased the height, leaf area and dry matter of green gram and cowpea. Depth of root penetration and its lateral spread also increased with mulching with the increase in dry weight of root by 60-80 per cent.

The results of the studies conducted at CAZRI by Gupta (1985) have shown that the use of grass mulch at the rate of 6 t/ha increased the growth and yield of moong, moth and guar by one and a half times to two and a half times of control, also increased the production of cowpea and bajra by 57 per cent and 20 per cent more than the control (without mulch).

Uppal and Cheema (1981) from a 2 year study reported that the alkathene mulch, straw mulch + kaolin spray found to have a beneficial effect on the growth and yield of barley. Mulch significantly increased the number of effective tillers, grain test weight and grain yield. Straw mulch increases the yield of maize and sugar cane primarily through reduction of the excessively high soil temperature in summer months compared to no mulch. An increase in maize yield by 18 per cent and sugarcane by 16 per cent have been reported by Prihar et al. (1977) by using mulch over control.

Daulay et al. (1979) reported that application of bajra husk and polythene mulch gave 25 per cent higher grain yield over control in semi arid conditions. Under semi arid condition of western Rajasthan, mulch gave significantly higher yield of sorghum over mulch as reported by Bhasker (1985). Chaudhary and Prihar (1974) while reporting the effect of inter-row management in corn by straw mulch, Deep (5 cm) post planting cultivation, inter-row compaction and over control found that due to reduction in soil temperature corn gave higher yield over control. Mulches of grass and straw increased the potato yield in North India (Grewal and Singh, 1974). Zaman and Mallick (1988) reported that mulching also significantly increased yields although more so with straw than leaf mulch maximum yield of 1042 kg seed/ha. 503 kg dry matter/ha, 13.13 pods/plant 10.3 seed/pods and 100 seed wt of 3.11 gram were obtained for 2 irrigation combined with 5 t/ha straw mulch.

Chapter III

MATERIAL AND METHODS

The field experiment was conducted at the experimental farm, Department of Agricultural Meteorology, Haryana Agricultural University, Hisar during summer (April to June, 1989-90). The summer moong (Vigna radiata) variety K-851 was sown as experimental crop. The details of the methods followed and materials used are described in this chapter.

3.1 Location and climate

Hisar is situated at 29° 10'N latitude and 75° 46'E longitude at an elevation of 215.2 meters above the mean sea level.

The climate of Hisar area owes to its continental location on the outer margin of monsoon region only 1600 km away from the ocean. It has semiarid tropical climate. Southwesterly current of the summer monsoon brings rain from last week of June to mid September. Summers are very hot and winters are fairly cool. Maximum temperature above 45°C is not uncommon during summer and minimum temperature below 0°C is also recorded in winter (December to February).

The detailed meteorological data prevailed during the experimental period are presented in Table 1.

3.2 Soil characteristics

Soil samples were taken from different depths 0-15, 15-30, 30-60 and 60-90

Table - 1 : Weekly meteorological conditions at Hisar during 1990.

Standard weeks	Air temperature (°C)		Relative humidity (%)		Sunshine (hr/day)	Mean wind velocity (km/hr)	Open pan evaporation (mm)	Rainfall (mm)
	Max.	Min.	M	E				
15	33.9	17.0	67	20	6.3	10.3	7.4	2.2
16	37.7	19.1	58	19	5.6	10.0	8.3	0.0
17	40.1	20.1	44	15	7.6	9.2	10.1	0.0
18	36.9	21.4	62	26	10.1	8.8	9.0	T
19	38.4	24.2	60	28	9.2	10.0	9.1	0.0
20	41.6	26.2	55	24	10.5	6.3	11.3	0.0
21	42.4	25.1	34	12	10.1	7.1	12.6	0.0
22	41.4	26.1	50	22	10.6	7.4	12.1	0.0
23	42.5	25.6	44	17	9.8	6.1	12.1	0.0
24	40.1	24.4	54	22	8.6	7.4	10.1	7.8

cm at different places from the experimental field. The physical characteristics of the soil profile determined are shown in Table 2.

Table 2 : Some physical parameters of soil profile from the experimental field.

Soil depth	Soil type	Clay (%)	Sand (%)	Silt (%)	Bulk density (g cm^{-3})	Field capacity (% by volume)	Permanent wilting point (% by volume)
0-15	Sandy	17.5	61.0	21.5	1.42	17.60	5.7
15-30	Sandy	17.5	61.0	21.5	1.44	17.60	5.7
30-60	Sandy loam	20.5	51.5	28.0	1.49	17.41	6.0
60-90	Sandy loam	25.0	45.3	29.7	1.62	16.79	5.4

3.3 Cropping history of the field

The field supported following rotations during the 4 previous years.

Year	Crop rotation		
	Kharif	Rabi	Summer
1986-87	Bajra	Raya	-
1987-88	-do-	-do-	-
1988-89	-do-	-do-	-
1989-90	-do-	-do-	Summer moong

These rotations included experimental crops grown at uniform recommended dose of fertilizers for the purpose of evaluation of crop microclimate in relation to weather parameters.

3.4 Experimental details

Treatments

T_1 - Straw mulch (Sarson straw 5 t/ha)

T_2 - Black polythene sheet mulch

T_3 - White polythene sheet mulch

T_4 - Stress irrigation + straw mulch (5 t/ha)

T_5 - Control

Crop : Summer moong (*Vigna radiata*)

Variety : K-851

Spacing - Row to row = 30 cm
Plant to plant = 10 cm

The treatments were given in 12 x 10 meter plots in a randomized block design with 4 replications.

3.5 Layout

The layout of the experimental field has been shown in Fig. 1.

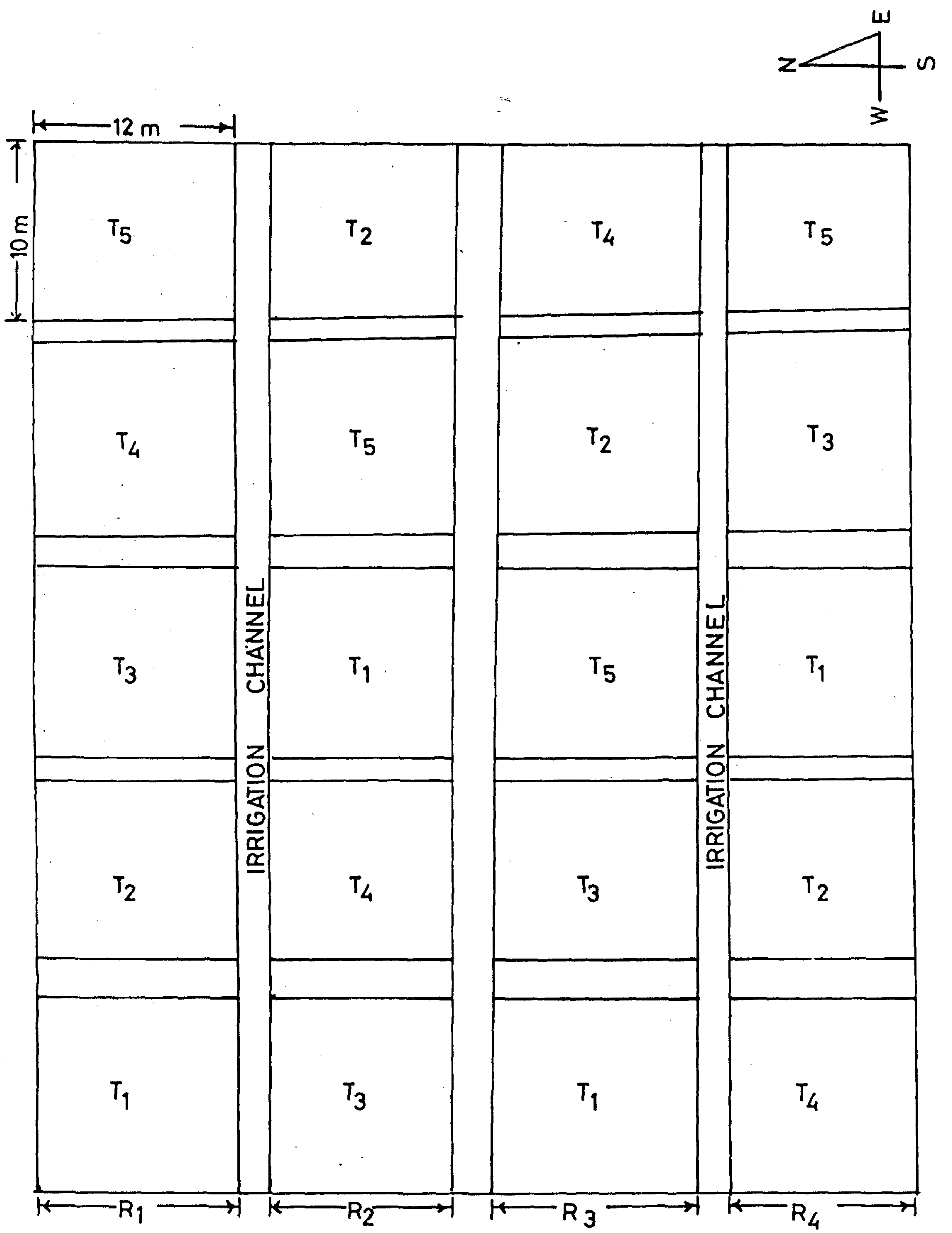


FIG. 1. LAYOUT PLAN OF THE EXPERIMENT

3.6 Cultural operations

3.6.1 Field preparation and sowing

Ploughing, levelling were done and pre sowing irrigation was applied. When the field was under working condition, it was ploughed up and planked twice. The crop was sown on 9th April, 1990 using seed rate of 20 kg/ha.

3.6.2 Fertilizer applications

The fertilizers for the crop were applied according to the recommendation in the package of practices, Haryana Agricultural University, Hisar at the time of sowing on soil test basis.

N	=	20 kg/ha through urea as starter dose
P_2O_5	=	40 kg/ha through single superphosphate
Zn	=	By Zn SO_4

3.6.3 Thining

Thining was done three weeks after sowing to maintain plant to plant spacing of 10 cm.

3.6.4 Weed control

Weeds were removed mechanically by hand hoe. The hoeing was done 25 DAS (days after sowing).

3.6.5 Irrigation

The moong crop was sown after a pre-sowing irrigation given on 2nd April, to achieve better crop establishment. In total, three irrigations were applied in 4 treatments viz. T_1, T_2, T_3 and T_5 and only one irrigation was applied in T_4 i.e. at flowering stage. First irrigation was applied 15 DAS and second irrigation on 35 DAS and third irrigation was applied in all treatments on 50 DAS.

3.6.6. Plant protection measures

One spray of Thiodan 200 ml in 500 litres water/hectare was done just after the incidence of insects in moong at vegetative phase to control yellow mosaic.

3.6.7 Harvesting

The crop was harvested on 16 June, 1990, 70 days after sowing when 80-90 per cent pods were mature. Harvesting was done manually with help of sickles. Three meter from each side as border area were harvested separately for minimizing the experimental error. After sun drying the harvested crop was threshed manually.

3.7 Observations

3.7.1 Soil and meteorological measurements

3.7.1.1 Soil moisture

Soil moisture determination was done by Neutron moisture meter from 0-7.5, 7.5-15, 15-30, 30-45, 45-60, 60-90 cm soil depths at 7 days interval from sowing to harvesting.

3.7.1.2 Soil temperature

The soil thermometers one each at 5 cm and 15 cm soil depth were fixed facing southwards in all treatments. The observations were recorded daily at 0727 and 1427 hours (I.S.T.) from sowing to harvesting.

3.7.1.3 Meteorological observations

Observations on daily rainfall, open pan evaporation, sunshine hours, wind speed and direction, maximum and minimum temperature and relative humidity during the study period were obtained from the meteorological observatory located adjacent to the experimental field, which was situated 50 m away from experimental field.

3.8 Micrometeorological observations

The following micrometeorological observations were recorded at vegetative, flowering and maturity stage. The observations were taken at two hourly interval in the experimental plots from 0700 to 1700 hrs.

3.8.1 Incoming and outgoing solar radiation

The amount of incoming shortwave solar radiation was measured with the help of pyranometer (Medoes and Co., Australia) on selected phenophases at two hours interval 100 cm above the crop canopy. The reflected shortwave radiation for the crop was measured with the help of albedometer with inbuilt pyranometers. Pyranometer was kept horizontal to the crop canopy.

3.8.2 Albedo or crop reflectivity

Albedo was computed as :

$$\text{Albedo} = \frac{\text{Reflected shortwave radiation}}{\text{Total incoming shortwave radiation}}$$

3.8.3 Net radiation

The net radiation was measured with the help of net radiometer (Medoes and Co., Australia) fixed at 1 meter height above the crop canopy. The output was measured and recorded with a digital micro-voltmeter. Net radiation was recorded at two hrs interval from 0700 to 1700 hrs at selected phenophases.

3.8.4 Soil heat flux

Soil heat flux was recorded with the help of soil heat flux plates (Medoes and Co., Australia) which were placed at 5 cm soil depth below the soil surface in experimental field and connected to a digital micro-volt meter. Soil heat flux was recorded at two hours interval from 0700 to 1700 hrs.

3.8.5 Canopy temperature

Infra red thermometer (Model AG 42) was used to measure the canopy temperature of the crop. These observations were recorded at 1430 hour (noon hours) keeping the sensor at 45° angle to crop canopy.

3.8.6 Temperature, vapour pressure and relative humidity

Dry and wet bulb temperatures were recorded with the help of Assman Psychrometer at the base, middle and top of crop canopy. These values were used for computing vapour pressure and relative humidity by using Psychrometeric Tables.

3.9 Morphological and phenological observations

3.9.1 Plant height

Plant height was measured from ground level to the tip of the plant at weekly intervals starting from 30 days after sowing till harvest. Five plants were selected randomly and were tagged in each treatment and average plant height was worked out.

3.9.2 Dry matter accumulation

Five randomly selected plants were removed from field, dried in sun and then put in the oven and weighed. The observations were taken at weekly interval starting 30 days after sowing and average dry matter per plant was calculated.

3.9.3 Leaf area index

Leaf area of five plants removed at random for dry matter observation was measured with the help of leaf area meter at weekly interval starting from 30 days after sowing. Leaf area index was computed by the following formula

$$LAI = \frac{\text{Total leaf area}}{\text{Ground area covered by the foliage}}$$

3.9.4 Number of leaves per plant

The number of leaves per plant were counted from germination to harvest of the crop at two days interval from five tagged plants and average leaves per plant were calculated.

3.9.5 Number of buds per plant

The number of buds per plant were counted at two days interval from five tagged plants and then averaged.

3.9.6 Number of flowers per plant

The number of flowers were counted at 2 days interval from five tagged plants after initiation of flowering and number of flower per plant were calculated by averaging.

3.10.1 Number of pods per plant

The number of pods of five tagged plants were counted at 2 days interval after initiation of pods and total number of pods per plants were counted at harvest.

3.10.2 Test weight

Weight of 1000 seed's sample taken at random from field was computed.

3.10.3 Seed yield per hectare

Seed yield of the experimental plots was recorded after threshing the produce and converted to yield per hectare.

3.10.4 Harvest index

Harvest index was calculated as

$$\frac{\text{Seed yield}}{\text{Biomass yield}} \times 100$$

3.10.5 Water use efficiency

Water use efficiency was calculated as

$$\text{WUE (\%)} = \frac{\text{Seed yield}}{\text{Consumptive use}} \times 100$$

3.10.6 Heat unit

Heat unit were computed as

$$\text{Heat unit} = \frac{\text{T max} + \text{T mini}}{2} - T_b$$

Where, T_{max} = Maximum temperature

T_{min} = Minimum temperature

T_b = Base temperature (10°C for summer crops Alagarswami et.al. 1977)

3.11 Statistical considerations

Treatments T_1, T_2, T_3, T_4 and T_5 were layed out as a randomized block design replicated four times. The analysis was performed as per procedure described in Panse and Sukhatme (1954). Simple linear regression equations were fitted on some of important parameters to know the effect of independent variable on the dependent variable. R^2 was also calculated to know the variation in the dependent variable by the independent variable. Significance of the regression coefficients was tested by t test.

4.1 Micrometeorological parameters

4.1.1 Energy balance component over moong crop

4.1.2 Short wave reflectivity

4.1.3 Optical characteristics of moong

4.1.4 Soil temperature (°C) at 5 and 15 cm soil depth

4.1.5 Wind roses

4.1.6 Canopy temperature

4.1.7 Leaf temperature, diffusive resistance and transpiration rate in summer moong

4.1.8 Water use and water use efficiency in summer moong

4.2 Growth and development observations

4.2.1 Plant height and heat unit

4.2.2 Leaf emergence and heat unit

4.2.3 Leaf emergence and cumulative soil temperature

4.2.4 Leaf area index

4.2.5 Dry matter production

4.3 Yield and yield attributing parameters

4.3.1 Number of buds and heat unit

4.3.2 Number of flowers and heat unit

4.3.3 Number of pods and heat unit

CHAPTER IV

RESULT AND DISCUSSION

The experimental results obtained are presented in the text of this chapter. This chapter have been divided into the following sub-heads :

4.1 Micro meteorological parameters

4.2 Plant growth and development observation

4.3 Yield and yield attributing parameters

4.1 Micro meteorological parameters

4.1.1 Energy balance components over moong crop

The energy balance parameters viz., solar radiation (Rs), net radiation (Rn), reflected radiation (Rf), soil heat flux (G), sensible heat flux (A) and latent heat of evapotranspiration (LE) were quantified at two hourly intervals from 0700 to 1700 hrs at three growth stages (vegetative, flowering, maturity) and are presented in figure 2a, b,c. The energy balance components presented almost similar trend in all the treatments, however, the magnitude of the various values varied from treatment to treatment. LE was greater than A and G. LE was higher in T_2 treatment (Black polythene) over the other treatments. The daily total of various energy components is presented in Table 3.

In all the treatments more than 50 per cent of Rs was available

Table 3 : Daily Energy balance component over moong as influenced by various treatments at different phenophases (mW/cm^2)

Treatment Date	Rs	Rf	Rn	Le	A	G
			Vegetative phase			
T_1 10-5-90	428.8	74.1	235.2	183.7 (78.1)	36.1 (15.3)	15.4 (6.6)
T_2 11-5-90	352.9	49.9	212.9	190.3 (80.1)	27.1 (12.6)	15.5 (7.3)
T_3 10-5-90	428.8	82.5	227.0	181.7 (80.0)	28.4 (12.6)	16.9 (7.4)
T_4 10-5-90	428.8	74.4	224.3	163.0 (72.7)	45.4 (20.2)	15.9 (7.1)
T_5 11-5-90	352.9	59.1	202.8	153.3 (75.6)	34.6 (17.1)	14.9 (7.3)
			Flowering phase			
T_1 22-5-90	398.8	81.1	255.2	190.8 (74.8)	51.0 (19.9)	13.8 (5.3)
T_2 22-5-90	398.8	72.0	252.7	202.1 (80.1)	36.8 (14.4)	13.8 (5.5)
T_3 22-5-90	398.8	87.2	254.3	195.2 (76.9)	43.9 (17.1)	15.2 (6.0)
T_4 22-5-90	398.8	80.7	247.0	267.5 (67.9)	62.7 (27.4)	11.8 (4.7)
T_5 23-5-90	346.4	70.7	251.7	176.6 (70.2)	62.0 (24.6)	13.1 (5.2)
			Maturity phase			
T_1 12-6-90	451.2	82.4	275.1	203.1 (73.8)	57.2 (20.8)	14.8 (5.4)
T_2 13-6-90	459.2	79.9	279.4	213.3 (76.3)	50.3 (18.0)	15.8 (5.7)
T_3 12-66-90	451.2	86.8	276.2	204.5 (74.0)	55.4 (20.1)	16.3 (5.9)
T_4 13-6-90	459.2	83.3	273.7	185.2 (67.7)	75.5 (27.6)	13.0 (4.7)
T_5 12-6-90	451.2	80.4	273.6	185.8 (67.9)	72.9 (26.6)	14.9 (5.5)

T_1 = Straw mulch (5 t/ha), T_2 = Black polythene sheet mulch
T_3 = White polythene sheet mulch, T_4 = Stress irrigation + mulch
T_5 = Control

(Figures in parentheses are percentages) as net radiation. Net radiation was partitioned into three main components viz., LE, A and G. More than 70 per cent of Rn was utilized as evapotranspiration. The LE varied from treatment to treatment as well as phenophase to phenophase. The LE varied from 72.7 to 80.1 per cent, 67.9 to 80.1 per cent and 67.7 to 76.3 per cent of Rn at vegetative, flowering and maturity stages, respectively. The maximum LE was observed at vegetative, flowering and maturity in T_2 treatment. The difference between LE at vegetative and flowering stage was less due to the less difference in leaf area index in these stages. Sensible heat flux varied from 12.6 to 27.6 per cent indicating that the main share holders of net energy were LE and A. Sensible heat flux variations were higher because of wide change in the outgoing long wave radiations from different type of treatments. Out of all the treatments T_4 treatment (stress irrigation + mulch) utilized less radiation in LE as well as G as compared to the other treatments. This may be due to higher sensible heat generated under stress conditions.

The major portion of net energy was used in LE at all three stages in all the treatments. LE was observed in the order of $T_2 > T_3 > T_1 > T_5 > T_4$. Sensible and soil heat flux components varied with the crop phenophase and also due to foliage characteristics in altering the energy balance. The higher amount of LE in T_2 treatment resulted in better crop growth, higher dry matter production, more leaf area index and higher yield contributing characters. The similar results reported by Rao (1986) and Singh (1988) for moong and raya crop.

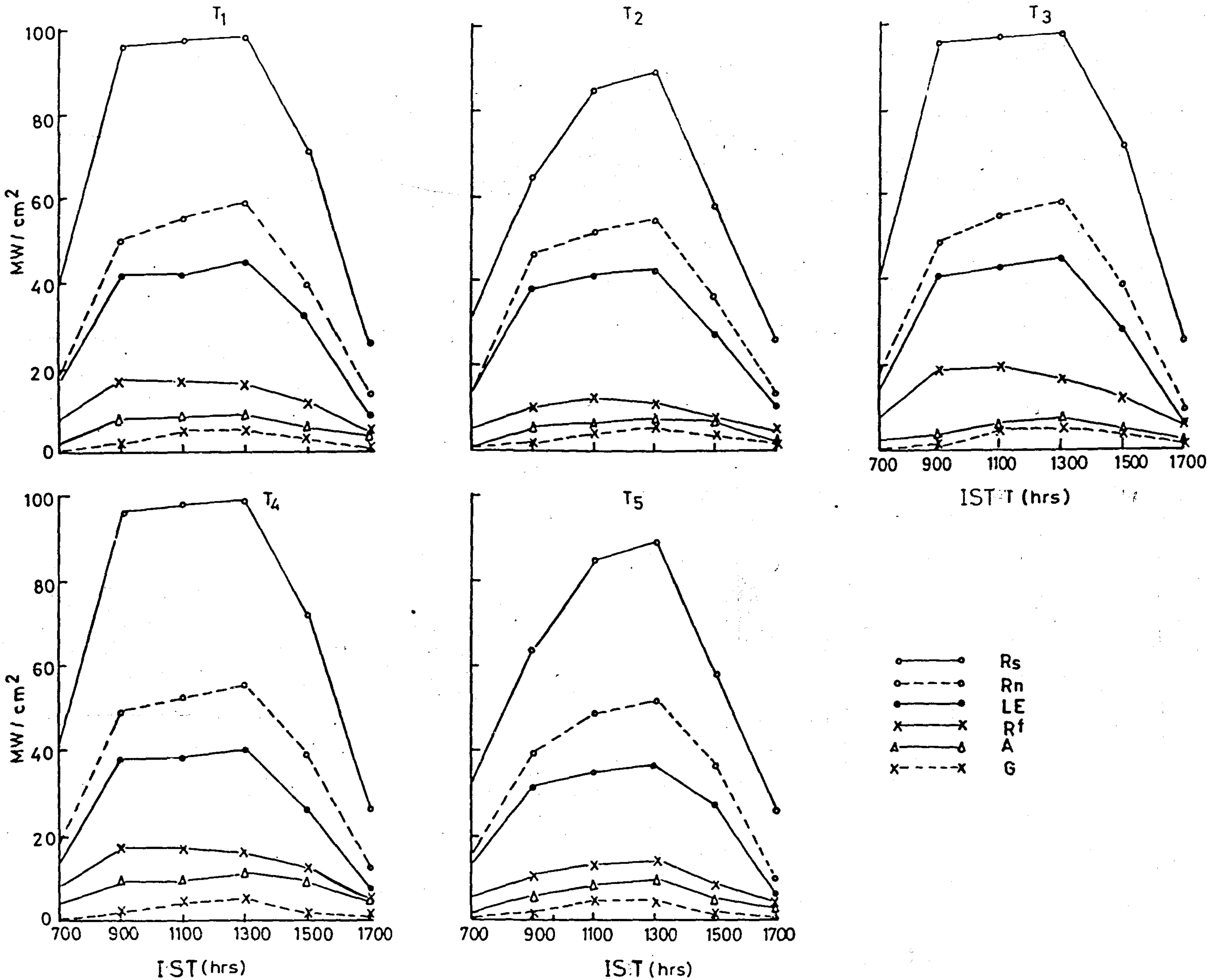


FIG. 2 A. ENERGY BALANCE COMPONENT OVER MOONG CROP AT VEGETATIVE

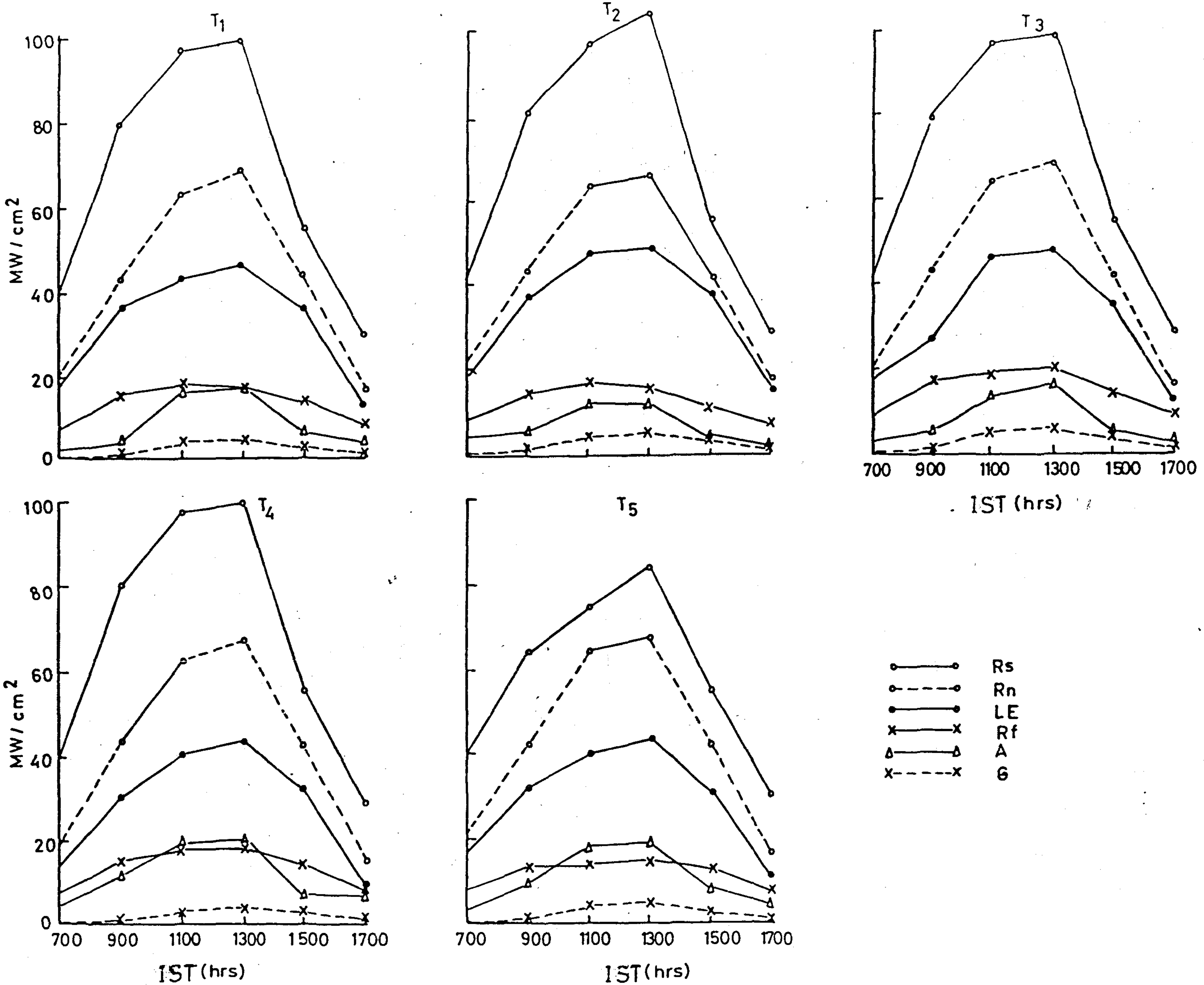


FIG. 2 B. ENERGY BALANCE COMPONENT OVER MOONG CROP AT FLOWERING.

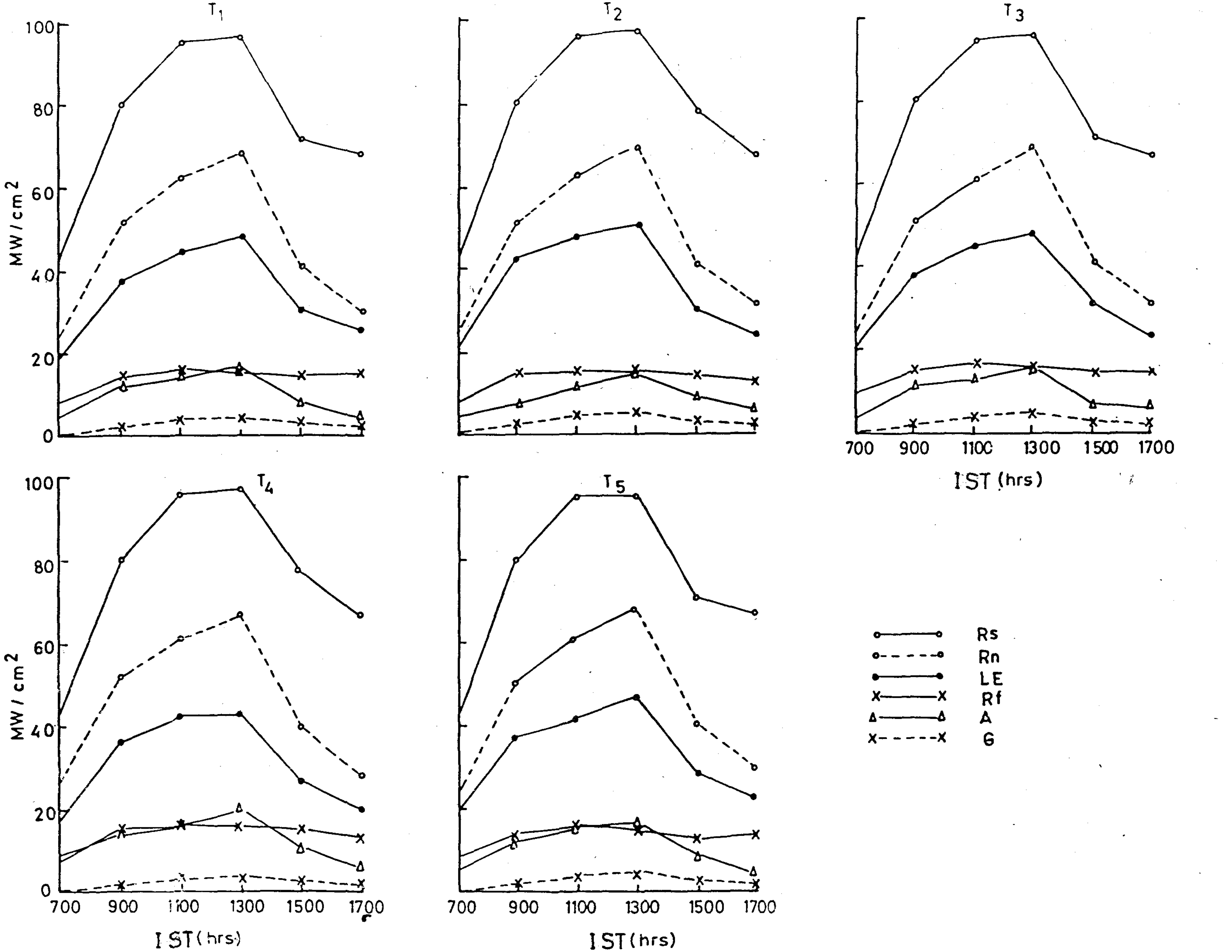


FIG. 2 C. ENERGY BALANCE COMPONENT OVER MOONG CROP AT MATURITY.

4.1.2 Short wave reflectivity

The short wave reflectivity was recorded at two hourly intervals in all treatments at three phenophases (vegetative, flowering and maturity) and is presented in Fig. 3.

In the morning and evening hours the reflected values were higher, whereas, during noon time these were minimum. This may be due to direct sun rays falling on crop at noon time, however during morning and evening hours increase was recorded due to obliqueness of the sun rays. The reflected values also varied from treatment to treatment as well as stage to stage. The highest values were obtained in T_3 treatment (white polythene) at all the three stages as compared to other treatments. This may be due to white surface (white polythene) reflects most of the radiation received by the surface. However, on the other hand, lowest reflected values in T_2 treatment. This may be due to black surfaces absorb more energy from incoming solar radiation. In addition, the reflected values depends on the canopy characters such as leaf angle, thickness, colour and moisture of the leaf.

4.1.3 Optical characteristics of moong

The transmitted, absorbed and reflected PAR radiations were measured at weekly interval starting from 30 days after sowing during noon hours in each treatment with the help of quantum sensor and are presented in Table 4. The trend of the absorption curves were same in

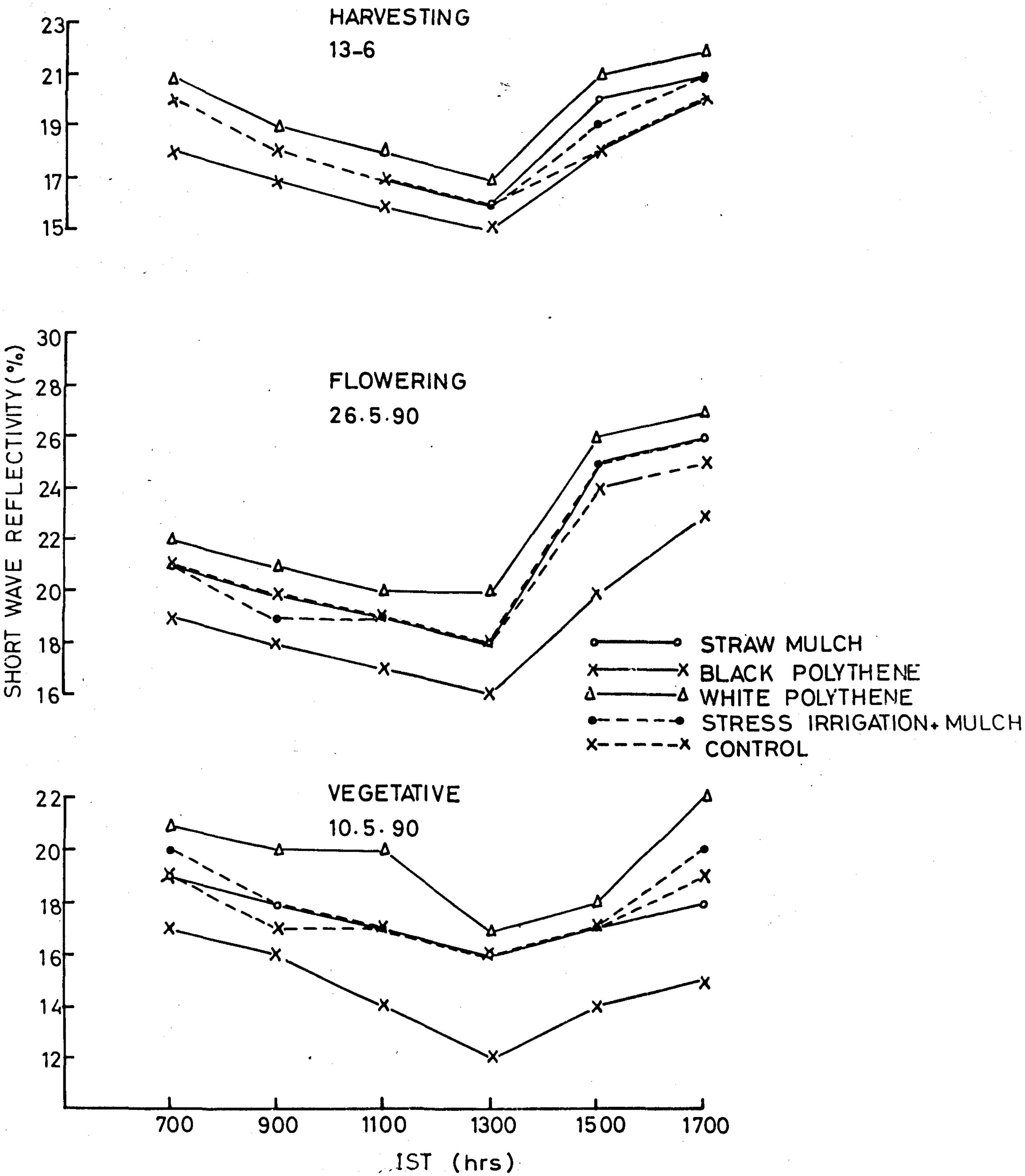


FIG.3. SHORT WAVE REFLECTIVITY OVER MOONG AS INFLUENCED BY VARIOUS TREATMENTS AT DIFFERENT PHENOPHASES

Table 4: Absorbed, transmitted and albedo (PAR) radiation over moong as influenced by various treatments at different growth intervals

Treatments	Days after sowing						
	30	38	45	53	61	66	Mean
Absorbed radiation (%)							
T_1	53.1	86.7	89.4	87.8	90.5	82.8	81.7
T_2	54.8	87.0	90.9	90.6	92.0	90.1	84.2
T_3	47.2	82.5	87.0	88.6	88.3	89.1	80.5
T_4	37.6	73.9	79.5	81.4	85.0	81.0	73.1
T_5	51.5	79.7	83.7	82.5	89.8	82.0	78.3
Transmitted radiation (%)							
T_1	35.2	7.6	5.0	7.6	6.3	10.4	12.0
T_2	35.0	7.2	4.2	4.0	5.5	2.0	9.7
T_3	40.2	10.3	5.2	4.8	5.8	2.6	11.5
T_4	53.4	20.9	13.3	14.4	11.2	11.1	20.9
T_5	41.2	13.3	10.3	9.3	7.2	11.3	15.4
Albedo (%)							
T_1	11.7	5.7	5.6	4.6	3.2	6.8	6.3
T_2	10.2	5.8	4.9	1.8	2.5	7.9	6.1
T_3	12.6	7.2	7.8	6.6	5.9	8.3	8.0
T_4	9.0	5.2	7.2	4.2	3.8	7.9	6.3
T_5	7.3	7.0	6.0	8.2	3.0	6.7	6.3

all treatments from 30 days till maturity. However, there were differences in absorption when compared over various growth stages. Less absorption was recorded in the initial stage of the crop growth due to the incomplete crop canopy. The maximum absorption were recorded during 45 to 53 days after sowing when the maximum leaf area index was attained. The values of absorbed radiations in all treatments varied from 37.6 to 92.0 per cent. The maximum absorption values were recorded in T_2 treatment (Black polythene) during all the observations. The lower values were recorded in T_4 treatment (stress irrigation + mulch). This may be due to stress conditions in T_4 treatment. The order of absorption values in different treatments were as $T_2 > T_3 > T_1 > T_5 > T_4$.

The transmitted values recorded during the study were lowest at 45 days after sowing. The maximum value were recorded at initial stage of the crop. In all treatments the transmitted values ranged from 2.0 to 53.4 per cent. The order of the various treatments recording transmitted values was $T_4 > T_5 > T_1 > T_3 > T_2$ and with the development of the crop the transmitted values decreased upto maturity.

Albedo values were measured. No specific trend observed in different treatments, however higher values were recorded in the initial stages of the crop growth and then lower values were observed at 60 day after sowing in all the treatments. The reflected radiation value varied from 2.5 to 12.6 per cent. Higher values were recorded in T_3 treatment (white polythene) where lower values of reflected radiations were recorded in T_2 treatment.

The optical characteristics shows the variations in the different radiation levels as influenced by the canopy development. These variations are also influenced by the crop canopy characters such as colour and thickness of the leaf, chlorophyll content and internal moisture status of the plant. Among the treatments T_2 treatment indicated higher absorption of PAR and thereby producing higher photosynthesis as also indicated by dry matter accumulation and leaf area index. Higher leaf area index in T_2 treatment has also resulted due to higher cumulative green matter and plant height. Higher number of pods, flowers and buds per plant in T_2 treatment as compared to other treatment. Similar results have been reported by Singh (1990) for summer moong crop.

4.1.4 Soil temperature (°C) at 5 and 15 cm soil depth

The variation in soil temperature in different treatments at 5 and 15 cm of soil depth is shown in figures 4A and B.The soil temperature were recorded twice a day, at (I.S.T.) time of 0727 and 1427 hrs. The variation in soil temperature in both the layers shows that under stress a cumulative soil temperature of 135.2°C and 86.5°C at 5 and 15 cm of soil depth respectively were recorded over the control treatment that is 3 irrigations (Table 5). Soil temperature variations were higher at 5 cm soil depth as compared to the 15 cm soil depths. In straw and white polythene mulched treatments there was reduction in soil temperature during the growing season as compared to the control. It was observed that a cumulative reduction of 66.6 and 35.2°C at 5 cm

Table 5 : Effect of various treatments on accumulated soil temperature in moong

Treatments	Soil depth 5 cm			Soil depth 15 cm		
	Cumulative temperature (°C)	Mean temperature (°C)	Δ t (°C)	Cumulative temperature (°C)	Mean temperature (°C)	Δ t (°C)
T_1	1616.6	28.4	-66.6	1645.4	26.9	-26.7
T_2	1714.5	30.1	+31.3	1710.8	30.0	+38.7
T_3	1648.0	28.9	-35.2	1659.9	29.2	-12.2
T_4	1818.4	31.9	+135.2	1758.6	30.9	+86.5
T_5	1683.2	29.5	0	1672.1	29.3	0

Δ Deviation from Control. T_5

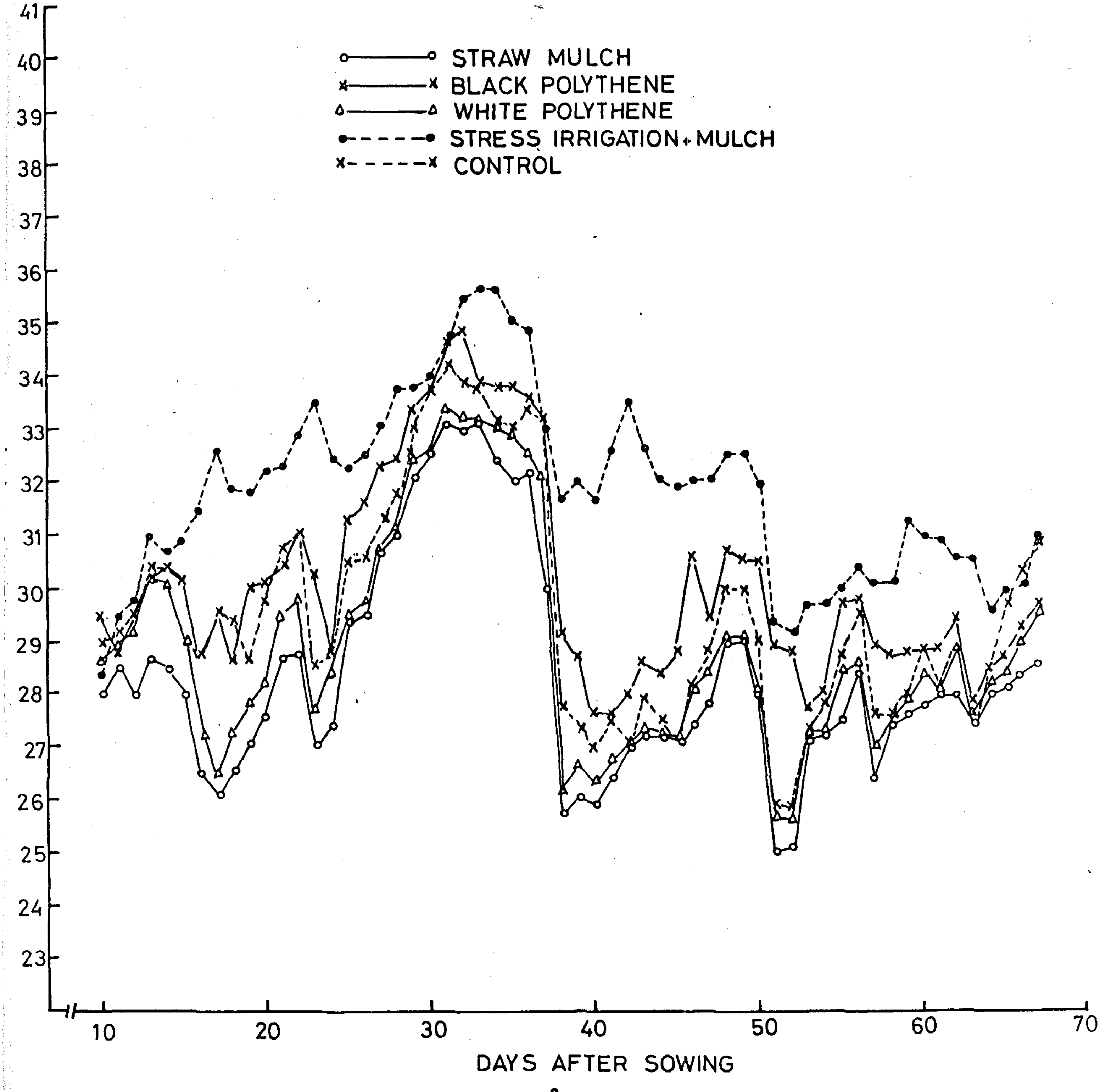


FIG.4 A. MEAN SOIL TEMPERATURE (°C) AS INFLUENCED BY VARIOUS TREATMENTS (5 cm DEPTH)

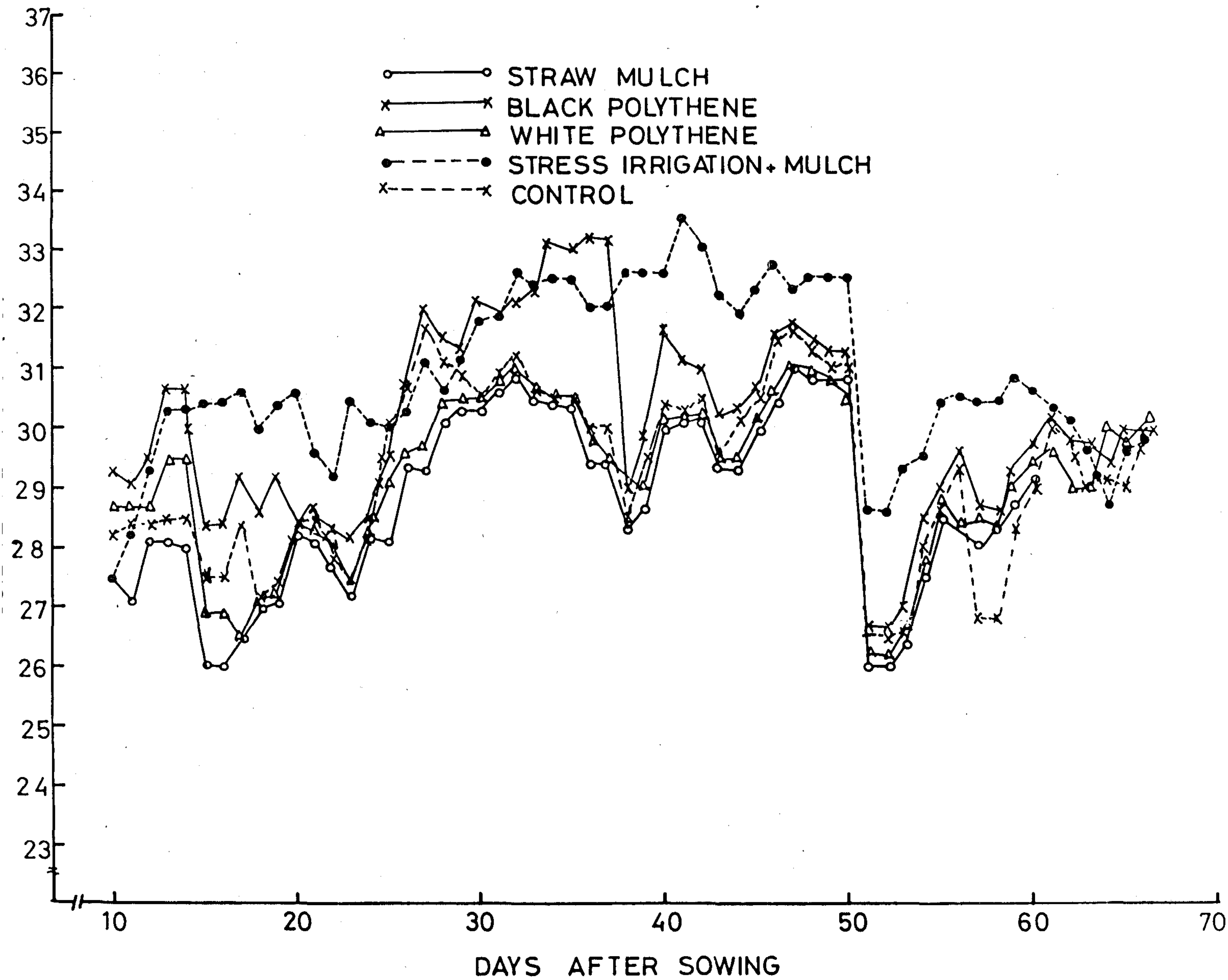
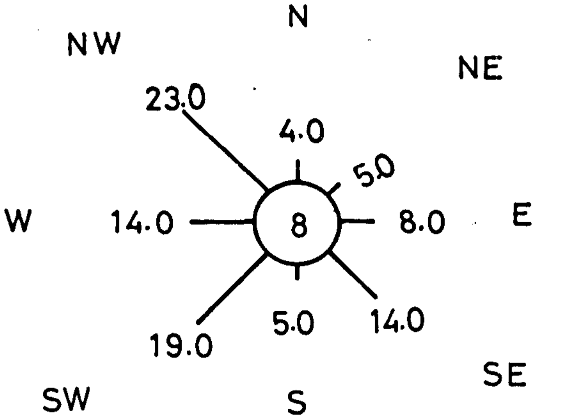


FIG.4 B. MEAN SOIL TEMPERATURE °C AS INFLUENCED BY VARIOUS TREATMENTS (15 cm DEPTH)

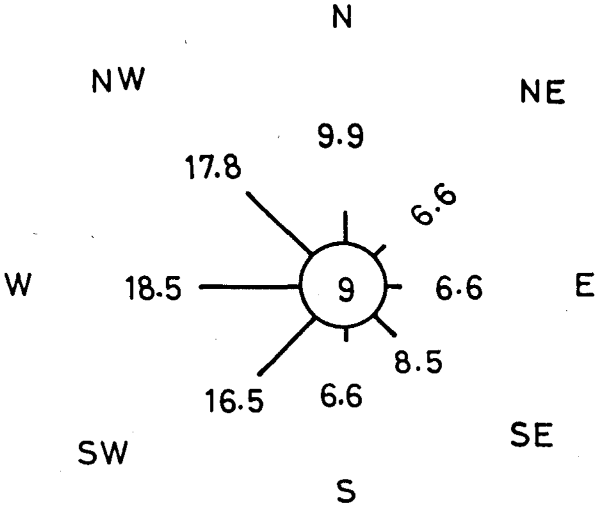
soil depth and 26.7 and 12.2°C at 15 cm soil depth in straw and white polythene treatments, respectively. It appears that mulch treatments reflected the more solar radiation as compared to the control treatment. The net sensible heat generated over the straw and white polythene mulched treatments was also less as compared to the sensible heat generated over the control treatment. In black polythene treatment there was an increase in the soil temperature at both the soil depths. It was observed that a cumulative increase of 31.3°C and 38.7°C at 5 and 15 cm soil depth occurred, respectively over the control treatment. Hence, it appears that black polythene has absorbed more radiation and generated higher sensible heat component as compared to the control treatment. These variation in soil temperature do not function independently but they are governed by the soil moisture. The mean soil temperature variation over the different treatments was within a narrow range of ±2°C over the control treatment. Due to soil temperature manipulation by mulching it has resulted in better growth and development of moong crop, more leaf area, dry matter production. Significant increase in yield contributing parameters was recorded in mulched treatments over control. Gurnah and Mutea (1982) also reported that soil temperature under mulched with grass, clear, black and white polyethylene were recorded at different depths. It was reported that grass mulch lowered the soil temperature, white polyethylene mulch either slightly raised the soil temperature or lowered it and black and clear polyethylene greatly increased the soil temperature with the clear polyethylene giving the highest temperatures. It was concluded that mulches can be used to control soil temperature.

4.1.5 Wind roses

Fig. 5 shows that during the summer season of 1990 north west, west and south westerly winds are more prevalent at Hisar. There was tendency of more westerly dry wind which needs to be protected through agricultural management practices to avoid the rapid loss of moisture with the evapotranspiration rates of 15 to 20 mm/day in summer. The wind rose clearly indicates that there is necessity for protecting the plots from dry winds under the Hisar climatic conditions during the summer season, otherwise there would be rapid loss of soil moisture and excessive increase in soil temperature which will retard the crop growth and development. The north westerly winds were 23 per cent against the normal of 17.8 per cent. The westerly and south westerly dry winds were constituting 33 per cent against the normal value of 35 per cent. Therefore, the summer season has almost behaved as a normal feature. Therefore, the plants were erected in north-south direction perpendicular to the westerly dry winds. The mulching treatment were also applied between rows so that surface resistance was offered to the flow of dry winds. This has resulted in break down of the wind eddies inside the crop canopy, however, their impact on the crop growth and development was difficult to isolate but it has provided beneficial effects in the yield and yield attributes.



SUMMER SEASON(1990)
(APRIL TO JUNE)



NORMAL SUMMER SEASON
(APRIL TO JUNE)

FIG. 5. WIND-ROSES DURING THE CROP SEASON

4.1.6 Canopy temperature

Canopy temperature is an important parameter which is influenced by soil water availability in plants and atmospheric environment. The canopy temperature was recorded daily in different treatments and presented in Fig. 6a. The water stressed treatment T_4 showed the highest canopy temperature, whereas lowest canopy temperature were recorded in T_2 treatment as compared to the other treatments. However, the differences of the crop canopy temperature between T_2 and T_4 treatments were observed to be 1.7°C at 64 days after sowing and a minimum of 0.8 was observed at 58 and 61 days after sowing. Throughout the growing season the canopy temperature was higher in T_4 treatment indicating that plants were under stress and lower in T_2 treatment indicating without stress conditions. The canopy temperature has direct bearing on the soil moisture status and influenced the yield attributes. Tc-Ta was higher in T_2 treatment as compared to T_4 treatment (Fig. 6b) throughout the growing season indicating the plants were never at stress. The favourable microclimatic condition in T_2 treatment has resulted in higher yield attributes particularly leaf area index, dry matter accumulation, thousand seed weight and grain yield were higher in T_2 treatment than the other treatment.

4.1.7 Leaf temperature, diffusive resistance and transpiration rate in summer moong

With the help of porometer leaf temperature, diffusive resistance and transpiration rate in fully matured leaf were recorded on 2nd and 12th

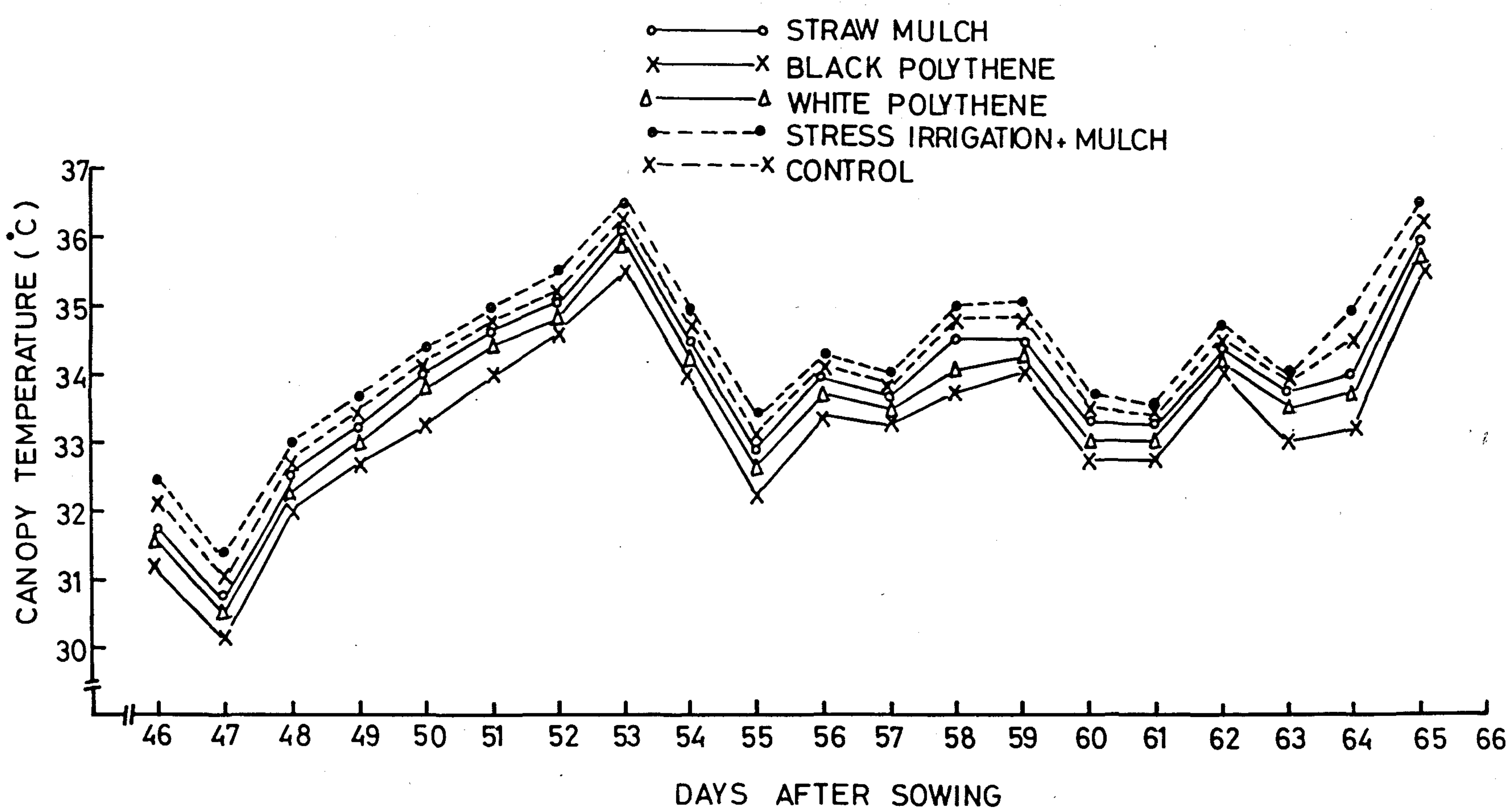


FIG.6 A. INFLUENCE OF VARIOUS TREATMENTS ON CANOPY TEMPERATURE(1400 hrs)

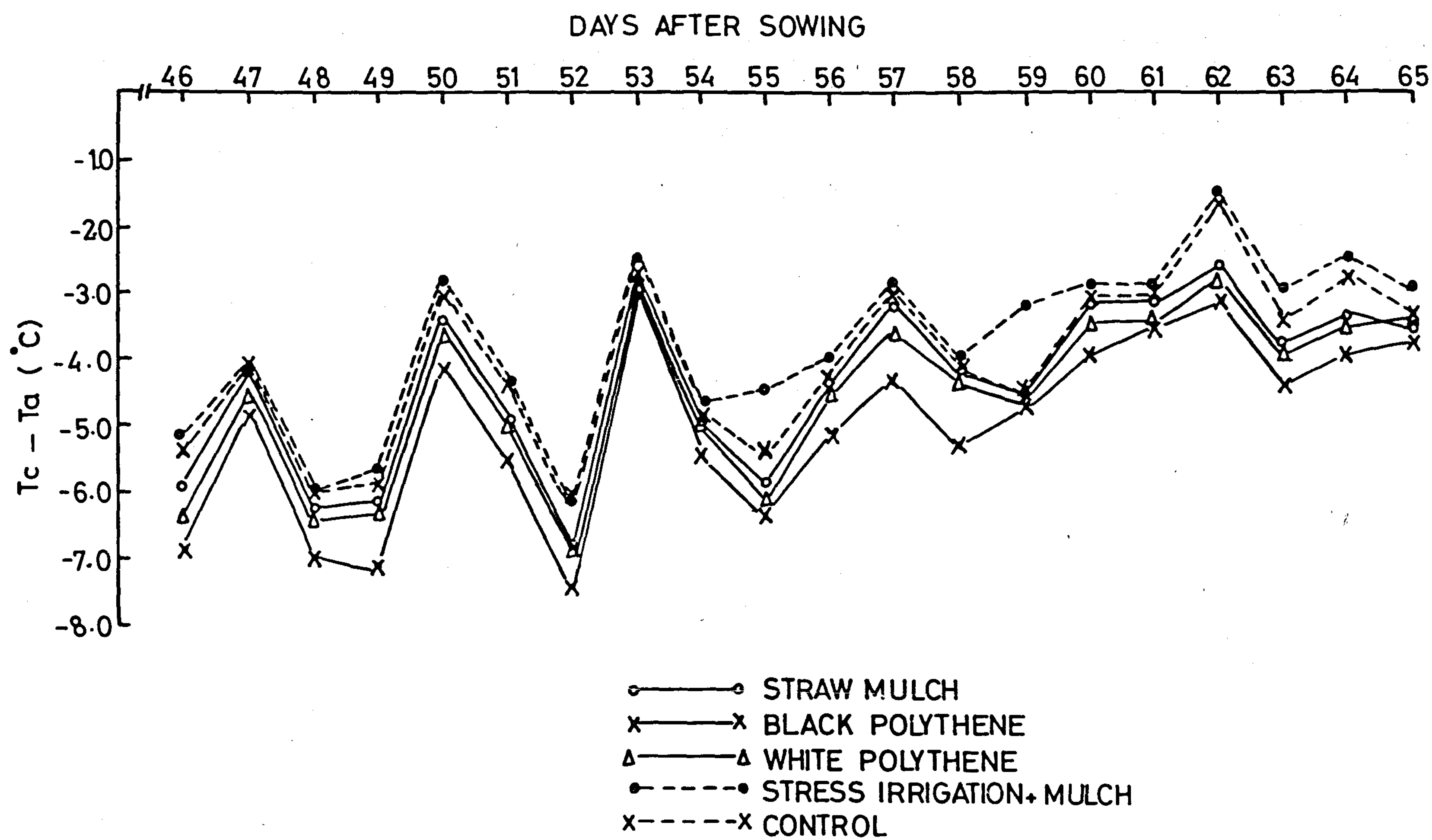


FIG. 6 B. DIFFERENTIAL CANOPY TEMPERATURE AND AIR TEMPERATURE AS INFLUENCED BY VARIOUS TREATMENTS

June, 1990 during noon hours. Table 6 shows the average values of the data recorded in five tagged plants in different treatments. In different treatments, except T_3, the lower side of the leaf was at a higher temperature than the upper side which is probably due to sensible heat affect during the summer season, and more transpiration from upper side of leaves than lower one. However, the difference recorded between the lower and upper side of the leaf temperature was higher on the 2nd June than the values recorded on 12th June.

Diffusive resistance between the different treatments varied from 1.0 to 4.52 Sec cm^{-1} depending on the leaf transpiration rate. Among the different treatments the diffusiveresistance was higher in T_1 and T_2 treatments, but on 12th June diffusive resistance was higher in T_2 treatment only. It was lowest in T_5 and T_1 on 12th June readings. The diffusive resistance values have been the directly influenced by the transpiration rate which is function of the amount of soil water available in the root zone of different treatments.

Fig. 7a show the relationship between leaf temperature, transpiration rate and diffusive resistance as recorded on 2nd and 12th June during noon hours. It was observed that the diffusive resistance increased with the increase in leaf temperature because with rise of temperature transpiration rate increased depending on the availability of water in plant and under stress conditions the leaf temperature has shown higher values which directly increase the diffusive resistance in the leaves (Fig. 7a) due to water scarcity in the leaves.

Table 6 : Influence of various treatments on leaf temperature, diffusive resistance and transpiration rate

Treat-ments	Leaf side	Leaf temperature (°C)		Diffusive resis-tance (sec/cm) (sec/cm)		Transpiration rate $\mu gm\,cm^2\ sec^{-1}$	
		Date		Date		Date	
		2.6.90	12.6.90	2.6.90	12.6.90	2.6.90	12.6.90
T_1	Lower	36.3	37.4	3.7	1.8	5.2	17.2
	Upper	33.7	37.7	1.51	1.6	17.29	19.8
T_2	Lower	35.8	38.5	2.6	2.1	11.97	15.2
	Upper	35.2	38.4	1.85	4.2	14.04	8.3
T_3	Lower	34.3	38.1	1.50	1.9	19.02	16.8
	Upper	35.8	38.2	2.12	2.0	14.35	15.3
T_4	Lower	36.8	38.3	4.52	2.3	7.0	15.4
	Upper	35.4	38.4	1.32	2.2	19.4	14.29
T_5	Lower	36.2	37.4	1.0	1.4	4.0	20.7
	Upper	34.2	37.9	1.55	2.2	15.86	11.1

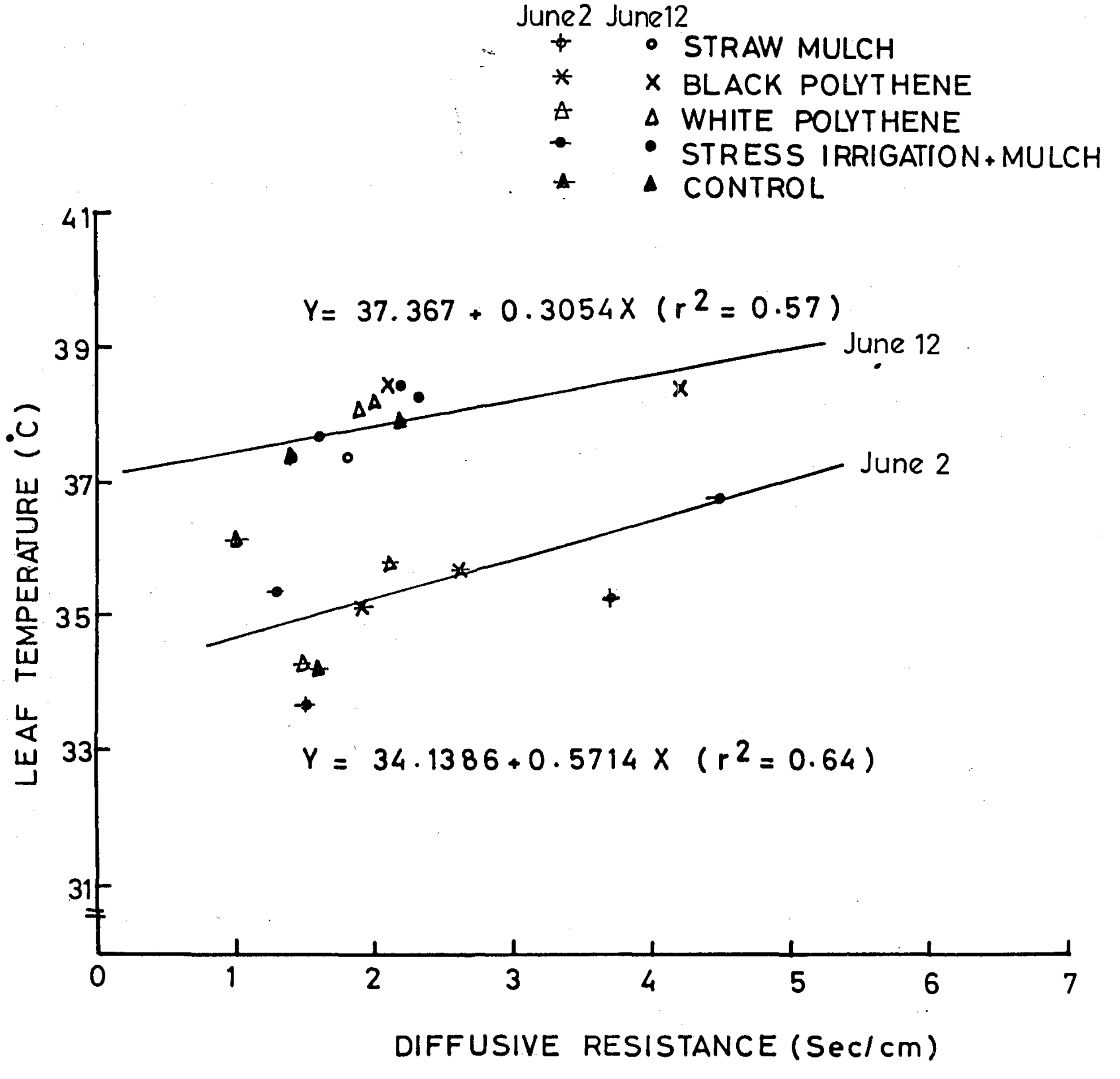


FIG. 7 A. RELATION BETWEEN LEAF TEMPERATURE AND DIFFUSIVE RESISTANCE IN DIFFERENT TREATMENTS ON JUNE 2 AND 12 1990

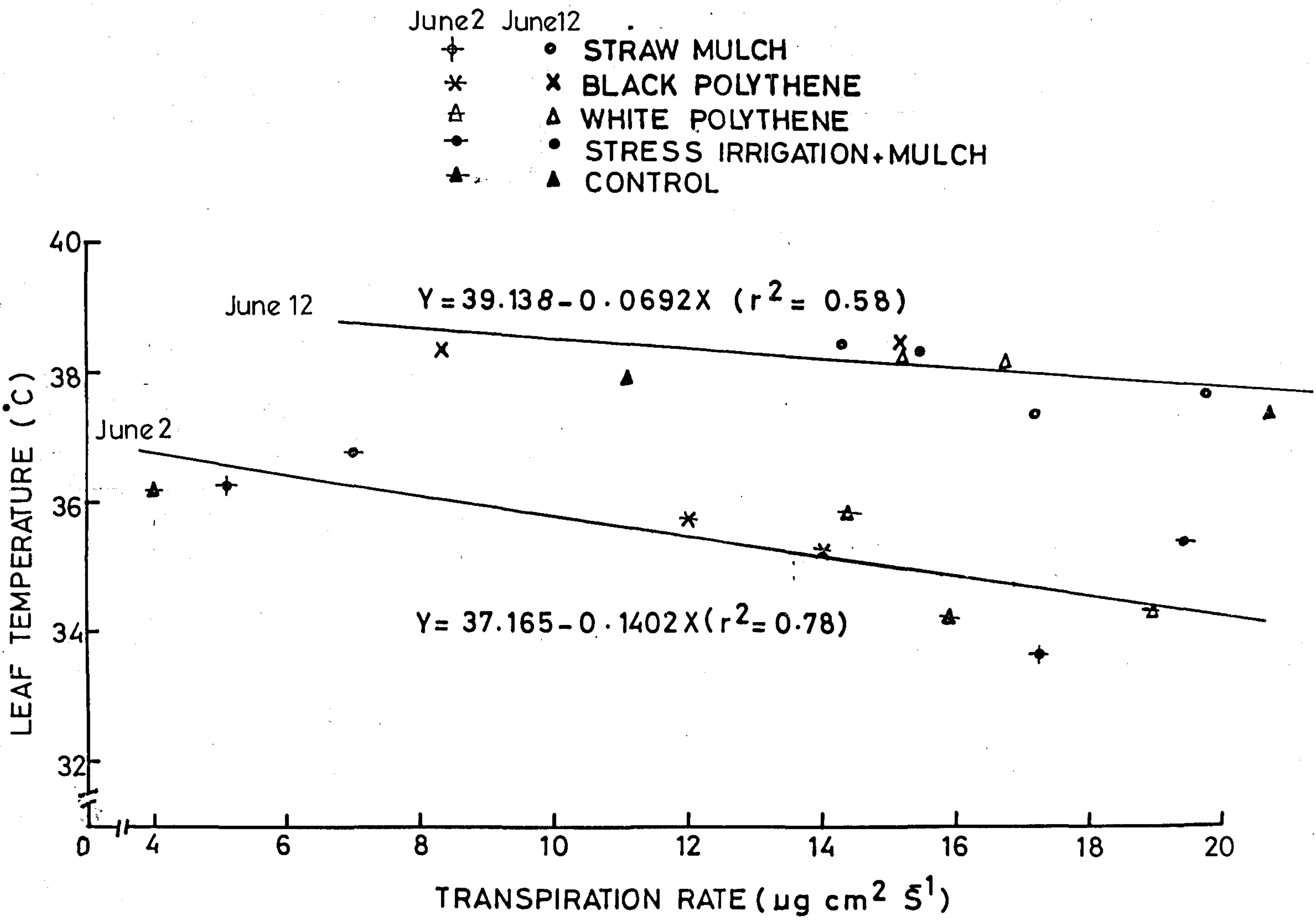


FIG. 7 B. RELATION BETWEEN LEAF TEMPERATURE AND TRANSPIRATION RATE

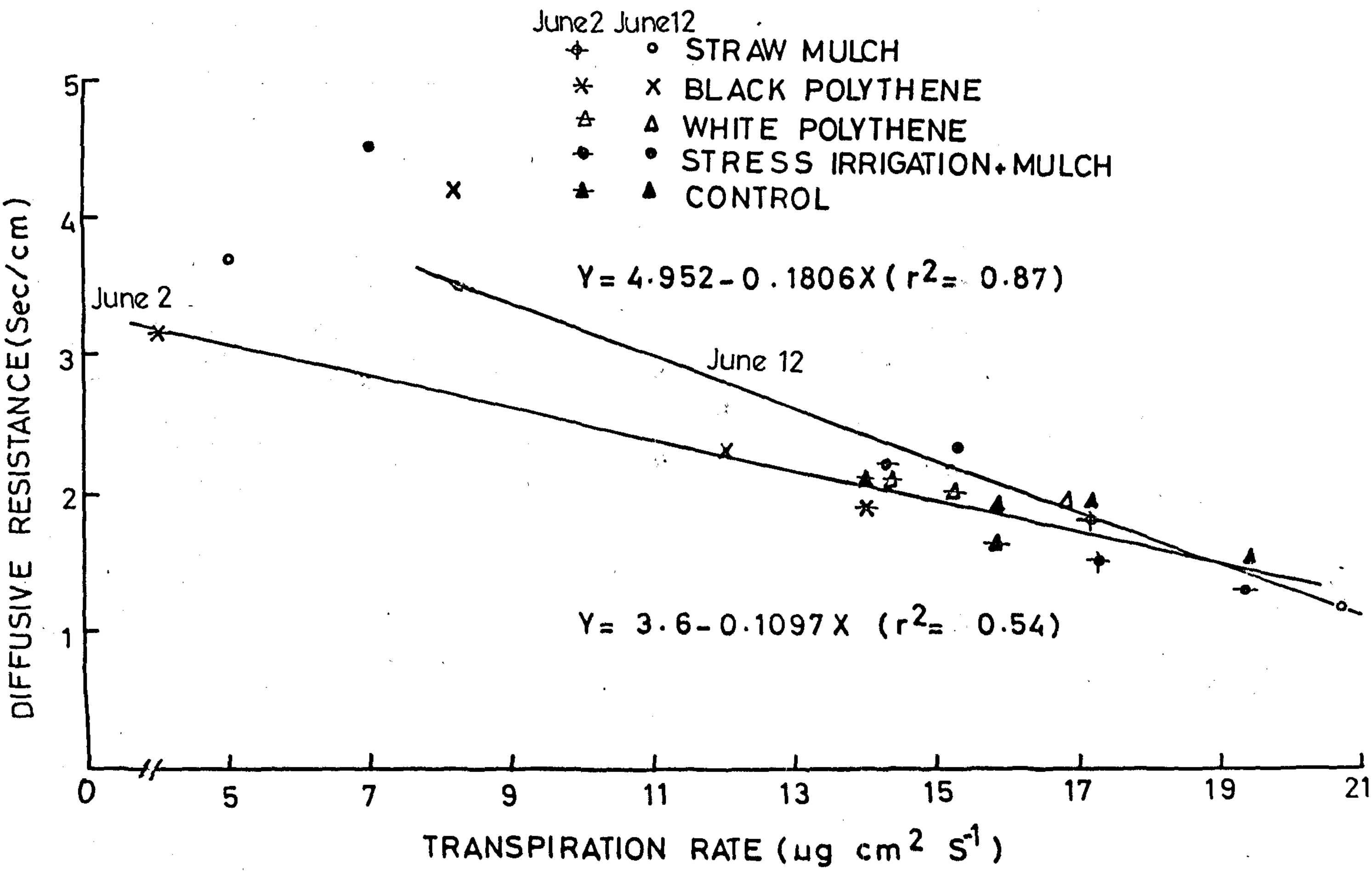


FIG.7C. RELATION BETWEEN DIFFUSIVE RESISTANCE AND TRANSPIRATION RATE

Fig. 7b showed the decrease in leaf temperature with the increase in transpiration rate. 58 to 78 per cent variation in leaf temperature was explained by the transpiration rate of the leaves. Under higher transpiration rate, the leaf becomes cooler and showed lower leaf temperature.

Fig. 7C shows the decrease in diffusive resistance values in different treatments with the increase in transpiration rate. The treatments which have shown lower diffusive resistance values presented higher transpiration rate and vice versa. These relations presents the interdependence between transpiration rate and leaf temperature through the diffusive resistance values.

4.1.8 Water use and water use efficiency

Water use and water use efficiency from sowing to harvest were estimated with the use of soil moisture data recorded with the help of neutron moisture meter in different treatments and presented in Table 7 Maximum water was consumed (56.4 cm) in T_5 (control) treatment, whereas, lowest (33.1 cm) was utilized in T_4 treatment. These differences in water use have been resulted due to differences in the root development and their exploitation of soil water to meet the water need under different treatments. Though the water use was higher in T_5 treatment,but the water use efficiency was lowest. Transpiration rate was higher but diffusive resistance and canopy temperature was lowest under T_2 treat-

Table 7 : Influence of various treatments on water use and water use efficiency

Treatments	Water use (cm) Days after sowing				Open pan Evaporation (cm) during the period	Total water use (cm)	Water use efficiency (q/ha-cm)
	12	35	49	66			
T_1	10.5	11.0	9.1	8.0	12.5	51.1	0.27
T_2	8.5	10.2	9.5	8.1	12.5	48.8	0.30
T_3	8.4	9.6	9.3	8.1	12.5	47.5	0.29
T_4	8.3	4.5	4.9	11.0	4.4	33.1	0.27
T_5	11.3	12.6	10.1	9.9	12.5	56.4	0.20

ment resulted better yield and yield attributes ultimately grain yield and water use efficiency was also highest under T_2 treatment. Water use efficiency was higher in T_2 treatment. Water use efficiency was lowest in T_5 treatment and resulted in less yield and yield attributes. With the efficient utilization of available water in T_2 treatment yield attributes particularly leaf area development, dry matter production, 1000 seed weight and gram yield were higher. Kalaghatagi et al. (1988) and Ghosh et al. (1983) also reported that mulching increased water use efficiency and decreased the water use over control.

4.2 Growth and development observations

4.2.1 Plant height and heat unit

Plant height was measured at weekly intervals manually and corresponding heat units were also determined for the same period. With the use of these data regression equations were fitted and presented in Fig.8 . Figure shows that there is a strong linear relationship between cumulative heat units and plant heights. 89 to 92 per cent of variation in plant height was explained by cumulative heat units among the treatments. The highest R^2 value was calculated in T_5 treatment and there seems to be not much difference in this relationship due to strong correlation under different treatments. A maximum of 40.2 cm and minimum of 35.1 cm in plant height was recorded in treatment T_2 and T_4, respectively.

Higher plant height in T_2 treatment is also influenced by the

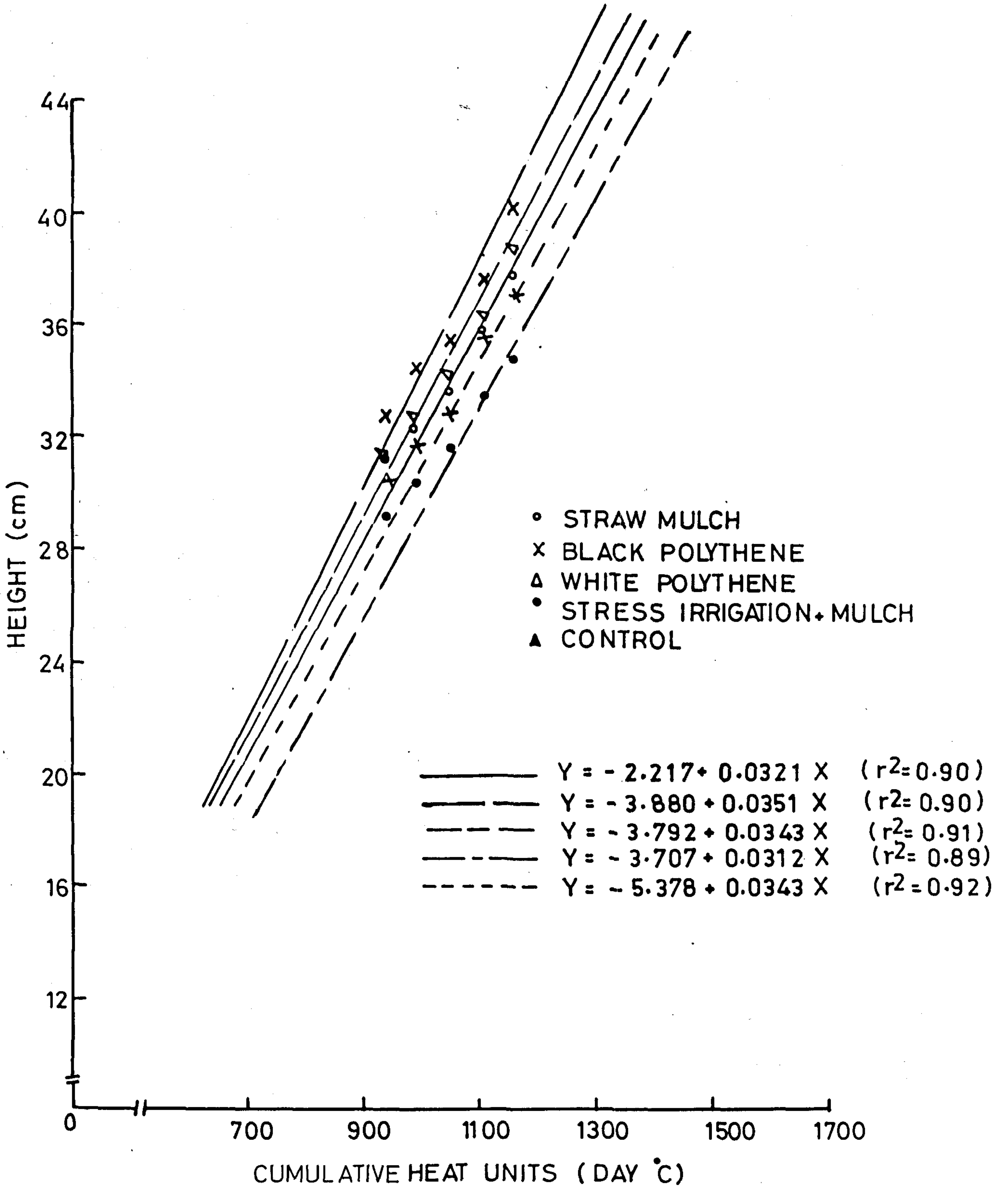


FIG. 8. RELATION BETWEEN PLANT HEIGHT AND HEAT UNITS

conserved soil moisture status in relation to the other treatments. However, in stress treatment T_4 due to less availability of the soil moisture the plant has been able to attain height more than 35 cm during the summer season therefore, the heat unit concept, with the base temperature of 10°C, it is possible to develop a relation to increasing height with growing season.

Normally higher plant height resulted higher leaf area index. More dry matter production and significantly higher pods, buds and flowers per plant in T_2 treatment as compared to other treatments resulted significantly increase in yield of T_2 treatment over control. In moong bean the dry matter accumulation has been distributed proportionately in different plant organs and therefore, the dry matter source generated before podding has resulted in better sink development. Gupta and Rao (1989) also reported that mulching increased the height, leaf area of green gram and cowpea.

4.2.2 Leaf emergence and heat unit

Leaf emergence was recorded from five tagged plants in each treatment. The emergence of the leaves and their corresponding accumulating heat units are presented in Figure 9. With accumulated heat unit of 1112 day °C, 9.6 leaves were emerged in T_2 treatment, 9.4 in T_3, 9.2 in T_1 and 9.0 in T_5 and T_4 treatments, respectively. Simple regression equations were fitted with the use of leaf emergence

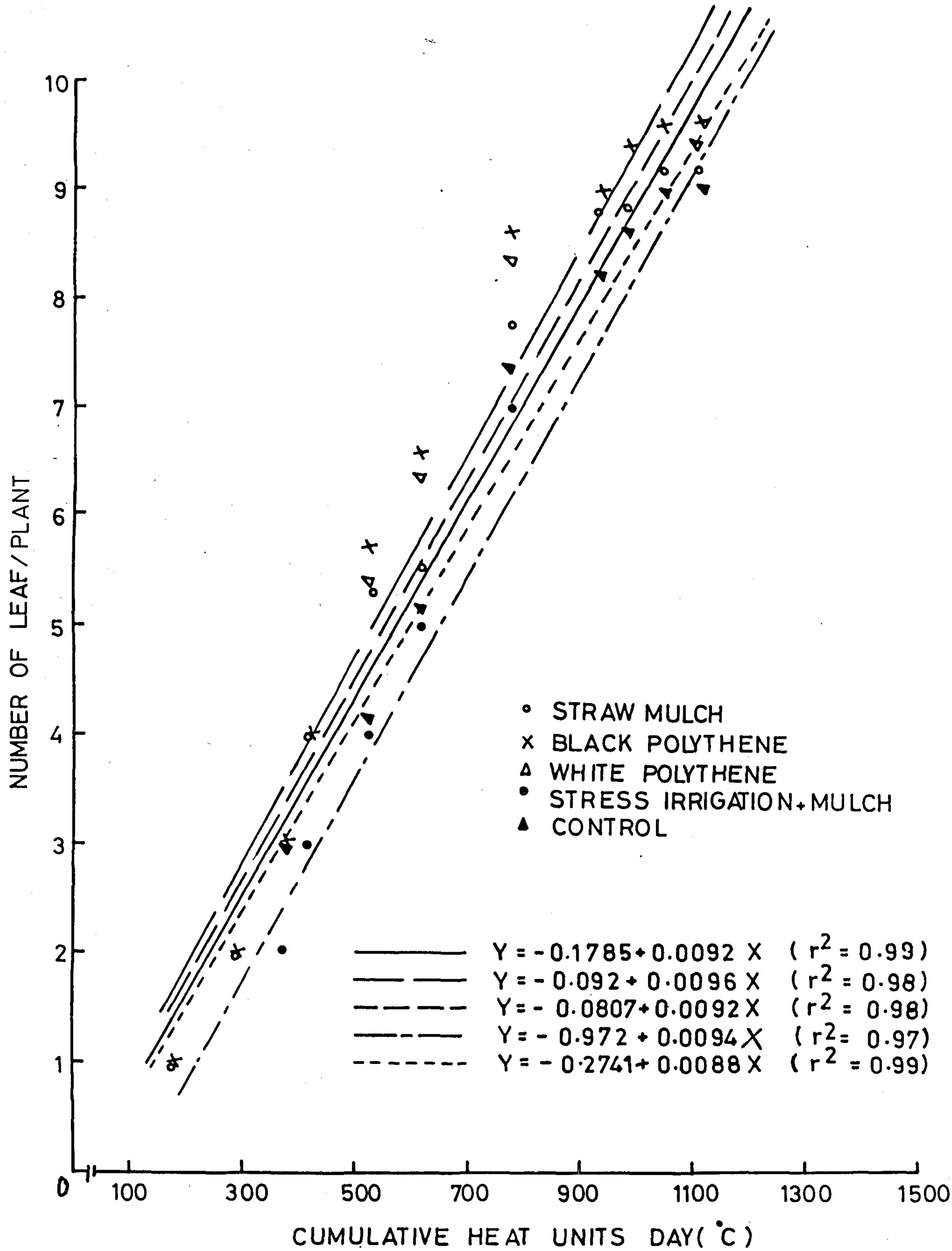


FIG. 9. RELATION BETWEEN LEAF EMERGENCE AND HEAT UNITS

and cumulated heat units. The regression equations for different treatments are presented in Figure 9 along the coefficient of determination which varied from 0.97 to 0.99. The Figure 9 shows that there is strong linear relationship between leaf emergence, and cumulative heat units. Since there is strong linear relation between leaf emergence and heat unit, it appears that in daylength donot influence emergence of leaves. It is largely effected by the temperature. However, effect of daylength has been observed in kharif and rabi crops. Similar results reported by Alagarswamy et al. (1977) in pearl millet crop. Number of leaves were higher in the T_2 treatment due to higher soil moisture availability, favourable micro climatic conditions and higher leaf area index. The higher leaf area index intercepted more PAR during crop growth and development which resulted in higher plant height, higher number of pods, flowers, buds per plant and more seed weight as compared to the other treatment. The higher number of buds, flowers per plant and thousand seed weight has significantly contributing in the higher yield of moong crop with the accumulation of higher leaf area index as higher radiation energy is intercepted for dry matter source which provides higher sink development.

4.2.3 Leaf emergence and cumulative soil temperature

The soil temperature at 5 cm depth was recorded at 07.30 and 14.30 hrs in all the treatments. The relation between leaf emergence and cumulative soil temperature is shown in Fig. 10. Maximum leaf

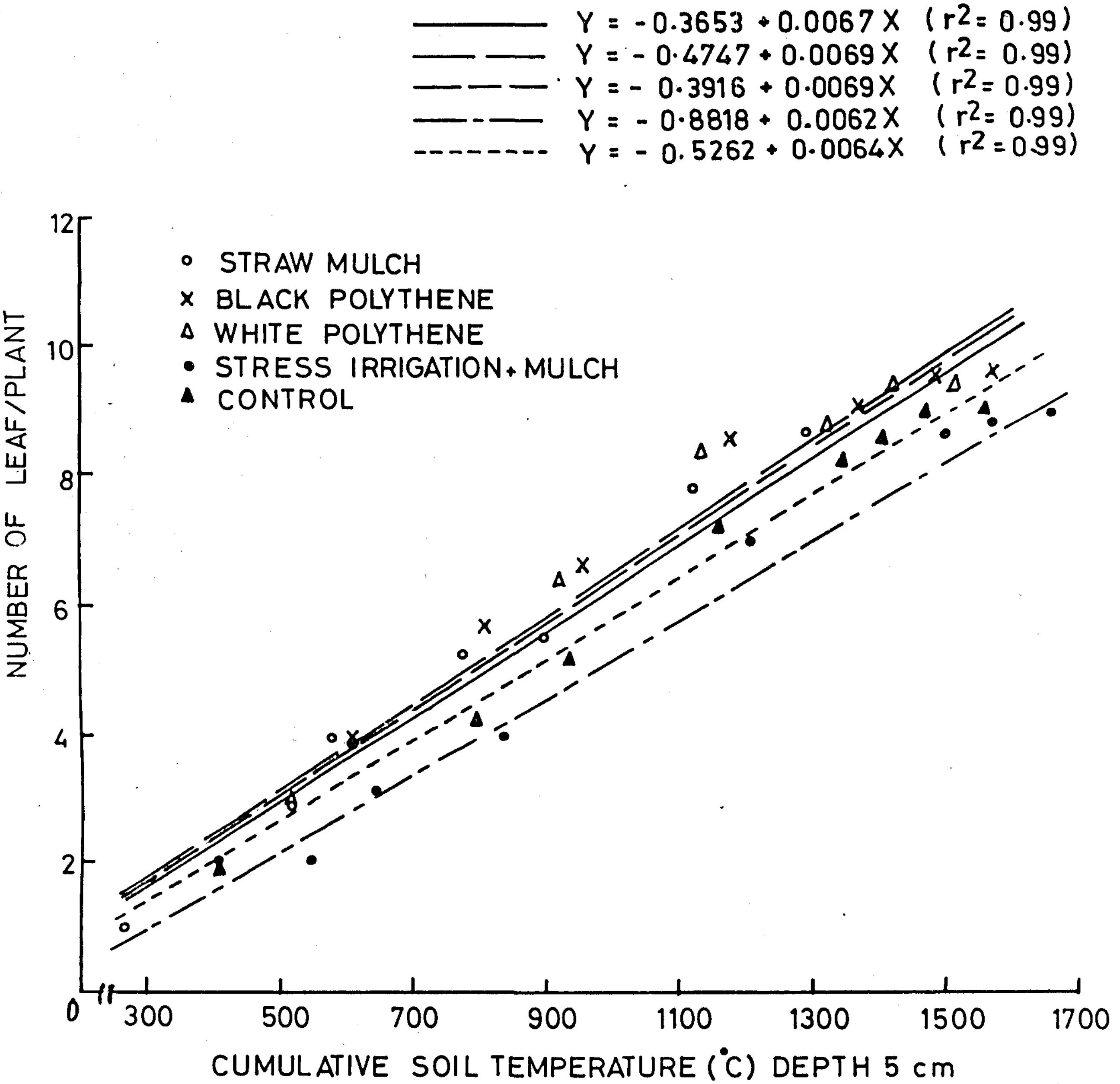


FIG.10. RELATION BETWEEN EMERGENCE OF LEAVES AND CUMULATIVE SOIL TEMPERATURE (5 cm)

number were recorded in T_2 treatment. Maximum cumulative soil temperature of 1661.3°C was observed in stress treatment. This may be true because of the less moisture availability.

Higher cumulative soil temperatures were observed under black polythene as compared to the other treatment. This may be due to more energy absorbed by black polythene sheet resultant in higher soil temperature in T_2 treatment. Similar results were reported by Clarkson (1960); Ghosh et al. (1983). However, in white polythene and straw mulch treatments, the reflected radiations were higher over the control plot resulting in the raduction of soil temperature reported by Ghosh et al. (1983) under rainfed pulse crops. The variation in soil temperature influenced the leaf emergence of moong crop.

A linear dependance of emergence of leaves with cumulative soil temperature was observed in all the treatments, however, there was saturation in the emergence of leaves at the cumulative soil temperature value of 1500°C (Fig. 10). The slight deviation from the linear dependance in different treatments Fig. 10 shows that there is dependance of day length in the emergence rate of leaves. Early emergence and more number of leaves noticed in T_2 treatment due to higher availability of moisture content and favourable micro meteorological conditions for growth and development of yield attributing characters.

More number of leaves resulted in higher leaf area index, higher dry matter production and better development of yield contributing characters. Gupta (1985) also reported that use of mulch increases the growth and yield of moong, moth and guar by one and a half times to two and a half times of control.

4.2.4 Leaf area index

Leaf area index was measured with the help of leaf area meter at weekly interval from 30 days after sowing upto maturity and is presented in Fig. 11. Among the different treatments leaf area index varied from 0.39 to 6.4. The maximum leaf area index was recorded around 53 days after sowing in all the treatments. The leaf area index values varied from treatment to treatment with the advancement of the crop. The increasing order of leaf area index was $T_2 > T_3 > T_1 > T_5 > T_4$. Due to stress condition in treatment T_4, the plants were not well developed as compared to the other treatments. The leaf area index was also less as compared to other treatments. Maximum leaf area index was recorded in T_2 treatment (black polythene) due to better growth and development of crop geometry under favourable micrometeorological parameter since higher soil moisture, radiation interception and reductions in soil temperature fluctuations. In the early phase (upto 30 days after sowing) of moong canopy developed very slowly and it has been not able to intercept most of the photosynthetic active radiation (PAR), however, from 30 days after sowing the canopy has developed quickly and attained maximum at 53 days after sowing and intercepted more than 80 per cent PAR. In the reproductive phenophase at 53 days

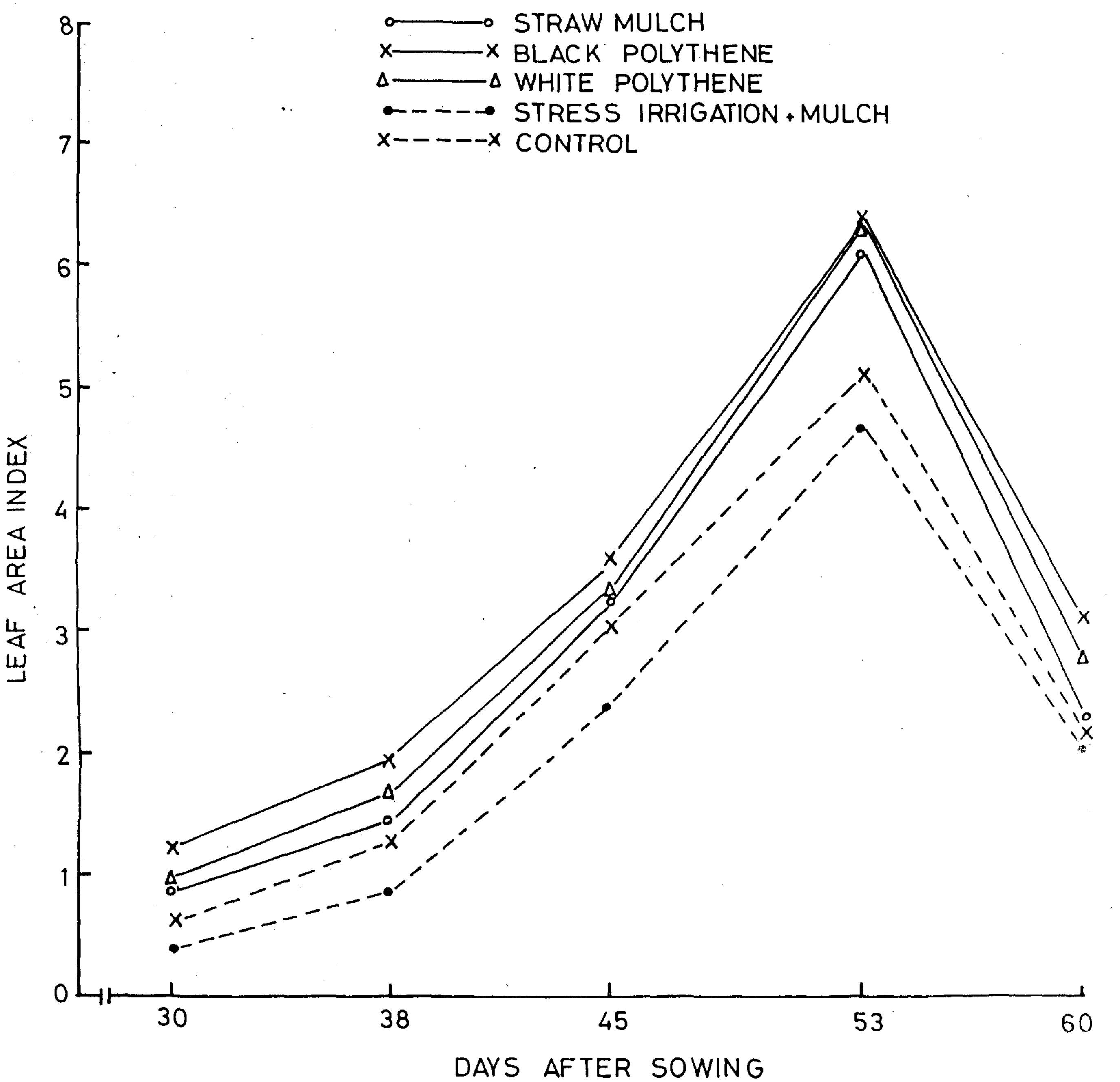


FIG. 11. INFLUENCE OF VARIOUS TREATMENTS ON LEAF AREA INDEX

after sowing, the reduction in leaf area index was observed due to shading of leaves. The higher leaf area index in T_2 treatment resulted in higher cumulative green matter due to higher PAR interception. The higher green matter generated provided source for higher plant height, higher number of pods, buds, flowers per plant and higher thousand seed weight as compared to the other treatments. Yield attributing characters were also positively effected with leaf area index values in different treatments. Chakravarty et al. (1986), Gupta and Rao (1989) and Kromer and Freese (1980) also reported that the mulching increased the height, and leaf area index of green gram and cowpea which contributed in higher yield attributing characters.

4.2.5 Dry matter

Dry matter observations were recorded at weekly interval with the use of five randomly sampled plants in each treatment. The dry matter production increased with the crop advancement upto 60 days after sowing and there after there was decrease in dry matter production (Fig. 12), however, due to shedding of leaves, it decreased in reproductive phenophase. Among the treatments higher dry matter production was recorded in T_2 treatment (black polythene) and lower in T_4 treatment (stress irrigation + mulch) (Fig. 12). The variation in dry matter production between the different treatments behaved in similar manner as to that of the leaf area index ($T_2 > T_3 > T_1 > T_5 > T_4$). T_2 and T_3 treatments produced highest dry matter production, leaf area index

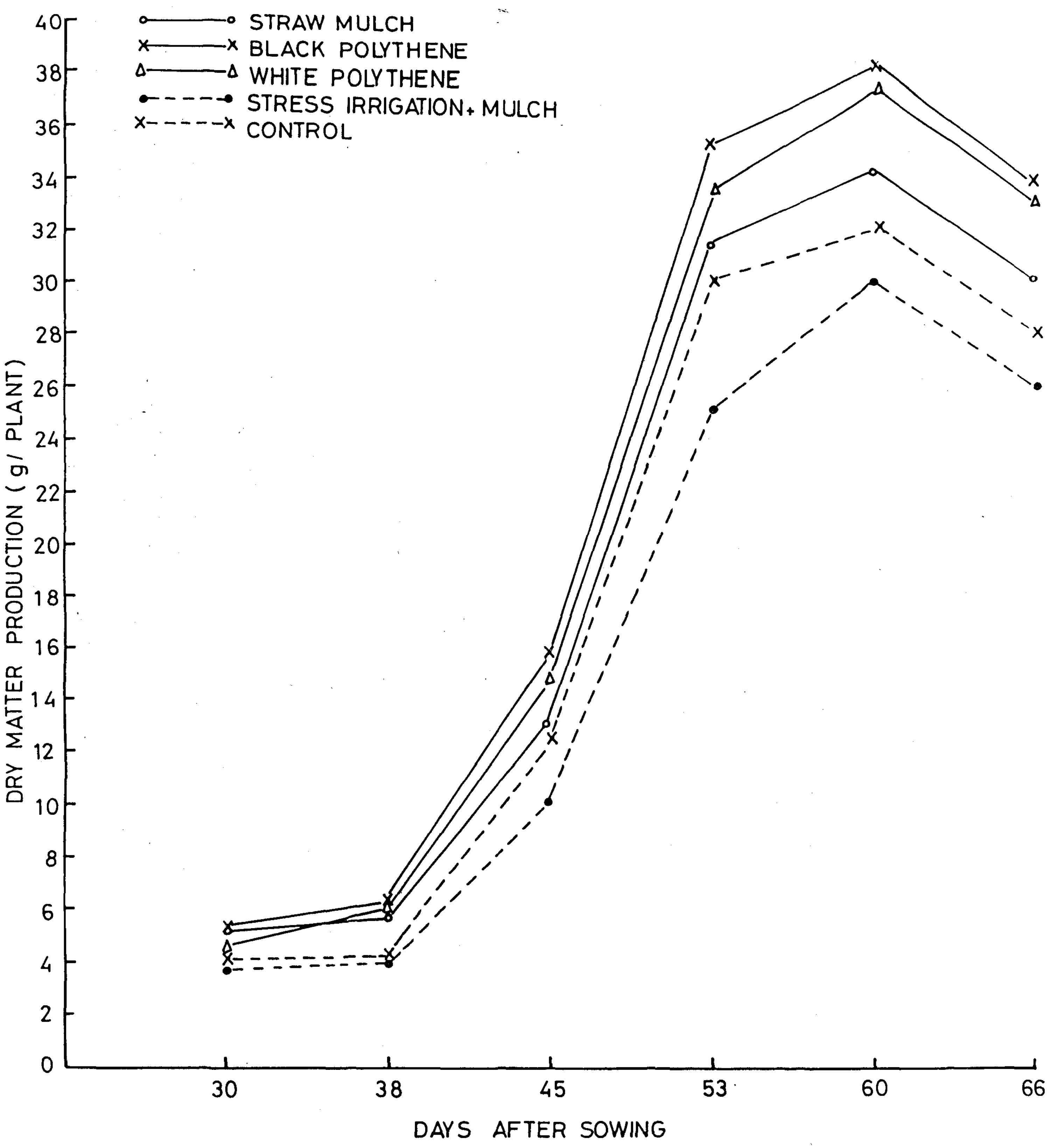


FIG.12. INFLUENCE OF VARIOUS TREATMENTS ON DRY MATTER PRODUCTION

as well as grain yield because of better radiation interception and higher efficiency of dry matter production under relatively better soil moisture regimes. Similar results were reported by Ghosh et al. (1983) is summer moong crop under rainfed conditions. The dry matter accumulation from 38 to 53 days after sowing was observed to behave in a linear response. However, 53 days after sowing it saturated attaining maxima. This accumulation of dry matter has been reported to be directly influenced with the interception of radiation by the foliage (as the canopy develops). The rapid increase during vegetative phase in the dry matter accumulation is a direct function of the intercepted photosynthetic active radiation as reported by Monteith (1970). The shedding and yellowing of leaves started when grain buds started to develop in the reproductive phenophase.

Higher dry matter production resulted in more number of pods per plant in T_2 treatment as compared to the other treatments. Gupta and Rao (1989), Zaman and Mallick (1988) also reported that mulching also significant increased yields although more so with straw than leaf mulch. Maximum yield of 1042 kg seed/ha, 503 kg dry matter/ha were obtained with two irrigations combined with 5 t/ha straw mulch. Yield of cowpea and egg plants, in terms of accumulation of dry matter was positively effected by mulching (Daisley et al., 1988).

4.3 Yield and yield attributes

Yield attributes Vs heat units

4.3.1 Buds

Number of buds on five tagged plants in each treatment were

Table 8 : Influence of various treatments as yield and its contributory parameters

Treatment	Plant height (cm)	No. of peak bud/ plant	No. of peak flowers/ plant	No. of pods/ plant	1000-seed weight (gms)	Max. Leaf area index	Max. Dry matter/ plant (gms)	Total dry matter product q/ha	Seed yield q/ha	Harvest index %
T_1	38.2	5.2	5.6	33.0	49.0	6.0	31.5	104.0	13.5	13.0
T_2	40.2	6.0	6.0	37.0	55.0	6.4	35.2	116.2	15.0	13.0
T_3	39.2	5.5	5.8	35.0	51.0	6.3	33.6	110.8	14.0	13.0
T_4	35.1	4.0	4.0	28.0	40.0	4.7	25.2	83.2	9.2	11.0
T_5	38.0	5.0	5.4	29.0	45.0	5.1	30.0	99.0	11.3	11.0
Mean	38.1	5.2	5.4	32.0	48.0	5.7	31.1	112.8	12.6	12.2
C.D. at 5% level SEm+	-	0.97 **	0.86 **	2.3 *	2.44 *	0.46 *	2.5 *	-	1.5 *	-

* = Significant

** = Non significant

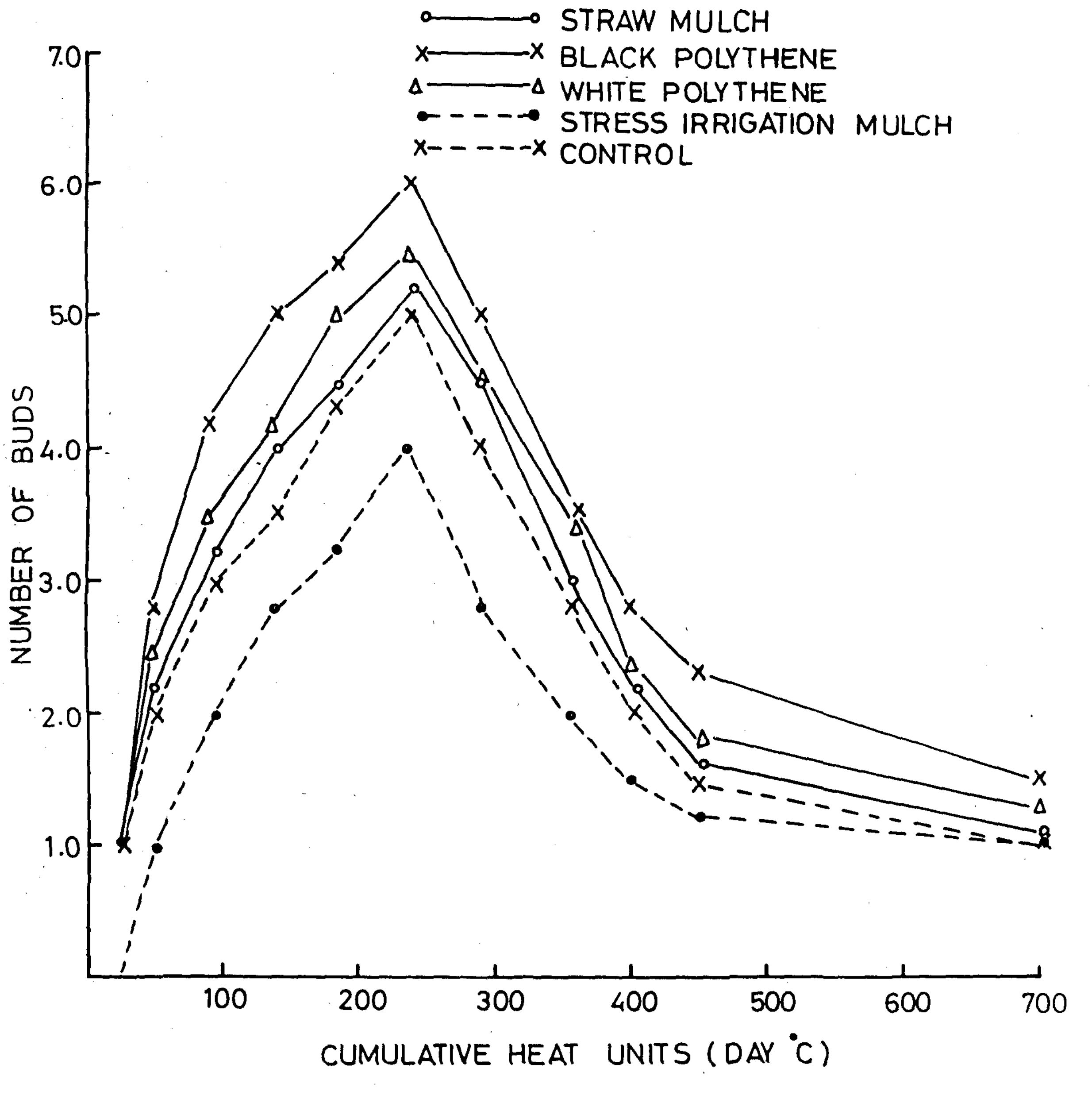


FIG.13. RELATION BETWEEN NUMBER OF BUDS AND HEAT UNITS (DAY °C)

counted at two days interval from bud initiation (38 days after sowing) to maturity and heat units were cumulated for this period (Fig. 13). Fig. shows that the number of buds are higher in T_2 treatment (black polythene) and less number of buds in T_4 treatment (stress irrigation + mulch). It was observed that with the consumption of 238.9 day °C heat units there were 6.0, 5.5, 5.2, 5.0 and 4.0 buds in T_2, T_3, T_1, T_5 and T_4 treatments, respectively. The number of buds were maximum around 238.9 day °C and there after buds decreased upto maturity. Maximum number of buds were recorded around 238.9 day °C in different treatments with relatively higher number of buds in T_2 treatment (black polythene) over others.

Mulches provided reduction in soil temperature fluctuations, conserved higher soil moisture and provided favourable microclimate. Radiation interception resulted in more buds per plant in T_2 treatment as compared to other treatments. Higher number of buds per plant resulted in higher flowers, pods per plant and higher moong yield. There was significant response of mulch regarding all the yield component of barley and lentil and number of capsules of linseed also reported by Mandal et al. (1989).

4.3.2 Flowers

The number of flowers for five tagged plants for all the treatments were recorded at two days interval from flower initiation (40 days after sowing) to maturity and heat units were cumulated for this period and

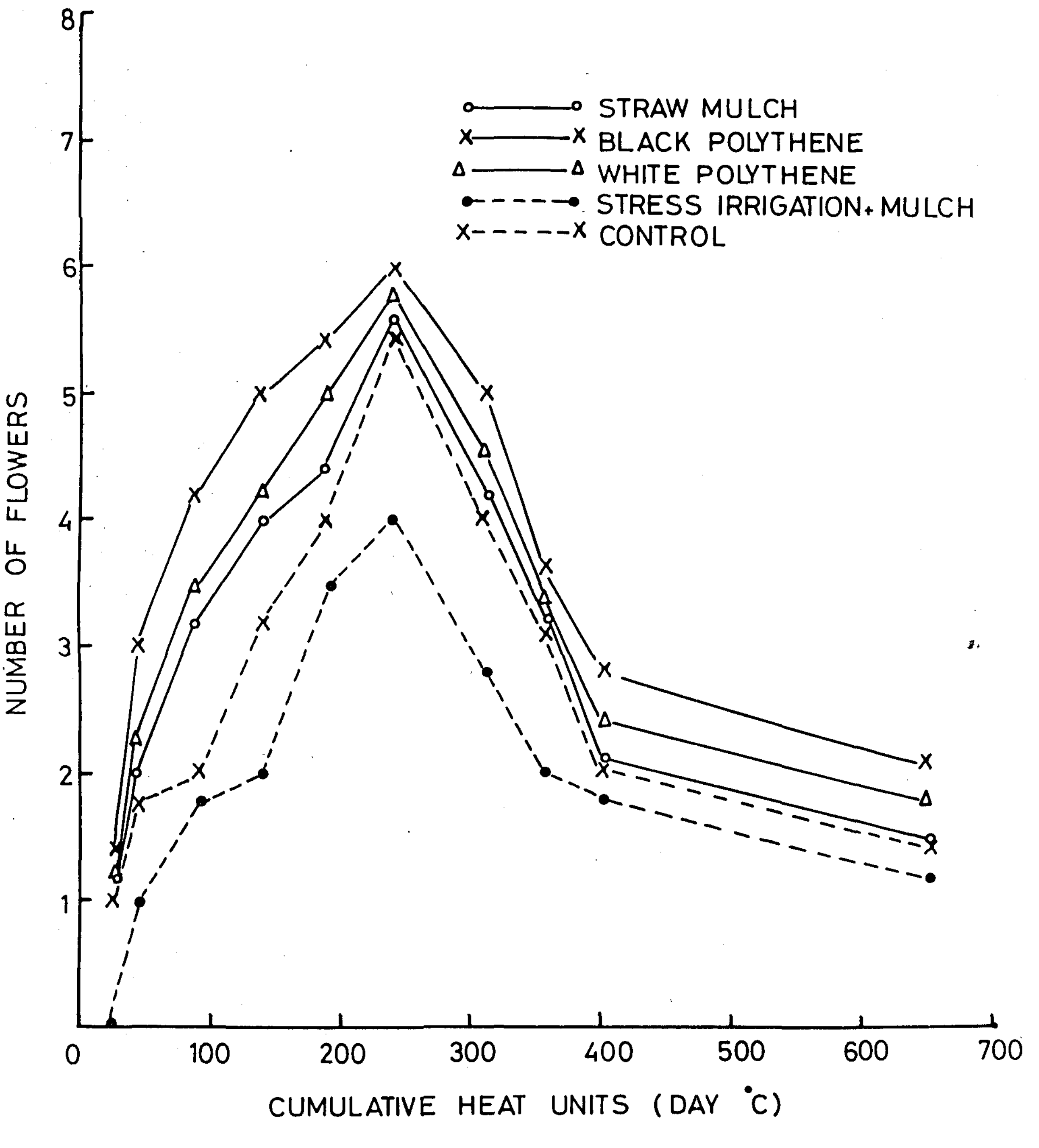


FIG.14. RELATION BETWEEN NUMBER OF FLOWERS AND CUMULATIVE HEAT UNITS (DAY °C)

presented in Fig. 14 which shows the relation between heat units and moong flowers. The number of flowers increased starting from 23.75 to 241.85 day °C in all the treatments. However, after that the number of flowers decreased upto maturity. The order of maximum number of flowers is (as follows) $T_2 > T_3 > T_1 > T_5 > T_4$. This may be due to maximum favourable microclimatic parameter i.e. temperature, radiation, evaporation prevailed in this order. At 241.85 day °C heat units the maximum number of flowers (6.0) recorded in T_2 treatment. T_2 mulch treatment resulted in higher number of flowers over the other treatments as soil moisture availability was higher over control and reduction in soil temperature fluctuations were achieved. The peak flowering was observed around 240 day °C in moong bean.

Due to favourable microclimatic parameters i.e. temperature radiation and conserved higher moisture content the higher number of flowers recorded in T_2 treatment resulted significantly increased in pods per plant and 1000-seed weight has significantly contributing in the higher gram yield of moong crop. Similar results were reported by Mandal et al. (1989).

4.3.3 Pods

The number of pods for five tagged plants for all the treatments at two days interval from pod initiation (42 days after sowing) to maturity and heat units were cumulated for this period. Fig. 15 shows the relation between heat unit and number of pods in summer moong. The maximum

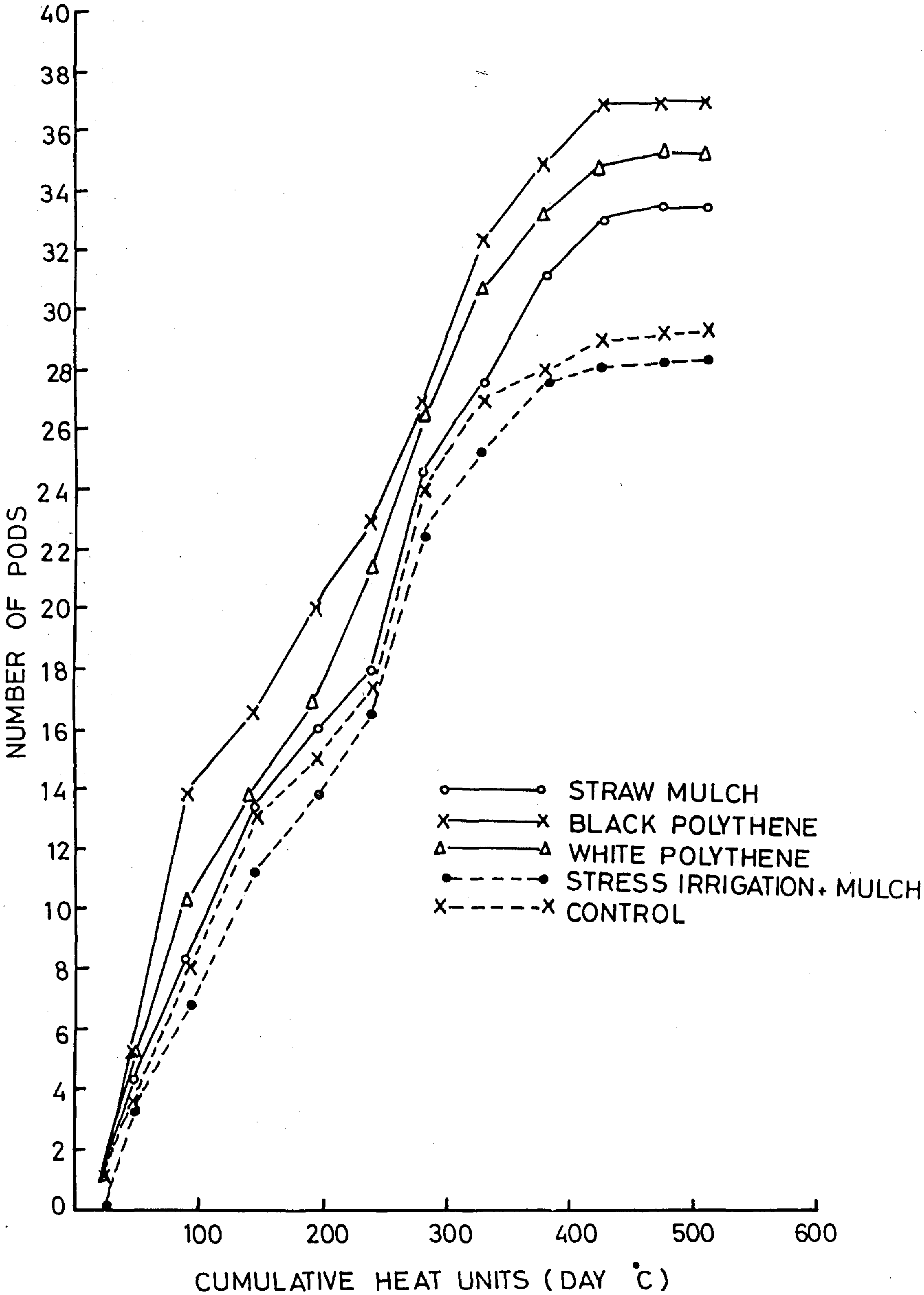


FIG.15. RELATION BETWEEN NUMBER OF POD AND CUMULATIVE HEAT UNITS (DAY °C)

number of pods (37.0) were observed in T_2 treatment at the consumption of 517.4 day °C heat units, however with the same heat units lesser number of pods (28.2) were observed in T_4 treatment. This may be due to mainly the higher leaf area and dry matter accumulation recorded in T_2 whereas, lesser leaf area and dry matter was available in T_4 as compared to T_2 treatment. The increasing trend of the number of pods similar to the flowers and buds was observed in different treatments. With the better availability of soil moisture in T_2 treatment over the other treatments resulted in better contribution in the yield attributes. With the cumulative higher dry matter in T_2 treatment the source resulted in relatively higher soils under the favourable microclimatic conditions under this mulch treatment. Due to favourable microclimatic parameters i.e. radiation, temperature and higher water content in T_2 treatment, the yield contributing parameters are significantly higher in T_2 treatment (Table 8). Number of pods per plant was higher, more test weight, more number of flowes and buds resulted in better yield. The seed pod yield of sesame increase upto 97 per cent and dry seed upto 72 per cent over control soil after mulching. Black film mulching was as effective as solarization for increasing the yield of sesame (Stapleton and Garza-lopez, 1988).

CHAPTER V

SUMMARY AND CONCLUSION

The research project on "A study on microclimate modification in summer moong with the use of mulches", was carried out at the research farm of the Department of Agricultural Meteorology, Haryana Agricultural University, Hisar during summer season 1990 with the following objectives :

1- To evaluate crop growth and microclimatic environment interaction for summer moong.

2- To test different methods for modification of microclimate and evaluate the sensitivity of the crop to stress conditions.

3- To determine suitable agrometeorological conditions for summer moong and effectivity of the micro environment modification technique.

4- To study the effect of modified microclimate parameter on yield and yield attributing parameters in summer moong.

The summer moong variety K 851 was sown on 9th April, 1990 after a pre-sowing irrigation. The experiment treatments were :

T_1 = Straw mulch (sarson straw 5 t/ha)

T_2 = Black polythene sheet mulch

T_3 = White polythene sheet mulch

T_4 = Stress irrigation + mulch

T_5 = Control

These treatments were compared in 12 m x 10 m plots in a randomized block design with 4 replications. In order to achieve crop establishment, three irrigations were given after sowing on 24.4.90, 3.5.90 and 26.5.90 in T_1, T_2, T_3 and T_5 treatments and one irrigation given on 26.5.90 in T_4 treatment (stress irrigation + mulch).

Micro-meteorological observations were taken at vegetative, flowering and maturity stages for albedo, solar radiation, net radiation, dry and wet bulb temperatures, vapor pressure, relative humidity. Soil temperature at 5 and 15 cm soil depths and canopy temperatures were regularly monitored. Soil moisture in the 0-90 cm profile was determined before and after irrigation during the crop season. Daily meteorological data on maximum and minimum temperatures, relative humidity, sunshine hours, wind direction, evaporation from open pan, and rainfall were taken from the meteorological observatory located about 50 m from the experimental field. The summary of results from the experimental study is presented in the following text.

The energy balance components showed similar trend in all the treatments, however, the magnitude of various values varied from treatment to treatment. LE was greater than A and G. LE was higher in T_2 treatment over the other treatments. In all the treatments more than 50 per cent of of Rs was available as net radiation further the net radiation was partitioned into three main components viz., LE, A and G and more than 70 per cent of Rn was utilized as evapotranspiration. It was also observed that the LE values varied from treatment to treatment as well as phenophase to phenophase.

However, it was higher in T_2 treatment at all the stages than other treatments. The LE and A were the main share holders of net energy. Out of the five experimental treatments, T_4 utilized less radiation in LE as well as G in comparison to the rest of the treatments. Further the major portion of net energy was used in LE, at three stages in all treatments and LE was in the order of $T_2 > T_3 > T_1 > T_5 > T_4$.

In the morning and evening hours, the reflected values were higher, whereas during noon-time, these were minimum. However, during morning and evening hours increase was recorded due to obliqueness of the sun-rays. The reflected values also varied over the treatments as well as stages. The highest values were obtained in T_3 treatment at all three stages. Lower reflected values were observed in T_2 treatment. In addition, the reflected values depends on the canopy characters such as leaf angle, thickness, colour and moisture of the leaf.

The trend of the absorption curves were same in all treatments from 30 days till maturity. Less absorption was recorded in the initial stage of the crop growth. The maximum absorption were recorded during 45 to 53 days after sowing when the maximum leaf area index was attained. The maximum absorption values were recorded in T_2 treatment among the five treatments, whereas, the lowest values were recorded in T_4 treatment. The order of values in different treatments were as $T_2 > T_3 > T_1 > T_5 > T_4$.

The transmitted radiation values recorded in experiment showed that the lowest transmission occurred at 45 days after sowing, while the maximum at initial stage of the crop. The order of the transmitted values recorded in this experiment were $T_4 > T_5 > T_1 > T_3 > T_2$.

No specific trend was observed in respect of albedo over different treatments. Highest values were recorded in T_3 and lowest in T_2. Soil temperature variations were higher at 5 cm soil depth as compared to the 15 cm soil depths. In straw and white polythene treatments (T_1 and T_3) a reduction in soil temperature was observed throughout the crop season in comparison of control.

From such observation, it appears that mulches in these two treatments reflected more solar radiation as compared to the control treatment. Also the net sensible heat generated over the straw and white polythene mulched treatments was less as compared to the control treatments resulting in lower soil temperature. On the other side, in black polythene mulched treatment an increase in the soil temperature at both the soil depths was observed. It appears that black polythene absorbed more radiation and generated higher sensible heat as compared to the control treatment, thus resulting in higher soil temperatures.

During summer season (April to June) of 1990 North West, West and South westerly winds were the dominating wind directions at Hisar which are majorly dry. Therefore, the crops in this season needs to be protected through adoption of appropriate agricultural management. The mulching treatments were applied between rows so that surface resistance was affected to the flow of dry winds and resulted in break down of the wind eddies inside the crop canopy.

The water stressed treatment T_4 showed the highest canopy temperature whereas, lowest canopy temperature were recorded in T_2 treatment as compared to the other treatments. However, the differences of the crop canopy temperature between T_2 and T_4 treatments when scanned over the crop season it was highest (1.7°C) at 64 days after sowing and lowest (0.8°C) at 58 and 61 days after sowing. The canopy temperature was higher in T_4 treatment indicating that the plants were under stress and lower in T_2 treatment indicating sufficient moisture availability. Tc-Ta was higher in T_2 treatment as compared to T_4 treatment throughout the growing season indicating to the fact that the plants were never at stress in T_2.

In all the mulched treatments, except T_3, the lower side of leaf was at a higher temperature than the upper side which is probably due to sensible heat affect during the summer season, and more transpiration from upper side of leaves than the lower one. However, the difference recorded between the lower and upper side of the leaf temperatures was higher on the 2nd June than the values recorded on 12th June. Among the different treatments, the diffusive resistance was higher in T_1 and T_2 treatments, but on 12th June diffiusive resistance was higher in T_2 treatment only. It was lowest in T_5 and T_1 treatments in the 12th June observations. It was observed that the diffusive resistance increased with the increase in leaf temperature under stress conditions, the leaf temperature was higher which directly increased the diffusive resistance in the leaves. The decrease in leaf temperature occurred with the increase in transpiration rate, this resulting in decreased diffusive resistance values. The treatments which showed lower diffusive resistance values presented higher transpiration rate and vice-versa.

Maximum water was consumed (56.4 cm) in T_5 (control) treatment whereas, lowest (33.1 cm) was utilized in T_4 treatment. Though the water use was higher in T_5 treatment but the water use efficiency was lowest. Water use efficiency was highest in T_2 treatment.

There is a strong linear relationship between cumulative heat units and plant heights. 89 to 92 per cent of variations in plant height was explained by cumulative heat units in different treatments. The highest R2 values were recorded in T_5 treatment. Maximum plant height (40.2 cm) and minimum (35.1 cm) was recorded in treatments. T_2 and T_4, respectively. With the heat unit concept, using base temperature of 10°C it is possible to develop a relation between increasing height with growing season.

With accumulated heat unit of 1112 day °C 9.6 leaves were emerged in T_2 treatment, 9.4 in T_3, 9.2 in T_1 and 9.0 in T_3 and T_4 treatments.

There is a strong linear relationship between leaf emergence and cumulative heat units. Number of leaves were higher in the T_2 treatment. Early emergence and more number of leaves was noticed in T_2 treatment due to higher availability of moisture content.

Among the different treatments leaf area index varied from 0.39 to 6.4. The maximum leaf area index was recorded around 53 days after sowing in all the treatments.

The trend of leaf area index among different treatments was T_2 $T_3 > T_1 > T_5 > T_4$. The dry matter production increased with the advancement in crop age upto 60 days after sowing and thereafter, there was no change in dry matter production. Among the treatments highest dry matter production was recorded in T_2 treatment and lowest in T_4 treatment. The dry matter production in different treatments behaved in a similar manner as to the one observed for leaf area index ($T_2 > T_3 > T_1 > T_5 > T_4$). The dry matter accumulation from 38 to 53 days after sowing was observed to behave in a linear response. However, after 53 days after sowing it saturated, attaining maxima.

The number of buds, flowers and pods per plant were higher in T_2 treatment and lesser number of buds, flowers and pods per plant in T_4 treatment. It was observed that with the consumption of 238.91 day °C heat units there were 6.0, 5.5, 5.2, 5.0 and 4.0 buds in T_2, T_3, T_1, T_5 ant T_4 treatments, respectively.

The number of buds were maximum around 238.91 day °C and thereafter bud appearance decreased towards maturity. Maximum number of buds were recorded around 250 days °C in different treatments with relatively higher number of buds in T_2 treatment over others. The number of flowers increased, starting from 23.75 to 241.85 day °C in all the treatments. However, after this the number of flowers decreased as the crop advanced towards maturity. The order of maximum number of flowers is as follows $T_2 > T_3 > T_1 > T_5 > T_4$. At 241.85 day °C heat units the maximum number of flowers (6.0) recorded in T_2 treatment. The maximum number of pods (37.0) were observed in T_2 treatment at the consumption of 517.41 day °C heat units. However, with the same heat units lesser number of pods (28.2) were observed in T_4 treatment. The increasing trend of the number of pods was similar to the flowers and buds in different treatments.

Though no specific conclusion can be drawn based on one year data, still the black polythene mulching did altered the microclimate favourably and resulted in improved growth and development of summer moong. The black polythene mulching helped in significant improvement in the yield and yield characteristics of the crop. The water use efficiency was also maximum with the use of black polythene mulch. The study may be broad based by making it multi-locationary (with different soil types) and be conducted for three consecutive seasons at least to draw specific conclusions.

During the vegetative stage the mean air temperature, relative humidity, wind speed and cunsumptive use were 29.8°c, 39.2 percent, 7.4 Km/hr and 20.2 Cm respectively. At flowring stage the mean air temperature, relative humidity, wind speed and cunsumptive use were 34.1°c, 23.[illegible] percent, [illegible]1.3 Km/hr and 11.5 Cm respectively. At Pod formation stage the mean air temperature, relative humidity wind speed and cunsumptive use were 32.7°c, 30.7 percent, 7.6. Km/hr and 8.5 Cm respectively. And at maturity stage the mean air temperature, relative humidity, wind speed and cunsumptive use were 32.8°c, 35.4 percent, 9.7 Km/hr and 8.6 Cm respectively. There micrometeorological parameters were most favourable for the growth and development of summer moong under the climatic conditions of Hisar. These may be considered optimum microclimatic conditions for summer moong.

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