CROP-WEATHER RELATIONS IN MAIZE (*Zea mays* L.) UNDER DIFFERENT SOWING WINDOWS AND PLANTING GEOMETRY IN NORTHERN TRANSITION ZONE OF KARNATAKA

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CERTIFICATE

This is to certify that the thesis entitled "CROP-WEATHER RELATIONS IN MAIZE (*Zea mays* L.) UNDER DIFFERENT SOWING WINDOWS AND PLANTING GEOMETRY IN NORTHERN TRANSITION ZONE OF KARNATAKA" submitted by Mr. ANNAPPA Y. HUGAR for the degree of DOCTOR OF PHILOSOPHY in AGRONOMY to the University of Agricultural Sciences, Dharwad is a record of research work carried out by him during the period of his study in this University, under my guidance and supervision, and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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1. INTRODUCTION

Maize (*Zea mays* L) is one of the most versatile crops of the world, having wider adaptability under varied agro-climatic conditions. Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. It is cultivated on nearly 150 m ha in about 160 countries having wide diversity of soil, climate, biodiversity and management practices that contributes 36 per cent (782 m t) in the global grain production. USA is the largest producer of maize contributing nearly 35 per cent of the total production in the world and maize is the driver of the US economy. USA has the highest productivity (> 9.6 t ha^{-1}) which is double the global average (4.92 t ha^{-1}), whereas, area under maize production in India, is about 8.67 m ha.and produces about 22.26 m t with the average productivity of about 2.57 t ha^{-1} (Anon., 2014a).

Maize is the third most important cereal crop species in the world after rice and wheat and is grown across a wide range of climates, but mainly in the warmer temperate regions and humid subtropics. Maize has multiple uses, including for human foods, animal feeds and the manufacture of pharmaceutical and industrial products. It is the staple food source for people in many countries. As an animal feed, it is highly desirable because of the high energy and feed value of the kernel, leaf and stem. It can be used to produce starch, ethanol and plastics and as a base for antibiotic production. Over the past 40 years the total global sown to maize area has increased by about 40 per cent and production has doubled.

In India, maize is grown on a wide range of environments, extending from extreme semi-arid to sub-humid and humid regions. The crop is also very popular in the low- and mid-hill areas of the western and northeastern regions. Broadly, maize cultivation can be classified into two production environments: (1) traditional maize growing areas, including Bihar, Madhya Pradesh, Rajasthan and Uttar Pradesh and (2) non-traditional maize areas, including Karnataka and Andhra Pradesh. In traditional areas, the crop is often grown in marginal eco-regions, primarily as a subsistence crop to meet food needs. In contrast, maize in the non-traditional areas is grown for commercial purposes *i.e.*, mainly to meet the feed requirements of the booming poultry and dairy sector.

Maize in India is grown in diverse environments–from the dry area of Chitradurga, Karnataka, to the warm, wet plateau of Chindwara, Madhya Pradesh. Since maize is largely grown under rainfed conditions during the rainy season, the crop is sown after the onset of the monsoon. Sowing time ranges from the first fortnight of June to the first fortnight of July, depending upon the onset of the monsoon.Maize productivity during the winter season is higher than during the rainy season. During winter, maize enjoys a favourable environment of cooler temperatures, clear sky and higher solar radiation, is less affected by insect-pests and thereby yields better (Joshi *et al.*, 2005).

In India, maize is emerging as third most important cereal crop after rice and wheat. Corn production has nearly doubled from around 12.0 mt. in the early 2000s to around 24 mt. today. This remarkable production growth has been largely driven by adoption of single cross hybrids in the late 1980's and continuous demand in domestic and export market. The increasing use of maize as feed, increasing interest of the consumers in nutritionally enriched products and rising demand for maize seed are the core driving forces behind emerging importance of maize crop in India. However, despite the production strength, Indian corn yields are significantly below the yields in major corn producing countries. There is immense scope for an increase in India's corn production by increasing area under hybrids, adoption of better genetics and improved agronomic practices. Maize, being a day neutral plant, is grown throughout the year in India. It is predominantly a *kharif* crop with 85 per cent of the area under cultivation in the season. It accounts for ~9 per cent of total food grain production in the country.

Maize production in India has grown at a growth rate of 5.5 per cent over the last ten years from 14 mt in 2004-05 to 23 mt in 2013-14. Factors such as adaptability to diverse agro-climatic conditions, lower labour costs and lowering of water table in the rice belt of India have contributed to the increase in acreage. Introduction of Single cross hybrid (SCH) seeds coupled with adequate rainfall contributed to 20 per cent increase in yield. Maize production is dominated by Andhra Pradesh and Karnataka, producing ~38 per cent of India's maize. Nine states *viz.* Karnataka, Andhra Pradesh, Tamil Nadu, Rajasthan, Maharashtra, Bihar, Uttar Pradesh, Madhya Pradesh and Gujarat account for 85 per cent of India's maize production and 80 per cent of area under cultivation. The differences in yield across the globe are mainly due to environmental, technological, economic and organizational factors. In most developed countries the climate is temperate; also they use more inputs and had a well mechanized system for the maize production (Anon., 2014b).

Both temperature and incident solar radiation quantitatively influence the variation in potential maize yield across environments. The primary influence of temperature is on growth duration.Under favourable growing conditions, biomass accumulation is directly proportional to the amount of radiation intercepted and for a given harvest index, grain yield is directly proportional to biomass. Consequently, high maize yield is associated with low temperature and higher solar radiation. The yield potential of maize cultivars with 18 leaves growing in tropical environments is lower than in temperate environments, despite high levels of solar radiation. In the tropics, higher temperature is the dominant influence markedly decreasing the duration of crop growth (Muchow *et al*., 1990). Since Reaumur first introduced the concept of heat units or thermal time in 1730, many methods for calculating thermal time have been used successfully in agricultural sciences (McMaster and Wilhelm, 1997).

The accumulation of biomass by crops results from the amount of incident photosynthetically active radiation (PAR) intercepted by the canopy and from the efficiency with which the intercepted PAR is converted into dry matter. The terms intercepted radiation and absorbed radiation are often used interchangeably in literature, but distinction has been made between the two terms by Asrar *et al.* (1984). Intercepted radiation does not explicitly consider radiation absorption. Although photons must be intercepted before they can be absorbed, some are scattered (reflected or transmitted). However, Gallo and Daughtry (1986) observed that the differences between IPAR and APAR were less than 3.5 per cent from planting until just before physiological maturity of corn.

The variation in planting dates and plant geometry, row spacing and plant density modifies the microclimate to which the plants are exposed and it is responsible for biomass production and ultimately the yield. Therefore, it is necessary to understand the knowledge of plant environment interaction for increasing yield of crop. Optimum time of sowing is one of the important factors which provide score for better utilization of natural resources by the crop during its growth to take full advantage of favourable weather conditions during growing season.

Planting date was reported to affect the growth and yield of maize significantly. To date, the challenge for maize growers is finding the narrow window between planting too early and planting too late (Nielson *et al.*, 2002). Either early planting or late planting can result in lower yield because the probability exists that unfavourable climatic conditions can occur after planting or during the growing season. Norwood (2001) suggested that farmers should plant on more than one planting date in order to safeguard against unpredicted seasons. The vulnerability of maize to adverse climatic change has become an important issue and therefore, a research priority. What should be done to mitigate the effects of uncertain weather and erratic rainfall remains a challenge and question to researchers and farmers countrywide.

Optimum time of sowing is one of the important factors which provide scope for better utilization of natural resources by the crop during its growing season. Suitable time of sowing enables the crop to take full advantage of favourable weather conditions during growing seasons. Studies have shown that, delay in sowing of maize beyond July results in yield reduction. In the event of late onset of monsoon rains and erratic rainfall farmers are forced to take-up sowing late *i.e.*, beyond 15th July even extended to the end of August month. Shift in sowing date directly influence both thermo- and photoperiod and consequently a great bearing on the phasic development and partitioning of dry matter (Leelarani *et al.*, 2013).

Perhaps the most determinant cultural practice, from the 1930's to present, is increasing the density at which hybrid maize is planted. Over the past 50 years, the density at which maize was planted, in the U. S. Corn Belt, has increased at an average rate of 1000 plants ha^{-1} yr^{-1} (Duvick, 2005). Compared with older hybrids, modern hybrids respond more favourably to high plant densities due to higher leaf area index (LAI) at silking, which results in more interception of photosynthetically active radiation and more dry matter accumulation during vegetative development (Tollenaar and Aguilera, 1992). Decreasing the distance between neighbour rows at any particular plant population has several potential advantages. First, it reduces competition among plants within rows for light, water and nutrients due to a more equidistant plant arrangement (Olson and Sander, 1988; Porter *et al.*, 1997). Secondly, the maximization of light interception derived from early canopy closure also reduces light transmittance through the canopy (McLachlan *et al.*, 1993). Also, smaller amount of sun light striking the ground, decreases the potential for weed interference, especially for shade intolerant species (Teasdale, 1995). Thirdly, the quicker shading of soil surface during early part of the season results in less water being lost by evaporation (Karlen and Camp, 1985).

In northern transitional zone of Karnataka maize is best suited to use the natural resources more efficiently. Maize yields are higher when sown with the onset of monsoon. However, during recent years after the onset of monsoon, rains are delayed with dry spells leading to delayed sowing resulting in poor growth and yield. Planting pattern is another agronomic practice that optimizes the use of other resources. Phenological development of crop closely follows the changes in weather conditions occurring during crop growing period. So, a detailed study of crop phenological events in maize would provide a base for understanding different growth and developmental processes as related to weather parameters. The crop geometry and sowing time lead to changes in the crop microclimate which has a direct influence on the plant growth and development and resource utilization. Hence, there is a need to assess the microclimatic modifications in the maize as influenced by different planting geometry under different growing environment.

Keeping above factors in view, the present experiment is designed to study the crop weather relationships (interactions) in maize under different growing environments and planting geometry with the following objectives:

1. To study the influence of various weather parameters on crop phenology, growth and development of maize under different growing environment and planting geometry.

2. To study the microclimatic variations in maize under different growing environment and planting geometry.

3. To workout the economics.

2. REVIEW OF LITERATURE

The literature on studies of microclimate *viz.*, soil temperature, canopy temperature, photosynthetically active radiation (PAR), light and other weather parameters and the variation under different growing environments, row spacing, planting densities and planting geometry and also the crop interactions with the environmental factors are given as follows under different headings as below :

2.1 Influence of different weather parameters on crop phenology, growth, development, yield and yield attributes.

2.2 Influence of different growing environments (sowing time) on maize crop phenology, growth, development, yield and yield attributes.

2.3 Influence of different row spacing, plant density and crop geometry on crop phenology, growth, development, yield and yield attributes.

2.4 Interaction effect of sowing time and density/spacing on crop phenology, growth, development, yield and yield attributes.

2.1 Influence of different weather parameters on crop phenology, growth, development, yield and yield attributes

The crop growth response is influenced largely by the micro-climate in the crop canopy. Micro-climate in the crop varies from top of the canopy to the soil surface and affects crop development and yield. Various environmental factors influencing growth are, interception of photosynthetically active radiation, air and leaf temperature, relative humidity, prevailing wind speed, CO_2 concentration and soil moisture availability. Temperature and light play a key role in influencing crop production.Occurrence of different phenological events during crop growth period in relation to temperature can be estimated by using accumulated heat units or growing degree days (Gouri *et al.*, 2005). Thermal time is an independent variable to describe plant development (Dwyer and Stewart, 1986). It can be used as a tool for characterizing thermal responses in different crops. Knowledge of accumulated GDD can provide an estimate of harvest date as well as crop development stage (Ketring and Wheles, 1989; and Bonhomme, 2000).

2.1.1 Soil temperature, leaf temperature and canopy temperature

a) Soil temperature

Soil temperature is crucial during the seed germination. Alessi and Power (1971) stated that corn seeds will not germinate if the soil temperature is lower than 10 ^{0}C. Bollero *et al.* (1996) showed that lower early season soil temperature (15 ^{0}C) increased leaf area of the lower canopy whereas at 25 ^{0}C, the upper canopy was larger. Larger upper canopies tend to enhance higher grain yields since top leaves intercept most of the radiation and translocate to the ear during grain filling (Simmonds and Jones, 1985).

Soil temperature strongly affects the rate of corn growth until the sixth leaf stage when the growing point emerges above ground level (Hanway, 1982; Coelho and Dale, 1980). Coelho and Dale (1980) indicated that the number of soil GDD from planting until the sixth leaf stage was also constant and was approximately four times the sum from planting until emergence. Warrington and Kanemasu (1983) found a linear increase in leaf appearance rate as mean temperatures increased from 15 to 28 ^{0}C which supports the propose constancy of GDD from planting to sixth leaf.

When the apical meristem is underground early in crops life cycle, it is perhaps more correct to assume that development rate responds to soil temperature at meristem depth. Correspondingly, it has been shown that soil temperature affects dates of emergence (Hayhoe and Dwyer, 1990; Hayhoe *et al.*, 1996). Leaf elongation rates were almost exclusively determined by mean soil temperature (R^2>0.85) (Giauffret *et al.*, 1995).

Local environmental factors play an important role in good crop establishment. For instance, a combination of a warm soil temperature (20–30 ^{0}C), soil moisture at or above field capacity and a soil aggregate distribution with a geometric mean diameter between 1.0 and 6.8 mm, has been reported as favourable for rapid maize emergence. On the other hand, a combination of a low soil temperature (<12.5 ^{0}C) and high soil water content can cause poor maize stand establishment (Dwyer *et al.*, 1999).

Stone *et al.* (1999) studied the effect of soil temperature on maize phenology, canopy development, biomass and yield. Soil temperature controlled the rate of development while the meristem was underground, which was until six fully expanded leaves had appeared. Biomass and yield increased by 21 per cent between the coolest and warmest soil temperature treatments. This occurred because increased soil temperature accelerated the rates of leaf tip appearance and full leaf expansion, enabling the crop to more rapidly attain maximum green leaf area index. This enabled a better synchrony between time of peak radiation interception and peak radiation incidence. During time of decreasing photoperiod, this enabled crops grown in warmer soil to intercept more radiation and to accumulate more biomass and yield. The extent to which soil temperature affects yield will therefore vary with sowing time and latitude of growth location.

During the autotrophic phase of germination, plant energy is directly affected by soil temperature (Stone, 2001). In maize, seedling growth is maximized at a soil temperature of 26^{o} C and above this temperature, root and shoot mass both decline by 10 % for each degree increase until 35 ^{0}C when growth is severely retarded. Reduced seedling growth has been suggested to be associated with poor reserve mobilization, with reduced protein synthesis observed in seedlings grown under elevated temperatures (Riley, 1957). Seedlings growing in high soil temperatures are likely to suffer further damage as the associated slower growth rate delays canopy closure, consequently reducing soil shading.

b) Leaf temperature

Leaf temperature is an easily measured physiological parameter, which allows an indirect way to estimate plant transpiration and it is well correlated with water availability.

It is well known from energy balance considerations that leaf temperature varies with evaporation from leaves and hence is a function of stomata conductance. Pallas *et al.* (1967) pointed out that leaf temperature was usually positively correlated with the light intensity and negatively correlated with transpiration and soil water. Leaf temperatures of plants under low soil water potential at the same radiant energy levels 4 hours prior to irrigation were 3.4, 1.3 and 0.5 above the ambient air temperature. However, leaf temperature does not bear a fixed relationship with air temperature. Net radiation, air movement and the humidity of the air all affect leaf temperature and it is therefore necessary to measure it in order to fully understand the plant response to the given environment.

Gates (1968) explained that environment is connected with a leaf through the flow of energy and the interaction of environment with a plant. Energy delivered to the plant is converted to heat within the plant, affecting the plant temperature, or energy is consumed through photochemical and thermo-chemical events of the metabolic and physiological processes.

Takechi (1973) has done detailed studies on leaf temperature. According to his studies, the difference between leaf temperature and air temperature depends on leaf absorption of solar radiation and transpiration. It is assumed that soybean leaves transpired more than corn leaves in the case of strong solar radiation. Jackson *et al.* (1977) stated that for many plants when that plant is transpiring fully, the leaf temperature is 1 – 4 ^{0}C below air temperature.

Leaf temperature is dependent on environmental factors such as air temperature, humidity, wind speed and incident radiation, as well as stomatal aperture, many attempts have been made to normalize the data to account for environmental variation. The first normalization for environmental variation was in terms of air temperature (*T*a), achieved by accumulating differences between leaf temperature (*T* leaf) and *T*a as a measure of plant stress (Jackson *et al.*, 1977). Further normalisation was achieved by Idso *et al.* (1981) who developed the 'crop water stress index' (CWSI), which relates the observed temperature to the temperature of non-stressed and non-transpiring crops under the same environmental conditions; by noting the ambient humidity at the same time, effects of humidity variation could also be corrected. Jackson (1982) reported that plant temperature was generally lower than ambient air temperature and canopy temperature in the stress treatment, most likely because of the cooling effects of transpiration.

In general, water stress causes stomata closure in plants and this leads to higher leaf temperature (Sdoodee and Kaewkong, 2006). Leaf temperature is a physiological trait that can be used for monitoring plant water status (Jimenez-Bello *et al.*, 2011).

c) Canopy temperature

Crop canopy temperature is an indicator of the vegetal response to environmental factors that can stress the plants. Inadequate soil water stresses the plant, causing the plant to transpire at a rate less than the evaporative demand of the atmosphere. The water passing through the leaf surface through transpiration cools the leaves. As water becomes limiting, transpiration decreases and leaf temperature increases.

Canopy temperature is a satisfactory index of water stress because greater transpiration rates result in cooler leaf temperatures. In contrast, when evapo transpiration from the leaf is restricted, the absorbed radiation can warm the leaf above the air temperature instead of evaporating water (Tanner, 1968).

2.1.2 Soil moisture

Zaidi *et al.* (2004) found that excess soil moisture during early stages severely affected growth of maize, which eventually resulted in poor kernel development and yield. Khoshvaghti *et al.* (2013) indicated that plant height, cob leaf area, tassel weight and thereby grain yield per ha were decreased under water limitation at grain filling stage. As water stress occurred in reproductive stage, leaf number per plant, stem diameter and cob diameter were not significant. As stem diameter during water stress was not declined, this indicates that remobilization of assimilate was not occurred in this condition.

2.1.3 Crop phenology, growing degree day, heat units and thermal requirements

Since 1730 when Reaumur introduced the concept of heat units, or thermal time, many methods of calculating heat units have been used successfully in the agricultural sciences. Particularly in the areas of crop phenology and development, the concept of heat units has vastly improved description and prediction of phenological events compared to other approaches such as time of the year or number of days (Bootsma, 1977). The heat unit system was adopted for determining the maturity dates of different crops from which accurate yield and maturity prediction could be assessed.

Temperature also affects the duration of crop growth (Allison, 1979) and hence the maximum time that the incident radiation can be intercepted. Of particular importance is the length of the grain filling period since the dry matter accumulated in the grain in maize is largely from dry matter that the crop accumulates after flowering.

It has been shown that the duration of grain filling is decreased with increasing temperature and that the shorter grain filling period is often associated with lower grain yield (Hunter *et al*., 1977; Badu-Apraku *et al*., 1983).

The phyllochron may be different when constant versus alternating day/night temperatures are used, despite similar mean temperatures, especially when part of the day is at extreme high or low temperature (Warrington and Kanemasu, 1983). For field grown hybrid maize, the phyllochron ranges between 36 and 52 degree days (base 8 ^{0}C) per leaf tip (Birch *et al*., 1998 and Vinocur and Richie, 2001), however, values between 37 and 42 GDD are most frequent. Some of the variation among studies may be due to whether soil or air temperature was used (Vinocur and Ritchie, 2001).

Though maize is a day neutral plant, the flowering and maturity of its varieties are however, dependent to available temperature and sunshine hours and it is location specific (Rao *et al*., 1999). Accumulated heat is the most important environmental factor to the growth rate of the maize plant (McMaster and Wilhelm, 1997). According to Schulze *et al.* (1997), 1500 to 1700 GDD are required for growing maize for grain, but can vary according to cultivar.

The plant cannot develop from one stage to another without receiving the necessary heat units. Hence, the knowledge on the calculation of the heat summation unit (HSU), mostly called the growing degree days (GDD) and their further mathematical derivations like helio-thermal; unit (HTU), pheno-thermal index (PTI) and heat use efficiency (HUE) will be the basic principles to understand the phenology and follow the proper planting times for different crop varieties over the spatial and temporal variations (Rajput, 1980 and Sreenivas *et al*., 2010).

Narcico *et al.* (1992) gave GDD requirements for different phenological phases and different maize hybrid classes using a base temperature of 8 to 9 ^{0}C. Early maturing hybrids required 620-625 and 1200-1330 ^{0}C days from sowing to flowering and from sowing to ripening, respectively. Whereas, medium to late maturing hybrids required 730-740 and 1420 ^{0}C days from sowing to flowering and from sowing to ripening, respectively.

The effect of temperature on development rate has been described using a thermal time concept, such as the growing degree day (GDD) which assumes that phenological development is constant per degree of temperature between a base temperature (TMINL) and an upper threshold temperature (TMAXL) above and below which the development rate is zero. The simplicity of the GDD and its improvement over a day count for prediction of development has led to its widespread adoption, particularly for the vegetative period (planting to silking). Estimates of TMINL for the vegetative period range from 10 ^{0}C (Brown and Bootsma, 1993), to 8 ^{0}C (Ritchie and Nesmith, 1991) to 6 ^{0}C (Derieux and Bonhomme, 1982). Estimates of TMAXL for the same period range from 19 to 34 ^{0}C (Ellis *et al.*, 1992; Ritchie and Nesmith, 1991 and Tollenaar *et al.*, 1979).

Tollenaar (1990) reported that the phyllochron is relatively constant when expressed in thermal units during the leaf growth phase *i.e.*, the period from sowing to the appearance of the topmost leaf. In most cases the phyllochron is unique for each hybrid and it is assumed to be constant and independent of the temperature of the region. The phyllochron for maize differs greatly among tropical, warm temperatue and cool temperature latitudinal zones. According to Kiniry and Bonhomme (1991), the phyllochron is 30 per cent higher for tropical than for temperate areas. However, many researchers have found that the phyllochron is not constant for maize and other species, but is dependent upon environmental conditions during the vegetative phase (McMaster and Wilhelm, 1997; Jame *et al.*, 1999). The growth phases of any variety of crops are determined basically with growing season in which the atmospheric ambient temperature and solar radiation are the major governing factors. Several researchers have shown the influence of temperature on phenology and yield of crops and expressed it under field conditions through accumulated heat unit system (Bishnoi *et al.*, 1995).

Birch *et al.* (1998) observed that the thermal interval for leaf tip appearance (phyllochron) is critical for predicting the duration of vegetative development. The phyllochron in maize is shorter in temperate than in tropical and sub-tropical environments. Temperature was the dominance influence, with phyllochron increasing by 1.7 ^{o}Cd per ^{o}C increase in daily mean temperature as daily mean temperature before tassel initiation increased from 12.5 to 25.5 ^{o}C and declined or remained constant when mean daily temperature before tassel initiation exceeded 25.5 ^{o}C. Only small differences in phyllochron occurred among cultivars. Phyllochron increased by 2 to 4 ^oC d per MJ photosynthetically active radiation (PAR) as irradiance decreased from 9.6 to 1.1 MJ PAR per m^2 per day.

Nielsen *et al.* (2002) revealed that in dent corn in US corn belt, thermal time from planting to R_1 decreased an average of 34 GDDs for June versus early May plantings, while the grain fill period (R_1 to R_6) decreased an additional 110 GDDs with late plantings. Total accumulated GDDs from planting to R_6 decreased 10 per cent or about 144 GDDs for corn planted in early June compared to early May. When considering early May versus early June plantings, the average linear response to delayed planting were 3.8 fewer GDDs per day of delayed planting.

The maize plant can be regarded as a starch factory. The plant utilizes water and nutrients from the soil, carbon dioxide from the atmosphere and solar radiation as the energy source to manufacture plant food of which starch is the main component. In this process heat in the atmosphere play an essential role in determining the final yield and quality of the grain (Pannar, 2002).

Plants have a definite temperature requirement before they attain certain phenological stage and to forecast the phenology and crop production attributes for a large acreage, there has been the development of crop models (Jones *et al.*, 2003). According to Zheng *et al.* (2005) in China, maize requires specific temperature and day length in various developmental stages for successful growth and yield. From sowing to emergence 12, 25 and 31 ^0C minimum, optimum and maximum temperature, respectively; from emergence to tasselling 14.8, 24 and 33 ^0C minimum, optimum and maximum temperature, respectively and 12.5 hours of day length; from tasselling to silking 14.9, 28 and 33 ^0C minimum, optimum and maximum temperature, respectively and 12.5 hours of day length; and from silking to maturing 12.7, 25 and 33 ^0C minimum, optimum and maximum temperature, respectively and 12.5 hours of day length.

Tojo Soler *et al.* (2005) at Brazil, observed that the value for the phyllochron was about 50 GDD per leaf until approximately the appearance of the 12th leaf and then declined. The phyllochron, along with timing of floral initiation may influence time to flowering, as all unemerged leaves present at time of floral initiation must fully develop before flowering can occur. Identifying genetic variation within maize for the phyllochron may improve its response to its environment (Padilla and Otegui, 2005).

Capristo *et al.* (2007) reported that the duration of the cycle from emergence to flowering varied from 537 to 781 GDD and from emergence to physiological maturity from 1221 to 1656 GDD. Cumulative biomass from emergence to flowering increased linearly with hybrid cycle length. Long season hybrids showed the highest cumulative interception but the lowest radiation use efficiency (RUE) during reproductive growth. Total above ground biomass increased from 1624 to 2422 g m^{-2} with hybrid maturity class and grain yields were lowest for short season hybrids (832 g m^{-2}) and similarly between mid and long-season hybrids (avg. 1256 g m^{-2}). Increases in maturity class were associated with increase in grain number (from 2432 to 5078 grains m^{-2}) and reduction in individual grain growth rate (from 9.1 to 4.9 mg grain day^{-1}).

The life cycle of individual maize leaves (*i.e.* from leaf tip appearance to physiological maturity) has been intensely measured in a fully irrigated field maize crop at Lincoln. Canterbury, New Zealand. A maximum LAI of approximately 4.5 was achieved at final leaf expansion. The thermal time requirement for leaf appearance (phyllochron) was constant after the 4th leaf position at 46 GDD per leaf. Total leaf expansion, characterized by the appearance of leaf ligules, showed a bi-linear pattern at a rate of 65 GDD per leaf until the 7th leaf position and 26^0 C d per leaf after that. The rate of senescence onset was 13.5 GDD per leaf until the 7th leaf position and 25 GDD per leaf after that. Finally, the rate of complete senescence was 11.5 GDD per leaf until the 7th leaf. This pattern of differential leaf expansion and senescence for individual leaf positions explained the progression of LAI senescence in two distinct phases. The first phase, from final leaf expansion until approximately the onset of senescence in the 7th leaf, showed a slow rate of LAI decline with negligible changes in light interception. After that, LAI declined at approximately 0.08 per cent per day causing a steep reduction in light interception (Teixeira *et al.*, 2011).

Vegetative and reproductive development of maize is delayed or hastened at elevated temperature depending upon the time of crop emergence throughout the year.

When, sowing and crop emergence take place early in spring season (September and October) and late in summer (January and February), the vegetative and reproductive development of maize are hastened whereas when sowing and crop emergence take place in the warmest period of the year (November and December), vegetative and reproductive of maize are delayed under elevated temperature scenarios (Streck *et al.*, 2012).

Accurate prediction of phenological development in maize (*Zea mays* L.) is fundamental to determining crop adaptation and yield potential. Temperature increase can impact crop production in a number of ways, but arguably the most important of these is the impact of temperature on crop phenology. The importance of phenology for crop productivity is well understood. The phenology of a crop will determine its adaptation to a region, its ability to mature and set grain within a growing season and the synchrony of key developmental phases with ambient environmental conditions critical for productivity (Kumudini *et al.*, 2014).

2.1.4 Solar radiation, photosynthetically active radiation (PAR), radiation use efficiency

Both photoperiod and temperature can influence the timing of developmental events in maize (Tollenaar *et al.*, 1979 and Warrington and Kanemasu, 1983) with considerable genetic differences in sensitivity to photoperiod (Hunter *et al.*, 1977; and Kiniry *et al.*, 1983). While temperature probably affects the durations of all successive stages of development, it is generally assumed that photoperiod sensitivity ends at TI (Kiniry and Bonhomme, 1991). Significant effects of the photoperiod experienced shortly after TI on subsequent developmental times have been detected. However, these effects can probably be ignored in the field, because they are essentially negated by a carryover effect of photoperiod before TI on post-TI developmental times (Ellis *et al.*, 1992). Consequently, it is acceptable to limit observations to the period from sowing until TI when investigating the effects of photoperiod on maize development.

The relationship between crop growth rate and absorbed irradiance is consistent with the linear response of the leaf carbon (C) exchange rate to absorbed irradiance at low incident radiation. At high irradiance, however, the response of the leaf C exchange rate to absorbed irradiance deviates from linearity as the leaf photosynthetic rate becomes light saturated. Although the photosynthetic rate of individual leaves in a canopy of field-grown maize is likely to become light saturated occasionally during periods of high irradiance, the accumulated net canopy photosynthetic rate (*i.e.*, crop growth rate) over extended periods of time appears to be linearly related to intercepted radiation. For instance, Williams *et al.* (1965) reported that crop growth rates over a 12-d period continued to increase with an increase in light interception by maize canopies up to 100 % of an average incident global radiation of 30.8 MJ m^{-2} d^{-1}.

Williams *et al.* (1965) and Biscoe and Gallagher (1977), Monteith (1977) showed that dry matter production early in the season is related to the amount of radiation intercepted by the crop. The interception of PPFD by maize reached the highest level between 50 and 60 days after planting when the LAI was at its maximum. Afterwards, with leaf senescence, the LAI dropped and the PPFD interception decreased (Sivakumar and Viramani, 1984).

Bonhomme *et al.* (1994) at France, reported a linear response of dry matter accumulation of three maize hybrids to accumulated absorbed photosynthetically active radiation (PAR) during the growing season. Absorptance of PAR by crop canopies can be calculated from concurrent measurements of incident PAR, PAR reflectance and PAR transmittance. Absorptance, reflectance and transmittance are the fractions of the incident /lux that are absorbed, reflected and transmitted, respectively (McCree, 1981). Various studies have recently been published on the absorptance of PAR by crop canopies (Sivakumar and Virmani, 1984; Gallo and Daughtry, 1986), although measurements in most studies have been restricted to a period near solar noon.

Crop dry matter production, in the absence of other limiting factors is determined by the absorption of photosynthetically active radiation (PAR) by a crop canopy and the efficiency with which absorbed PAR is converted into dry matter. Conversion efficiency was estimated from rates of above ground matter accumulation and PAR absorption from approximately 2 wk before to 6 wk after silking. PAR absorption was estimated from continuous measurements of incident part PAR reflectance and PAR transmittance. Crop growth rates declined during the phase of development under study due to a decline in incident PAR and a decline in conversion efficiency from 5.8 to 3.5 %; PAR absorptance was approximately 89 % and remained fairly stable (Tollenaar and Bruulsema, 1988).

Differences in dry matter accumulation among crop cultivars can be attributed to differences in either the absorptance of incident photosynthetically active radiation (PAR) and/or the conversion of absorbed PAR into dry matter (Tollenaar and Aguilera, 1992). Increased dry matter accumulation may be attributable either to increased absorbance of incident photosynthetically active radiation (PAR) and/or improved efficiency of converting absorbed PAR into dry matter. Some evidence suggests that recent hybrids absorb more of the seasonal incident PAR than older hybrids. Maximum LAI for more recent hybrids in Ontario is larger than for older ones (Tollenaar, 1991) and leaves of recent hybrids stay green longer during the final phase of the life cycle (Tollenaar, 1991). In contrast, no conclusive evidence has been reported that the efficiency of converting absorbed PAR into dry matter has increased. Maximum leaf photosynthetic rates did not differ among old and new hybrids (Dwyer and Tollenaar, 1989), but photosynthetic rates appeared to decline more rapidly for old hybrids following a low night temperature (Dwyer and Tollenaar, 1989).

Variability within a crop species in the amount of dry mass produced per unit intercepted solar radiation or radiation use efficiency (RUE) is important for the quantification of plant productivity. RUE is easily measured in field experiments and is used to quantify plant growth. It is used to integrate leaf area, solar radiation interception and productivity per unit leaf area into crop productivity. Differences in dry matter accumulation among crop cultivars can be attributed to differences in either the absorption of incident photosynthetically active radiation (PAR) and/or the conversion of absorbed PAR into dry matter (Tollenaar and Aguilera 1992). Linearity has been found between CO_2 assimilation of canopies integrated over one day (daily assimilation) and daily absorbed or intercepted PAR, implying constant photosynthetic RUE on a daily basis (Sinclair and Muchow 1999).

Increased dry matter accumulation of new maize hybrids after silking can be attributed, in a large part, to increased radiation use efficiency. Drought stress reduces the efficiency with which absorbed PAR is used by the crop to produce new dry matter (RUE) (Earl and Davis, 2003). This can be detected as a decrease in the amount of crop dry matter accumulated per unit of PAR absorbed over a given period of time (Stone *et al.*, 2001) or as a reduction in the instantaneous whole-canopy net CO_2 exchange rate per unit absorbed PAR (Jones *et al.*, 1984). Slow development of maize (*Zea mays* L.) canopies may limit light interception and potential productivity (Westgate *et al.*, 1997). There are numerous reports of lower RUE after silking (Major *et al.*, 1991).

Both the amount of radiation incident on the crop and the proportion of this radiation that is intercepted are important determinants of maize yield. Leaf canopy development as influenced by ambient temperature determines the leaf area index of the crop and thereby determines the proportion of the incident radiation which is intercepted (Muchow and Carberry, 1989). Muchow and Davis (1988) and Cirilo and Andrade (1994) reported that maximum RUE occurs during vegetative growth and declines during grain filling. Similarly, Otegui *et al.* (1995) estimated the season long RUE as 3.39 g per MJ IPAR but calculated a large value during vegetative development (41.4 g/MJ IPAR).

Most of the plant biomass originates directly from photosynthesis, the process in which photon energy is converted to chemical energy. Photosynthesis is the only natural conversion mechanism of photon energy into chemical energy and it is responsible for 90 to 95 per cent of the plant biomass accumulation (Gomez *et al.*, 2005). The crop photosynthetic rate of plant is dependent on the absorption of photosynthetically active radiation (PAR), by the leaves as well as the green and actively growing plant parts that contain chlorophyll pigments. Thus, the photosynthesis rate of plant is a function of canopy architecture as defined in terms of area and distribution of leaf, leaf angle, leaf surface characteristics, as well as intensity of photosynthetically active radiation. However, the response of plant to PAR is the genetic character of the plant species regulated by number of biophysical factors like temperature humidity, concentration of CO_2 *etc.*

The incoming radiation that is absorbed in a given crop layer after reflecting from the canopy or proceeding towards the soil becomes the energy source of the heating process (sensible heat flux) and evapotranspiration (latent energy flux). If there is no water restriction, evapotranspiration is the main energy consumer of the plant stand (Kocsis and Anda, 2012).

2.2 Influence of different growing environments (sowing time) on maize

Of all the management aspects (cultivar selection, plant density, amount and timing of fertilizers *etc.*) of growing a maize crop, planting date is an important aspect and is probably subject to variation due to differences in weather at planting time between seasons and within the range of climates (Otegui *et al.*, 1995). The year-to-year variation in plant establishment, pest and disease incidence makes it difficult to predict optimum planting dates for maize crop (Oktem *et al.*, 2000). In practice, recommended dates are normally drawn up from the results of long-running series of agronomic experiments, which can give mean planting dates for highest yield together with realistic estimates of expected yield penalties for each week of delay in planting (Lauer *et al.*, 1999). However, in accepting such guidelines, several reservations must be appreciated in addition to the fact that use of the recommended date is not a guarantee of highest yield under growing season (Oktem *et al.*, 2000).

The literature available on effect of sowing date on maize was reviewed and described as under by using various headings as follows.

2.2.1 Crop phenology and heat unit requirement

Maize phenology is generally divided into vegetative (from emergence to tasselling according to the number of fully expanded leaves, n, designated by V_n) and reproduction (from silking to physiological maturity according to the degree of kernel development, designated by R_n) stages (Ritchie *et al.*, 1992). Within these stages, several transitions are important in term of management by producers (i) crop emergence (date of onset of photosynthetic activity) termed (VE) (ii) tasselling tassels emerge, termed (VT) and (iii) initiation of senescence (Date at which green leaf visibly begins to decrease). Adverse conditions during the grain filling period affect the size of kernels that can eventually be harvested. It is obviously important to be aware of the time of tasseling and also to identify stress induced abnormalities during the period of rapid leaf expansion (V_6 to V_{14}) so that corrective measures can be considered (Vina *et al.*, 2004).

Estimates of thermal time required for grain filling (period between silking and maturity) vary considerably, however, with the GDD system frequently overestimating thermal time required for grain filling. A better understanding of the phenological response of maize to thermal time as planting is delayed is necessary to improve the accuracy of maturity time of hybrid for late planting situations (Berger, 1969). Sutton and Stucker (1974) opined that a thermal interval between plantings and black layer decreased as planting was delayed from early to late planting. Thus late plantings reduced cumulative intercepted photosynthetically active radiation (PAR) from silking to physiological maturity mainly because of their low values of daily incident radiation (Tollenaar and Aguilera, 1992).

Krishnasamy and Ramaswamy (1987) elucidated the correlations between weather elements (maximum and minimum temperature, relative humidity, hours to bright sunshine, amount of rainfall and number of rainy days) and number of days to panicle initiation and from panicle initiation to 50 per cent flowering in four different hybrids of sorghum. They reported negative correlation between minimum temperature and days to panicle initiation in MS 2077A and a positive correlation between maximum temperature and days to panicle initiation in CS 3541. Similarly, afternoon relative humidity exhibited negative correlation with panicle initiation in MS 2077A while positive relationship was noticed in CS 3541. From these reports they concluded that the extent of synchronization of flowering was dependent on the degree of level of interaction between the varieties and the environmental factors considered.

Temperature and light are the major factors regulating phenological response, thus most responses focus on the thermal time accumulation, day length and vernalization. The growing degree days (GDDs) requirement of maize cultivars showed variation with sowing dates depending upon temperature during each growth phase and also the cultivar (Singh *et al.*, 1990).

Genotypic variation in flowering in the most inductive regimes (a mean pre-flowering temperature of 24.3 ^{0}C for the medium- and 20.8 ^{0}C for the late-maturing genotypes, combined with a mean pre-flowering photoperiod of 12.6 and 12.8 h d^{-1}) ranged from 70 and 76 days and from 85 to 112 days, respectively. There were no photoperiodic effects on flowering over the range from 12.6 to 13.1 h d^{-1}, but the artificially extended day delayed flowering, especially in the late-maturing genotypes (Omanga, 1994).

It was noted that the time to flowering and the duration of growth was strongly influenced for climatic adaptation and yield potential of crop plants. Similarly, delayed sowing in *kharif* and summer season reduced days to tasseling, silking and duration of crop and also the grain yield (Lenka, 1998). Berzsenyi, *et al.* (1998) found that delay in sowing reduced the number of days from sowing to seedling emergence from 6 to 5 days. The leaf emergence was found rapid in delayed sowing and occurred early up to 54 days after emergence as against 61 days after emergence in normal condition than with early planting. Silking and seed black layer formation occurred significantly in fewer GDDs as planting was delayed from early May to early June (Neilsen *et al.*, 2002).

Daynard and Duncan (1972) found that delayed planting increased the thermal time interval from planting to mid-silking but decreased the thermal interval between mid-silking and black layer formation. The period between emergence and anthesis of maize hybrids planted earlier in the season can be up to two weeks longer than when the same cultivar is planted later (Sangoi, 1993).

Stewart, *et al.* (1997) reported that delayed planting increased growing degree days (GDDs) to black layers for three hybrids in a drought year but decreased GDDs to black layer for the same three hybrids in the following year under less stressful conditions. According to the Canadian studies, the GDDs system provides a reliable estimate of thermal time required for vegetative (interval between planting and silking) development. Early planting tends to place the tasseling and silking period ahead of the greatest risk of moisture stress and drought damage (Otegui and Melon, 1997).

Tollenaar and Bruulsema (1988) found that the time from silking to physiological maturity lengthened with delay in planting dates because cool temperatures prevailed late in the season of the late planted crops which prevented true maturity since grains never formed a true black layer. During this extra period, plants will uptake more solar radiation and store the energy because the lower temperatures limit their growth and consumption of this energy. As a result of this slower pattern of development, early-planted maize plants are smaller and less leafy at anthesis (Sangoi and Salvador, 1998b and Silva *et al.*, 1998).

Maize leaf tip appearance dates and leaf numbers were observed on four sowing dates to provide variations in the thermal regime of developing plants. Solar irradiance and temperature of the air (1.5 m height), apex and soil (1-, 3-1 and 5- cm depths) were recorded on 0-5 h (half hourly) intervals. The daily average soil temperature at the 3- to 5- cm depth was reasonably close (+0.6 ^{0}C in average) to the daily average apex temperature for use as a surrogate for apex temperature to increase the accuracy of maize development simulation in the sowing to ninth leaf tip stage. Thereafter, the air temperature was sufficiently accurate to estimate plant development. Using apex temperatures from leaf 3 to 9, this study indicated that the phyllochron was near 55 ^{0}C day per leaf tip appearance. The consistent bias between air and apex temperature from sowing to V_6 found in this study clearly indicates the necessity of using the right temperature in thermal calculations for accurate maize development simulations (Vincour and Ritchie, 2001).

Delayed planting shortens the effective growing season for corn (*Zea mays* L.) increasing the risk of exposure to lethal cold temperatures late in the season before grain maturation. Consequently, growers often must decide whether to switch to early maturity hybrids to minimize this risk. The objective of the study was to determine whether delayed planting influenced the growing degree day (GDD) ratings of silking and kernel back-layer (BL) development of corn. The effects of delayed planting on the phenological response of three corn hybrid maturities common to the eastern US Corn Belt were investigated at four locations in Indian and Ohio over 4 years. Thermal time from planting to silk emergence decreased on an average by 34 GDDs for June Vs. early May plantings while the grain fill period decreased an additional 110 GDDs with late plantings. The total decrease in GDDs from planting to BL was 144 GDDs for corn planted in early June compared with early May, equal to linear response to delayed planting of 3.8 fewer GDDs per day of delayed planting. The three hybrids responded differently to delayed planting with greater GDD decreases occurring with late maturity hybrid. Linear rates of GDD decrease with delayed planting ranged from 4.5 to 3.2 GDDs per day of delayed planting for late and early maturity hybrids, respectively. Delayed planting decreases the GDD requirements of corn hybrids, resulting in less risk to grain maturation for adapted hybrid maturities from late-season killing freezes than previously thought (Thomison and Nielson, 2002).

Cicchino *et al.* (2010) reported that heat stress delayed silking and caused a decline in the developmental rate (DR). Interestingly, heating also delayed anthesis and increased the occurrence of male-sterile plants, a condition rarely reported in this species. The relative impact of stressful temperatures was captured by the stress index (SI). Computed SIs indicated that each degree above optimum temperature (TO) was amplified in terms of hourly temperature records (TTh) and translated into a delay of at least 2.1 ^{0}C h to silking (on a base temperature of 12.7 ^{0}C), a response that has been never determined previously in field conditions.

Kushwaha *et al.* (2010) at Pantnagar, observed that minimum significant GDD accumulation at various growth stages at P3 sowing date. It was 67.70, 874.2, 982.5 and 1566.3 at emergence, 75 per cent tasseling, 75 per cent silking and at maturity respectively. Minimum significant GDD accumulation as affected by nitrogen level was observed at N2 level (938.6) for 75 per cent tasseling at N3 level (1055.7) for 75 per cent silking and 1624.23 at N2 level upto maturity. The result sowed that minimum GDD accumulation was maximum significant (1067.2) at 75 per cent silking at S_2 spacing and was 1628.8 at S_1 spacing for 75 per cent tasseling.

At Rampur Chitwan, Nepal during the winter season of 2009-10. The results indicated that the number of days required to attain different phenological stages were short for the early winter and gradually long for late winter plantings. For all the phenological studies, plants of normal sowing condition (September 1) recorded comparatively higher heat units than the late planting (October 1 and November 1) for all cultivars. Both early and late plantings recorded the higher helio-thermal units at advanced growth phases than at the early stages. The pheno-thermal indices at the earlier growth stages were significantly higher for early planting than the late planting. The heat use efficiency (HUE) was found to be higher under normal plantings as compared to the late plantings (Amgain, 2011).

The data on phenology of maize in maize and soybean intercropping system revealed that maize took 12 days for seedling growth in all the treatments whereas, for completion of vegetative growth intercropped maize took about 67 to 70 days as compared to 66 days in sole maize. While for completion of fertilization, sole maize took 71 days as compared to 72 to 76 days in maize intercropped with soybean. Similar trend was followed for physiological maturity. This was 118 days in sole maize and 119 to 123 days in maize intercropped with soybean, where the physiological maturity was delayed by 1 to 5 days depending on the population of intercrop soybean. The delay in maize maturity may be due to complementary effect by soybean through nitrogen fixation and greater availability of nitrogen which delays phenophases in intercropping (Yogesh, 2011).

Sowing date significantly influenced maize development form germination till harvesting. Maize needed on average 49 growing degree days (GDD) from sowing till emergence, 463 to 518 (depending on the hybrid) GDD from emergence till silking, but from silking till maturity stage when 250 g per kg of dry matter (DM) content in fresh maize was achieved - 257 GDD. A strong negative ($p=0.0$) correlation between the soil temperature at 10 cm depth and the number of days from maize sowing till full emergence was noted. Earlier sown maize needed more days till germination (18-8 days) and from germination till silking (79-67), whereas the period after silking till maturity stage, when 250 g of DM per kg of fresh maize were reached was 40 to 47 days depending on the hybrid but regardless of the sowing date. Plants sown on the last sowing date (25 May) were significantly taller and plant density was higher ($p>0.05$) if compared with earlier sown maize (Gaile, 2012).

2.1.2 Growth

Daynard (1972) observed that delayed planting to mid silk but decreased the thermal interval between midsilk and BL formation. Also, suggested that extended periods of cool temperatures, not frost, were a more probable cause of what he characterized as “premature” BL formation. He noted that BL formation occurred shortly after cold spells when mean daily maximum temperatures averaged 13 ^{0}C or less. Other researchers have observed similar effects on corn maturation (Miles, 1943).

Tollenaar and Aguilera (1992) in a study on the relationship between weather parameters and growth and yield parameters revealed that a mean morning relative humidity range of 74.6 to 79.8 per cent was found to be optimum from emergence to sixth leaf stage for higher DMP at sixth leaf and tasseling stages and more number of grains per cob. Similarly, mean minimum temperature range of 22.8 to 23.2 ^{0}C from emergence to silking (P6) was found to be optimum for higher DMP at physiological maturity and grain yield at maturity in *kharif* maize. Higher DMP at physiological maturity and grain yield of maize was obtained with mean temperature of 26.3 to 26.9 ^{0}C from emergence to physiological maturity. They observed difference in DM accumulation during development may result from differences in climate, differential absorption of PAR due to variation in plant population and LAI, or differences in the efficiency of converting absorbed photosynthesis active radiation (APAR) into DM.

Cirilo and Andrade (1994) reported that delays in sowing date hastened development between seedling emergence and silking, decreasing cumulative incident radiation on the crop during the vegetative period. However, late sowings increased crop growth rate during the vegetative period because of high radiation use efficiency and higher per cent radiation interception. Conversely, late sowings decreased crop growth rate during grain filling, because of low radiation use efficiency and low incident radiation. Late sowings affected grain yield by decreasing kernel weight and kernel number per unit area. Moreover, maize subjected to these treatments accumulated more dry matter before silking than from silking to physiological maturity, while the inverse was true for early sowings. Thus, delaying the sowing date strongly decreased dry matter partitioning to grain.

In maize planting date modifies the radiative and thermal conditions during growth. The amount of incident radiation and the proportion of this radiation that is intercepted by the crop directly determine crop growth rate. Delay in planting date resulted in important reductions in the amount of incident radiation accumulation from emergence to silking, because it hastened development. Low temperatures during grain filling in late plantings limited seed growth as well as crop photosynthesis. Thus, the ratio between final seed number and dry matter at silking dropped drastically for the late plantings, indicating a predominance of vegetative growth over reproductive growth (Cirilo and Andrade (1994) and Ahsan *et al.* (2011)).

Planting maize too early and too late resulted in reduced leaf area index, leaf area, dry matter production and yield. Berzsenyi, *et al.* (1998) persuaded that growth indices in the vegetative stage were greater with late sowings as compared to early sowings. However, the values were greater in early sowings during reproductive growth stages. In addition, Maddonni, *et al.* (1998) found that in late plantings, both solar radiation and temperature declined during grain filling. This, lowered solar radiation resulted in grain growth in excess of biomass production, indicating a possible source limitation. On the other hand, low temperature may have a negative effect on seed weight through reductions in both radiation use efficiency and biomass partitioning to the grains (Cirilo and Andrade, 1994 and Ali *et al.,* 2014).

At Hyderabad, Leelarani *et al.* (2012) conducted an experiment during *kharif* 2009 and 2010 with four dates of sowing (7 Jul, 21 Jul, 6 Aug and 22 Aug in 2009 and 18 Jun, 02 Jul, 17 Jul and 02 Aug. in 2010). During both the years of study, crop sown from 18 June to 21 July recorded significantly more dry matter. Sowing beyond 21 July in 2009 and 17 July in 2010 reduced the DM production by 11 per cent, over early sown crop. Dry matter increased steadily after crop establishment until maturity in all the treatments. The crop accumulated more DM during 2009 as compare to 2010 a wet season. In 2009, 21 July (D_2) sown crop and 7 July (D_1) sown crop produced at par dry matter at sixth leaf, tasseling, silking and physiological maturity stages. Lowest DM accumulation at all these stages was observed in 22 August (D_4) sown crop. In 2010, 18 June (D_1) sown crop showed maximum DM accumulation at sixth leaf (9.8 g/plant), tasseling (83.3 g/plant), silking (89.9 g/plant) and maturity stages (203.2 g/plant) and was on par with 2 July (D_2) sown crop and significantly superior to 17 July (D_3) and 2 August (D_4) sown crop. Sowing beyond 21 July and 17 July reduced difference in DM production in 2009 and 2010 by 11 and 13 per cent, respectively over early sown crop.

Moosavi *et al.* (2012) reported that delay in sowing from July 4 to August 6 decreased significantly the plant height, stem diameter, leaf area index, total fresh and dry yield by 15.7, 20.9, 42.1, 24.7 and 25.9 %, respectively in maize. Leaf area index (LAI) at tassel (VT) also was dependent on planting date, as decreases were not observed in the low stress and high stress groups until late June planting dates. In the early season stress environment, the early June planting dates produced the greatest LAI at VT (3.90) and mid April planting dates produced the lowest (3.34). These results suggest the scenarios exist where later planting may be a viable alternative for maintaining dryland corn yields in select environments (Sidelar *et al.*, 2010).

2.2.3 Yield and yield attributes

Eight per cent of the yield increase in Minnesota during the 1930 to 1979 time period was credited to a shift toward early planting by 10 days (Cardwell, 1982), which was approximately equal to a yield increase of 0.031 Mg per ha for every additional day that was added to the growth period. Because early planting increases the length of time that plants can take advantage of favourable growing conditions and accumulate biomass, the highest yields generally results where the growing season is longest and soil moisture is non-limiting (Kucharik, 2006).

However, the results of planting date experiments can be highly inconsistent between seasons and sites. For example, it is usual for a relatively late sown crop to out yield the control crop sown within the optimum period (Ali *et al.*, 2014). There are several reasons for such inconsistencies and unexpected results. First, the soil conditions at different planting dates will inevitably be different and unfavourable conditions (excess or deficiency of soil moisture, serious incidence of diseases, *etc.*) can occur at almost any point during the normal planting dates. Consequently, the observed differences in the performance of crops sown on different dates are commonly a reflection of differences in established plant density. Secondly, crops sown at different dates pass through each developmental stage at slightly different times and, therefore, under different environmental conditions (especially photoperiod and temperature) ; thus any one of the developmental stages which determine the components of yield could conceivably occur under more or less favourable conditions in late-sown crops. For these reasons, it is not easy to carry out a critical comparison of the grain yields and their components of the different crops in a sowing date experiment. Scarsbrook and Doss (1973) reported that yield of maize is a function of many plant and environmental factors which are often interrelated.

A 3 year study indicated that maize sown on October 22 took fewer days for seedling emergence, tassel emergence, silking and maturity than that sown on November 11 and December 1. Seedling emergence required similar growing degree days in all seedlings, but the requirement at emergence of tassels, silking and maturity was in the order October 21 < November 11 < December 1 (Narwal *et al.*, 1986).

Maize planted earlier develops better and has a higher yield potential because the vegetative period of its development occurs in the cooler part of the season when moisture stress is less likely. Generally, there are many benefits related to early planting date compared to late planting date and this include a long growth duration that allows a greater choice of hybrid maturities and wider window of opportunities for replant decisions. In addition, Sheperd, *et al.* (1991) reported that early planting date could contribute significantly to higher maize yields. The authors also highlighted that higher yield is not the only advantage of early planting because other benefits can also be achieved from high plant density and high fertilizer rates. It also allows harvesting earlier in the season when conditions are usually better and field and time losses can be minimized (Hicks *et al.*, 1993). In addition, very simply early planting increases net returns without adding production costs.

Although the acceleration in the rate of crop development associated with increased plant density or with delay in planting date means that the duration of the phase of spikelet initiation is reduced, the overall effects of these two management factors upon cob size are different (Bashetti and Westgate, 1993). Cirilo and Andrade (1994) found no effect of planting date on spikelet primordial counted at silking in the apical ears of two maize hybrids. They suggested that seed abortion rather than a morphogenetic process was the dominant factor determining the final seed set.

On the other hand, late planting or planting after the optimum period consistently resulted in lower yields. Delayed planting shortens the effective growing season for maize, increasing the risk of exposure to lethal cold temperatures late in the season before grain maturation. Yield reduction in late plantings could be attributed to a short growth duration, insect and disease pressure, heat and moisture stress during pollination. Otegui and Melon (1997), revealed that delayed plantings are generally accompanied by increased temperatures during the growing season, which accelerate crop development and decrease accumulated solar radiation, resulting in less biomass production, seed set and grain yield.

Reduced seeds cob^{-1} is the most consistent, irreversible component of yield reduction under drought stress (Anderson *et al.*, 2004). The number of florets that may become seeds cannot exceed exposed silk number and declines from this potential as silks lose receptivity and senesce with age (Bashetti and Westgate, 1993). Hybrids with faster silk growth rates may have more silks available for pollination at the beginning of flowering. However, when environmental conditions are below optimum, seed number may be limited by asynchrony (pollen is not shed when silks are exposed or receptive) (Anderson *et al.*, 2004), loss of silk receptivity (silk is no longer functional to support pollen tube growth (Bashetti and Westgate, 1993) or developmental failure of the ovary. Such limitations to seed number may have drastic impacts on grain or seed production profitability and may be influenced by silk characteristics for a given hybrid or inbred (Anderson *et al.*, 2004).

Khola *et al.* (1999) at Dehra Dun under rainfed condition in silt clay loam soil, observed that normal sowing of maize with the onset of monsoon (25th June) resulted in significantly higher maize grain yield (24.17 and 24.97 q ha^{-1} during 1993 and 1994, respectively) as compared to early sowing (10th June) and delayed sowing (10th July). The per cent reduction in maize grain yield in early and delayed sowings was to the extent of 32.7 and 38.0 per cent during 1993 and 45.8 and 55.3 per cent during 1994, respectively as compared to the normal sowing. This reduced yield in early sowing was mainly due to dry soil conditions at the time of sowing, attack of insects, diseases, birds *etc.* Whereas, under late sowing, seedling and subsequent growth hampered due to high rainfall, subsequent high soil moisture regimes and smaller growing period.

Environmental changes associated with different sowing dates (sunshine, temperature) have a modifying effect on the growth and development of maize plant. Each hybrid has an optimum sowing date and greater the deviation from this optimum (early or late sowing), the greater the yield loss (Sarvari and Futo, 2000).

Jayasree *et al.* (2008) observed at Guntur, Andhra Pradesh, in red soil that the maize yield decreased significantly when sowing was delayed from onset of monsoon to fortnightly interval thereafter under rainfed condition. However, grain yield (3810 kg ha^{-1}) obtained from June first fortnight of sowing was at par with June second fortnight sowing (3550 kg ha^{-1}). The magnitude of reduction in yield from June first fortnight sowing to July second fortnight was to the extent of 34.6 per cent.

Delaying planting generally increased days to flowering and the anthesis-silking interval (ASI) and reduced dry matter production and yield and yield components. In Azir, planting of corn on 13 July reduced grain yield by 42 per cent in 2006 because of a dry spell during crop establishment. Delaying planting to 21 and 28 July also reduced grain yield by 19 and 28.5 per cent, respectively over the 2 years. Averaged over the 2 years yield reduction was 29.5 and 42 per cent when corn was planted on 21 and 28 July respectively in Damboa (Kamara *et al.*, 2009).

Beiragi *et al.* (2011) evaluated 18 new corn varieties consisting of 15 foreign early and mid-mature single cross hybrids and three Iranian commercial hybrids at two sowing dates (5th and 20th June). This study showed that among all hybrids, EXP 1 (16.03 t ha^{-1}) and OSSK 617 (15.51 t ha^{-1}) had the highest yields in early planting (5 June) and EXP 1 (16.52 t ha^{-1}) and KDC 370 (16.22 t ha^{-1}) recorded the highest yields under late planting (20th June) conditions. Further, the results also indicated that yield components such as 100 kernel weight, kernels row^{-1}, kernel depth and ear length were adversely affected in delayed planting condition.

Delay in sowing of maize beyond July results in yield reduction. Shift in sowing dates directly influence both thermo and photoperiod and consequently a great bearing on the phasic development and partitioning of dry matter (Leelarani *et al.*, 2013).

Hemalatha *et al.* (2013) revealed that early sowing (June 1st) significantly increased the yield of maize than subsequent dates of sowing because of higher accumulation of heat units. Delay in sowing resulted in reduction of cob yield which might be due to minimum accumulation of heat units. Among different dates of sowing early sowing on June 1st outperformed all the other dates. If the sowing was delayed upto August 1st, there was a yield reduction to an extent of 47-52 per cent. Therefore the first fortnight of June is always better to avoid moisture stress and also weed and pest problems in maize.

2.3 Influence of different row spacing, plant density and crop geometry

2.3.1 Micrometeorological studies

2.3.1.1 Soil temperature, leaf temperature and canopy temperature

Soil temperature, a factor limiting the production and diversity of crops, presumably differs between skip-row and equidistant row plantings owing to differences in radiation transmission. Soil temperature was sensitive to changes in crop row characteristics (e.g., direction, width, spacing) as a result of canopy-radiation interactions.

When plant density was reduced by 50 per cent at an ambient air temperature of 20.5 ^{0}C, the observed maximum temperature differences between plots were 0.7 and 1.5 ^{0}C for mean leaf and soil temperatures respectively. Sensitivity analysis using one-dimensional energy transfer schemes have been used as a starting point for explaining observed surface temperature differences between plot and within plot (Houldcroft *et al.*, 2003).

2.3.1.2 Light, radiation and photosynthetically active radiation (PAR)

Williams *et al.* (1968) reported that parameters of canopy architecture were related to light interception and productivity with corn grown at population densities from 17500 to 125000 plants per ha. With nutrients and soil moisture non-limiting, the amount of solar radiation intercepted by the foliage canopy was a major determinant of crop growth during the vegetative stage. Leaf arrangements with a preponderance of erect leaves, occurring just before the tassels emerged, allowed the deepest penetration of light into the foliage canopy and gave the highest crop growth rates.

Planting patterns influence the distribution of radiation in the canopy as well as the total amount of incident radiation intercepted by a crop. Yao and Shaw (1964) observed that 0.53 m rows intercepted approximately 7 per cent more light than 1.07 m rows at a plant population of 70000 plants per ha. Scarsbrook and Doss (1973b) reported 0.51 m rows attenuate radiation with the upper layers of the canopy more than

1.02 m rows. Narrow rows also intercept more total radiation than wider rows, considering the entire canopy. Corn planted in 0.51 m rows intercepted approximately 11 per cent more light than 1.02 m rows at a plant population of 80000 plants per ha.

Solar radiation interception by the crop is greater with narrow rows and soil interception is greater with wide rows. This change in the distribution of source and sink locations can provide the temperature differentials which cause air flow in the canopy such as inter-row advection. The greater cover provided by narrow rows should restrict air movement and diminish mixing of unsaturated air from above the canopy with more humid within canopy air.

Mock (1977) also recorded increased light interception for corn hybrids from 89 to 97 per cent by increasing plant densities from 40000 to 80000 plants per ha in Iowa. Such enhanced light interception would be expected to increase grain yield about 0.5 metric tonnes per ha in Hawai, assuming the regression.

In the absence of biotic or abiotic stresses, maize yield is related to the amount of solar radiation intercepted by the crop (Tollenaar and Bruulsema, 1988; Muchow *et al.*, 1990).Particularly in a short growing season (Williams *et al.*, 1965; Tollenaar and Bruulsema, 1988). Early canopy closure not only maximizes light interception (Williams *et al.*, 1965; and Ottman and Welch, 1989), it also decreases evaporation from the soil surface (Karlen and Camp, 1985). Timing of canopy closure can be altered by varying row spacings and/or PPD (Williams *et al.*, 1965; Tetio-Kagho and Gardner, 1988a; Ottman and Welch, 1989). But, response to row pacing and PPD varies with available moisture and genotypes (Karlen and Camp, 1985; Neilson, 1988; Hodges and Evans, 1990). Only hybrids resistant to lodging and barrenness perform well when managed for early canopy closure (Neilson, 1988).

Leaf area index among density-hybrid treatments ranged from 2.0 to 4.8 and PAR absorption of the latter was 9 % higher than that of the former. Although crop growth rates of the plant densities were not different during the grain-filling period, differences in PAR absorption were too small to show a significant effect of plant density on conversion efficiency. Photosynthetic conversion efficiency appears to be influenced by phase of development but the effects of plant density on efficiency appear to be small (Tollenaar and Bruulsema, 1988).

Increasing row width had a positive influence on radiation penetration but decreased total radiation interception. The lower yield of the 1.52 m twin planting pattern can be explained primarily by less radiation interception by the canopy as a whole offsetting any advantage gained by intercepting a greater proportion of radiation with the lower leaves (Ottman and Welch, 1989).

There was no interaction of population density with hybrids over years but there was a difference in RUE due to population density. RUE being higher at the higher densities. This finding must be related to more effective interception of PAR at the high densities. Earlier we indicated that there was a linear relationship between the logarithm of yield per plant or APAR v/s. density. These results indicate that the RUE of the canopy increases when there is increased shading at higher density. Sinclair and Horie (1989) noted that RUE is a function of the relative amounts of sunlit and shaded leaves and that RUE is reduced at low light saturated. Leaves that are photosynthetically light saturated are less efficient than those in the shade so that as the fraction of shaded leaf area increases, RUE also increases slightly. Crosbie *et al.* (1977) found that CER increased as plant density increased for maize grown in Iowa.

Radiation use efficiency increased with population density across hybrids regardless of maturity. The results also indicated that RUE was higher at high plant population density, consistent with previous studies where more efficient photosynthesis occurred under conditions of mutual shading of leaves in the canopy. Finally, it was concluded that chilling injury due to cool night temperatures may have decreased seasonal RUE (Major *et al.*, 1991).

It has been well documented that increased light interception has the ability to substantially increase maize grain yields. This has been achieved through such practices as increasing plant population (Cox, 1997; Nunez and Kamprath, 1969; Westgate *et al.*, 1997), reducing row spacing (Lutz *et al.*, 1971; Ottman and Welch, 1989; Porter *et al.*, 1997) and through research suggesting that leaf architectures of modern maize hybrids can optimize light interception to increase grain yield (Stewart *et al.*, 2003).

Maize planted at medium density (7.1 plants/m^2) with N-S orientation reduced within canopy maximum temperatures at 40 cm above the ground by 1.2 ^{0}C. The temperature reduction was associated with a reduction of irradiance upto 70 per cent. The reduction, especially in temperature was highly sensitive to row orientation and plant density and at some combinations resulted in increased in temperature. For the purpose of cauliflower-maize intercropping in the lowland tropics, a plant density of 7 plants per m^2 at N-S orientation appeared promising and gave an irradiance of above 300 W per m^2 at midday about 15 weeks after sowing (Jaya *et al.*, 2001).

Increased plant population promoted (i) an enhanced light attenuation within the canopy (k coefficient = 0.43, 0.55, 0.53 and 0.65 for 3, 9, 10 and 12 plants/m^2, respectively). Senescence was reduced by kernel set restrictions that enhanced post-flowering assimilate availability, indicating the process was accelerated by assimilate starvation at high plant populations independently of the green leaf area established per growing kernel (Borras *et al.*, 2003). Maize crops cultivated at high plant populations or in narrow rows exhibit an increased light attenuation within the different leaf strata (Flenet *et al.*, 1996; Maddonni *et al.*, 2001), which is known to affect the vertical profile of leaf N content of maize crops (Drouet and Bonhomme, 1999).

Parthasarathi *et al.* (2012) tried three plant density levels, normal spacing (S_1-60 x 20 cm), narrow spacing (S_2-45 x 20 cm) and reduced narrow spacing (S_3-30 x 30 cm) levels. He observed that the reduction in yield of maize by reducing the soil moisture was compensated by increasing the plant density which led to alter or change in the radiation use efficiency, light interception and light extinction coefficient. The increase in plant density will increase the light interception and radiation use efficiency causes improvement in dry matter accumulation and yield of maize. The grain yield is a function of actual improvement in light interception at silking stage in narrow row spaced plants, the plant population/unit land area play an important role in the RUE and subsequently the grain yield. Apart, the grain yield is also determined by number of kernels per plant and kernel weight during the grain filling period also substantially increase the grain yield by more translocation of photo assimilated especially at post silking period and this mostly depends on the PAR and RUE. The absorbed PAR value of crop was increased with increase in plant population in narrow spacing treatment S_2 (14.0) followed by normal spacings S_1 and reduced narrow spacings (S_3). Among the three spacing levels, the high density planting gave more biomass in S_2 (10007 kg ha^{-1}) than S_1 (9413 kg ha^{-1}) and S_3 (8651 kg ha^{-1}). The RUE is increased with increasing the plant population levels. The higher plant density recorded higher radiation use efficiency (2.54) in S_2 next by S_3 and S_1.

2.3.2 Influence of plant population on growth, development, yield and yield attributes

2.3.2.1 Growth and development

Dry matter production in crop plants is directly related to the utilization of solar radiation, which is influenced by canopy structure. Williams *et al.* (1968) observed that the effect of canopy architecture on vertical distribution of light within the maize canopy was a major determinant of photosynthetic efficiency and growth. Radiation is transmitted through and between leaves and its flux density and spectral composition changes rapidly with depth. Canopy light interception and photosynthesis were closely related to leaf area index (LAI) upto the critical LAI, that which is required to intercept 95 per cent incident irradiance (Pearce *et al.*, 1967). Williams *et al.* (1968) found that light interception and crop growth rate (CGR) increased linearly as LAI increased upto 3, but CGR increased asymptotically as LAI was increased further to a maximum at 99 per cent light interception. Earl and Tollenaar,(1997) reported that plant height in maize increased remained static and decreased as light decreased from 100 to 40 per cent, 30 to 20 per cent and 20 to 10 per cent of full sunlight, respectively. A particularly striking feature of a maize canopy is the large attenuation of high in the top 50 cm of the canopy at high PPD (>50000 plants/ha) a critical factor in canopy illumination (Loomis *et al.*, 1968). Also, Karlen (1985) reported that total dry matter increases 6 to 40 per cent when plant density increases from about 55000 to 88000 plants per ha. Ayisi and Poswall (1997) reported that leaf area index is major factor determining photosynthesis and dry matter accumulation. Edwards *et al.* (2005) observed increase in dry matter accumulation for corn hybrids at high density compared to low density due to more light interception.

Major *et al.* (1991) in Albera, Canada, reported an increase in whole plant dry matter with population density upto 14.5 plants per m^2 for 10 hybrids. Kernel, stalk and total dry matter per plant decreased reciprocally with increasing density. Kernel yield per land area increased parabolically upto a maximum yield of 1080 g per m^2 at about 10.0 plants per m^2, whereas stalk and total dry matter yield increased asymptotically upto 12.5 plants per m^2, shelling percentage was constant with increasing density, but harvest index decreased, though not significantly.

Leaf area and light interception were highly concentrated at ear level, but level of light interception shifted upward with increasing population density (PPD). LAI were 1.7, 2.6 and 4.0 at tasseling for the 1.7, 2.6 and 6.3 plants per m^2, respectively. High interception by tassels was approximately 2, 30 and 40 per cent for 1.9, 3.5 and 6.3 plants per m^2, respectively while that for whole canopy was 75, 90 and 97 per cent, respectively. As early as 35 day after planting (DAP) canopy interception was 40, 60 and 75 per cent for 1.9, 3.5 and 6.3 plants per m^2, respectively. Leaf area index, TDM, crop growth rate and plant height were significantly influenced by PPD. They concluded that increasing PPD of maize increased LAI and vegetative DM yield but affects light distribution within the canopy by shifting it from lower to upper canopy strata and increasing fraction intercepted by tassels (Tetio-Kagho and Gardner, 1988).

Sachan and Gangawar (1996) during *kharif* at Kanpur observed that growth attributes of maize *viz.*, plant height, stem girth and number of functional leaves were significantly higher with wider row spacing (60 cm) than with narrow row spacing (45 cm). Singh *et al.* (1997) reported that dry matter production at 90 and 120 days after sowing increased significantly with increase in population levels from 55556 plants ha^{-1} to 1, 11, 111 plants ha^{-1} on silty loam soils of Faizabad (U P) during winter season. Singh and Tajbaksh (2006) conducted a field trial during *kharif* season on loamy sand soils of Ludhiana (Punjab) and found that dry matter accumulation was significantly the highest under plant population of 100000 plants ha^{-1} (60 cm x 16.6 cm) than that of with 50000 plants ha^{-1} (60 cm x 33.3 cm) or 75000 plants ha^{-1} (60 cm x 22.2 cm).

Some experiments have shown that, a LAI between 3 and 4 may be optimal for achieving maximum yield (Lindquist *et al.*, 2005). Increasing plant population density (PPD) may accelerate leaf senescence (Tethio-Kagho and Gardner, 1988a), increase the shading of leaves and reduce the net assimilation of individual plants. An increase in PP of 2-13 plants per m^2 decreased net assimilation per plant from 0.85 to 0.11 mg CO_2 per m^2 per sec. but increased grain yield per area (Dwyer *et al.*, 1991). This increase in grain yield can be explained by the increase in LAI and net crop assimilation. LAI increased with PPD from 4.5 to 13.5 plants per m^2 (Bavec and Bavec, 2002). These results are consistent with (Dwyer *et al.*, 1991) that show that higher PPD may increase maize LAI to more than 5.

Williams *et al.* (1965) found a decrease in leaf area per plant with an increase in plant density for maize. Grant (1989) assumed that leaf area growth on a maize plant is a function of leaf dry weight and the increase in leaf dry weight. However, they tested this hypothesis on plants growth in a range of rather low plant densities (1.5 – 10.3/m^2), resulting in only small differences in leaf area per plant, even between the extreme plant densities. Bos *et al.* (2000) reported that plant density affected leaf area expansion of maize mainly through effects on leaf appearance rates and that these effects were closely related to density effects on plant growth rate per leaf appearance interval. Modern maize hybrids only rarely form tillers. Leaf area development on one (main) stem fully determines the leaf area development per plant and effects on plant density must be related to effects on leaf area growth of this main stem.

Plant population affected the post-flowering source-sink ratio through its effects on plant leaf area, the amount of light intercepted per plant and kernel number per plant. All these traits decrease in response to increased plant density (Tetio-Kagho and Gardner, 1988a, b; Westgate *et al*., 1997; Andrade *et al*., 2000 and Maddonni *et al*., 2001).

Singh and Singh (2002) from their field study during rainy season on clay loam soils of Udaipur (Rajasthan), observed significantly higher dry matter production plant^{-1} with lower planting density of 66000 plants ha^{-1} (60 cm x 25 cm) as compared to that with higher densities of 83000 plants ha^{-1} (60 cm x 20 cm), 133333 plants ha^{-1} (50 cm x 15 cm) and 166666 plants ha^{-1} (50 cm x 12 cm). Chandankar *et al.* (2005) from Akola reported increase in plant height of maize hybrid (Pro Agro 4640) with higher plant density (111111 plants ha^{-1}) than with lower planting density (83333 plants ha^{-1}). Muniswamy *et al.* (2007) reported that plant height, leaf area and stem girth of maize increased linearly with the increase in spacing from 60 cm x 10 cm to 60 cm x 20 cm during *kharif* season at Bangalore. Boomsma *et al.* (2009) from their field study reported that plant height declined with increase in plant density from 54000 plants ha^{-1} to 79000 plants ha^{-1} or 109000 plants ha^{-1} on silty clay loam soils of Indiana. Suryavanshi *et al.* (2009) revealed that spacing of 60 cm x 30 cm was significantly superior to spacing of 60 cm x 20 cm in increasing the leaf area and total dry matter production per plant of maize on clay soils of Parbhani (Maharashtra). Plant height, dry matter accumulation and per cent barrenness were increased with increase in planting densities and the highest values of these parameters were recorded at higher planting density of 133333 plants ha^{-1} on clay loam soil and 100000 plants ha^{-1} on sandy clam loam soils at Bapatla, respectively (Zakkam *et al.*, 2012 and Venkata Rao, 2012).

According to Dehdashti and Riahinia (2008), an increase of plant population from 10.5 to 13.9 plants per m^2 increased LAI, TDW, CGR, RI and grain yield on average by 0.205 m, 48.4 g per m^2, 1.14 g per m^2 per day, 0.89 per cent and 222.7 kg per ha for each plant per m^2 added but decreased NAR by 0.205 g per m^2 per day for each 1 plant per m^2 added. Moreover, when row spacing was reduced, RI, TDW, LAI, CGR and grain yield increased. But, by reducing row spacing, NAR was decreased.

At Telangana, an increase in plant population density from 67000 to 111000 plants per ha recorded increase in plant height, leaf area index, while it caused decline in dry matter per plant. Higher plant population of 111000 plants per ha significantly increased the plant height of maize (235.0 cm) at maturity compared to other plant populations that reflects the competition for space and solar radiation between the plants. Maximum LAI was found with the highest plant density *i.e.*, 111000 plants per ha at 60, 90 DAS and at maturity (3.6, 3.98 and 3.81, respectively). Plant population of 67000 plants per ha was found to be significantly superior in producing maximum dry matter per plant at all the crop stages. Plant population as low as 67000 plants per ha showed significantly early 50 per cent silking (76.4 days) and physiological maturity (116.7 days) as compared to higher plant populations because of early vigorous growth due to less competition among the plants, inducing early silking and maturity (Wasnik *et al.*, 2012).

Bisht *et al.* (2012) at Pantnagar, revealed that leaf area index (LAI) and dry matter accumulation were significantly higher under high and low plant density, respectively. Low plant density (66666 plants/ha) also recorded significantly higher crop growth rate (2.85 g/day) and net assimilation rate (10.81 g m^{-2}/day) during 30-60 DAS. However, leaf area ratio (139.72 cm^2 g^{-1}) and relative growth rate (20.88 mg g^{-1} day^{-1}) were more under higher plant density (100000 plants ha^{-1}) during 30-60 and 60-90 DAS, respectively.

2.3.2.2 Yield and yield attributes

Producing corn in narrow rows is not new concept. Research in the 1960s compared wide row spacings (102 cm) with narrow row spacings (<76 cm). In Iowa, Shibles *et al.* (1966) showed roughly a 1.5 per cent yield increase for 76 cm row spacings compared with 102 cm row spacings and an additional 3.5 per cent yield advantage for 51 cm row spacings. In Virginia, Lutz *et al.* (1971) reported a 5 per cent yield increase for 76 cm row spacings compared with 102 cm row spacings and an additional 2.7 per cent yield advantage for 38 cm row spacings.

Plants are more evenly distributed when sown in narrower row spacings and the efficiency of light interception is improved. An increase in light interception when row spacing is reduced has been reported for corn (Egharevba, 1975).

In Canada, Fulton (1970) reported that under conditions of adequate soil moisture, higher plant densities (54, 362 plants/ha) produced higher yields than lower densities (39, 536 plants/ha) and rows spaced at 50 cm produced higher yields than rows spaced 100 cm apart. In addition, reported a significant plant density x row spacing (50 cm) interaction in only one of four experimental years, indicating that the effect of narrow row spacings was greater at high plant densities than at low plant densities. Conversely, increasing planting density from 66666 plants per ha to 133333 plants per ha reduced the yield attributes and yield of maize. Yield attributes of maize *viz*., grains per cob, test weight and shelling percentage were significantly higher at lower planting density, which might be due to reduced competition for various growth resources especially moisture and nutrients. The yield of maize was significantly superior at lower planting density, due to cumulative effect of increased yield parameters. Stover yield produced by the planting density of 133333 plants per ha was significantly higher and resulted in lower harvest index than 88888 and 66666 plants per ha (Zakkam *et al*., 2012).

Monga and Gautam (1970) revealed that yield of maize increased with increased intra-row spacing and the highest grain yield was obtained under the treatment having 30.0 cm intra-row spacing, which was significantly superior to that of 22.5 and 15.0 cm intra-row spacings at IARI, New Delhi. Similar findings were also reported by Mali and Singh (1989) from Udaipur and Tyagi *et al.* (1998) from Hissar.

Krishnamurthy *et al.* (1974) observed more barrenness, less grain weight per cob, test weight and shelling percentage with increase in plant population of maize from 55000 plants ha^{-1} (60 cm x 30 cm) to 83000 plants ha^{-1} (60 cm x 20 cm) on red sandy loam soils of Bangalore. Barthakur *et al.* (1975) conducted an experiment at Jorhat and observed that narrow inter-row spacing (50 cm) resulted higher yield than wider inter- row spacing (75 cm). Verma and Singh (1976) reported that grain and stover yield of spring maize were significantly improved with the increase in plant density from 65000 plants ha^{-1} to 85000 plants ha^{-1} on sandy loam soils of Bichpuri, Agra.

Singh and Tajbaksh (1986) recorded significantly higher cob length and test weight of maize at lower plant population of 50000 plants ha^{-1} (60 cm x 33.3 cm) over 75000 plants ha^{-1} (60 cm x 22.2 cm) and 100000 plants ha^{-1} (60 cm x 16.6 cm) on loamy sand soils at Ludhiana. Reddy *et al.* (1987) during *rabi* season observed the highest test weight of maize with lower plant density of 59200 plants ha^{-1} than higher density of 66600 plants ha^{-1}, 76200 plants ha^{-1} and 88800 plants ha^{-1} on sandy loam soils of Hyderabad. Sandhu and Mavi (1987) also reported similar results from Ludhiana on loamy sand soil.

Reddy *et al.* (1987) reported that, cob length, grains per cob, shelling percentage, 1,000 grain weight and grain yield per cob decreased from 17.98 to 17.26 cm, 311.3 to 246.9, 75.47 to 74.56 %, 292.2 to 271.3 g and 87.23 to 62.91 g, respectively with increase in plant population from 59, 200 to 88800 per ha in hybrids of maize (*Zea mays* L.). A population of 76200 per ha gave the maximum grain yield in both the years (4, 595 and 5, 132 kg ha^{-1}).

Bangarwa *et al.* (1989) stated that generally the yield of a single maize plant decreases with increasing plant population, whereas the yield per unit area increases. Harvest index (HI) is one of the indices currently used to evaluate a crops partitioning efficiency. Increasing population density resulted in significant decreases in HI. The effect of population density and relative maturity rating on the HI of corn has been tested to a limited extent. When densities were increased, especially above the level at which grain yield was maximal, HI decreased.

Singh *et al.* (1997) from Faizabad (UP) during *rabi* season reported significantly higher number of grains row^{-1}, grains cob^{-1}, grain weight cob^{-1}, test weight and shelling percentage of maize at lower plant density of 55555 plants ha^{-1} over higher plant density of 66666 plants ha^{-1}, 83333 plants ha^{-1} and 111111 plants ha^{-1} on silty loam soils.

From an experiment conducted on clay loam soils of Banswara (Rajasthan), Ameta and Dhakar (2000) revealed that with each successive increase in plant population from 65000 plants ha^{-1} to 95000 plants ha^{-1} there was significant increase in the grain yield of maize during winter season. Emam (2001) reported that grain yield of maize responded to higher planting densities up to 83000 plants ha^{-1} and this was owing to increase in rate of grain filling with no significant change in duration of grain filling period at Koushkak, Iran. Widdicombe and Thelen (2002) found higher yields for corn grown in narrow rows versus wide conventional rows irrespective of hybrids and plant populations tested in Indiana and Michigan of USA.

Sudhakara Babu and Mitra (1989) observed that grain yield increased with increase in population density. Highest plant population density (99999 plants ha^{-1}) recorded maximum grain yield 52.3 q ha^{-1}.Grain yield increased from 35.8 to 46.3 q ha^{-1} (an increase of 10.53 q ha^{-1} *i.e.*, 29.4 %) when the population density was increased from 33333 to 66666 plants per ha. A further rise in the population from 66666 plants to 99999 plants per ha resulted in the further increase in grain yield (5.99 q ha^{-1} *i.e.*, 12.9 %). Although, the yield components decreased with increase in population densities from 33333 to 99999 plants per ha the grain yield increased with increasing population densities. This was probably because of the cumulative effect of more number of plants accommodated per unit area in higher population densities.

According to Tollenaar (1992), grain yield of prolific genotypes at a very low PPD may be less limited by number of kernels per plant than grain yield of single eared cultivars. An increase of PPD from 4.5 to 9.0 plants per m^2 increased grain yield on average by 1.5 t per ha for each 1.5 plants per m^2 added, but only by 0.75 t per ha from 10.5 to 13.5 plants per m^2 (Bavec and Bavec, 2002).

The grain yield under 110000 plants per ha was 14.88 and 12.20 per cent more than under 145000 and 83000 plants per ha, respectively. The plant height and dry matter (g m^{-2}) was affected significantly upto 110000 plants per ha, while stover yield increased with increase in plant densities. Number of effective cobs per plant, number of grains per cob, 100 grain weight, grain weight per cob, extent of cob filling (%) and grain yield per plant decreased with higher plant density (Sanjeev and Bangarwa, 1997).

Gollar (1996) at Dharwad, revealed that grain yield of maize was increased by 14, 21, 33 and 34 per cent respectively with increase in plant density to 74074, 83333, 111111 (30 cm x 30 cm) and 111111 (45 cm x 20 cm) plants per ha from the recommended plant density of 55555 plants per ha. Higher plant density also resulted in higher benefit:cost ratio due to significant enhancement in net income.

In the northern Corn Belt, corn grain yield increased 2 and 4 per cent and harvest moisture decreased by factor of 2.1 per cent when row width was narrowed from 76 cm to 56 cm and 38 cm, respectively. The highest plant density evaluated 90000 plants per ha had the highest grain yield. Grain moisture decreased and grain test weight increased slightly as plant density increased (Widdicombe and Thelen, 2002).

Ear length, ear diameter and grain weight per ear decreased with increasing plant densities. The highest ear length, ear diameter and grain weight per ear were obtained from the lowest (50000 plants/ha) plant density (19.2 cm, 47.6 mm and 190.1 g, respectively) and the lowest values were obtained from the highest (100000 plants/ha) plant density (16.2 cm, 45.7 mm, 136 g, respectively). Grain yield increased with increasing plant densities upto 90000 plants per ha (9406 kg ha^{-1} average) but slightly decreased at 100000 plants per ha in two year study and there were no significant differences among 80000 plants per ha, 90000 plants per ha and 100000 plants per ha densities (Gozubenli *et al.*, 2003).

Hashemi *et al.* (2005) reported that the highest grain yield in all experimental sites was obtained from 9 plants per m^2 and for total biomass yield between 9 to 12 plants per m^2, kernel yield per plant decreased linearly in all hybrids as plant density intensified. All yield components had a linear decline in response to increased competition pressure. The reduction in kernel yield was attributed most to the reduction in number of kernels per row. But competition between the vegetative stage and anthesis had a more effect on grain yield reduction, which ranged from 8 to 21 per cent in different hybrids and experimental sites. Increased assimilate supply and enough plant removal again confirmed that adjustments in grain yield primarily occur through kernel number per row.

Planting of maize at 83333 plants ha^{-1} resulted in significantly higher yield attributes *viz.*, ear diameter, grain weight $plant^{-1}$, test weight and grains ear^{-1} than at 111111 plants ha^{-1} on clay loam soils of Akola (Chandankar *et al.*, 2005). Sharratt and McWilliams (2005) from their two years of study at Morris found that corn row spacing did not influence grain yield in first year, but did affect yield in second year as corn grown in 38 cm rows produced 10 per cent more grain than corn grown in 76 cm rows. Harvest index was also not influenced significantly between narrow and conventional wider row spacings. Maddonni *et al.* (2006) reported that an increase in plant population from 3 to 9 plants m^{-2}, increased kernel number per cob and grain yield but reduced kernel weight on silty clay loam soils at Argentina.

The results of the experiment conducted at Tirupati, by Ramu and Reddy (2007) revealed that grain yield of maize increased significantly with increase in plant population from 55555 plants ha^{-1} to 66666 plants ha^{-1}, beyond which the increase in yield was not statistically significant. Reddy *et al.* (1987) conducted an experiment on clay loam soils at Warangal (A P) during *rabi* season and observed that sowing of maize under no- till condition at wider spacing of 60 cm x 25 cm (66666 plants ha^{-1}) resulted in significantly higher yield attributes (such as number of kernels cob^{-1} and 100 kernel weight) and grain yield over the other two spacings tested, 50 cm x 25 cm (80000 plants ha^{-1}) and 40 cm x 25 cm (100000 plants ha^{-1}).Yield attributes (cob length, number of kernels cob^{-1}, kernel weight cob^{-1} and shelling percentage) were significantly higher at lower planting density but kernel (80.5 q ha^{-1}) and stover yields (100.8 q ha^{-1}) were significantly higher at 100000 plants ha^{-1} than that recorded with 67000 plants ha^{-1} under no-till conditions (Venkata Rao, 2012).

Increasing plant density for short season maize increases cumulative intercepted PAR, which compensates for a short growing season to achieve high yield with substantially less irrigation (Edwards *et al.*, 2005). In Iran (Zabol), Dahmardeh (2011) tried three plant densities (P1=60000 plants ha^{-1}, P2 = 80000 plants ha^{-1} and P3 = 100000 plants ha^{-1}).Grain yield and PAR absorption increase with increasing plant density. At Telangana, an increase in plant population density from 67000 to 111000 plants ha^{-1} recorded increase in cob length, cob girth, shelling percentage and test weight. Plant population of 111000 recorded significant increase in grain yield by 26, 18 and 10 per cent over 67 000, 87000 and 89000 plants ha^{-1} (Wasnik *et al.*, 2012).

According to Tyagi *et al.* (1998), grain yield improved significantly with the increase in plant population upto 66666 plants ha^{-1}. The increase in grain yield was 30.51 and 25.64 per cent at 66666 plants ha^{-1} over 53333 plants ha^{-1} during 1995 and 1996, respectively. But stover yield significantly improved with the increasing population upto 88888 plants ha^{-1}. Although all the yield attributing characters were higher at lower population, the increased value of these characters under lower population failed to supersede that of higher plant population with respect to grain yield. Lower plant population could not compensate the large plant population per unit area for these characters. Srikanth *et al.* (2009) at Coimbatore revealed that wider spacing of 75 x 20 cm recorded higher yield attributes, yield and higher crude protein content during *kharif* season.

An increase in grain and stover yields of maize was found with increase in plant density. High plant density at 100000 plants ha^{-1} produced 4.41 and 12.23 q ha^{-1} more grain and 14.45 and 27.08 q ha^{-1} stover yields than 83333 and 66666 plants ha^{-1}, respectively (Bisht *et al.*, 2013).

The extinction coefficient showed a linear decrease as row spacing increased (Flenet *et al.*, 1996). Barbieri *et al.* (2000) observed that reducing the distance between rows could increase radiation interception and grain yield. Narrow rows significantly increased kernel number per unit area and grain yield. Average increase in response to narrow rows were 14.5 and 20.5 per cent for kernel number and grain yield, respectively. With conventional row spacing, relative grain yield responses to narrow rows decreased as crop radiation intercepted at flowering increased. Results indicated that 27 to 46 per cent increase in grain yield were obtained in response to narrow rows.

Narrow row corn had a more uniform root distribution and intercepted 5 to 15 per cent more PAR on clear days, the latter of which likely aided in suppressing soil temperatures and evaporation during vegetative growth compared with corn grown in conventional rows. The results of this study suggest that any yield advantage to growing corn in narrow rows result from establishing a more uniform root and leaf distribution that aids in exploiting soil water and light resources and reducing soil temperature and evaporation compared with corn grown in wide conventional rows (Sharratt and McWilliams, 2005).

Row spacing is important in crop canopy structure (Andrade *et al.*, 2002; Sharratt and McWilliams, 2005). A better canopy structure can result in better solar radiation interception and consequently affect light availability.

At the Regional Agricultural Research Station, Jamalpur during *rabi* season, there was significant variation among the planting geometry. The highest grain yield was obtained from the planting geometry 60 cm × 20 cm (83333 plants m^{-2}) which was statistically similar to that of 75 cm × 20 cm (66666 plants m^{-2}). The lowest grain yield was obtained from the planting geometry 75 cm ×25 cm (53333 plants m^{-2}) (Biswas *et al.*, 2014).

2.4 Interactions of sowing time and density/spacing

Sowing date and plant density are very important parameters in crop production. The optimum sowing date and plant density paves the way for better use of time, light, temperature, precipitation and other factors. Planting date is critical in cold climates due to the potential for frost damages in late of season (Kondra, 1977). Rastegar (2004) reported that delay in sowing from April 25 to June 9 decreased total yield of corn by 38 per cent.

There was a significant interaction between row spacing and planting date regarding to grain yield. The advantage of using narrow rows was higher when maize was sown earlier in the growing season. The yield edge promoted by the use of narrow rows may be related to a higher interception of solar radiation and greater radiation use efficiency (Sangoi *et al.*, 2001). It is likely that the greater distance between adjacent plants within rows obtained with the use of narrow rows enhanced maize ability to convert the intercepted solar radiation to grain production. Several authors had noted that dry matter production in maize is related more closely to the utilization of solar radiation than to its interception (Daughtry *et al.*, 1983; Tollenaar and Bruulsema, 1988 and Westgate *et al.*, 1997).

The influence of planting date and plant density on corn grain yield may be related to interepted PAR and LAI. In Argentina, delayed planting dates were shown to increase IPAR levels at the silking stage by increasing leaf area development due to higher temperatures during vegetative growth (Cirilo and Andrade, 1994). However, yields were still lower with delayed planting dates due to reduced amounts of cumulative incident PAR. With a full season hybrid (95 day relative maturity) in 76 cm rows in West-central Minnesota, grain yield was maximized with a density of 99000 plants ha^{-1}, which corresponded with 96 to 97 per cent IPAR and 4.4 to 5.7 LAI at the silking stage (Westgate *et al.*, 1997). With 49000 plants per ha, however there was only 92 per cent IPAR and 3.3 to 3.4 LAI at the silking stage and grain yield was 18 to 22 per cent less. Higher grain yield has also been associated with increased LAI at silking. In densities of 90000 to 120000 plants per ha compared with 2.5 to 3.8 at 30000 to 45000 plants ha^{-1} (Maddonni *et al.*, 2006). They also noted that increases in LAI were associated with increased IPAR and grain yield. While corn response to the individual effects of planting date and plant density has been well researched in the northern Corn Belt, it remains unclear, whether corn response to plant density differs with planting date.

At two locations in Illionis, the optimum plant density for corn grain yield was consistent across planting dates ranging from early April to late May for two mid season hybrids (Nafziger, 1994). Although, these hybrids were selected because of their expected differential yield response to plant density, they did not differ in their response to planting date, plant density or the planting date x plant density interaction at either location. In the northern Corn Belt, the growing season and relative maturities of the hybrids planted with shorter relative maturities typically require higher plant densities to maximize grain yield (Paszkiewicz and Butzen, 2007). The effects of planting date may also be more pronounced in the northern Corn Belt, thereby influencing corn response to plant density. In southern Minnesota, corn growers are sometimes confronted with late planting situations and modify plant density may be one way to offset the yield and economic losses associated with delayed planting.

Khushu *et al.* (2008) during *kharif* season of 2004 and 2005 studied the partitioning of biomass in maize crop under different micro-climatic conditions created by different agronomic practices like dates of sowing, spacing and moisture levels. The total above ground biomass accumulation was found higher in irrigated condition as compared to the rainfed condition. It was found higher when the crop was sown on June 10 (D_1) as compared to delayed sowing (June 25-D_2) under both rainfed and irrigated conditions. The contribution of dry matter production towards leaves was more than stem before tassel initiation, however with the commencement of reproductive phase, the biomass accumulation was diverted more towards the stem followed by leaves and reproductive parts upto dough stage. Delay in sowing caused reduction in the biomass accumulation in different parts. Further, wider spacing produced higher biomass than narrow spacing and broadcasting. The higher biomass accumulation led to better source and sink relationship.

Six plant densities ranging from 38400 to 107900 plants per ha were evaluated within three planting dates that occurred on 2 weeks interval beginning in late April to early May. Yield and net return to seed cost were not affected when planting was delayed 2 week, but were 15 and 18 to 30 per cent lower when planting was delayed 4 weeks, respectively. Yield loss due to late planting was associated with a 7 per cent decrease in kernel weight and no change in kernels per square meter. Responses to plant density for stalk diameter, intercepted PAR (IPAR) and leaf area index (LAI) at silking, lodging, grain yield and components and net return to seed cost for 25 economic scenarios did not differ with planting date. There was a quadratic-plateau response of grain yield to plant density with yield maximized at >81700 plants per ha. These results from a 102 day relative maturity hybrid over six site years in southern Minnesota show that increased density may not be able to offset the yield and economic losses associated with late planting (Van roekel and Coulter, 2011).

A significant reduction of grain yield was observed as the sowing was delayed. Yield reduction of the second date of sowing compared to the first was 85 and 45 per cent for Perla Pandino and Bayo Blando, respectively. The importance of plant density as a function of the correct row spacing is clearly shown. With the row spacing in use in the considered area (0.9 m) and with the narrowest (0.5 m), the best yields were obtained with 10 plants per m^2 (5.5 t/ha). The density of maize may be increased up until 10 plants per m^2 in order to achieve the most productive results by using row spacings of 0.5 to 0.9 m, respectively depending on the genotypes used. For varieties, with a reduced height, it is possible to use a more narrow row spacing, whilst for tall plants over 2 m, a wide row spacing is recommended (Casini, 2012).

Results of Peykarestan and Seify (2012) at Iran, showed that during *kharif* season, sowing date effect was significant on number of grains per ear, number of nodes per stalk, ear height, ear diameter, husked green ear weight, 1000-grain weight, plant height and grain yield of pop corn. Densities significantly affected plant height, ear diameter, ear height, grain yield, husked green ear weight and 1000 grain weight. Interaction effect of sowing date x density was only affected 1000 grain weight, grain yield and husked green ear weight,whereas, the rest of studied traits were remained unaffected. The highest grain yield (7815 kg ha^{-1}) was that of July 6th coupled with 80000 plants ha^{-1} of density. It is concluded that optimum density for pop corn was 80000 plants ha^{-1}.

The results of Moosavi (2012b) showed that delay in sowing from July 4 to August 6 decreased significantly the plant height, stem diameter, leaf area index, total fresh and dry yield by 15.7, 20.9, 42.1, 24.7 and 25.9 per cent, respectively. With increasing plant density from 50000 to 140000 plants ha^{-1}, stem diameter decreased by 21.6 per cent but plant height increased 15.1 per cent. Moreover, leaf area index and total dry yield, increased 3.39 and 1.84 times, respectively. According to the results, the treatment of sowing date of July 4 with density of 140000 plants ha^{-1} found superior over other combinations.

Experiment was conducted by Mokhtarpour *et al.* (2013) in Gorgan (Iran), with five sowing dates- June 24th, July, 9th, July, 24th, August 18th and 23 August) and four plant densities (45000, 55000, 65000 and 75000 plants ha^{-1}). The results showed that totally biomass affected by year, sowing date and plant density and maximum biomass obtained with 33400 kg ha^{-1} in first year. Also maximum biomass achieved with 44240 kg ha^{-1} in June 24th and 75000 plants ha^{-1}. Also fresh and dry weight of forage (cob, ear, spout, stem and leaf) was affected by sowing date. At most fresh and dry weight of forage achieved on June 24th with 53370 kg ha^{-1} and 33570 kg ha^{-1} respectively. Maximum protein and crude fibre with 745 kg ha^{-1} and 1717 kg ha^{-1} achieved in 75000 plants ha^{-1} respectively. On the other hands, with increase plant density ear length decrease and economic value of sweet corn decrease so 45000 to 55000 plants ha^{-1} in summer sowing could be recommended.

3. MATERIAL AND METHODS

The present investigation entitled “Crop-weather relations in maize (*Zea mays* L.) under different sowing windows and planting geometry in northern transition zone of Karnataka” was conducted during *kharif* season of 2013 and 2014. The details of materials used and the techniques followed to carry out investigation are mentioned in this chapter under different subtitles.

3.1 Experimental site

The experiment was conducted at Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad, during *kharif* season of 2013 and 2014 under rainfed condition in plot No 75 of Block ‘D’. The geographical co-ordinates of Dharwad are 15^0 26’ N latitude and 75^0 7’ E longitude with an altitude of 678 m above mean sea level.

3.2 Climatic condition

The climatic conditions of the location are described under the following heads.

3.2.1 General climate

Geographically, Dharwad is situated in the tropical region. The average (63 year) annual rainfall of the place is 711.1 mm. Out of the total rainfall, about 66 per cent received through south-west monsoon during the months of June to September, while remaining received during the post-monsoon months (October-November) and during pre monsoon months (April-May). The maximum temperature (T_{max}) ranges between 27.3 ^{0}C (June and July) to 36.6 ^{0}C during April, while the minimum temperature (T_{min}) ranges between 13.2 ^{0}C (December) to 21.7 ^{0}C (June). The annual average maximum and minimum temperatures are 30.5 ^{0}C and 18.5 ^{0}C, respectively. The annual average relative humidity recorded is 75.7 per cent.

3.2.2 Climatic conditions during experimental period (*kharif*, 2013 and 2014)

The meteorological data recorded on the important weather parameters during the cropping season are presented in Table 1. These data were obtained from Main Agricultural Research Station, Dharwad.

Observatory, MARS, Dharwad

Field view at early vegetative stage

Field view at late vegetative stage

Field view at grand growth stage

Plate 1. General view of the experiment

Table 1: Mean monthly meteorological data for the experimental year (2013 and 2014) and the average of past 63 years (1950-2012) of Main Agricultural Research Station, UAS, Dharwad

Months	Rainfall (mm)			Temperature (^oC)						Relative humidity (%)		
	2013	2014	1950-2012	2013		2014		1950-2012		2013	2014	1950-2012
				T max	T min	T max	T min	T max	T min			
January	0.0	0.0	0.8	31.2	14.5	29.5	14.7	28.7	14.1	47	54	65
February	2.2	0.0	11.3	32.6	16.9	31.1	16.1	31.6	16.5	51	45	54
March	42.0	11.4	1.5	35.4	19.4	34.4	18.6	34.9	19.6	49	42	64
April	10.0	44.9	48.7	36.9	20.3	36.4	21.1	36.6	20.1	51	49	78
May	124.6	197.4	19.7	35.5	21.8	33.7	21.2	35.2	21.0	61	61	75
June	75.4	29.3	105.4	28.0	20.7	31.0	21.5	30.2	21.7	83	72	86
July	177.8	242.2	153.1	25.4	20.4	27.1	20.8	27.3	20.9	89	84	89
August	97.2	158.4	100.8	26.6	19.9	26.8	20.5	27.3	20.1	85	84	89
September	133.6	100.2	107.2	27.8	20.2	28.0	20.3	27.9	20.0	84	81	87
October	75.4	103.4	125.3	28.8	19.5	29.7	19.1	29.5	18.6	77	72	79
November	2.2	48.8	32.1	29.0	15.8	29.0	15.5	28.9	15.9	64	59	73
December	0.0	26.2	5.1	28.5	12.7	27.8	14.5	27.8	13.2	53	64	69
Mean				**30.5**	**18.5**	**30.4**	**18.7**	**30.5**	**18.5**	82	64	**76**
Total	**740.4**	**962.2**	**711.1**					-	-	-	-	-

Source: M.A.R.S.,Dharwad

RH = Relative humidity T max = Maximum temperature T min = Minimum temperature

Weather during the crop period (June to December)

Actual rainfall received during June, 2013 to December 2013 was 561.6 mm, with 55 rainy days. The mean maximum and minimum temperature during the crop growth period ranged between 25.4 ^{0}C (July) to 29.0 ^{0}C (November); and 12.7 ^{0}C (December) to 20.7 ^{0}C (June), respectively. The average relative humidity was highest (89 %) during July and lowest in December (Table 1).

During second year of experimentation *i.e.* 2014, total rainfall received from June, 2014 to December 2014 was 708.5 mm, with 58 rainy days. The mean maximum and minimum temperature during the crop growth period ranged between 26.8 ^{0}C (August) to 31 ^{0}C (June) and 14.5 ^{0}C (December) to 21.5 ^{0}C (June), respectively. Maximum average relative humidity (84 %) was observed during August.

3.3 Soil of the experimental field

The experiment was conducted on Vertisols and for soil analysis, random soil samples of experimental site were collected from 0 to 30 cm depth before sowing and each sample was mixed together to form a composite sample. The soil sample was analysed to determine the physico-chemical properties and the results are presented in Table 2.

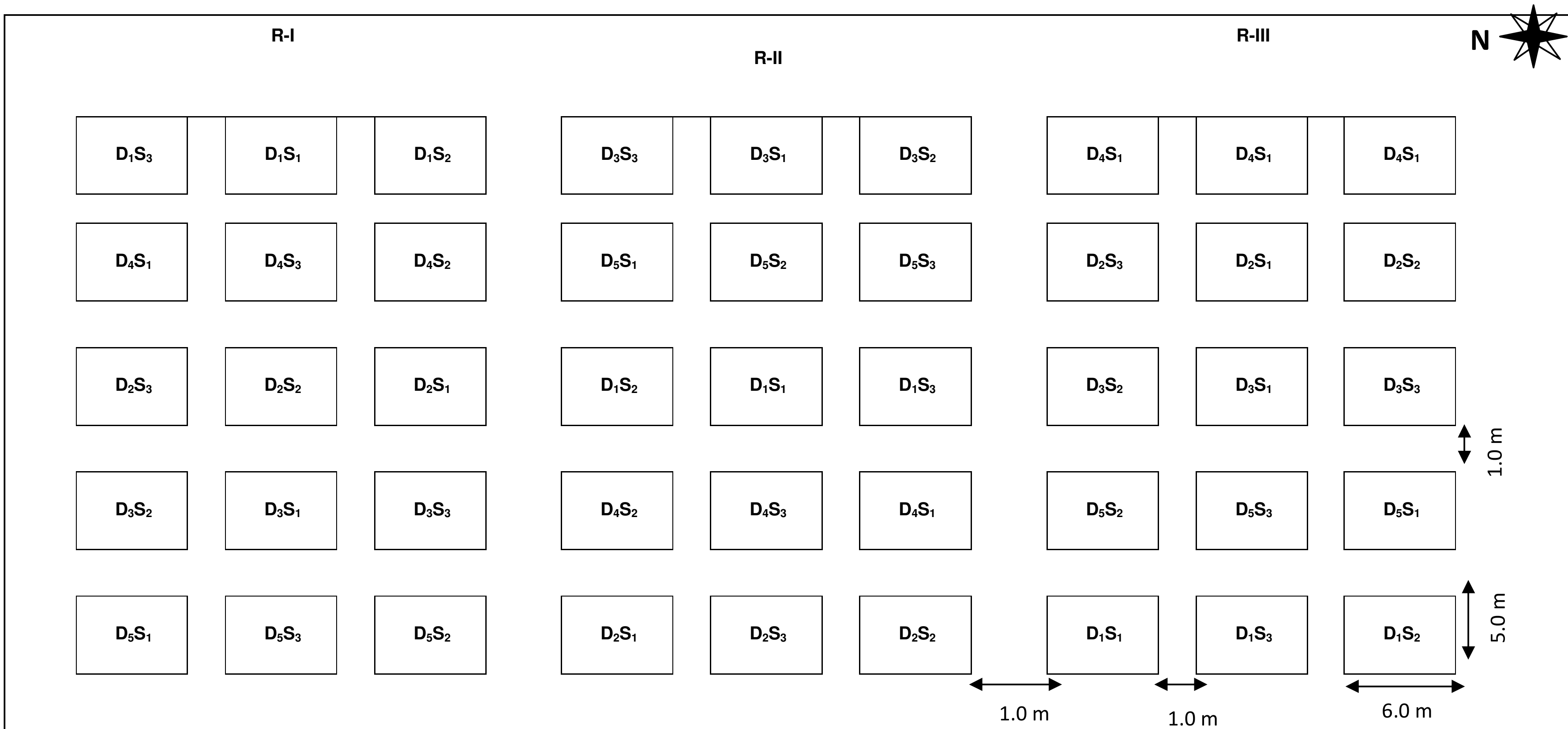
The soil of the experimental field is clayey in texture with neutral pH (7.3). The soil was low in available nitrogen (238.0 kg ha^{-1}), medium in available phosphorus (30.8 kg ha^{-1}) and high in available potassium (330.0 kg ha^{-1}).

3.4 Experimental details

The experiment was laid out in the split plot design, allocating sowing dates to main plots and planting geometries to subplots comprising fifteen treatment combinations with three replications. The layout plan of the experiment is depicted in Fig. 1 and the details of the treatments are given below.

Table 2: Methods adopted in analysis of physical and chemical properties of the experimental site

Sl. No.	Particulars	Values	Method adopted
A. physical properties			
1.	Particle size analysis		
	a. Coarse sand (%)	6.04	Hydrometer method (Piper, 1966)
	b. Fine sand (%)	12.8	
	c. Silt (%)	30.0	
	d. Clay (%)	50.2	
	e. Textural class	Clayey	
B. Chemical properties			
	1. Organic carbon (%)	0.74	Walkley and Black wet oxidation method (Jackson, 1967)
	2. pH	7.3	Glass electrode pH meter (Piper, 1966)
	3. Available nitrogen (kg ha^{-1})	238	Modified kjeldhal method (Jackson, 1967)
	4. Available P_2O_5 (kg ha^{-1})	30.8	Olsen's method (Muhr *et al.*, 1965)
	5. Available K_2O (kg ha^{-1})	330.0	Flame photometer method (Muhr *et al.*, 1965)



Main plot

Date of sowing (D)

D_1: June I fortnight

D_2: June II fortnight

D_3: July I fortnight

D_4: July II fortnight

D_5:August I fortnight

Sub plots

Planting geometry (S)

S_1 – 45 cm x 20 cm

S_2 – 60 cm x 20 cm

S_3 – 75 cm x 20 cm

D_1S_1 – June I FN with 45 cm x 20 cm

D_2S_1 – June II FN with 45 cm x 20 cm

D_3S_1 – July I FN with 45 cm x 20 cm

D_4S_1 – July II FN with 45 cm x 20 cm

D_5S_1 – August I FN with 45 cm x 20 cm

D_1S_2 – June I FN with 60 cm x 20 cm

D_2S_2 – June II FN with 60 cm x 20 cm

D_3S_2 – July I FN with 60 cm x 20 cm

D_4S_2 – July II FN with 60 cm x 20 cm

D_5S_2 – August I FN with 60 cm x 20 cm

D_1S_3 – June I FN with 75 cm x 20 cm

D_2S_3 – June II FN with 75 cm x 20 cm

D_3S_3 – July I FN with 75 cm x 20 cm

D_4S_3 – July II FN with 75 cm x 20 cm

D_5S_3 – August I FN with 75 cm x 20 cm

Fig. 1: Plan of layout of the experiment

3.4.1 Treatment details

Main plots (D) : Sowing dates

D_1 : June I fortnight (23 - 24th SMW)

D_2 : June II fortnight (25 - 26th SMW)

D_3 : July I fortnight (27 - 28th SMW)

D_4 : July II fortnight (29 - 30th SMW)

D_5 : August I fortnight (31 – 32nd SMW)

Subplots (S) : Planting geometry

S_1 : 45 cm x 20 cm (111111 plants/ha)

S_2 : 60 cm x 20 cm (83333 plants/ha)

S_3 : 75 cm x 20 cm (66666 plants/ha)

3.4.2 Other experimental details

Design	: Split plot
Total No. of treatments	: Fifteen (5 x 3 = 15)
Number of replications	: Three (3)
Cultivar	: Dekalb Super 900 M (Hybrid)
Gross plot size	: 30.0 sq.m (6 m x 5 m)
Net plot	:
	S_1 45 cm x 20 cm : 17.01 sq m (4.2 m x 4.05 m)
	S_2 60 cm x 20 cm : 15.12 sq. m. (4.2 m x 3.60 m)
	S_3 75 cm x 20 cm : 12.60 sq. m. (4.2 m x 3.00 m)

Location	: Plot No. 75, MARS, Dharwad
Season/year	: *Kharif*, 2013 and 2014
Situation	: Rainfed

3.5 Details of cultivation

Different crop husbandary practices used for the experimentations are as follows.

3.5.1 Land preparation

The land was ploughed by tractor mounted MB plough after the harvest of previous crop followed by two harrowings and leveled with wooden plank to prepare desirable seed bed and laid out as per the plan and kept ready for sowing.

3.5.2 Fertilizer application

Recommended fertilizer levels (100:50:25 kg N,P_2O_5 and K_2O per ha) in the form of Urea, DAP and MOP as per the plant density were applied. For each sowing date, 50 per cent of recommended nitrogen and full dose of phosphorus and potash were applied as basal application and remaining 50 per cent of nitrogen was top dressed 30 days after sowing (DAS).

3.5.3 Seeds and sowing

Healthy seeds of single cross hybrid maize (*Dekalb* Super 900 M) were used for sowing during 2013 and 2014. Before sowing, seed rows were marked with respective wooden markers for each treatment with different row spacing. Then, in the seed rows at each spot two seeds were carefully hand dibbled upto a depth of 4 to 5 cm and covered with soil. Phorate granules were applied as a prophylactic measure to avoid termite, bird and rodent damage.

Date of sowing	Rain	Actual Sowing date (s)	
	*Nakshatra	2013	2014
D_1: June I fortnight	*Mrigashira*	17th June ** (168th Julian day)	16th June** (167th Julian day)
D_2: June II fortnight	*Aaridra*	1st July** (182nd Julian day)	25th June** (176th Julian day)
D_3: July I fortnight	*Punarvasu*	13th July (194th Julian day)	8th July (189th Julian day)
D_4: July II fortnight	*Pushiya*	29th July (210th Julian day)	24th July (205th Julian day)
D_5: August I fortnight	*Aashlesha*	13th August (225th Julian day)	11th August (223rd Julian day)

* according to *Hindu calendar*

** due to delayed onset of monsoon and deficit rainfall during the period (June I FN (fortnight) to June II FN) sprinkler irrigations were given to impose the treatment and for seedling establishment

3.5.4 Gap filling and thinning

Gap filling was done eight DAS to maintain the required/recommended optimum plant density for each treatment wherever necessary. Also, thinning of excess plants was done eight DAE and maintained required plant density.

3.5.5 Hand weeding and intercultivation

Experimental plots were kept weed-free during crop growth period with one intercultivation and two hand weedings at 25 and 45 days after sowing. Intercultivation was done using hand hoe.

3.5.6 Plant protection

To control stem borer incidence in the late sown maize crop, 3-4 granules of carbofuran were applied in the leaf whorls of each plant at three leaf stage.

3.5.7 Harvesting and threshing

The crop was manually harvested as and when each sowing dates attained the physiological maturity. Two outer rows of each treatment from both sides were harvested as border lines and kept separately before harvesting from net plots. Dehusked maize cobs in the net plot were harvested and kept for sun drying in the threshing yard with labels. After sun drying the cobs were threshed mechanically and grain weight of each net plot was recorded. The stover yield was recorded after sun drying for 10 to 15 days and both grain and stover yield were computed on hectare basis.

3.6 Crop phenological observations

The observation on the days taken for various phenological (seedling, sixth leaf, tasseling, silking and physiological maturity) events were recorded from the five tagged plants in each plot. Whenever, more than three plants from each plot attained a particular stage, that date was recorded for attainment of the stage. This method determines the leaf stage in maize by counting the number of leaves on a plant with visible leaf collars, beginning with the lower most, short, rounded tip, true leaf and ending with the uppermost leaf with a visible leaf collar. The leaf collar is the light coloured collar like “band” located at the base of an exposed leaf blade, near the spot where the leaf blade comes in contact with the stem of the plant. Leaves were marked as collared leaves for subsequent staging, tasseling dates were determined when 50 per cent of the plants had visible tassel and silking dates were determined when 50 per cent of the plants had visible silks. The time of physiological maturity was determined by assessing the presence of black layer at the base of the grain. This black layer indicates that no further accumulation of grain mass is possible (Daynard and Duncan, 1969).

3.7 Biometric observations

Various biometric observations were recorded treatment-wise from randomly selected five plants from each net plot during the course of investigation. The details of observations and techniques followed for each observation are described wherever necessary.

3.7.1.1 Plant height

The plant height was measured from base of the plant above ground to the base of collar of fully opened leaf until tassel emergence. Later, the plant height was measured from the base of plant to the tip of tassel and expressed in centimeter (cm).

3.7.1.2 Leaf area per plant (dm^2)

Leaf area per plant during leaf expansion was estimated by measuring length and maximum width of every leaf of five randomly chosen plants (tagged) within each treatment and non-destructive measurements were taken on the same plants throughout the season. The length of fully opened leaf lamina was measured as the distance between the collar and tip. Leaf width was taken at the widest point of the leaf lamina. Then the leaf area (one side) of each individual leaf calculated by multiplying length by maximum width by 0.75 (Montgomery, 1911, McKee, 1964 and Saxena and Singh, 1968). Sum of areas of all the leaves in a plant was expressed as leaf area per plant and expressed as dm^2 per plant.

Leaf area = Leaf length x Maximum leaf width x 0.75 (factor)

3.7.1.3 Leaf area index (LAI)

Leaf area index was estimated as the sum of leaf areas per plant occupied per unit land area (Sestak *et al.*, 1971).

$$LAI = \frac{A}{P}$$

Where,

LAI = Leaf area index

A = Leaf area per plant (dm^2)

P = Land area occupied per plant (dm^2)

3.7.1.4 Dry matter production and partitioning

Randomly selected five plants from destructive sampling area taken at different phenological stages were used to record dry matter production and partitioning. The sample plants were separated into leaf (including leaf sheath), stem, cobs with husk (cob sheath) and tassel. Thereafter, these samples were air dried for few days and then oven dried at 65 + 5 ^{0}C temperature till constant weight was attained. Dry weight was recorded separately at each stage for each part by weighing on electronic balance and the weight was expressed in grams (g) per plant.

3.7.2 Yield and yield attributes

Maize cobs (dehusked) from five labeled plants were manually harvested after attainment physiological maturity in each treatment, bagged and processed individually for taking observations on yield attributes.

3.7.2.1 Cob weight per plant (g)

After harvest of cobs in the net plot, they were sun dried for 10 days and dry weight was measured for each cob and average weight of five cobs was recorded and expressed in grams (g).

3.7.2.2 Grain weight per cob (g)

The grains (kernel) from sun dried cobs of five plants were threshed with hand sheller and dried grains (kernels) were weighed on electronic balance. The average weight was recorded as grain weight (kernel) per cob and expressed in grams (g).

3.7.2.3 Number of seed (kernel) rows per cob

The number of kernel rows per cob was counted at harvest and average of five cobs was recorded as number of seed rows per cob.

3.7.2.4 Cob length (cm)

Length of cob measured from base to the tip of the cob and the average was recorded as cob length and expressed in centimeters (cm).

3.7.2.5 Test weight (100 grain weight)

The weight of hundred maize grains (kernels) was recorded from the grain samples drawn from each of the net plot grain yields.

3.7.3.1 Grain yield (kg ha^{-1})

At physiological maturity, cobs (dehusked) from net plot were manually harvested treatmentwise and then sun dried till complete drying of cobs. Completely dried cobs from net plot of each treatment were threshed using machine and the net plot grain yield was recorded and computed on hectare basis as kilograms per hectare (kg ha^{-1}).

3.7.3.2 Stover yield

The stover yield was recorded for each plot after sun drying for 10 to 15 days and computed on hectare basis and expressed as tonnes per hectare (t ha^{-1}).

3.7.3.3 Harvest index

The harvest index is defined as the ratio of economical yield to the biological yield (Donald, 1962) and expressed in percentage. HI was calculated as:

$$\text{Harvest index (\%, HI)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.8 Computation of agro-meteorological indices

The following agrometeorological indices were computed using the daily meteorological data.

3.8.1 Growing degree days (GDD)

Temperature is a major environmental factor that determines the rate of plant development. The thermal time or heat units (HU) consumed by the crop for different phenological stages in maize were computed as per the formula.

$$\text{GDD } (^0\text{C days}) = \sum_{a}^{n} \left(\frac{(T_{max} + T_{min})}{2} \right) - T_b$$

Where,

T_{max} is daily maximum temperature (^{0}C)

T_{min} is daily minimum temperature (^{0}C)

T_b is base temperature (threshold temperature) below which no growth

(T_b for maize is 10 ^{0}C) (Narcico *et al.*, 1992)

'a' is starting date of phenophase

'n' is ending date of that phenophase

3.8.2 Heat use efficiency (HUE)

Heat use efficiency was calculated as the ratio of dry matter (DM) and cumulative thermal time ($\sum$ GDD ^{0}C day) between two consecutive phenological stages of the crop.

$$\text{HUE (g m}^{-2}/\ ^0\text{C day)} = \frac{\text{DMP (g m}^{-2})}{\sum \text{GDD (}^0\text{C day)}}$$

3.8.3 Phenothermal index (PTI) (^{0}C day per day)

$$\text{Phenothermal index} = \frac{\text{GDD (}^0\text{C day)}}{\text{No. of days taken for any two consecutive phenophases}}$$

3.8.4 Meteorological observations

Daily observation of meteorological parameters *viz.*, maximum and minimum temperature, morning and evening relative humidity, morning and evening vapour pressure rainfall and wind speed were recorded and collected from agro-meteorological observatory of Main Agricultural Research Station situated near by the experimental field.

3.9 Micrometeorological observations

3.9.1 Soil temperature

Soil temperature was measured by placing soil thermometers at two depths (at 5 cm and 15 cm) in the soil in between the seed rows in each treatment. The soil temperature was recorded manually in the morning (0700 hrs) and afternoon (1430 hrs) during different phenological stages (seedling (V_1), sixth leaf (V_6), tasseling (VT), silking (R_1) and physiological maturity). Surface soil temperature were taken with hand held infra red thermometer by pointing it to the soil surface (skin) from a distance of 50 cm with 45^{o} angle. Soil surface temperature—air temperature differentials were observed (Plate 2).

3.9.2 Within canopy air temperature and relative humidity

Using handheld weather tracker (Model – Kestrel 4500) at three heights within canopy (top, mid and bottom) were recorded both in the morning (0700 hrs) and afternoon (1430 hrs) during different phenological stages (seedling (V_1), sixth leaf (V_6), tasseling (VT), silking (R_1) and physiological maturity).Mean canopy—air temperature differentials were observed.

3.9.3 Leaf temperature

Leaf temperature was measured with handheld infrared thermometer (Gun) (Model:Equinox DT8503). These measurements were taken by pointing the infrared thermometer (Gun) on the top of the canopy to the upper second, full grown sunlit leaf of maize plant. Mid rib of the leaf is availed while taking the observations. The field of view of IR thermometer was 4^{0} solid angle and the instrument (gun) was held at an angle of about 45^{0} to the crop canopy at a distance of 50 cm, so as to minimize the soil background influence on canopy temperature. These observations were taken between 1400 and 1430 hrs (IST) at different phenophases (seedling (V_1), sixth leaf (V_6), tasseling (VT), silking (R_1) and physiological maturity). Leaf-air temperature differentials were observed.

3.9.4 Light transmission ratio (LTR)

The light intensity was measured on the canopy of maize using lux meter (Model:Equinox) at different phenological stages. The light intensity was recorded above the canopy (I_0) and at the ground level (I). These observations were taken between 12 noon and 1.00 pm during seedling (V_1), sixth leaf (V_6), tasseling (VT), silking (R_1) and physiological maturity and the light intensity expressed in foot candles LTR was calculated using the formula suggested by Yoshida *et al.* (1972).

$$LTR\ (\%) = \frac{I}{I_0} \times 100$$

Line quantom sensor with data logger

PAR observation using line quantom sensor (below canopy)

PAR observation using line quantom sensor (above canopy)

Soil temperature observation using soil thermometer

Leaf temperature observation using infrared gun

Light observation using lux meter

Plate 2. Micro meteorological observations during different phenological stages

Where,

I = Light intensity at ground level

I_0 = Light intensity received above the canopy

Light absorption ratio (LAR) was worked out from LTR values as follows

LAR (%) = 100 - LTR (%)

3.9.5 Photosynthetic Active Radiation (PAR) studies

During photosynthesis, plants use energy in the region of electro magnetic spectrum from 400 – 700 nm. The radiation in this range referred to as PAR (Photosynthetically Active Radiation) can be measured in energy units of quanta (photons) per unit time per unit surface area (μ mol m^{-2} s^{-1}).

The various components of PAR *viz.*, incoming (PARo), intercepted (IPAR), transmitted (TPAR) and reflected (RPAR) were measured with the help of line quantum sensor (Plate 2). It specially averages radiation over its one meter length and thus minimizes the error was used. It was connected to the data logger (L1-1400). The sensor was leveled and always held horizontal during measurements. All measurements were made under clear sky between 1100 to 1400 hrs to eliminate the effects of solar elevation (Sivakumar and Viramani, 1984). The measurements were made at different phenological stages (three leaf, sixth leaf, tasseling, silking and physiological maturity). PARo was measured by keeping the line quantum sensor facing up above the top of the canopy. Whereas, TPAR was measured by placing line quantum sensor above the ground perpendicular (across) the rows. IPAR was calculated using the equation (Gallo and Daughtry, 1986).

$$\text{IPAR} = \text{PARo} - \text{TPAR}$$

Total reflected PAR by the canopy (RPARc) and soil was measured by inverting the line quantum sensor and holding it above the canopy across the rows. The reflected PAR by soil (RPARs) was measured by inverting line quantum sensor and holding it 15 cm above the soil across the rows, RPAR by canopy was determined by using equation.

$$\text{RPAR} = \text{RPARc} - \text{RPARs}$$

APAR was worked out by adopting the equation,

APAR = (PARo + RPARs) – (TPAR + RPARc) (Gallo and Daughtry, 1986).

$$\text{Per cent TPAR} = \frac{\text{TPAR}}{\text{Incident PAR}} \times 100$$

$$\text{Per cent APAR} = \frac{\text{APAR}}{\text{Incident PAR}} \times 100$$

$$\text{Per cent IPAR} = \frac{\text{IPAR}}{\text{Incident PAR}} \times 100$$

Details of instrument used

L1-191SA Line quantum sensor

The L1-191 sensor is designed for measuring PAR (Photosynthetically Active Radiation) in applications where the radiation is to be measured in spatially non-uniform canopies (such as within canopies). To achieve this sensor features a sensing area extending to one meter length. The L1-191 SA has quantum (photon) response through the wavelength range of 400 – 700 nm for PPFD (Photosynthetic Photon Flux Densitry) as generally preferred for PAR measurements and has an output in units of mole,

Where, 1 □ mol m^{-2} s^{-1} = 1 □ E m^{-2} s^{-1} = 6.02 x 1017 photon m^{-2} s^{-1}

The L1-191 SA line quantum sensor, which spatially averages radiation over its one meter length, minimize the errors and allows single person to easily make many measurements within a short period of time. The sensor was connected to the datalogger. Since, the sensing area is a flat acrylic diffuser, the response of given angle of incidence is fairly constant, as the azimuth angle around the sensor is varied. It is specified at less than + at a 45^0 angle of elevation for 360^0 sensor rotation.

Specifications

Absolute calibration : + 10 % traceable to NBS. The L1-191 SA is calibrated under natural daylight clear conditions, via transfer calibration using a reference

L1-191SA line quantum sensor. Transfer error is + 5 % (including the + 10 %)

Sensitivity : Typically 3 µA per 1000 µ mol m^{-2} s^{-1}

Linearity : Maximum deviation of 1 % upto 10000 µ mol m^{-2} s^{-1}

Stability : < + 2 % changes over a one year period

Response time : 10 µs

Temperature dependence : + 0.15 % per ^{0}C maximum

Cosine correction : Acrylic diffuser

Azimuth : At 45^{0} elevation < + 2 % error over 360^{0}

Sensitivity area : 1 m L x 12.7 mm W

Detector : High proof anodized aluminium case with acrylic diffuser and stainless steel hardware

Size : 116 cm L x 2.54 cm W x 2.5 cm D

Weight : 1.8 kg

Cable length : 3.1 m (10.0 ft)

3.9.6 Soil moisture content

Soil samples were drawn upto 45 cm depth (0-15, 15-30 and 30-45 cm) using screw auger at different phenological stages (seedling (V_1), sixth leaf (V_6), tasseling (VT), silking (R_1) and physiological maturity). The soil moisture content was determined gravimetrically. The soil samples were collected in air tight aluminium moisture containers. Wet weight of soil sample was recorded immediately. The same soil samples were kept in hot air oven at 105 ^{0}C for about 24 hours to get a constant weight. The available soil moisture was calculated using the formula as suggested by Reddy and Reddy (2000).

$$\text{Moisture content of soil (\%)} = \frac{WS_1 - WS_2}{WS_2} \times 100$$

Where,

WS_1 = Wet weight of soil sample (g)

WS_2 = Oven dry weight of soil sample (g)

3.10 Economics

3.10.1 Gross return (` ha^{-1})

The income from maize main product (grain) and byproduct (stover) of maize considered for accounting gross return. The minimum support prices prevailed at the time of selling, were considered to calculate the gross return.

3.10.2 Net return (` ha^{-1})

Net return was calculated by subtracting the cost of cultivation (` ha^{-1}) from the gross return.

3.10.3 Benefit: cost ratio

The ratio of gross return and cost of cultivation was worked out for each treatment and was used as benefit: cost ratio (B : C) to compare the performance of different treatments.

$$\text{B : C ratio} = \frac{\text{Gross return (` ha}^{-1}\text{)}}{\text{Cost of cultivation (` ha}^{-1}\text{)}}$$

3.11 Statistical analysis and the interpretation of data

Data were analyzed using statistical software MSTAT-C and the means were compared by Duncan Multiple Range Test at 5 % level. Calculation of correlation coefficients ('r') were done using *SPSS* 16 *version* computer software.

4. EXPERIMENTAL RESULTS

Keeping in view of the objectives of the research entitled “Crop-weather relations in maize (*Zea mays* L.) under different sowing windows and planting geometry in northern transition zone of Karnataka”, field experiment was conducted during *kharif* season of 2013 and 2014. Various observations recorded during the course of investigation and data collected thereof have been duly analyzed and presented in this chapter under suitable heads with the help of appropriate tables and suitable figures.

In order to get an idea about the weather conditions prevailed during *kharif* season 2013 and 2014, the meteorological data recorded on the important weather parameters during the cropping period and are presented in Table 3. The meteorological data were recorded at Agromet observatory, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, which is situated near the experimental site. The data is presented along with mean values of 27 years (1985-2012). From the daily data collected, weekly mean values except for rainfall (weekly total) for the standard meteorological weeks (SMWs) are presented in Table 3 and presented in Fig. 2.

4.1 Weather prevailed during the crop period

4.1.1.1 Maximum temperature (^{0}C)

During *kharif* 2013 weekly mean maximum temperature gradually decreased from 29.2 ^{0}C in 23rd SMW to 25.5 ^{0}C in 28th SMW and then again increased to 29.4 ^{0}C in 35th SMW and then again declined to 26.5 ^{0}C in 39th SMW and raised to 30.3 ^{0}C in 42nd SMW. Thereafter it decreased gradually up to 52^{n}d SMW. Whereas, *kharif* 2014 weekly mean maximum temperature decreased from 32.2 ^{0}C in 23rd SMW to 25.2 ^{0}C in 31st SMW and then again increased to 29.4 ^{0}C in 34th SMW and then again declined to 24.8 ^{0}C in 35th SMW and gradually raised to 31.2 ^{0}C in 42nd SMW. There after it decreased gradually up to 51st SMW. The weekly mean maximum temperature of 2013 (27.7 ^{0}C) were slightly below normal (28 ^{0}C) (mean of 27 years) and a slightly higher mean values were observed during 2014 compared to normal (28 ^{0}C).

Table 3: Weekly Mean of 27 years (1985-2012) and actual values (2013 and 2014) of the weather parameters during the crop growing period

Period	SMW	Rainfall (mm)			Deviation from normal		T max (^{0}C)			T min (^{0}C)			RH m (%)			RH e (%)			NRD			WS (kmph)		
		1985-12 M	2013 A	2014 A	2013	2014	1985-12 M	2013 A	2014 A	1985-12 M	2013 A	2014 A	1985-12 M	2013 A	2014 A	1985-12 M	2013 A	2014 A	1985-12 M	2013 A	2014 A	1985-12 M	2013 A	2014 A
June 4-10	23	24.2	2.8	5.4	-21.4	-18.8	30.3	29.2	32.2	21.5	20.8	22.0	85.1	92	88	71.1	66	56	3.0	0	1	7.2	10.1	11
June 11-17	24	31.6	21.4	3.0	-10.2	-28.6	27.6	26.9	30.4	21.1	20.9	21.7	90.8	93	90	79.4	79	54	2.9	5	0	7.3	12.9	11
June 18-24	25	26.6	8.6	16.7	-18.0	-9.9	28.4	27.7	28.7	21.1	20.7	21.5	89.9	93	90	74.7	71	64	2.0	1	2	7.3	11.3	13
June 25-01	26	21.4	24.8	0.0	3.4	-21.4	28.1	27.3	31.9	21.1	20.6	20.8	90.0	94	87	76.0	76	48	2.1	4	0	7.5	11.7	11
July 02-08	27	28.3	16.2	2.6	-12.1	-25.7	27.6	26.7	30.4	20.8	20.6	20.8	91.0	95	88	78.1	74	58	3.1	2	0	7.9	11.1	11
July 09-15	28	17.2	27.8	18.4	10.6	1.2	28.0	25.5	26.8	20.6	20.3	20.4	90.9	95	92	75.2	81	81	2.0	4	3	8.0	10.0	14
July 16-22	29	35.9	36.8	48.8	0.9	12.9	26.7	25.7	25.3	20.9	20.7	21.1	92.0	95	95	84.0	84	80	4.0	3	7	8.0	11.6	15
July 23-29	30	48.0	85.6	93.6	37.6	45.6	26.4	23.9	25.9	20.6	20.1	20.8	93.8	95	95	80.9	88	81	3.8	6	5	7.9	13.1	13
July 30-05	31	33.8	59.6	102.6	25.8	68.8	26.4	25.0	25.2	20.6	20.1	20.9	92.9	95	96	81.0	85	85	3.0	6	5	8.0	14.4	13
Aug. 06-12	32	13.7	18.4	47.0	4.7	33.3	27.0	27.2	25.5	20.8	20.0	20.7	91.6	94	94	76.9	78	76	1.1	1	5	7.9	10.3	10
Aug. 13-19	33	14.6	12.0	8.0	-2.6	-6.6	27.4	26.3	27.8	20.5	20.5	20.3	91.3	95	93	76.5	79	67	1.9	1	2	7.8	10.1	9
Aug. 20-26	34	43.8	11.6	51.8	-32.2	8.0	27.6	26.3	29.4	20.4	19.5	20.5	92.8	92	93	76.0	79	65	2.0	3	5	7.8	11.1	7
Aug. 27-02	35	45.8	8.0	32.4	-37.8	-13.4	25.7	29.4	24.8	20.4	19.3	20.1	94.0	91	95	82.4	63	85	4.1	1	5	7.3	8.0	11
Sept. 03-09	36	20.7	9.4	19.4	-11.3	-1.3	26.2	28.6	25.9	20.4	20.0	20.3	93.0	94	93	77.5	73	77	2.2	2	3	7.1	7.1	11
Sept. 10-16	37	12.4	97.0	0.0	84.6	-12.4	27.1	28.0	28.2	20.2	21.0	20.0	90.9	95	93	71.3	73	67	1.0	6	0	7.0	5.3	10
Sept. 17-23	38	47.2	15.4	6.2	-31.8	-41.0	27.0	27.2	28.0	19.5	20.4	19.9	88.6	95	91	71.7	75	67	1.9	3	1	7.0	9.6	8
Sept. 24-30	39	24.9	6.4	70.0	-18.5	45.1	28.4	26.5	30.5	19.7	19.7	20.9	88.6	94	89	66.9	77	66	2.0	1	3	7.0	9.3	5
Oct. 01-07	40	44.0	10.2	36.8	-33.8	-7.2	29.8	27.5	30.5	20.1	20.0	19.7	90.9	93	87	64.6	73	55	2.9	1	3	6.9	9.1	4
Oct. 08-14	41	67.5	0.0	2.6	-67.5	-64.9	29.6	29.2	29.9	19.8	19.4	20.4	88.4	93	92	63.6	59	62	2.0	0	1	6.9	7.9	5
Oct. 15-21	42	22.6	17.6	0.6	-5.0	-22.0	29.2	30.3	31.2	19.6	19.4	19.4	87.8	90	83	63.6	50	48	2.0	1	0	6.9	5.4	5
Oct. 22-28	43	20.7	47.6	63.4	26.9	42.7	28.1	27.8	27.6	18.0	20.0	18.7	83.4	92	89	58.4	73	67	1.0	3	3	7.0	5.7	7
Oct. 29-04	44	11.7	0.0	0.0	-11.7	-11.7	27.8	29.3	29.0	18.3	17.7	15.1	86.7	87	72	62.6	50	36	1.0	0	0	7.2	5.0	6
Nov. 05-11	45	16.5	0.0	0.0	-16.5	-16.5	28.1	28.8	29.9	17.4	15.9	16.0	80.6	86	72	54.2	50	39	0.9	0	0	7.7	5.6	4
Nov. 12-18	46	3.9	0.0	48.8	-3.9	44.9	29.6	28.0	28.3	16.7	14.0	17.6	75.8	73	88	48.0	50	57	0.0	0	2	7.7	6.6	6
Nov. 19-25	47	8.6	0.0	0.0	-8.6	-8.6	29.2	29.4	28.9	15.8	15.2	15.5	78.7	75	80	52.7	40	45	0.9	0	0	7.8	4.3	5
Nov. 26-02	48	1.6	2.2	0.0	0.6	-1.6	28.9	29.6	28.6	16.7	17.5	12.8	84.2	86	66	53.3	50	30	0.0	0	0	7.8	5.1	6
Dec. 03-09	49	0.6	0.0	0.0	-0.6	-0.6	28.6	28.5	28.9	15.0	13.3	13.7	79.4	74	71	51.4	36	40	0.0	0	0	7.7	6.9	4
Dec. 10-16	50	1.0	0.0	26.2	-1.0	25.2	28.6	28.7	27.9	14.1	11.7	18.1	78.5	60	92	51.3	29	60	0.0	0	1	7.7	5.6	3
Dec. 17-23	51	0.1	0.0	0.0	-0.1	-0.1	28.3	28.3	26.6	12.0	11.2	13.7	73.0	66	83	42.5	30	48	0.0	0	0	7.8	5.3	6
Dec. 24-31	52	1.3	0.0	0.0	-1.3	-1.3	28.8	28.1	27.4	14.6	12.9	12.9	76.6	77	79	49.3	38	47	0.0	0	0	6.6	6.9	4
Total/avg		**690.2**	**539.4**	**704.3**	**-150.8**	**14.1**	**28.0**	**27.7**	**28.4**	**18.9**	**18.4**	**18.9**	**87.0**	**88.3**	**87.2**	**67.2**	**64.3**	**60.4**	**53**	**54.0**	**57.0**	**7.5**	**8.5**	**8.3**

Source: M.A.R.S.,Dharwad

T max= Maximum temperature T min= Minimum temperature RH m= morning relative humidity RH e= Evening Relative humidity NRD= No. of rainy days WS= Wind speed

M=Mean of 27 years (1985-2012) A= Actual values (during 2013 and 2014 cropping season) SMW= Standard Meteorological Weeks

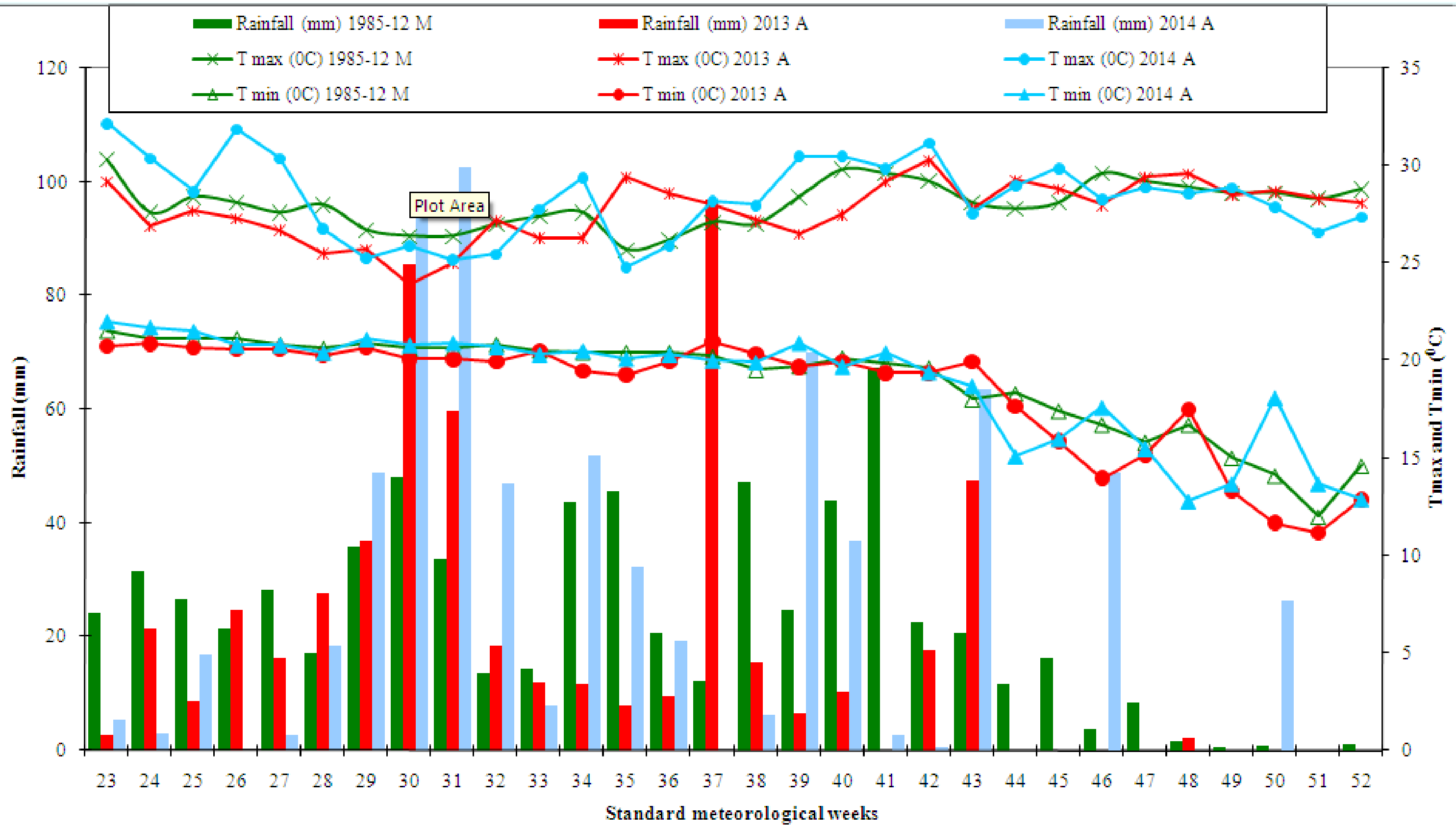


Fig. 2: Weekly (Standard meteorological week-wise) mean of 27 years (1985-2012) and actual values (2013 and 2014) of the weather parameters during the crop growing period

4.1.1.2 Minimum temperature (^{0}C)

The weekly minimum temperature varied from 20.8 ^{0}C (23rd SMW) to 11.2 ^{0}C (51st SMW) during cropping season of 2013. During 2014 *kharif* season, the values ranged from 22.0 ^{0}C (23rd SMW) to 12.9 ^{0}C (51st SMW). The weekly mean minimum temperature of 2013 was slightly lower (18.4 ^{0}C) than normal (18.9 ^{0}C) of 27 years. But, the weekly mean minimum temperature of 2014 (18.9 ^{0}C) was same as that of normal.

4.1.2 Relative humidity (%)

During 2013 weekly morning relative humidity gradually increased from 23rd SMW (92 %) to 33rd SMW (95 %) and declined up to 35th SMW (91 %). Again it increased to 95 per cent during 38th SMW. Thereafter, it declined up to 50th SMW to attain a lowest value of 60 per cent. Weekly mean morning relative humidity values (88 %) exceeded the normal (87 %). Similarly, during 2014, weekly morning relative humidity gradually increased from 23rd SMW (88 %) to 31st SMW (96 %) and gradually declined up to 48th SMW (66 %).Compared to normal (87 %), weekly mean morning relative humidity values were slightly higher (87.2 %).

The weekly evening relative humidity during 2013 ranged from 29 to 88 per cent and were 30 to 85 % during 2014. The evening relative humidity values for 2013 (64 %) and 2014 (60 %) were slightly lower than the 27 years mean values (67 %).

4.1.3 Rainfall (mm)

During, 2013, cropping period, a total of 539.4 mm rainfall in 54 rainy days and during 2014 cropping season, 704.3 mm rainfall in 57 rainy days was received. Compared to normal rainfall (690.2 mm), there was a deficit in 2013 by 21.9 per cent, while, 2 per cent higher rainfall was observed during 2014.

4.1.4 Wind speed (kmph)

Compared to normal wind speed (7.2 to 8.0 kmph), higher wind speed values prevailed from 23rd SMW to 31st SMW, during both 2013 (10.1 to 14.4 kmph) and 2014 (10 – 15 kmph) cropping period. Thereafter it was declined upto the end of cropping period. In comparison with the 27 years mean values (7.5 kmph), the mean wind speed value for the entire cropping period was higher for both 2013 (8.5 kmph) and 2014 (8.3 kmph).

4.2 Crop weather relations under different growing environments and planting geometry

4.2.1 Mean maximum and minimum temperature

Mean maximum and minimum temperature (^{0}C) at different phenophases of maize under different sowing dates for 2013 and 2014 are presented in Table 4.

During 2013, the maximum and minimum temperatures in early sowing (June I FN, D_1) were 27.4 and 20.6 at sowing to seedling emergence, 26.7 and 20.6 at seedling emergence to sixth leaf stage, 25.5 and 20.2 at sixth leaf to tasseling, 25.9 and 20.0 at tasseling to silking, 28.5 and 19.9 at silking to milk stage and 27.5 and 20.0 at milk to physiological maturity stage. Both maximum and minimum temperatures decreased with delayed sowings (except for D_5, August I FN) from sowing to sixth leaf stage. In the later stages of crop *i.e.*, sixth leaf to tasseling, maximum temperature increased with delayed sowings, whereas, it did not show any specific trend in the later stages except at milk to physiological maturity, where it increased with delayed sowings (except at August I FN sowing). Minimum temperature also did not show any specific trend but it increased upto D_3 (July I FN) and later it decreased. During milk to physiological maturity stage, it decreased with delayed sowings.

Similarly for 2014, June I FN (D_1) sowings experienced a maximum and minimum temperatures of 28.7 and 21.2 at sowing to seedling emergence, 30.8 and 21.0 at seedling emergence to sixth leaf stage, 25.7 to 20.8 at sixth leaf to tasseling, 27.4 and 20.4 at tasseling to silking, 27.0 and 20.4 at silking to milk stage and 28.9 and 20.1 at milk to physiological maturity stages. Maximum temperature increased with delayed sowings during sixth leaf to tasseling, silking to milk and milk to physiological maturity stages. Whereas, minimum temperature decreased with delayed sowings during the above mentioned stages.

Table 4: Maximum and minimum temperature (°C) at different phenophases of maize under different growing environments (sowing dates) during 2013 and 2014 cropping period

Sowing dates	Sowing to seedling emergence		Seedling emergence to six leaf stage		Six leaf to tasseling		Tasseling to silking		Silking to milk		Milk to Physiological maturity		Grain yield (kg/ha)
	Maximum temperature (°C)												
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	
D_1 – June I FN	27.4	28.7	26.7	30.8	25.5	25.7	25.9	27.4	28.5	27.0	27.5	28.9	8082
D_2 – June II FN	26.4	31.8	25.1	28.5	27.1	26.1	29.9	29.6	27.5	26.2	28.6	29.8	7716
D_3 – July I FN	26.0	28.2	25.1	25.5	27.5	26.8	28.6	26.3	27.1	28.9	28.9	29.6	7400
D_4 – July I FN	24.4	25.7	26.5	26.0	28.1	27.1	26.4	28.4	28.1	30.0	29.1	29.5	5892
D_5 – August I FN	26.5	26.8	27.9	27.5	27.3	27.7	29.4	29.8	29.5	30.7	28.6	28.5	5035
	Minimum temperature (°C)												
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	
D_1 – June I FN	20.6	21.2	20.6	21.0	20.2	20.8	20.0	20.4	19.9	20.4	20.0	20.1	8082
D_2 – June II FN	20.6	20.8	20.4	20.7	19.8	20.7	20.0	20.3	20.4	20.1	19.7	20.2	7716
D_3 – July I FN	20.5	20.5	20.2	20.9	19.9	20.4	20.9	20.1	20.1	20.2	19.4	18.9	7400
D_4 – July I FN	20.0	20.7	20.2	20.7	20.0	20.2	19.7	20.0	19.7	20.3	18.4	17.7	5892
D_5 – August I FN	20.5	20.3	19.7	20.3	20.2	20.2	19.7	20.1	19.6	19.9	16.0	16.8	5035

4.2.2 Morning and afternoon Relative humidity (%)

During 2013, both morning and afternoon relative humidity increased with delayed sowings during sowing to seedling emergence stage. But, they increased upto D_3 and later decreased with delayed sowings for seedling emergence to sixth leaf stage, sixth leaf to tasseling stage and tasseling to silking, but they decreased with delayed sowings during milk to physiological maturity. During 2014, morning relative humidity decreased with delayed sowing at all the phenological stages except during sowing to sixth leaf stage, whereas afternoon relative humidity decreased with delayed sowings at sixth leaf to tasseling, silking to milk stage and milk to physiological maturity stages (Table 5).

4.2.3 Rainfall (mm) received by maize at different phenophases under different growing environments (sowing dates) for 2013 and 2014 (Table 6)

June I FN sowing (D_1)

During 2013, the maize crop received the highest amount of rainfall (206 mm) during sixth leaf to tasseling stage. It was followed by silking to milk stage (106 mm), seedling emergence to to sixth leaf stage (72 mm), milk to physiological maturity (41.4 mm), sowing to seedling emergence (13.2 mm) and tasseling to silking stage (13 mm).However, a total amount of 451.6 mm was received from sowing to physiological maturity with 51 rainy days. Similarly, for 2014 the highest amount of rainfall (309.6 mm) was received during sixth leaf to tasseling, followed by silking to milk (106.4 mm) and milk to physiological maturity stage (104.6 mm). The lowest amount of rain fall (3.5 mm) was received during seedling emergence to sixth leaf stage.

June II FN (D_2)

During 2013, maximum amount of rainfall (180.4 mm) was received during seedling emergence to sixth leaf stage, followed by silking to milk stage (123 mm) and milk to physiological maturity stage (64.8 mm). The lowest amount of rainfall (6 mm) was received during tasseling to silk stage. During 2014, maize received the highest amount of rainfall (285.2 mm) during sixth leaf to tasseling stage. It was followed by 115.6 mm during milk to physiological maturity stage. Sowing to seedling stage hardly received any rainfall.

Table 5: Morning and afternoon relative humidity (%) at different phenophases of maize under different growing environments (sowing dates) during 2013 and 2014 cropping period

Sowing dates	Morning relative humidity (%)												Grain yield (kg/ha)
	Sowing to seedling emergence		Seedling emergence to six leaf stage		Six leaf to tasseling		Tasseling to silking		Silking to milk		Milk to Physiological maturity		
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	
D_1 – June I FN	94	92	94	87	95	95	93	93	93	94	94	90	8082
D_2 – June II FN	95	88	95	90	93	95	93	93	95	94	92	90	7716
D_3 – July I FN	93	91	95	95	93	94	94	92	94	91	91	86	7400
D_4 – July I FN	94	95	94	94	94	93	94	92	93	89	89	81	5892
D_5 – August I FN	94	92	92	94	94	92	94	86	91	87	81	80	5035
	Afternoon relative humidity (%)												
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	
D_1 – June I FN	71	67	77	54	83	81	82	66	70	76	72	65	8082
D_2 – June II FN	77	48	84	68	76	77	66	66	76	77	64	62	7716
D_3 – July I FN	78	72	85	83	74	74	72	71	75	66	60	55	7400
D_4 – July I FN	89	77	80	78	71	73	78	71	67	62	56	48	5892
D_5 – August I FN	78	66	72	73	75	69	63	62	57	56	51	50	5035

Table 6: Rainfall (mm) received during different phenophases of maize cropping period under different sowing dates during 2013 and 2014

Phenophase	D_1 – June I FN		D_2 – June II FN		D_3 – July I FN		D_4 – July II FN		D_5 – August I FN	
	2013	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**
Sowing to seedling emergence	13.2 (2)	15.8 (2)	18.6 (3)	0 (0)	12.4 (2)	7.4 (1)	39.4 (3)	59.4 3)	8.8 (1)	17.8 (1)
Seedling emergence to six leaf stage	72.0 (10)	3.5 (0)	180.4 (15)	39.2 (5)	193 (16)	257.2 (19)	62.4 (8)	154.4 (11)	28.2 (5)	89.6 (11)
Six leaf to tasseling	206 (17)	309.6 (25)	76 (9)	285.2 (23)	71.8 (9)	153 (19)	131.6 (12)	110 1(5)	133 (12)	86.6 (7)
Tasseling to silking	13 (3)	2.4 (0)	6 (1)	48.4 (4)	69.6 (4)	5.6 (1)	12.4 (2)	6.2 (1)	0 (0)	30.8 (2)
Silking to milk	106 (8)	106.4 (14)	123 (11)	51.8 (8)	23.4 (4)	95.4 (5)	10.4 (1)	109.4 (7)	50.6 (3)	20.8 (3)
Milk to Physiological maturity	41.4 (11)	104.6 (7)	64.8 (7)	115.6 (8)	74.6 (3)	103.4 (7)	65.2 (2)	64 (3)	14.6 (3)	112.2 (5)
Sowing to physiological maturity (Total rainfall in mm)	**451.6 (51)**	**542.3 (48)**	**468.8 (46)**	**540.2 (48)**	**448.8 (38)**	**622 (22)**	**321.4 (28)**	**503.4 (40)**	**235.2 (24)**	**357.8 (29)**
Grain yield (kg ha^{-1})	**8055**	**8110**	**7254**	**8177**	**6575**	**8224**	**5107**	**6678**	**4662**	**5408**

*Figures in parentheses indicate number of rainy days

July I FN sowing (D_3)

During 2013, seedling emergence to sixth leaf stage received the highest amount of rainfall (193 mm), followed by 74.6 mm, 71.8 mm and 69.6 mm during milk to physiological maturity stage, sixth leaf to tasseling and tasseling to silking stages, respectively. Lowest amount of rainfall (12.4 mm) was received during sowing to seedling emergence stage.For 2014 also, the highest amount of rainfall (257.2 mm) was received during seedling emergence to sixth leaf stage, followed by 153 mm during sixth leaf to tasseling and 103.4 mm during milk to physiological maturity stage. Tasseling to silking stage received the lowest amount of rainfall (5.6 mm).

July II FN sowing (D_4)

During 2013, sixth leaf to tasseling stage received the highest amount of rainfall (131.6 mm). It was followed by milk to physiological maturity (65.2 mm) and seedling emergence to sixth leaf stage (62.4 mm).Lowest rainfall (12.4 mm) was received during tasseling to silking stage. During 2014, the highest amount of rainfall (154.4 mm) was received during seedling emergence to sixth leaf stage, followed by sixth leaf to tasseling stage (110.0 mm) and silking to milk stage (109.4 mm).

August I FN sowing (D_5)

During 2013, sixth leaf to tasseling received the highest amount of rainfall (133 mm), followed by 50.6 mm during silking to milk stage. For 2014, the highest amount of rainfall (112.2 mm) was received during milk to physiological maturity stage followed by seedling to emergence to sixth leaf stage (89.6 mm) and sixth leaf to tasseling stage (86.6 mm). The lowest rainfall (17.8 mm) was received during sowing to seedling emergence stage.

The overall rainfall distribution for both the years for different sowing dates, indicate that, during 2013, maximum amount of rainfall (468.8 mm) for the cropping period was received by June II FN sown crop (D_2), followed by June I FN (D_1) sowing (451.6 mm), July I FN (D_3) sowing (444.8 mm) and lowest (235.2 mm) for August I FN sowing (D_5).Whereas, for 2014, the highest amount of rainfall (622 mm) was observed for July I FN sown crop (D_3), followed by June I FN sowing (542.3 mm) and June II FN sown crop (540.2 mm). The lowest amount of rainfall (357.8 mm) was received by August I FN sown crop (D_5)

4.2.4 Crop phenology

Days taken to attain each phenological phase for maize were significantly influenced by sowing dates and planting geometry during both the years and in their pooled analysis (Table 7).

Sowing dates

During crop season of 2013, except seedling stage, sixth leaf stage (24.1 to 32 days), tasseling (53 to 62 days), silking (59 to 67.1 days) and physiological maturity stages (104.1 to 118 days) were advanced with delayed sowings. Whereas, 2014 crop season recorded 22.1 to 29 days for sixth leaf stage, 47 to 60 days for tasseling, 54 to 65 days for silking and 102 to 117 days to attain physiological maturity stage. Similar trend was observed in pooled mean.

Planting geometry

Among the three planting geometries tried, 45 x 20 cm (S_1) took more number of days to attain seedling emergence (6.1 and 6.1 days), sixth leaf stage (29.3 and 25.7 days), tasseling (59.5 and 56.1 days), silking (65.3 and 62.1 days) and physiological maturity (111.7 and 110.4 days) stages during 2013 and 2014, respectively compared to 60 cm x 20 cm (S_2) and 75 x 20 cm (S_3). Pooled data also indicate similar trend.

Interactions

Pooled mean indicate that, treatment combination of delayed sowing with wider spacing attained different phenological stages in less number of days. They took 23 days, 49.3 days, 55.8 days, 102.7 days to attain sixth leaf stage, tasseling, silking and physiological maturity stages compared to other treatment combinations (24 to 31 day, 54.2 to 61.7 days, 62.2 to 66.7 days and 105.3 to 115.7 days for respective phenological stages).

Table 7: Maize phenology as influenced by different growing environments and planting geometry

Treatments	Phenology (days)															Grain yield (kg/ha)
	Emergence (V_0)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity			
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	
Date of sowing (D)																
D_1: June I fortnight	5.0b	5.0b	5.00b	31.0b	23.0b	27.00c	62.0a	57.0b	59.5a	67.1a	63.1b	65.1a	118.0a	112.0b	115.0a	**8082a**
D_2: June II fortnight	5.0b	5.0b	5.00b	32.0a	24.0c	28.00b	62.0a	57.0b	59.5a	66.9a	62.9b	64.9a	116.0b	112.0b	114.0b	**7716ab**
D_3: July I fortnight	6.0a	6.0a	6.00a	29.0c	29.0a	29.00a	60.0b	60.0a	60.0a	67.0a	65.0a	66.0a	111.0c	117.0a	114.0b	**7400b**
D_4: July II fortnight	6.0a	6.0a	6.00a	25.0d	25.0b	25.00d	56.0c	55.0c	55.5b	63.0b	62.0c	62.5b	106.0d	106.0c	106.0c	**5892c**
D_5:August I fortnight	6.0a	6.0a	6.00a	24.1e	22.1e	23.11e	53.0d	47.0d	50.0c	59.0c	54.0d	56.5c	104.1e	102.0d	103.1d	**5035d**
Planting geometry (S)																
S_1 – 45 cm x 20 cm	6.1a	6.1a	6.07a	29.3a	25.7a	27.53a	59.5a	56.1a	57.8a	65.3a	62.1a	63.7a	111.7a	110.4a	111.1a	**7529a**
S_2 – 60 cm x 20 cm	5.8a	5.8a	5.80a	28.0b	24.4b	26.20b	58.3b	54.9b	56.6b	64.3b	61.1b	62.7b	110.9ab	109.9a	110.4b	**6909b**
S_3 – 75 cm x 20 cm	4.9b	4.9b	4.93b	27.3b	23.7b	25.53b	57.9b	54.5c	56.2b	64.1b	60.9b	62.5b	110.4b	109.1b	109.7c	**6037c**
Date of sowing (D) x Planting geometry (S)																
D_1S_1	5.3be	5.3be	5.33be	32.0ab	24.0eg	28.00bd	62.3a	57.3bc	59.8b	67.7a	63.7ac	65.7a	118.7a	112.7b	115.7a	**8461a**
D_1S_2	5.0ce	5.0ce	5.00ce	31.0bc	23.0fh	27.00ce	62.0a	57.0c	59.5bc	67.0a	63.0bc	65.0ab	118.0ab	112.0bc	115.0ab	**8318a**
D_1S_3	4.7de	4.7de	4.67de	30.0cd	22.0h	26.00ef	61.7a	56.7c	59.2bc	66.7a	62.7bc	64.7ac	117.3ac	111.3bc	114.3ac	**7468cd**
D_2S_1	5.7ad	5.7ad	5.67ad	33.3a	25.3de	29.33ab	62.0a	57.0c	59.5bc	67.7a	63.7ac	65.7ab	116.7ac	113.0b	114.8ab	**8237ab**
D_2S_2	5.0ce	5.0ce	5.00ce	31.3bc	23.3fh	27.33ce	62.0a	57.0c	59.5bc	66.3a	62.3bc	64.3bc	116.0bc	112.3bc	114.2ac	**8005a-c**
D_2S_3	4.3e	4.3e	4.33e	31.3bc	23.3fh	27.33ce	62.0a	57.0c	59.5bc	66.7a	62.7bc	64.7ac	115.3c	110.7c	113.0c	**6905de**
D_3S_1	6.3ab	6.3ab	6.33ab	31.0bc	31.0a	31.00a	61.7a	61.7a	61.7a	67.7a	65.7a	66.7a	111.7d	116.7a	114.2ac	**7943a-c**
D_3S_2	6.0ac	6.0ac	6.00ac	28.7de	28.7b	28.67bc	59.3b	59.3b	59.3bc	67.0a	65.0ab	66.0ab	111.0d	118.0a	114.5ac	**7617bc**
D_3S_3	5.7ad	5.7ad	5.67ad	27.3ef	27.3bc	27.33ce	59.0b	59.0c	59.0cd	66.3a	64.3bc	65.3bc	110.3d	116.3a	113.3bc	**6639e**
D_4S_1	6.7a	6.7a	6.67a	26.3fg	26.3cd	26.33df	57.7b	56.7c	57.2d	63.7b	62.7bc	63.2bd	107.0e	106.7d	106.8d	**7421cd**
D_4S_2	6.7a	6.7a	6.67a	24.7gh	24.7df	24.67fg	55.7c	54.7d	55.2e	62.7b	61.7c	62.2d	105.7ef	106.0d	105.8d	**5446fg**
D_4S_3	4.7de	4.7de	4.67de	24.0h	24.0eg	24.00g	54.7c	53.7d	54.2e	62.7b	61.7c	62.2d	105.3ef	105.3d	105.3de	**4810gh**
D_5S_1	6.3ab	6.3ab	6.33ab	24.0h	22.0eg	23.00g	54.0cd	48.0e	51.0f	60.0c	55.0d	57.5e	104.7f	103.0e	103.8ef	**5582f**
D_5S_2	6.3ab	6.3ab	6.33ab	24.3h	22.3h	23.33g	52.7d	46.7e	49.7f	58.7c	53.7d	56.2e	104.0f	101.3e	102.7f	**5161fg**
D_5S_3	5.3be	5.3be	5.33bc	24.0h	22.0h	23.00g	52.3d	46.3e	49.3f	58.3c	53.3d	55.8e	103.7f	101.7e	102.7f	**4363h**

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05

4.2.5 Growing degree day (GDD) - ^{0}C day

Thermal time requirement or GDD for completion of different phenological stages of maize differed significantly due to sowing dates and planting geometry during both the years and in their pooled analysis (Table 8).

Sowing dates

Among the five sowing dates tried, except for seedling emergence (V_6), June I FN sown crop recorded more number of accumulated heat units to attain sixth leaf stage, tasseling, silking and physiological maturity. It (D_1) took 396.8, 822.1, 887.9 and 1597.3 ^{0}C day (thermal units) for sixth leaf tasseling, silking and physiological maturity stages, respectively. It was followed by June II FN and July I FN sown maize crop, which consumed 813.3, 888, 1562.7 GDDs (^{0}C day) for June II FN and 797.4, 886.7 and 1510 GDDs (^{0}C day) for July I FN sown crop to attain tasseling, silking and physiological maturity stages, respectively. The lowest number of accumulated heat units were recorded by August I FN sown crop to attain all phenological stages (301.4, 728.3, 813.9 and 1387.4 ^{0}C day for sixth leaf, tasseling, silking and physiological maturity stages, respectively). However, the heat unit consumption pattern was little different during early vegetative stage of maize in 2014. Here, seedling emergence stage was not influenced significantly with respect to heat unit consumption. But, July I FN (D_3) recorded more number of accumulated heat units (GDD) for sixth leaf stage (385.02 ^{0}C day) compared to other sowing dates (304.3 to 360.4 ^{0}C day). June I FN sown maize consumed significantly more number of heat units to attain tasseling (809.5 ^{0}C day) and silking stage (892.9 ^{0}C day). However, it was on par with June II FN sowing and consumed 800.3 and 888.0 ^{0}C day for tasseling and silking stage, respectively. But, July I FN (D_3) sowing consumed significantly more number of heat units (1622 ^{0}C day) compared to other sowing dates to attain physiological maturity. As far as pooled analysis is considered June I FN and June II FN sown crop consumed higher number of heat units to attain all phenological stages than delayed sowings (July I FN to August I FN).

Table 8: Accumulated Growing degree days (^oC day) as influenced by different growing environments and planting geometry

Treatments	Growing degree days (^oC day)															Grain yield (kg/ha)
	Emergence (V_0)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity			
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	
Date of sowing (D)																
D_1: June I fortnight	70.0cd	74.10a	72.1c	396.3a	360.44b	378.4a	822.1a	809.5a	815.8a	887.9a	892.9a	890.4a	1597.3a	1588.6b	1593.0a	**8082a**
D_2: June II fortnight	67.4d	82.19a	74.8bc	387.1a	356.47b	371.8a	813.3ab	800.3a	806.8ab	888.2a	888.0a	888.1a	1562.7a	1588.0b	1575.3a	**7716ab**
D_3: July I fortnight	81.5a	82.31a	81.9a	332.2b	385.02a	358.6b	797.4b	794.2a	795.8b	886.7a	846.4b	866.5b	1510.0ab	1622.0a	1566.0a	**7400b**
D_4: July II fortnight	74.5bc	81.36a	77.9ab	303.5c	334.94c	319.2c	764.6c	703.0b	733.8c	856.9b	801.7c	829.3c	1436.7bc	1474.3c	1455.5b	**5892c**
D_5:August I fortnight	79.5ab	83.26a	81.4a	301.4a	304.28d	302.8d	728.3d	656.3c	692.3d	813.9c	761.7d	787.8d	1387.4c	1416.5d	1402.0c	**5035d**
Planting geometry (S)																
S_1 – 45 cm x 20 cm	80.5a	88.39a	84.5a	354.7a	365.96a	360.3a	809.5a	775.1a	792.3a	893.1a	844.1a	868.6a	1516.5a	1548.1a	1532.3a	**7529a**
S_2 – 60 cm x 20 cm	74.0ab	82.23b	78.1b	342.8b	345.31b	344.0b	782.0b	748.0b	765.0b	863.3b	839.3a	851.3b	1504.2ab	1538.0b	1521.1a	**6909b**
S_3 – 75 cm x 20 cm	69.3b	71.31c	70.3c	334.9c	333.42c	334.2c	763.9c	734.9b	749.4c	843.7c	831.0b	837.3c	1475.8b	1527.5c	1501.7a	**6037c**
Date of sowing (D) x Planting geometry (S)																
D_1S_1	73.3ac	84.8ac	79.0ac	412.0a	374.1bc	393.0a	853.5a	823.0ab	838.2a	921.7a	904.9a	913.3a	1609.3a	1598.9cd	1604.1a	**8461a**
D_1S_2	73.3ac	74.1c	73.7ce	391.0b	365.0bd	378.0b	811.7bc	807.3ac	809.5bd	876.6bd	895.0ab	885.8bc	1602.7a	1588.7de	1595.7ab	**8318a**
D_1S_3	63.5c	63.4e	63.5e	386.0bc	342.2eg	364.1cd	801.2bc	798.2ac	799.7ce	865.3be	878.7b	872.0cd	1580.0ab	1578.2e	1579.1ac	**7468cd**
D_2S_1	73.8ac	92.4a	83.1ac	393.3b	373.7bc	383.5ab	827.1ab	830.8a	828.9ab	903.2ab	891.7ab	897.5ab	1598.0a	1595.0ce	1596.5ab	**8237ab**
D_2S_2	65.8bc	82.2ad	74.0ce	393.3b	352.2ce	372.8bc	827.1ab	790.1bc	808.6bd	903.2ab	891.7ab	897.4ab	1550.0ac	1588.0de	1569.0ac	**8005a-c**
D_2S_3	62.7c	72.0de	67.3de	374.7c	343.6df	359.1de	785.8cd	780.0c	782.9de	858.1ce	880.7b	869.4cd	1540.0ac	1581.0de	1560.5bc	**6905de**
D_3S_1	88.5a	85.3ac	86.9ab	343.7d	405.8a	374.7bc	824.6ab	812.7ac	818.7ac	916.9a	855.3c	886.1bc	1518.3bd	1630.0a	1574.2ac	**7943a-c**
D_3S_2	80.0ac	83.3ad	81.7ac	328.0e	381.8b	354.9de	787.7cd	787.2bc	787.5de	875.9bd	846.3cd	861.1de	1520.0bd	1626.0ab	1573.0ac	**7617bc**
D_3S_3	76.0ac	78.3bd	77.1ad	325.0e	367.5bc	346.2ef	779.8ce	782.7c	781.3e	867.2be	837.4d	852.3de	1491.7cd	1610.0bc	1550.8c	**6639e**
D_4S_1	80.8ac	89.8ab	85.3ab	314.5ef	353.7ce	334.1f	792.1bc	707.1d	749.6f	887.3ac	805.5e	846.4e	1463.3de	1484.4f	1473.9d	**7421cd**
D_4S_2	72.9ac	89.8ab	81.3ac	299.9fh	330.3fg	315.1g	755.5df	703.8d	729.6fg	846.9df	800.3e	823.6f	1446.7de	1471.9f	1459.3de	**5446fg**
D_4S_3	70.0ac	64.5e	67.2de	296.3gh	320.9g	308.6gh	746.2ef	698.1d	722.2g	836.5ef	799.4e	818.0fg	1400.0ef	1466.7f	1433.3ef	**4810gh**
D_5S_1	86.3ab	89.7ab	88.0a	309.9fg	322.6fg	316.3g	750.0ef	701.7d	725.8fg	836.5ef	763.2f	799.9gh	1393.3ef	1432.4g	1412.8fg	**5582f**
D_5S_2	78.1ac	81.7ad	79.9ac	301.6fh	297.3h	299.5hi	728.3fg	651.7e	690.0h	813.9fg	763.2f	788.5hi	1401.7ef	1415.6gh	1408.6fg	**5161fg**
D_5S_3	74.2ac	78.4bd	76.3bd	292.6h	293.0h	292.8i	706.5g	615.7f	661.1i	791.3g	758.8f	775.0i	1367.3f	1401.7h	1384.5g	**4363h**

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

Planting geometry

Among the three planting geometries tried, 45 x 20 cm spacing (S_1) recorded more number of accumulated heat units to attain all phenological stages from seedling emergence to physiological maturity during both the years. Similar trend was observed in pooled analysis, where, S_1 (45 x 20 cm) recorded higher number of heat units (84.5, 360.3, 792.3, 868.6 and 1532.5 ^{0}C day) over 60 x 20 cm (78.1,344.0,765.0,851.3 and 1521.1 ^{0}C day) and 75 cm x 20 cm (70.3,334.2,749.4,837.3 and 1501.7 ^{0}C day) to attain seedling emergence, sixth leaf stage, tasseling, silking and physiological maturity stages, respectively.

Interaction

During 2013 combination of D_1 (June I FN) with S_1 (45 x 20 cm) recorded the highest number of accumulated heat units to attain sixth leaf stage (412 GDD), tasseling (853.5 GDD), silking (721.7 GDD) and physiological maturity (1609.3 GDDs). During 2014 combination of D_3 x S_1 recorded the highest number of accumulated heat units to attain V_6 stage (405.8 GDD) and physiological maturity (1630 GDD). But, D_2 (June II FN) with S_1 (45 x 20 cm) recorded the highest number of accumulated heat units to attain tasseling (830.8 GDD). Combination of D_1 x S_1 recorded the highest number of heat units (904.9 GDDs) to attain silking. Whereas, pooled analysis clearly indicated that combination of June I FN sowing with narrow spacing (45 x 20 cm) recorded the highest number of accumulated heat units to attain V_6 (393 GDD), tasseling (838.2 GDD), silking (913.3 GDD) and physiological maturity (1604.1 GDD).

4.2.6 Phenothermal Index (PTI, ^{0}C day day^{-1})

The phenothermal index of maize varied significantly due to sowing dates and planting geometry at different phenological stages during both the years of experiment and in their pooled analysis (Table 9).

Sowing dates

Among sowing dates, in pooled mean of 2013 and 2014, June I fortnight (D_1) sown maize recorded significantly higher phenothermal index (14.23, 13.74, 13.70 and 13.86 ^{0}C days day^{-1}) to complete sixth leaf stage, tasseling, silking and physiological maturity stages, respectively compared to other sowing dates (delayed).

Table 9: Phenothermal index (^{0}C day day^{-1}) as influenced by different growing environments and planting geometry

Treatments	Phenothermal index														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	14.37a	14.99ab	14.68a	12.80a	15.67a	14.23a	13.26ab	14.21a	13.74ab	13.23b	14.15a	13.69b	13.54a	14.18a	13.86a
D_2: June II fortnight	13.62a	16.46a	15.04a	12.11b	14.86b	13.49b	13.12b	14.04a	13.58ac	13.28b	14.12a	13.70b	13.47a	14.18a	13.83a
D_3: July I fortnight	13.64a	13.83b	13.74a	11.49c	13.30c	12.39d	13.29ab	13.47b	13.38bc	13.23b	13.23b	13.23c	13.61a	13.86b	13.73ab
D_4: July II fortnight	12.76a	13.59b	13.18a	12.15b	13.40c	12.77cd	13.65ab	12.79c	13.22c	13.60a	12.93b	13.27c	13.55a	13.91b	13.73ab
D_5:August I fortnight	13.34a	13.97b	13.66a	12.50ab	13.77c	13.13bc	13.74a	13.96ab	13.85a	13.79a	14.11a	13.95a	13.32a	13.89b	13.61b
Planting geometry (S)															
S_1 – 45 cm x 20 cm	13.41a	14.70a	14.05a	12.14a	14.31a	13.23a	13.61a	13.86a	13.74a	13.68a	13.61a	13.65a	13.57a	14.02a	13.79a
S_2 – 60 cm x 20 cm	12.98a	14.45a	13.71a	12.24a	14.20a	13.22a	13.43ab	13.65a	13.54ab	13.43ab	13.78a	13.60a	13.56a	13.99a	13.78a
S_3 – 75 cm x 20 cm	14.25a	14.56a	14.41a	12.25a	14.08a	13.17a	13.21b	13.58a	13.39b	13.17b	13.74a	13.46a	13.37a	14.00a	13.68a
Interaction (D x S)															
D_1S_1	13.90a	15.95ad	14.93ab	12.89ab	15.59ab	14.24a	13.71ab	14.37a	14.04ab	13.62ac	14.22a	13.92ab	13.56a	14.19ab	13.88ab
D_1S_2	14.85a	15.23ae	15.04ab	12.63ac	15.87a	14.25a	13.09ac	14.17ab	13.63ae	13.09bc	14.21a	13.65ac	13.58a	14.18ab	13.88ab
D_1S_3	14.36a	13.80be	14.08ab	12.87ab	15.55ab	14.21a	13.00bc	14.09ab	13.54ae	12.98c	14.03a	13.51ac	13.47a	14.18ab	13.82ab
D_2S_1	13.16a	16.31ac	14.73ab	11.81ce	14.75c	13.28bc	13.35ac	14.58a	13.97ac	13.35ac	14.01a	13.68ac	13.70a	14.12ad	13.91a
D_2S_2	13.17a	16.44ab	14.80ab	12.56ac	15.10bc	13.83ab	13.34ac	13.86ac	13.60ae	13.62ac	14.31a	13.96ab	13.36a	14.14ac	13.75ab
D_2S_3	14.54a	16.63a	15.59a	11.96ae	14.73c	13.35bc	12.67c	13.69cd	13.18de	12.87c	14.06a	13.47bc	13.35a	14.29a	13.82ab
D_3S_1	14.02a	13.56ce	13.79ab	11.13e	13.13d	12.13e	13.38ac	13.25be	13.31be	13.55ac	13.09cd	13.32c	13.60a	13.97be	13.79ab
D_3S_2	13.49a	14.14ae	13.82ab	11.45de	13.32d	12.38d	13.28ac	13.35be	13.31be	13.07c	13.16cd	13.11c	13.69a	13.78e	13.74ab
D_3S_3	13.41a	13.81be	13.61ab	11.90be	13.45d	12.67ce	13.22ac	13.82d	13.52ae	13.07c	13.44bc	13.25c	13.52a	13.84e	13.68ab
D_4S_1	12.20a	13.47de	12.84ab	11.94ae	13.43d	12.69ce	13.74ab	12.48e	13.11e	13.94a	12.85d	13.40bc	13.68a	13.92ce	13.80ab
D_4S_2	11.08a	13.47de	12.28b	12.17ad	13.39d	12.78ce	13.57ab	12.88de	13.22ce	13.52ac	12.98cd	13.25c	13.69a	13.89e	13.79ab
D_4S_3	15.00a	13.83de	14.41ab	12.34ad	13.37d	12.86cd	13.65ab	13.02ce	13.34be	13.35ac	12.96cd	13.16c	13.29a	13.92ce	13.61ab
D_5S_1	13.76a	14.21ae	13.99ab	12.92a	14.67c	13.80ab	13.89a	14.63a	14.26a	13.94a	13.88ab	13.91ab	13.30a	13.91de	13.61ab
D_5S_2	12.30a	12.96e	12.63ab	12.40ad	13.31d	12.85ce	13.84a	13.98ac	13.91ad	13.87ab	14.23a	14.05a	13.48a	13.97be	13.72ab
D_5S_3	13.96a	14.75ae	14.36ab	12.19ad	13.32d	12.75ce	13.50ab	13.29be	13.40be	13.57ac	14.23a	13.90ab	13.19a	13.79e	13.49b

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

Planting geometry

Among the three planting geometries tried, 45 x 20 cm (S_1) recorded higher values of PTI (13.2, 13.7, 13.7 and 13.8 ^{0}C days day^{-1}) compared to wider planting geometries of 60 cm x 20 cm and 75 cm x 20 cm. But, the differences were non-significant except certain exceptions.

Interactions

Interaction effects were not differed significantly.

4.2.7 Heat Use Efficiency (HUE) (g m^{-2} ^{0}C day^{-1})

The heat use efficiency (g m^{-2}/ ^{0}C day) of maize varied significantly due to sowing dates and planting geometry at different phenological stages during both the years of experiment and in their pooled analysis (Table 10).

Sowing dates

June I FN (D_1) recorded significantly higher HUE (1.22, 1.49 and 1.82 g m^{-2}/ ^{0}C day) at tasseling, silking and physiological maturity stage, respectively compared to latter delayed sowings.

Planting geometry

Among the planting geometries also, 45 cm x 20 cm (S_1) recorded significantly higher HUE (1.24, 1.52 and 1.96 g m^{-2}/ ^{0}C day) at tasseling, silking and physiological maturity stages, respectively compared to wider planting geometries (60 cm x 20 cm and 75 cm x 20 cm).

Interaction

Interaction effects also indicated that the combination of early sowing (June I FN) with narrow row spacing (45 cm x 20 cm) recorded higher values of heat use efficiency at tasseling (1.45 g m^{-2}/ ^{0}C day), silking (1.79 g m^{-2}/ ^{0}C day) and physiological maturity (2.21 g m^{-2}/ ^{0}C day) stages compared to other treatment combinations.

Table 10: Heat use efficiency (g/m²/⁰C day) as influenced by different growing environments and planting geometry

Treatments	Heat use efficiency (g/m²/⁰C day)											
	Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)												
D_1: June I fortnight	0.16a	0.12a	0.14a	1.18a	1.10a	1.14a	1.48a	1.31b	1.40a	1.72a	1. 70a	1.71a
D_2: June II fortnight	0.15a	0.12a	0.14a	1.07ab	1.03a	1.05a	1.35ab	1.24b	1.30ab	1.65ab	1.64a	1.65a
D_3: July I fortnight	0.16a	0.12a	0.14a	1.03b	1.16a	1.09a	1.22bc	1.51a	1.37a	1.61ab	1.71a	1.66a
D_4: July II fortnight	0.15a	0.12a	0.14a	0.97bc	1.11a	1.04a	1.16bc	1.30b	1.23ab	1.49bc	1.64a	1.57ab
D_5:August I fortnight	0.13b	0.12a	0.13a	0.87c	1.14a	1.01a	1.04c	1.33b	1.19b	1.37c	1.55a	1.46b
Planting geometry (S)												
S_1 – 45 cm x 20 cm	0.17a	0.14a	0.15a	1.16a	1.27a	1.22a	1.45a	1.58a	1.51a	1.83a	1.90a	1.86a
S_2 – 60 cm x 20 cm	0.15b	0.12b	0.13b	1.00b	1.08b	1.04b	1.22b	1.30b	1.26b	1.52b	1.59b	1.55b
S_3 – 75 cm x 20 cm	0.13c	0.11c	0.12c	0.91c	0.97c	0.94c	1.09c	1.15c	1.12c	1.36c	1.46c	1.41c
Interaction (D x S)												
D_1S_1	0.19a	0.14a	0.16a	1.41a	1.32a	1.36a	1.78a	1.58ab	1.68a	2.13a	2.02a	2.07a
D_1S_2	0.15bc	0.11bd	0.13ce	1.14bd	1.02bd	1.08cd	1.43b	1.23df	1.33c	1.63cd	1.55ce	1.59cd
D_1S_3	0.14cd	0.11bd	0.12df	1.01ce	0.96cd	0.99de	1.23c	1.14ef	1.18df	1.40df	1.52ce	1.46ce
D_2S_1	0.18a	0.14a	0.16a	1.23ab	1.17b	1.20bc	1.65a	1.44bd	1.54b	1.88b	1.85ab	1.87b
D_2S_2	0.14bc	0.12bd	0.13ce	1.00ce	1.01bd	1.01de	1.23c	1.21df	1.22cf	1.58ce	1.62be	1.60cd
D_2S_3	0.13cd	0.10d	0.12ef	0.99ce	0.90d	0.95de	1.19cd	1.07f	1.13ef	1.50cf	1.46e	1.48ce
D_3S_1	0.18a	0.14a	0.16ab	1.18bc	1.34a	1.26ab	1.41b	1.77a	1.59ab	1.89b	1.95a	1.92ab
D_3S_2	0.16b	0.12bd	0.14cd	1.02ce	1.15b	1.09cd	1.22c	1.49bc	1.36ce	1.57ce	1.70bd	1.64c
D_3S_3	0.13cd	0.10d	0.12ef	0.88ef	0.98cd	0.93de	1.04de	1.28cf	1.16df	1.36ef	1.49de	1.42de
D_4S_1	0.16b	0.13ab	0.14bc	0.97ce	1.14b	1.06cd	1.17cd	1.34be	1.25ce	1.56ce	1.73bc	1.64c
D_4S_2	0.15bc	0.12ac	0.14cd	1.01ce	1.15b	1.08cd	1.21c	1.35de	1.28cd	1.52cf	1.63be	1.57c
D_4S_3	0.15bc	0.12bd	0.13ce	0.93df	1.04bd	0.98de	1.11ce	1.21df	1.16df	1.41df	1.57ce	1.49ce
D_5S_1	0.15bc	0.14a	0.14bc	1.03be	1.38a	1.21bc	1.25c	1.75a	1.50b	1.67c	1.97a	1.82b
D_5S_2	0.14cd	0.12ac	0.13cf	0.84cf	1.08bc	0.96de	1.01ef	1.20df	1.10f	1.29fg	1.44ef	1.37e
D_5S_3	0.119d	0.105cd	0.112f	0.73f	0.97cd	0.85e	0.88f	1.03f	0.95g	1.14g	1.24f	1.19f

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

4.2.8 Radiation studies

4.2.8.1 Light transmission ratio (LTR) - %

The light transmission ratio (LTR) in maize differed significantly due to different sowing dates and planting geometry at all the phenophases except at seedling stage during both the years and in their pooled analysis (Table 11).

Sowing dates

Among the five sowing dates tried during 2013, significantly higher per cent light transmission ratio was observed in delayed sowing (August I FN) during sixth leaf (82.43), tasseling (10.66), silking (9.81) and physiological maturity (30.82).While, for 2014, LTR was to an extent of 75.6, 10.31, 8.17 and 28.97 per cent at sixth leaf, tasseling, silking and physiological maturity stage, respectively over early sowings. Least LTR was noticed in case of early sown crops at all the phenological stages. Similar trend was noticed in pooled analysis.

Planting geometry

Among the planting geometries tried, wider spacing (S_3) recorded significantly more LTR over other spacings in both 2013 and 2014 at all the phenological stages. In case of pooled analysis per cent LTR for S_3 (75 x 20 cm) was to an extent of 81.90 (sixth leaf), 11.06 (tasseling), 8.72 (silking) and 28.24 (physiological maturity).

Interaction

Combination of late sowing with wider spacing (75 x 20 cm) recorded significantly more light transmission ratio at all the phenological stages except at seedling stage and sixth leaf stages for both the years and in pooled analysis. LTR for August I FN sowing with 75 x 20 cm (S_3) during tasseling, silking and physiological maturity was to an extent of 11.52, 10.59 and 34.10 per cent respectively. Similarly for 2014, it was to an extent of 13.25, 10.67 and 30.49 per cent, respectively. Similar trend was observed in pooled analysis.

Table 11: Light transmission ratio (LTR-%) as influenced by different growing environments and planting geometry

Treatments	Light transmission ratio (%)														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	99.47a	99.46a	99.47a	72.90c	79.36a	76.13b	7.29d	8.90b	8.09b	6.20c	7.19b	6.69d	19.21c	21.58b	20.39b
D_2: June II fortnight	99.48a	99.40a	99.44a	73.34c	76.72ab	75.03b	8.80c	9.13b	8.97b	7.48b	7.78ab	7.63bc	22.04bc	21.31b	21.67b
D_3: July I fortnight	99.40a	99.45a	99.43a	79.26b	73.34b	76.30b	9.62bc	8.02c	8.82c	8.37b	6.30c	7.33c	25.63b	17.82c	21.72b
D_4: July II fortnight	99.35a	99.33a	99.34a	81.64a	79.26a	80.45a	10.14ab	10.27a	10.20a	8.82a	7.33b	8.07b	29.62a	25.03a	27.33a
D_5:August I fortnight	99.36a	99.30a	99.33a	82.43a	75.59ab	79.01a	10.66a	10.31a	10.48a	9.81a	8.17a	8.99a	30.82a	27.13a	28.97a
Planting geometry (S)															
S_1 – 45 cm x 20 cm	99.43a	99.40a	99.41a	71.67a	71.40b	71.53b	8.38b	6.50c	7.44c	7.32b	6.07c	6.69c	22.32b	15.37c	18.84c
S_2 – 60 cm x 20 cm	99.41a	99.38a	99.40a	80.05a	77.41a	78.73a	9.50a	9.38b	9.44b	8.31a	7.31b	7.81b	26.42a	23.52b	24.97b
S_3 – 75 cm x 20 cm	99.39a	99.38a	99.39a	82.01a	81.76a	81.89a	10.03a	12.10a	11.06a	8.77a	8.67a	8.72a	27.65a	28.83a	28.24a
Interaction (D x S)															
D_1S_1	99.45ac	99.48ab	99.46ac	71.24cd	76.47ac	73.85bf	7.12a	3.53g	5.33h	6.06f	6.77d	6.41f	18.77f	16.24g	17.51h
D_1S_2	99.50ab	99.47ac	99.49ab	72.90ad	78.86ac	75.88af	7.29fg	9.17cd	8.23ef	6.20ef	7.42cd	6.81ef	19.21f	25.96cd	22.59fg
D_1S_3	99.46ac	99.45ad	99.45ac	74.54ad	82.76ab	78.65ae	7.45fg	13.99a	10.72b	6.34ef	7.37cd	6.85ef	19.64f	22.52df	21.08g
D_2S_1	99.58a	99.43ad	99.51a	67.08d	71.25bc	69.16f	8.05eg	6.10f	7.07g	6.84df	6.48d	6.66f	19.77f	8.86h	14.31h
D_2S_2	99.42ac	99.32bd	99.37ac	74.60ad	73.09ac	73.84bf	8.95dg	10.14bc	9.55cd	7.61cf	7.85bd	7.73ce	22.88ef	19.09fg	20.99g
D_2S_3	99.45ac	99.44ad	99.45ac	78.33ad	85.83a	82.08ac	9.40bf	11.15b	10.28bc	7.99ce	9.01b	8.50bc	23.48ef	35.97a	29.72ac
D_3S_1	99.38bd	99.49ab	99.44ac	71.67bd	67.08c	69.37ef	8.60da	7.48ef	8.04ag	7.48cf	3.47e	5.48g	20.88f	8.03h	14.45h
D_3S_2	99.43ac	99.52a	99.47ab	82.33ac	74.60ac	78.47af	9.88ae	7.57df	8.73df	8.60bd	6.84d	7.72ce	27.15ce	20.25ef	23.70eg
D_3S_3	99.39ad	99.36ad	99.37ac	83.78ac	78.33ac	81.05ad	10.39ad	9.01ce	9.70bd	9.04ac	8.58bc	8.81b	28.85bd	25.18cd	27.01ce
D_4S_1	99.45ac	99.34ad	99.39ac	73.82ad	71.67bc	72.74cf	8.86dg	6.75f	7.80fg	7.71cf	6.74d	7.23df	25.78de	20.68ef	23.23fg
D_4S_2	99.38bd	99.33ad	99.35ac	84.80ac	82.33ab	83.57a	10.18ae	10.99d	10.58bc	8.85ac	7.50cd	8.18bd	30.89ac	24.41cd	27.65bd
D_4S_3	99.22d	99.31bd	99.27c	86.29ab	83.78ab	85.03a	11.39ab	13.07a	12.23a	9.91ab	7.73bd	8.82d	32.21ab	30.00b	31.10ab
D_5S_1	99.27cd	99.26d	99.27c	74.53ad	70.52bc	72.53df	9.26cf	8.65ce	8.95de	8.52bd	6.88d	7.70ce	26.40ce	23.05de	24.72df
D_5S_2	99.34bd	99.28cd	99.31bc	85.63ac	78.15ac	81.89ad	11.20ac	9.02ce	10.11bc	10.31ab	6.96d	8.63bc	31.95ab	27.86bc	29.91ac
D_5S_3	99.45ac	99.35ad	99.40ac	87.13a	78.11ac	82.62ab	11.52a	13.25a	12.39a	10.59a	10.67a	10.63a	34.10a	30.49b	32.29a

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

4.2.8.2 Light absorption ratio (LAR)- %

The different sowing dates and planting geometries influenced significantly the light absorption ratio (LAR) in maize at all the phenophases except at seedling stage during both the years as well in their pooled analysis (Table 12).

Sowing dates

During 2013, at all the stages (Six leaf, tasseling, silking and physiological maturity) higher LAR (27.1, 92.6, 93.80 and 80.8 %, respectively) was recorded in June I FN (D_1) sown maize compared to delayed sowings. But for 2014, higher LAR during sixth leaf (26.7), tasseling (91.9), silking (93.7) and at physiological maturity (82.2) was recorded in case of July I FN (D_3) sown crop. In pooled analysis, except at silking at all the stages (V_6, tasseling and physiological maturity) the LAR was on par at June I FN, June II FN and July I FN sown maize crop.

Planting geometry

S_1 (45 x 20 cm) recorded significantly the higher light absorption ratio (LAR) at all the phenological stages except at seedling stage during both the years and in pooled analysis. During 2013, LAR was to an extent of 28.3, 91.6, 92.7 and 77.7.During 2014, it was to an extent of 28.6, 93.5, 93.9 and 84.6 at V_6, tasseling, silking and physiological maturity stages. Least LAR was observed in case of wider spacing of 75 x 20 cm (S_3) in both the years as well in pooled mean.

Interactions

In pooled mean, combination of August I FN (D_5) with wider spacing (75 x 20 cm) recorded the lowest LAR at sixth leaf stage (17.4), tasseling (87.6), silking (89.4) and physiological maturity stages (67.7). However, early sown maize crop with narrow spacing of 45 x 20 cm recorded higher LAR in the above mentioned stages for both the years as well as in pooled analysis.

4.2.8.3 Photosynthetic Active Radiation (PAR)

Photosynthetically active radiation incident, reflected from canopy, transmitted and reflected from soil were recorded during different phenophases (V_3, V_6, tasseling,

Table 12: Light absorption ratio (LAR- %) as influenced by different growing environments and planting geometry

Treatments	Light absorption ratio (%)														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	0.53a	0.54a	0.53a	27.10a	20.64b	23.87a	92.60a	91.10b	91.85a	93.80a	92.81b	93.31a	80.79a	78.42b	79.61a
D_2: June II fortnight	0.52a	0.60a	0.56a	26.66a	23.28ab	24.97a	91.20ab	90.87b	91.03a	92.52b	92.22bc	92.37bc	77.96ab	78.69b	78.33a
D_3: July I fortnight	0.60a	0.55a	0.57a	20.74b	26.66a	23.70a	90.38b	91.98a	91.18a	91.63c	93.70a	92.67b	74.37b	82.18a	78.28a
D_4: July II fortnight	0.65a	0.67a	0.66a	18.59bc	20.74b	19.66b	89.86b	89.73c	89.80b	91.18c	92.67b	91.93c	70.38c	74.97c	72.67b
D_5:August I fortnight	0.64a	0.70a	0.67a	17.57c	24.41a	20.99b	89.34b	89.69c	89.52b	90.19d	91.83c	91.01d	69.18c	72.87c	71.03b
Planting geometry (S)															
S_1 – 45 cm x 20 cm	0.57a	0.60a	0.59a	28.33a	28.60a	28.47a	91.62a	93.50a	92.56a	92.68a	93.93a	93.31a	77.68a	84.63a	81.16a
S_2 – 60 cm x 20 cm	0.59a	0.62a	0.60a	20.08b	22.59b	21.34b	90.50b	90.62b	90.56b	91.69b	92.69b	92.19b	73.58b	76.48b	75.03b
S_3 – 75 cm x 20 cm	0.61a	0.62a	0.61a	17.99b	18.24c	18.11c	89.90b	87.90c	88.90c	91.23b	91.33c	91.28c	72.35b	71.17c	71.76c
Interaction (D x S)															
D_1S_1	0.55bd	0.52cd	0.54ac	28.76ab	23.53bd	26.15b	92.88a	96.47a	94.67a	93.94a	93.23b	93.59b	81.23a	83.76b	82.49a
D_1S_2	0.50cd	0.53bd	0.51bc	27.10bc	21.14ce	24.12bc	92.71ab	90.83de	91.77bd	93.80ab	92.58bc	93.19bc	80.79a	74.04ef	77.41bc
D_1S_3	0.54bd	0.55ad	0.55ac	25.46bc	17.24ef	21.35cd	92.21ac	86.01g	89.11g	93.66ab	92.63bc	93.15bc	80.36a	77.48ce	78.92b
D_2S_1	0.42d	0.57ad	0.49c	32.92a	28.75ab	30.84a	91.95ac	93.90b	92.93b	93.16ac	93.52b	93.34b	80.23a	91.14a	85.69a
D_2S_2	0.58bd	0.68ac	0.63ac	25.40bc	26.91ac	26.16d	91.05ae	89.86ef	90.45dg	92.39ad	92.15bd	92.27ce	77.12ab	80.91bc	79.01b
D_2S_3	0.55bd	0.56ad	0.55ac	21.67cd	14.17f	17.92de	90.60ae	88.85f	89.72fg	92.01bd	90.99d	91.50ef	76.52ab	64.03h	70.28fh
D_3S_1	0.62ac	0.51cd	0.56ac	28.33ab	32.92a	30.63a	91.40ad	92.52bc	91.96bc	92.52ad	96.53a	94.52a	79.12a	91.97a	85.55a
D_3S_2	0.57bd	0.48d	0.53bc	17.67de	25.40bc	21.53cd	90.12de	92.43bd	91.27ce	91.40ce	93.16b	92.28ce	72.85bd	79.75cd	76.30bd
D_3S_3	0.61ad	0.64ad	0.63ac	16.22e	21.67ce	18.95de	89.61ce	90.99ce	90.30eg	90.96df	91.42cd	91.19f	71.15ce	74.82ef	72.99df
D_4S_1	0.55bd	0.66ad	0.61ac	26.18bc	28.33ab	27.26ab	91.14ae	93.25b	92.20bc	92.29ad	93.26b	92.77bd	74.22bc	79.32cd	76.77bc
D_4S_2	0.62ac	0.67ad	0.65ac	15.86e	17.67df	16.77e	89.82ce	89.01f	89.42g	91.15df	92.50bc	91.82df	69.11df	75.59ef	72.35eg
D_4S_3	0.78a	0.69ac	0.73a	13.71e	16.22ef	14.97e	88.61e	86.93g	87.77h	90.09ef	92.27bd	91.18f	67.79ef	70.00g	68.90gh
D_5S_1	0.73ab	0.74a	0.73a	25.47bc	29.48ab	27.47ab	90.74ae	91.35ce	91.05cf	91.48ce	93.12b	92.30ce	73.60bd	76.95de	75.28ce
D_5S_2	0.66ac	0.72ab	0.69ab	14.37e	21.86ce	18.11de	88.80de	90.98ce	89.89ef	89.69ef	93.04b	91.37ef	68.05ef	72.14fg	70.09fh
D_5S_3	0.55bd	0.65ad	0.60ac	12.87e	21.89ce	17.38de	88.48e	86.75g	87.61f	89.41f	89.33e	89.37g	65.90f	69.51g	67.71h

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

silking and physiological maturity) between 11.00 to 14.00 hrs in the afternoon. (Table 13 to 21).

4.2.8.3.1 Incident PAR (PAR_O)

Photosynthetically active radiation incident on maize canopy at different phenophases differed significantly due to sowing dates and planting geometry as well in their pooled analysis (Table 13).

Sowing dates

During vegetative stage *i.e.*, V_3 and V_6 quantum of incident PAR was not consistent and higher PAR_O was recorded by June II FN sown crop during both crop seasons i.e., 2013 (1352 µmoles/m^2/s) and 2014 (2685) as well as the pooled mean (2018 µmoles m^{-2} s^{-1}) at V_3 stage, whereas higher PAR_O (1512 and 2414) were recorded by June II FN and July II FN sown crop during 2013 and 2014, respectively at V_6 stage. During 2013, July II FN sown crop received significantly higher incident PAR (2858 and 2441) at tasseling and silking stages. But, July I FN (D_3) sown crop received maximum incident PAR (3055 and 2730) during 2014.

Planting geometry

Among the three geometries tried, S_1 (45 x 20 cm) received significantly higher (1343, 2621 and 2248) incident PAR at V_3, tasseling and silking during 2013 and at silking (2256) and physiological maturity (2155) during 2014. Pooled data clearly indicate that, except V_6, the narrow (45 x 20 cm) planting geometry had higher incident PAR at all the phenological stages than other planting geometries. The corresponding values of 1712, 2621, 2252 and 1887 were received at V_3, tasseling, silking and physiological maturity stages, respectively.

Interactions

Combination of D_4 x S_1 received significantly higher incident PAR (3046 and 2589) at tasseling and silking stages, respectively during 2013 and D_3 x S_1 (3098 and 3002) at tasseling and silking stages during 2014. Pooled data also indicate the similar trend in both the stages.

Table 13: Incident PAR (PARo, μmol m^{-2} s^{-1}) as influenced by different growing environments and planting geometry

Treatments	Incident PAR (PARo, μmol m^{-2} s^{-1})														
	Three leaf (V_3)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	1304a	1722c	1513c	1187c	1863b	1525b	2321b	2849ab	2585a	2007b	2202b	2104b	1835a	1702bc	1768b
D_2: June II fortnight	1352a	2685a	2018a	1512a	1161e	1336c	2285b	1803c	2044b	1965b	2171b	2068b	1602bc	1871b	1737b
D_3: July I fortnight	1223a	1545d	1384d	961d	1275d	1118d	2309b	3055a	2682a	1963b	2730a	2346a	1735ab	1634c	1684b
D_4: July II fortnight	1211a	2475b	1843b	1386b	2414a	1900a	2858a	2739b	2799a	2441a	1797c	2119b	1454cd	2398a	1926a
D_5:August I fortnight	1283a	1754c	1518c	832e	1494c	1163d	2394b	3026a	2710a	2035b	2017b	2026b	1402d	2458a	1930a
Planting geometry (S)															
S_1 – 45 cm x 20 cm	1343a	2082a	1712a	1068b	1518b	1293b	2621a	2621b	2621a	2248a	2256a	2252a	1618ab	2155a	1887a
S_2 – 60 cm x 20 cm	1268b	2039a	1654ab	1122b	1557b	1340b	2468b	2768a	2618a	2105b	2198ab	2151b	1638a	1828c	1733c
S_3 – 75 cm x 20 cm	1212b	1987a	1600b	1337a	1849a	1593a	2212c	2694ab	2453b	1893c	2097b	1995c	1560b	2055b	1807b
Interaction (D x S)															
D_1S_1	1350ad	1855c	1603d	1210e	1705b	1457c	2594bd	2643e	2619c	2305bc	2228bc	2267bd	1826ab	1815gh	1820df
D_1S_2	1313be	1753cd	1533de	1123ef	1624bc	1374cd	2563cd	3016ac	2790ac	2179bd	2211bc	2195be	1860a	1587ij	1724gh
D_1S_3	1248cf	1558de	1403eg	1227de	2261a	1744b	1807h	2888ae	2348d	1536h	2167bd	1851h	1818ac	1703hi	1761dg
D_2S_1	1403ac	2657ab	2030a	1151ef	1146df	1149fg	2537cd	1596g	2067e	2156cd	2407b	2282bd	1729ac	2016ef	1873cd
D_2S_2	1419ab	2648ab	2033a	1358cd	1016f	1187eg	2433ce	2014f	2223de	2068cf	1929de	1998eh	1542de	1629hi	1586i
D_2S_3	1233df	2751a	1992ab	2027a	1320de	1673b	1885gh	1800fg	1843f	1669gh	2178bd	1924gh	1536de	1969fg	1753fg
D_3S_1	1218df	1687ce	1452dg	968gh	1069ef	1019g	2481cd	3098a	2790ac	2109ce	3002a	2555a	1665cd	1690hi	1677gh
D_3S_2	1181df	1499de	1340g	898gi	1341de	1120fg	2133fg	3099a	2616c	1813fg	2992a	2402ab	1853a	1431j	1642hi
D_3S_3	1271be	1450e	1360fg	1017fg	1413cd	1215df	2314df	2969ad	2641bc	1966df	2197bc	2082dg	1686bd	1780hi	1733fh
D_4S_1	1265be	2516ab	1890ac	1156ef	2336a	1746b	3046a	2728c	2887a	2589a	2005ce	2297bc	1446ef	2582ab	2014ab
D_4S_2	1281be	2407b	1844bc	1464bc	2421a	1942a	2662bc	2703de	2683bc	2296bc	1871ef	2083dg	1463ef	2187de	1825df
D_4S_3	1088f	2501ab	1794c	1539b	2486a	2013a	2867ab	2787be	2827ab	2437ab	1516g	1976fh	1452ef	2425bc	1938bc
D_5S_1	1478a	1695ce	1586d	853hi	1333de	1093fg	2447ce	3040ab	2744ac	2080ce	1637fg	1859h	1426ef	2673a	2050a
D_5S_2	1148ef	1891c	1519df	769i	1384cd	1076fg	2550cd	3010ac	2780ac	2168cd	1986ce	2077dg	1473e	2305cd	1889cd
D_5S_3	1223df	1676ce	1449dg	874gi	1765c	1320ce	2184ef	3027ac	2606c	1857eg	2426b	2141cf	1307f	2396bc	1851ce

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

4.2.8.3.2 Canopy reflected PAR (PARc)

PARc also varied significantly due to sowing dates and planting geometries at different phenophases (V_3, V_6, tasseling, silking and physiological maturity stages) (Table 14).

Sowing dates

During 2013, PARc was differed significantly at all the phenophases except at V_3 stages July I FN (D_3) sown crop reflected significantly higher PARc at tasseling, silking and physiological maturity (156.6, 131.8 and 101.4 μmoles/m^2/s, respectively). During 2014, June I FN (D_1) sowing reflected significantly higher PAR from canopy (69.4 and 121.9) at V_6 and silking stage. However, the pooled analysis indicate that D_3 (July I FN) sown crop reflected significantly more PAR (146 and 105.3) at tasseling and silking stages. Significantly the lowest PAR (93.7 and 101.5) was reflected from crop canopy with June I FN sown crop (D_1).

Planting geometry

75 x 20 cm (S_3) recorded significantly the higher canopy reflected PAR during 2013 (53.4 and 103.2) at V_6 and physiological maturity and 60 x 20 cm recorded higher (126.1 and 107.4) during 2013 at tasseling and silking stages, whereas pooled data suggest the superiority of 60 x 20 cm at tasseling (123.3) and physiological maturity stages.

Interactions

Combination of D_3 x S_1 reflected significantly more PAR from canopy (168 and 139) during 2013 at tasseling and silking stages. But, D_1 x S_3 recorded more reflected PAR from canopy (139.3) during 2014. Pooled data did not indicate any specific trend. It differed at different stages.

4.2.8.3.3 Transmitted PAR (TPARc)

TPAR also differed significantly due to sowing dates and planting geometries except at early vegetative stage (V_3) during both the years and in pooled analysis (Table 15).

Table 14: Canopy reflected PAR (PARc, μmol m^{-2} s^{-1}) as influenced by different growing environments and planting geometry

Treatments	Canopy Reflected PAR (PARc, μmol m^{-2} s^{-1})														
	Three leaf (V_3)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	**2014**	**Pooled**	**2013**	**2014**	**Pooled**	**2013**	**2014**	**Pooled**	**2013**	**2014**	**Pooled**	**2013**	**2014**	**Pooled**
Date of sowing (D)															
D_1: June I fortnight	43.5a	63.6bc	53.5bc	45.8b	69.4a	57.6a	75.8c	119.4b	97.6c	65.5b	121.9a	93.7b	89.0b	114.1d	101.5d
D_2: June II fortnight	45.1a	66.0b	55.5ab	58.7a	49.6d	54.2b	83.6c	85.7c	84.6c	71.0b	117.1a	94.1b	90.5b	128.2d	109.3d
D_3: July I fortnight	40.8a	57.8c	49.3d	38.4c	57.7c	48.1c	156.6a	135.4a	146.0a	131.8a	78.8c	105.3a	101.4a	153.8c	127.6c
D_4: July II fortnight	40.4a	60.0bc	50.2cd	56.5a	62.2b	59.3a	134.0b	121.7b	127.8b	113.9a	88.9b	101.4ab	98.5a	182.3b	140.4c
D_5:August I fortnight	42.8a	74.1a	58.4a	33.9d	54.7c	44.3d	140.6ab	94.5c	117.5b	119.5a	81.7c	100.6ab	81.0c	218.9a	150.0a
Planting geometry (S)															
S_1 – 45 cm x 20 cm	44.8a	65.4a	55.1a	42.8b	52.6b	47.7c	115.7b	110.5b	113.1b	97.7b	86.9c	92.3b	83.0c	167.3b	125.2b
S_2 – 60 cm x 20 cm	42.3b	63.4a	52.8a	43.8b	59.8a	51.8b	126.1a	120.4a	123.3a	107.4a	99.3b	103.4a	90.0b	128.5c	109.3c
S_3 – 75 cm x 20 cm	40.4b	64.1a	52.3a	53.4a	63.7a	58.6a	112.5d	103.2b	107.8c	95.9b	106.9a	101.4a	103.2a	182.6a	142.9a
Interaction (D x S)															
D_1S_1	45.0ad	61.2bd	53.1af	47.1cd	64.3ac	55.7cd	79.3eg	116.0ce	97.7e	68.3h	126.3c	97.3ce	82.4hi	131.3eg	106.9gh
D_1S_2	43.8be	62.7ad	53.2af	43.2de	68.6ab	55.9cd	93.3f	143.0a	118.2cd	80.4fg	100.1e	90.3e	82.5gi	88.3i	85.4i
D_1S_3	41.6cf	67.0ad	54.3ae	47.2cd	75.4a	61.3bc	54.7h	99.3eg	77.0f	47.9i	139.3b	93.6de	102.0bc	122.7gh	112.3fg
D_2S_1	46.8ac	73.0ab	59.9ab	46.0cd	46.0e	46.0fh	88.3fg	67.3i	77.8f	75.0gh	81.7gh	78.4f	84.0gi	131.3eg	107.7gh
D_2S_2	47.3ab	64.2ad	55.7ae	49.0c	48.9de	49.0eg	105.7e	119.8bd	112.8d	89.9ef	116.3d	103.1c	91.5df	106.0h	98.8h
D_2S_3	41.1df	60.9bd	51.0cf	81.1a	54.0ce	67.5a	56.6h	70.1hi	63.3g	48.1i	153.3a	100.7cd	96.0ce	147.1de	121.6ef
D_3S_1	40.6df	55.3d	48.0ef	38.7eg	47.7de	43.2gh	168.0a	133.3ac	150.7a	139.0a	90.0fg	114.5ab	88.3fh	157.5d	122.9e
D_3S_2	39.4df	57.0d	48.2df	35.9fh	61.3bc	48.6eg	157.3ac	137.0ab	147.2ab	133.7ac	110.3d	122.0a	99.0cd	127.2fg	113.1fg
D_3S_3	42.4be	61.0bd	51.7bf	40.7ef	64.0ac	52.3df	144.3c	136.0ab	140.2b	122.7c	36.0j	79.3f	117.0a	176.6c	146.8cd
D_4S_1	42.2be	66.3ad	54.2ae	47.1cd	58.0be	52.6de	117.7de	129.7ac	123.7c	100.0de	83.3gh	91.7e	90.0eg	189.0c	139.5d
D_4S_2	42.7be	58.3cd	50.5cf	59.6b	62.3bc	61.0bc	125.0de	111.0de	118.0cd	106.3d	94.3ef	100.3cd	97.5cd	146.0df	121.7ef
D_4S_3	36.3f	55.3d	45.8f	62.7b	66.3ac	64.5ab	159.3ab	124.3bd	141.8ab	135.4ab	89.0fg	112.2b	108.0bc	212.0b	160.0b
D_5S_1	49.3a	71.3ac	60.3a	34.7gh	47.0de	40.9h	125.0d	106.3df	115.7cd	106.3d	52.9i	79.6f	70.4j	227.3b	148.9c
D_5S_2	38.3ef	74.7ab	56.5ad	31.3h	58.0be	44.7gh	149.3bc	91.0fg	120.2cd	126.9bc	75.5h	101.2cd	79.4i	175.1c	127.3e
D_5S_3	40.8df	76.3a	58.5ac	35.6fh	59.0bd	47.3eh	147.3bc	86.2gh	116.7cd	125.2bc	116.7d	121.0a	93.2df	254.4a	173.8a

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

Table 15: Transmitted PAR (TPAR, µmol m^{-2} s^{-1}) as influenced by different growing environments and planting geometry

Treatments	Transmitted PAR (TPAR, µmol m^{-2} s^{-1})														
	Three leaf (V_3)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	1144.8ab	1545c	1345c	875.4b	1546b	1211b	133.9c	342b	238.0c	87.8c	172.0c	130c	384b	421c	403b
D_2: June II fortnight	1197.3a	2425a	1811a	1087.6a	929d	1008c	149.5c	195c	172.1d	98.1c	170.1c	134b	395b	451c	423b
D_3: July I fortnight	1082.9bc	1359a	1221d	770.2c	1033cd	901d	297.2b	290b	293.7a	216.0d	209.4b	213b	421a	419c	420b
D_4: July II fortnight	1058.9c	2249b	1654b	1129.8a	1916a	1523a	368.6a	668a	518.2a	267.9a	186.7c	227a	382b	505b	443a
D_5:August I fortnight	1162.2ab	1573ce	1368c	691.8d	1168c	930cd	391.9a	625a	508.3c	284.8a	347.1a	316c	357c	670a	513c
Planting geometry (S)															
S_1 – 45 cm x 20 cm	1146.0a	1821a	1483a	737.6c	1145b	941c	169.0c	237c	203.0b	120.6c	116.8c	119b	269c	242c	255b
S_2 – 60 cm x 20 cm	1145.5a	1843a	1494a	888.3b	1245b	1067b	287.7b	449b	368.3a	204.4b	225.6b	215a	341b	506b	424a
S_3 – 75 cm x 20 cm	1096.1a	1826a	1461a	1107.0a	1564a	1335a	348.1a	586a	467.0c	247.8a	308.8a	278c	554a	732a	643c
Interaction (D x S)															
D_1S_1	1151.3ae	1635c	1393c	740.7fg	1350cd	1045e	77.7g	165ij	121.4f	51.0g	57.5i	54g	275fg	204i	239e
D_1S_2	1176.8ad	1552cd	1364c	889.0e	1322ce	1106e	147.0f	409de	278.2e	96.4f	195.6ef	146f	323e	490f	406d
D_1S_3	1106.4cf	1448cd	1277cd	996.7d	1965a	1481bc	177.0ef	452d	314.5i	116.1f	263.0bc	190h	556b	570e	563g
D_2S_1	1217.1ac	2295ab	1756ab	700.7a	866gh	783fg	80.0g	127j	103.7h	52.5g	100.3h	76g	276fg	211i	243e
D_2S_2	1249.5ab	2416ab	1833a	923.3de	799h	861fg	182.3ef	196hi	188.9g	119.6ef	167.3fg	143f	324e	434fg	379bc
D_2S_3	1125.4be	2563a	1844a	1638.7a	1121dg	1380cd	186.3ef	261gh	223.8gh	122.3ef	242.7cd	182g	587a	707cd	647g
D_3S_1	1039.8ef	1460cd	1250cd	710.0fg	798h	754g	203.7de	211hi	207.5ef	148.1de	147.6g	148e	285f	201i	243e
D_3S_2	1094.3cf	1341d	1218d	743.7fg	1068eh	906f	278.5c	325fg	301.6d	202.4c	280.5d	241e	393d	403g	398e
D_3S_3	1114.5ce	1277a	1196d	857.0e	1232cf	1044e	409.4b	335f	372.0ef	297.5d	200.0e	249g	585a	654d	620fg
D_4S_1	1060.0df	2220b	1640b	819.3ef	1713b	1266d	241.4cd	327fg	284.4c	175.4cd	142.1g	159e	255g	271hi	263e
D_4S_2	1129.2be	2196b	1663b	1213.0c	1980a	1596ab	380.4b	686c	533.4a	276.5b	214.1de	245d	336e	459fg	397d
D_4S_3	987.4f	2330ab	1659b	1357.0de	2054fh	1706a	484.0a	990a	736.8ef	351.7a	203.7b	278g	555b	785b	670f
D_5S_1	1261.7a	1493cd	1377c	717.3fg	999h	858fg	242.0cd	354ef	297.8c	175.9cd	136.5g	156c	253g	322h	287d
D_5S_2	1077.9df	1712c	1395c	672.3g	1056eh	864fg	450.1a	628c	539.2b	327.1a	270.4bc	299a	331e	745bc	538a
D_5S_3	1147.0ae	1514cd	1331cd	685.7g	1448c	1067e	483.6a	892b	687.8c	351.5a	634.4a	493b	486c	942a	714bc

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

Sowing dates

Among the five sowing dates tried, July II FN (D_4) sown crop recorded significantly higher TPAR (1130 and 1916) at V_6 stage during both the seasons. Whereas, August I FN sown crop (D_5) recorded significantly higher TPAR (392 and 285) at tasseling stage and silking during first crop season.

July I FN recorded significantly higher TPAR (1523 and 518) at V_6 and tasseling stage in pooled analysis. Whereas, August I FN (D_5) sown crop had significantly higher TPAR (316 and 513) at silking and physiological maturity stages, respectively.

Planting geometries

TPAR was significantly influenced by planting geometries at all the phenological stages except at V_3 stage and 75 x 20 cm recorded significantly the highest TPAR during both years. TPAR values during 2013 were 1107, 348, 248 and 554 and during 2014, 1564, 586, 209 and 732 at V_6, tasseling, silking and physiological maturity stages, respectively. Least values were found in case of 45 x 20 cm during 2013 (1145, 237, 117 and 242, respectively) at the corresponding stages. Similar trend were observed for pooled analysis.

Interactions

The combination of late sowing (D_4) with wider spacing (75 x 20 cm) had significantly higher transmitted PAR (1706 and 737) at V_6 and tasseling stress, whereas D_5 x S_3 during silking (493) and physiological maturity (714) had higher TPAR in pooled analysis.

4.2.8.3.4 Soil reflected PAR (RPARs)

RPARs was also influenced significantly due to sowing dates and planting geometries during both the years and in pooled analysis (Table 16).

Sowing dates

Among the five sowing dates tried late sowing (D_4 and D_5) during July II FN and August I FN recorded significantly higher reflected PAR from soil during both the

Table 16: Reflected PAR (RPARs, µmol m^{-2} s^{-1}) as influenced by different growing environments and planting geometry

Treatments	Reflected from soil PAR (RPARs, µmol m^{-2} s^{-1})														
	Three leaf (V_3)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	32.6ab	52.3d	42.4c	23.4a	57.5a	40.4a	13.8b	14.1c	13.9c	11.7b	16.5b	14.1c	10.0b	13.6d	11.8d
D_2: June II fortnight	35.4a	61.5b	48.5a	24.6a	22.7c	23.7c	15.3b	14.0c	14.6c	13.0b	18.9a	15.9ab	11.0b	15.1c	13.1c
D_3: July I fortnight	31.4b	47.6e	39.5d	24.9a	56.6a	40.7a	16.1b	22.6b	19.4b	14.0b	17.0b	15.5bc	12.2b	14.5cd	13.3c
D_4: July II fortnight	33.2ab	55.9c	44.6b	24.6a	51.9b	38.2b	20.1a	27.5a	23.8a	17.5a	10.7c	14.1c	15.2a	17.6b	16.4b
D_5:August I fortnight	32.9ab	64.6a	48.7a	24.2a	24.4c	24.3c	19.6a	20.9b	20.2b	18.0a	16.6b	17.3a	16.6a	23.4a	20.0a
Planting geometry (S)															
S_1 – 45 cm x 20 cm	33.8a	54.8b	44.3b	23.5b	29.0c	26.3c	11.6b	14.5c	13.1c	10.2c	10.5c	10.3c	8.9c	12.1c	10.5c
S_2 – 60 cm x 20 cm	31.3a	56.5a	43.9b	24.0b	46.2b	35.1b	17.4a	17.7b	17.5b	15.2b	11.7b	13.4b	13.3b	18.1b	15.7b
S_3 – 75 cm x 20 cm	34.2a	57.7a	45.9a	25.5a	52.6a	39.0a	21.9a	27.3a	24.6a	19.2a	25.6a	22.4a	16.8a	20.2a	18.5a
Interaction (D x S)															
D_1S_1	34.6ad	51.7d	43.2fg	23.4d	48.7d	36.1d	8.0g	11.3h	9.7g	6.8f	6.9g	6.9i	5.8i	9.7f	7.7g
D_1S_2	30.0fg	52.1d	41.0g	22.2d	57.0c	39.6c	15.3de	14.7g	15.0f	13.0d	10.3f	11.7fg	11.1g	14.7e	12.9f
D_1S_3	33.1cf	53.2d	43.1fg	24.5bd	66.7b	45.6d	18.0bc	16.3fg	17.2e	15.3c	32.3b	23.8b	13.0f	16.5ce	14.8de
D_2S_1	34.2de	58.7c	46.5ce	22.3d	15.2h	18.8h	8.7fg	8.3h	8.5g	7.4ef	10.0f	8.7h	6.3i	9.7f	8.0g
D_2S_2	35.0ad	62.0b	48.5bc	25.0bd	22.2g	23.6g	16.8cd	11.3h	14.1f	14.3cd	11.0ef	12.6ef	12.1fg	16.2de	14.2ef
D_2S_3	37.0ac	63.8ab	50.4ab	26.6ac	30.7f	28.6f	20.3b	22.3de	21.3d	17.3d	35.7a	26.5a	14.7e	19.4bc	17.0c
D_3S_1	29.9fg	47.0e	38.4h	22.7d	23.1g	22.9g	10.6f	18.6f	14.6f	9.2e	17.3c	13.3e	8.0h	10.5f	9.2g
D_3S_2	26.4g	47.3e	36.9h	23.7cd	71.0ab	47.3d	14.4e	23.3cd	18.9e	12.5d	18.3c	15.4d	10.9g	15.0de	12.9f
D_3S_3	37.9ab	48.3e	43.1fg	28.4a	75.7a	52.0a	23.3a	26.0ce	24.7c	20.3a	15.3d	17.8c	17.7bc	17.9cd	17.8c
D_4S_1	31.9df	53.3d	42.6g	22.4d	42.0e	32.2e	15.3de	19.6ef	17.4e	13.3cd	8.0g	10.7g	11.6fg	14.1e	12.9f
D_4S_2	35.6ad	56.3c	46.0de	26.9ab	56.5c	41.7c	20.3d	22.2de	21.3d	17.7b	11.8ef	14.7d	15.4de	17.1ce	16.2cd
D_4S_3	32.2df	58.0c	45.1ef	24.5bd	57.2c	40.9c	24.7a	40.8a	32.7a	21.5a	12.4e	16.9c	18.7ab	21.5b	20.1d
D_5S_1	38.3a	63.3ab	50.8a	27.0ab	16.0h	21.5gh	15.3de	14.9g	15.1f	14.1cd	10.4f	12.3ef	13.0f	16.8ce	14.9de
D_5S_2	29.6fg	65.0a	47.3ce	22.3d	24.3g	23.3g	20.0b	16.9fg	18.4e	18.4b	7.1g	12.7ef	16.9cd	27.7a	22.3a
D_5S_3	30.6ef	65.3a	48.0cd	23.3d	33.0f	28.1f	23.3a	31.0b	27.2b	21.5a	32.3b	26.9a	19.7a	25.8a	22.8a

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

years as well in pooled mean (except at V_6 stage). RPAR was to an extent of 20.1, 27.5 and 23.8 for 2013, 2014 and pooled mean respectively at tasseling stage to D_4 and 18 and 17.3 for 2013 and pooled at silking and 16.6, 23.4 and 20 for 2013, 2014 and pooled mean at physiological maturity were recorded in August I FN (D_5) sown crop.

Planting geometry

Among the three planting geometries tried significantly more reflected PAR from soil was recorded in wider spaced (75 x 20 cm) maize at all the phenological stages during both 2013 and 2014 as well for pooled analysis. RPAR from soil was to an extent of 34.2, 25.5, 21.9, 19.2 and 16.8 during 2013 and 57.7, 52.6, 27.3, 25.6 and 20.2 during 2014, respectively at V_3, V_6, tasseling, silking and physiological maturity stages, respectively.

Interactions

Interestingly the interaction effects differed significantly at different phenophages at both the years as well in pooled analysis. During vegetative stage *i.e.*, at V_6 stage combination of D_3 x S_3 reflected significantly more PAR from soil compared to other treatment combinations during 2013 (28.4), 2014 (75.7) and pooled mean (52). But combination of D_4 x S_3 recorded significantly more RPAR from soil (40.8 and 32.7) during 2014 and in case of pooled analysis at tasseling stage. But, D_5 x S_3 recorded significantly the higher RPAR from soil during 2013 (21.5) and pooled data (26.9) during silking and at physiological maturity stage. Thus, the delayed sowing (D_4 and D_5) with wider spacing recorded significantly the higher reflected PAR from soil during both the years as well in pooled mean of both the years.

4.2.8.3.5 Intercepted PAR (IPAR)

IPAR also followed the same trend as that of APAR during both the years at all the phenological stages (Table 17).

Sowing dates

Sowing dates influenced the intercepted PAR (IPAR) at all the stages during 2013 and 2014. During 2013, July II FN (D_4) sown crop intercepted significantly the

Table 17: Intercepted PAR (IPAR, μmol m^{-2} s^{-1}) as influenced by different growing environments and planting geometry

Treatments	Intercepted PAR (IPAR, μmol m^{-2} s^{-1})														
	Three leaf (V_3)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	158.8a	177.3b	168.1bc	311.1b	317.7b	314b	2188b	2507b	2347a	1919ab	2030b	1974ab	1450a	1280b	1365bc
D_2: June II fortnight	154.2a	260.7a	207.4a	424.6a	232.2b	328ab	2136b	1608d	1872b	1867ab	2001b	1934ab	1207bc	1421b	1314bc
D_3: July I fortnight	140.1a	185.9d	163.0bc	190.8cd	241.8b	216c	2012b	2765a	2388a	1747b	2521a	2134a	1314ab	1214b	1264c
D_4: July II fortnight	152.1a	225.8ab	189.0ab	256.6bc	498.7a	378a	2490a	2072c	2281a	2173a	1610c	1892bc	1072c	1893a	1482a
D_5:August I fortnight	120.3b	180.9d	150.6c	140.1d	326.2b	233c	2002b	2401b	2201a	1750b	1669c	1710c	1045c	1788a	1417ab
Planting geometry (S)															
S_1 – 45 cm x 20 cm	196.5a	261.3a	228.9a	330.1a	372.8a	351a	2452a	2384a	2418a	2127a	2139a	2133a	1350a	1913a	1632a
S_2 – 60 cm x 20 cm	122.6b	196.0b	159.3b	234.2b	312.1b	273b	2181b	2319a	2250b	1900b	1972b	1936b	1297a	1322b	1309b
S_3 – 75 cm x 20 cm	116.2b	161.0c	138.6c	229.6b	285.1b	257b	1863c	2108b	1986c	1645c	1788c	1717c	1006b	1323b	1164c
Interaction (D x S)															
D_1S_1	198.7ac	220.7cd	209.7b	469.3a	355.2cd	412b	2516b	2478cd	2497a	2254ab	2171bc	2212b	1551a	1611bd	1581b
D_1S_2	136.1gh	201.0cd	168.5cd	234.0de	302.3de	268eh	2416b	2607bd	2511a	2082bc	2016cd	2049b	1538ab	1097ef	1317de
D_1S_3	141.6fg	110.3e	126.0f	230.0de	295.7de	263eh	1630e	2436cd	2033ef	1420f	1904df	1662c	1262cd	1133ef	1198fg
D_2S_1	185.4ad	362.0a	273.7a	450.3ab	280.7df	366bc	2457b	1469h	1963f	2104bc	2307b	2206c	1453ab	1805b	1629b
D_2S_2	169.5cf	231.5c	200.5d	435.0ab	217.0eg	326ce	2251bc	1818g	2034ef	1949c	1761df	1855b	1218d	1195ef	1207fg
D_2S_3	107.6hi	188.5cd	148.0df	388.3bc	199.0fg	294dg	1699e	1538h	1619g	1547f	1935ce	1741c	950e	1262e	1106g
D_3S_1	178.2de	226.3cd	202.2b	258.0d	271.0df	265eh	2277bc	2887a	2582a	1961c	2854a	2407c	1380bc	1489d	1435c
D_3S_2	86.2ij	158.3de	122.3f	154.7eg	272.7df	214hi	1854de	2774ab	2314bc	1611ef	2711a	2161a	1460ab	1028f	1244ef
D_3S_3	156.0dg	173.0ce	164.5ce	159.7eg	181.7g	171i	1904de	2634ad	2269cd	1669df	1997cd	1833b	1101d	1126ef	1113g
D_4S_1	204.5ab	295.7b	250.1a	337.0c	623.0a	480a	2805a	2400d	2603a	2414a	1862df	2138c	1191d	2311a	1751a
D_4S_2	151.8eg	210.3cd	181.1bc	251.0d	441.0b	346cd	2282bc	2017fg	2149ce	2020bc	1656fg	1838b	1127d	1728bc	1427c
D_4S_3	100.1ij	171.3ce	135.7ef	181.7df	432.0bc	307cf	2383bc	1797g	2090df	2085bc	1312h	1698c	897e	1640bd	1268df
D_5S_1	215.8j	201.7cd	208.8b	135.7fg	334.0d	235gi	2205bc	2687ac	2446ab	1904cd	1501gh	1702c	1174d	2351a	1762a
D_5S_2	69.6j	179.0ce	124.3f	96.3g	327.3d	212hi	2100cd	2380ae	2241cd	1840ce	1716eg	1778c	1142d	1560cd	1351cd
D_5S_3	75.5j	162.0ce	118.8f	188.3df	317.3d	253fh	1701e	2135def	1918f	1505f	1792df	1648c	821e	1454d	1137g

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

higher IPAR (2490 and 2173) at tasseling and crop intercepted intercepted significantly more IPAR (2765 and 2521) at tasseling and silking stages, respectively for 2014. Similar trend was observed for pooled analysis.

Planting geometry

Among the three geometries tried, 45 x 20 cm recorded significantly high intercepted PAR (IPAR) during both the years at all the phenological stages, 45 x 20 cm intercepted 197, 330, 2452, 2127 and 1350 IPAR during 2013 and 261, 373, 2384, 2139 and 1913, IPAR during 2014. Similar trend was observed in case of pooled analysis.

Interactions

Combination of D_4 x S_1 (July II FN with 45 x 20 cm) excelled during I year to intercept significantly more IPAR, whereas D_3 x S_1 registered significantly higher IPAR during tasseling and silking stages. Values were 2805 and 2414 for 2013 and 2887 and 2854 during 2014 at tasseling and silking stages, respectively. Similar trend as that of 2014 was noticed in case of pooled analysis. At physiological maturity, D_4 x S_1 intercepted significantly more (1751) IPAR in pooled analysis.

4.2.8.3.6 Absorbed PAR (APAR)

APAR was also influenced due to different sowing dates and planting geometry during both the years at all the phenological stages (Table 18).

Sowing dates

During 2013, among the five sowing dates tried, June I FN (D_1) sowing recorded significantly higher APAR (147.6 and 1371) at V_3 and physiological maturity stage. Whereas, July II FN (D_4) recorded significantly higher APAR (2376) and 2076) at tasseling and silking stages respectively. During 2014 July I FN (D_3) sowing recorded significantly higher (2652 and 2459) APAR at tasseling and silking stages respectively. Pooled analysis also followed the similar trend as that of 2014.

Table 18: Absorbed PAR (APAR, µmol m^{-2} s^{-1}) as influenced by different growing environments and planting geometry

Treatments	Absorbed PAR (APAR, µmol m^{-2} s^{-1})														
	Three leaf (V_3)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	147.6a	166.0c	156.8bd	288.6b	305.8b	297.2b	2126b	2402b	2263.6a	1865ab	1925b	1895ab	1371a	1180bc	1275ab
D_2: June II fortnight	144.3a	256.1a	200.2a	390.5a	205.3c	297.9b	2067b	1537d	1802.0b	1809ab	1903b	1856ab	1127bc	1308b	1218bc
D_3: July I fortnight	147.7a	175.7bc	161.7bc	177.3cd	240.7bc	209.0c	1872c	2652a	2261.8a	1629b	2459a	2044a	1224ab	1075c	1150c
D_4: July II fortnight	144.6a	221.7ab	183.1ab	224.7bc	488.3a	356.5a	2376a	1977c	2176.7a	2076a	1532c	1804bc	988c	1728a	1358a
D_5:August I fortnight	110.5b	171.3bc	140.9c	130.4d	296.0bc	213.2c	1881c	2327b	2104.1a	1648b	1604c	1626c	981c	1593a	1287ab
Planting geometry (S)															
S_1 – 45 cm x 20 cm	185.3a	250.6a	218.0a	310.9a	349.2a	330.0a	2348a	2288a	2318.1a	2040a	2063a	2051a	1276a	1758a	1517a
S_2 – 60 cm x 20 cm	121.8b	189.2b	155.5b	214.4b	298.4b	256.4b	2072b	2217a	2144.2b	1808b	1885b	1846b	1220a	1211b	1216b
S_3 – 75 cm x 20 cm	109.7b	154.6c	132.2c	201.6b	274.0b	237.8b	1773c	2032b	1902.6c	1569c	1707c	1638c	920b	1161b	1040c
Interaction (D x S)															
D_1S_1	187.7ac	211.2ce	199.4d	445.6a	339.7c	392.6b	2445ab	2374cd	2409.3a	2192ab	2051bc	2122ab	1474a	1489bd	1481b
D_1S_2	122.3fh	190.4ce	156.4ce	213.0cd	290.8cd	251.9df	2338bd	2478bd	2408.1a	2015bc	1926ce	1970b	1466a	1023fh	1245cd
D_1S_3	132.8eg	96.5f	114.6ef	207.3cd	286.9cd	247.1df	1594f	2353cd	1973.4cf	1387g	1797cf	1592cd	1173cd	1027fh	1100e
D_2S_1	172.8ad	347.7a	260.3a	426.6a	249.9de	338.2bc	2377bd	1410i	1893.5ef	2036bc	2235b	2136ab	1375ab	1684b	1530ab
D_2S_2	156.6ce	229.3bc	193.0bc	411.0a	190.3e	300.6cd	2162bd	1710gh	1935.8df	1873cd	1656fg	1765cd	1139de	1105fh	1122e
D_2S_3	103.4gh	191.4ce	147.4df	333.9b	175.7e	254.8df	1663f	1491hi	1576.7g	1516fg	1818cf	1667cd	868fg	1134fg	1001f
D_3S_1	167.2bd	218.0cd	192.6bc	241.9c	246.4de	244.2df	2120cd	2772a	2446.0a	1831cd	2781a	2306a	1300bc	1342de	1321c
D_3S_2	124.6eh	148.7ef	136.6df	142.5df	282.3cd	212.4fg	1712ef	2660ad	2186.0bc	1489fg	2619a	2054b	1371ab	916h	1144de
D_3S_3	151.2df	160.3de	155.8ce	147.4df	193.3e	170.4g	1783ef	2524ad	2153.5bd	1567eg	1976cd	1771c	1001ef	967gh	984f
D_4S_1	193.7ab	282.7d	238.2a	312.3b	607.0a	459.7a	2703a	2290de	2496.5a	2327a	1787df	2057b	1113de	2136a	1624a
D_4S_2	144.3f	208.3ce	176.3bd	218.2cd	435.2b	326.7c	2177bd	1928fg	2052.5ce	1931cd	1574fg	1752cd	1045de	1599bc	1322c
D_4S_3	95.9h	174.0ce	134.9df	143.5df	422.8b	283.2ce	2248bd	1714gh	1981.0cf	1971bd	1235h	1603cd	808g	1449cd	1129e
D_5S_1	205.1a	193.7ce	199.4b	127.9ef	303.0cd	215.4fg	2095cd	2595ac	2345.2ab	1812ce	1458gh	1635cd	1116de	2140a	1628a
D_5S_2	61.0i	169.3ce	115.1ef	87.3f	293.7cd	190.5fg	1971de	2307de	2138.9ab	1732df	1648fg	1690cd	1080de	1413ce	1246cd
D_5S_3	65.4i	151.0df	108.2f	176.0ce	291.3cd	233.7ef	1577f	2080ef	1828.3f	1401g	1707eg	1554de	747g	1226ef	986f

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

Planting geometry

Among the three planting geometries tried, S_1 (45x20 cm) recorded significantly the higher absorbed PAR (APAR) at all the phenological stages during both the years as well in pooled analysis. APAR values for 2013 were 185, 311, 2348, 2040 and 1276 and during 2014, 251, 349, 2288, 2063 and 1758 at V_3, V_6, tasseling, silking and physiological maturity stages for 45 x 20 cm, spacing. Similar trend was observed in case of pooled analysis.

Interactions

Combination of D_3 x S_1 (July I FN sowing with 45 x 20 cm) absorbed significantly higher PAR (APAR) during tasseling and silking stages, D_3 x S_1 recorded 2446 and 2306 at tasseling and silking for pooled analysis. But, D_5 x S_1 recorded significantly higher (1628) APAR at phenphysiological maturity. It was on par with D_4 x S_1 (1624).

4.2.8.3.7 Per cent Transmitted PAR (TPAR %)

Data in respect of per cent radiation transmitted as influenced by different phenophases are presented for 2013 and 2014 (Table 19).

Sowing dates

In general,TPAR (%) decreased with delay in sowing at all the phenological stages (except at physiological maturity). Among the five sowing dates early sown crop during I FN of June (D_1) had lowest T PAR (%) during 2013, the stage-wise values were 71.9, 5.8, 4.4 and 21.4 T PAR (%) at V_6, taseling, silking and physiological maturity, respectively. But, the trend differed during 2014, where July I FN (D_3) sown crop recorded the lowest values (9.5 and 7.7) during tasseling and silking. However, the pooled data indicate that the lowest TPAR (%) was recorded in the early sown (June I FN and June II FN) crops at all stages.

Planting geometry

Among the three planting geometries tried, least TPAR (%) was recorded with narrow spaced (45 x 20 cm) crop at all the phenophages. It recorded 85.4, 69.1, 6.4, 5.4

Table 19: Per cent transmitted PAR (%TPAR) as influenced by different growing environments and planting geometry

Treatments	Per cent transmitted PAR (% TPAR)														
	Three leaf (V_3)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	87.8	89.7	88.8	73.8	82.9	78.4	5.8	12.0	8.9	4.4	7.8	6.1	21.0	24.8	22.9
D_2: June II fortnight	88.6	90.3	89.4	71.9	80.0	76.0	6.5	10.8	8.7	5.0	7.8	6.4	24.7	24.1	24.4
D_3: July I fortnight	88.5	88.0	88.3	80.1	81.0	80.6	12.9	9.5	11.2	11.0	7.7	9.3	24.3	25.7	25.0
D_4: July II fortnight	87.4	90.9	89.2	81.5	79.3	80.4	12.9	24.4	18.6	11.0	10.4	10.7	26.3	21.1	23.7
D_5:August I fortnight	90.6	89.7	90.2	83.2	78.2	80.7	16.4	20.6	18.5	14.0	17.2	15.6	25.4	27.2	26.3
Planting geometry (S)															
S_1 – 45 cm x 20 cm	85.4	87.5	86.4	69.1	75.4	72.3	6.4	9.0	7.7	5.4	5.2	5.3	16.6	11.2	13.9
S_2 – 60 cm x 20 cm	90.3	90.4	90.4	79.1	80.0	79.5	11.7	16.2	13.9	9.7	10.3	10.0	20.8	27.7	24.3
S_3 – 75 cm x 20 cm	90.4	91.9	91.2	82.8	84.6	83.7	15.7	21.7	18.7	13.1	14.7	13.9	35.5	35.6	35.6
Interaction (D x S)															
D_1S_1	85.3	88.1	86.7	61.2	79.2	70.2	3.0	6.2	4.6	2.2	2.6	2.4	15.1	11.2	13.2
D_1S_2	89.6	88.5	89.1	79.2	81.4	80.3	5.7	13.6	9.7	4.4	8.8	6.6	17.3	30.9	24.1
D_1S_3	88.7	92.9	90.8	81.3	86.9	84.1	9.8	15.6	12.7	7.6	12.1	9.8	30.6	33.5	32.0
D_2S_1	86.8	86.4	86.6	60.9	75.5	68.2	3.2	8.0	5.6	2.4	4.2	3.3	15.9	10.5	13.2
D_2S_2	88.1	91.3	89.7	68.0	78.6	73.3	7.5	9.7	8.6	5.8	8.7	7.2	21.0	26.6	23.8
D_2S_3	91.3	93.2	92.2	80.8	84.9	82.9	9.9	14.5	12.2	7.3	11.1	9.2	38.2	35.9	37.0
D_3S_1	85.4	86.6	86.0	73.3	74.7	74.0	8.2	6.8	7.5	7.0	4.9	6.0	17.1	11.9	14.5
D_3S_2	92.7	89.4	91.1	82.8	79.7	81.2	13.1	10.5	11.8	11.2	9.4	10.3	21.2	28.2	24.7
D_3S_3	87.7	88.1	87.9	84.3	87.1	85.7	17.7	11.3	14.5	15.1	9.1	12.1	34.7	36.8	35.7
D_4S_1	83.8	88.2	86.0	70.9	73.3	72.1	7.9	12.0	10.0	6.8	7.1	6.9	17.6	10.5	14.1
D_4S_2	88.2	91.3	89.7	82.9	81.8	82.3	14.3	25.4	19.8	12.0	11.4	11.7	23.0	21.0	22.0
D_4S_3	90.8	93.2	92.0	88.2	82.6	85.4	16.9	35.5	26.2	14.4	13.4	13.9	38.2	32.4	35.3
D_5S_1	85.4	88.1	86.7	84.1	75.0	79.5	9.9	11.6	10.8	8.5	8.3	8.4	17.7	12.0	14.9
D_5S_2	93.9	90.5	92.2	87.5	76.3	81.9	17.7	20.9	19.3	15.1	13.6	14.4	22.5	32.3	27.4
D_5S_3	93.8	90.3	92.1	78.5	82.0	80.2	22.1	29.5	25.8	18.9	26.2	22.5	37.2	39.3	38.3

and 16.6 per cent during 2014 at V_3, V_6, tasseling, silking and physiological maturity stages, respectively. Pooled analysis followed the similar trend.

Interactions

Pooled data indicate that combination of June I FN sowing with 45 x 20 cm spacing recorded the lowest per cent transmitted PAR (68.2, 4.6, 2.4 and 13.2) at V_6, tasseling, silking and physiological maturity stages respectively. TPAR (%) increased with other combinations.

4.2.8.3.8 Per cent Intercepted PAR (IPAR %)

The per cent intercepted PAR varied among the sowing dates and planting geometries tried during 2013 and 2014 (Table 20).

Sowing dates

During 2013, among the five sowing dates tried, June I FN (D_1) recorded the highest per cent of intercepted PAR (28.1, 94.2, 95.6 and 79) at V_6, tasseling, silking and physiological maturity stages, respectively. Whereas, July I FN (S_3) sown crop recorded the highest per cent of intercepted PAR (90.5 and 92.3) at tasseling and silking stages in 2014. In pooled analysis the highest (24.0, 91.4, 93.9 and 77.1) percentage of intercepted PAR was recorded in June I FN sown crop at V_6, tasseling, silking and physiological maturity stages, respectively.

Planting geometry

Narrow spacing of 45 x 20 cm (S_1) showed its superiority with respect to per cent PAR interception at all the phenophases during both the years as well in pooled analysis.

During 2013, 45 cm x 20 cm (S_1) recorded 14.6, 30.9, 93.6, 94.6 and 83.4 per cent intercepted PAR during V_3, V_6, tasseling, silking and physiological maturity stages, respectively. During 2014, it (45 cm x 20 cm) recorded 12.5,24.6, 91.0,94.8 and 88.8 per cent IPAR for respective stages. Similar trend was noticed in case of pooled analysis.

Table 20: Per cent intercepted PAR (% IPAR) as influenced by different growing environments and planting geometry

Treatments	Per cent intercepted PAR (% IPAR)														
	Three leaf (V_3)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	12.2	10.3	11.2	26.2	17.1	21.6	94.2	88.0	91.1	95.6	92.2	93.9	79.0	75.2	77.1
D_2: June II fortnight	11.4	9.7	10.6	28.1	20.0	24.0	93.5	89.2	91.3	95.0	92.2	93.6	75.3	75.9	75.6
D_3: July I fortnight	11.5	12.0	11.7	19.9	19.0	19.4	87.1	90.5	88.8	89.0	92.3	90.7	75.7	74.3	75.0
D_4: July II fortnight	12.6	9.1	10.8	18.5	20.7	19.6	87.1	75.6	81.4	89.0	89.6	89.3	73.7	78.9	76.3
D_5:August I fortnight	9.4	10.3	9.8	16.8	21.8	19.3	83.6	79.4	81.5	86.0	82.8	84.4	74.6	72.8	73.7
Planting geometry (S)															
S_1 – 45 cm x 20 cm	14.6	12.5	13.6	30.9	24.6	27.7	93.6	91.0	92.3	94.6	94.8	94.7	83.4	88.8	86.1
S_2 – 60 cm x 20 cm	9.7	9.6	9.6	20.9	20.0	20.5	88.3	83.8	86.1	90.3	89.7	90.0	79.2	72.3	75.7
S_3 – 75 cm x 20 cm	9.6	8.1	8.8	17.2	15.4	16.3	84.3	78.3	81.3	86.9	85.3	86.1	64.5	64.4	64.4
Interaction (D x S)															
D_1S_1	14.7	11.9	13.3	38.8	20.8	29.8	97.0	93.8	95.4	97.8	97.4	97.6	84.9	88.8	86.8
D_1S_2	10.4	11.5	10.9	20.8	18.6	19.7	94.3	86.4	90.3	95.6	91.2	93.4	82.7	69.1	75.9
D_1S_3	11.3	7.1	9.2	18.8	13.1	15.9	90.2	84.4	87.3	92.4	87.9	90.2	69.4	66.5	68.0
D_2S_1	13.2	13.6	13.4	39.1	24.5	31.8	96.8	92.0	94.4	97.6	95.8	96.7	84.1	89.5	86.8
D_2S_2	11.9	8.7	10.3	32.0	21.4	26.7	92.5	90.3	91.4	94.2	91.3	92.8	79.0	73.4	76.2
D_2S_3	8.7	6.8	7.8	19.2	15.1	17.1	90.1	85.5	87.8	92.7	88.9	90.8	61.8	64.1	63.0
D_3S_1	14.6	13.4	14.0	26.7	25.3	26.0	91.8	93.2	92.5	93.0	95.1	94.0	82.9	88.1	85.5
D_3S_2	7.3	10.6	8.9	17.2	20.3	18.8	86.9	89.5	88.2	88.8	90.6	89.7	78.8	71.8	75.3
D_3S_3	12.3	11.9	12.1	15.7	12.9	14.3	82.3	88.7	85.5	84.9	90.9	87.9	65.3	63.2	64.3
D_4S_1	16.2	11.8	14.0	29.1	26.7	27.9	92.1	88.0	90.0	93.2	92.9	93.1	82.4	89.5	85.9
D_4S_2	11.8	8.7	10.3	17.1	18.2	17.7	85.7	74.6	80.2	88.0	88.6	88.3	77.0	79.0	78.0
D_4S_3	9.2	6.8	8.0	11.8	17.4	14.6	83.1	64.5	73.8	85.6	86.6	86.1	61.8	67.6	64.7
D_5S_1	14.6	11.9	13.3	15.9	25.1	20.5	90.1	88.4	89.2	91.5	91.7	91.6	82.3	88.0	85.1
D_5S_2	6.1	9.5	7.8	12.5	23.7	18.1	82.4	79.1	80.7	84.9	86.4	85.6	77.5	67.7	72.6
D_5S_3	6.2	9.7	7.9	21.5	18.0	19.8	77.9	70.5	74.2	81.1	73.8	77.5	62.8	60.7	61.7

Interactions

Combination of June I FN sowing with 45 x 20 cm recorded the highest percentage of intercepted PAR. In case of pooled analysis,D_1 x S_1, recorded 31.8, 95.4, 97.6 and 86.8 per cent of intercepted PAR at V_6, tasseling, silking and physiological maturity stages, respectively.

4.2.8.3.9 Per cent Absorbed PAR

In general, the per cent absorbed PAR decreased with delay in sowing and wider planting geometry in both the years at all the phenophases (Table-21).

Sowing dates

Per cent absorbed PAR was influenced by sowing dates and decreased with delay in sowing. During 2013, the highest percentage at absorbed PAR was recorded in June I FN (D_1) sown crop to an extent of 25.8, 91.6, 92.9 and 74.7 per cent at V_6, tasseling, silking and physiological maturity. But during 2014, July I FN (D_3) sown crop recorded the highest per cent absorbed PAR (86.8 and 90.1) at tasseling and silking stages respectively. But, the pooled analysis clearly indicate the superiority of June I FN sown crop with respect to highest percentage of absorbed PAR (21.8, 87.9, 90.2 and 72.0) at V_6, tasseling, silking and physiological maturity stages, respectively.

Planting geometry

Among the three planting geometries tried, the highest percentage of absorbed PAR was recorded in 45 x 20 cm (S_1) spaced crop. It was to an extent of 13.8, 29.1, 89.6, 90.7 and 78.8 per cent during 2013 and 12, 23, 87.3, 91.4 and 81.6 per cent during 2014 at V_3, V_6, tasseling, silking and physiological maturity stages, respectively. Similar trend was observed in pooled analysis. The lowest percentage of absorbed PAR (8.4, 15.0, 77.8, 82.1 and 57.7) at V_3, V_6, tasseling, silking and physiological maturity stages, respectively was recorded with widely spaced (75 x 20 cm) crop.

Interactions

Except at V_3 stage, combination of June I FN (D_1) with 45 x 20 cm spacing (S_1) recorded the highest percentage of absorbed PAR (37.1, 94.3, 95.1 and 80.8) at V_6,

Table 21: Per cent Absorbed PAR (% APAR) as influenced by different growing environments and planting geometry

Treatments	Per cent Absorbed PAR														
	Three leaf (V_3)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	11.3	9.6	10.5	24.3	16.4	20.4	91.6	84.3	87.9	92.9	87.4	90.2	74.7	69.3	72.0
D_2: June II fortnight	10.7	9.5	10.1	25.8	17.7	21.8	90.5	85.2	87.8	92.1	87.6	89.8	70.4	69.9	70.1
D_3: July I fortnight	12.1	11.4	11.7	18.4	18.9	18.7	81.0	86.8	83.9	83.0	90.1	86.5	70.6	65.8	68.2
D_4: July II fortnight	11.9	9.0	10.5	16.2	20.2	18.2	83.1	72.2	77.7	85.1	85.3	85.2	68.0	72.1	70.0
D_5:August I fortnight	8.6	9.8	9.2	15.7	19.8	17.7	78.6	76.9	77.7	81.0	79.6	80.3	70.0	64.8	67.4
Planting geometry (S)															
S_1 – 45 cm x 20 cm	13.8	12.0	12.9	29.1	23.0	26.1	89.6	87.3	88.4	90.7	91.4	91.1	78.8	81.6	80.2
S_2 – 60 cm x 20 cm	9.6	9.3	9.4	19.1	19.2	19.1	83.9	80.1	82.0	85.9	85.7	85.8	74.5	66.3	70.4
S_3 – 75 cm x 20 cm	9.1	7.8	8.4	15.1	14.8	15.0	80.2	75.4	77.8	82.9	81.4	82.1	59.0	56.5	57.7
Interaction (D x S)															
D_1S_1	13.9	11.4	12.6	36.8	19.9	28.4	94.3	89.8	92.0	95.1	92.1	93.6	80.7	82.1	81.4
D_1S_2	9.3	10.9	10.1	19.0	17.9	18.4	91.2	82.2	86.7	92.5	87.1	89.8	78.8	64.5	71.7
D_1S_3	10.6	6.2	8.4	16.9	12.7	14.8	88.2	81.5	84.8	90.3	82.9	86.6	64.5	60.3	62.4
D_2S_1	12.3	13.1	12.7	37.1	21.8	29.4	93.7	88.3	91.0	94.4	92.9	93.6	79.6	83.5	81.5
D_2S_2	11.0	8.7	9.8	30.3	18.7	24.5	88.9	84.9	86.9	90.6	85.9	88.2	73.8	67.8	70.8
D_2S_3	8.4	7.0	7.7	16.5	13.3	14.9	88.2	82.8	85.5	90.8	83.5	87.1	56.5	57.6	57.1
D_3S_1	13.7	12.9	13.3	25.0	23.0	24.0	85.4	89.5	87.5	86.8	92.7	89.7	78.1	79.4	78.8
D_3S_2	10.6	9.9	10.2	15.9	21.1	18.5	80.2	85.9	83.0	82.2	87.5	84.8	74.0	64.0	69.0
D_3S_3	11.9	11.1	11.5	14.5	13.7	14.1	77.1	85.0	81.0	79.7	90.0	84.8	59.4	54.3	56.9
D_4S_1	15.3	11.2	13.3	27.0	26.0	26.5	88.7	84.0	86.3	89.9	89.2	89.5	76.9	82.7	79.8
D_4S_2	11.3	8.7	10.0	14.9	18.0	16.4	81.8	71.3	76.6	84.1	84.1	84.1	71.4	73.1	72.3
D_4S_3	8.8	7.0	7.9	9.3	17.0	13.2	78.4	61.5	70.0	80.9	81.5	81.2	55.6	59.8	57.7
D_5S_1	13.9	11.4	12.7	15.0	22.7	18.9	85.6	85.4	85.5	87.1	89.1	88.1	78.3	80.1	79.2
D_5S_2	5.3	9.0	7.1	11.4	21.2	16.3	77.3	76.7	77.0	79.9	82.9	81.4	73.3	61.3	67.3
D_5S_3	5.3	9.0	7.2	20.1	16.5	18.3	72.2	68.7	70.4	75.5	70.4	72.9	57.2	51.1	54.2

tasseling, silkinmg and physiological maturity during 2013 and June II FN (D_2) sown crop recorded the highest percentage of absorbed PAR (92.9 and 83.2) at silking and physiological maturity stages, respectively. The pooled data clearly indicated that the combination of June I FN (D_1) with 45 x 20 cm planting geometry, recorded the highest percentage of absorbed PAR (29.4, 92, 93.6 and 81.4) at V_6, tasseling, silking and physiological maturity stages, respectively.

4.3 Growth parameters as influenced by different sowing dates and planting geometry

4.3.1.1 Plant height (cm)

Plant height (cm) also influenced significantly due to sowing dates and planting geometry. Also, the interaction effects were found significant (Table 22 and Plate 3).

Sowing dates

During 2013, June I FN sowing (D_1) recorded significantly taller plants (23.0 cm, 180.2 cm, 183.8 cm and 203.7 cm) at sixth leaf, tasseling, silking and physiological maturity stages, respectively. For 2014, July I FN sown crop recorded significantly taller (23.8 cm, 186.1 cm and 188.9 cm) at V_6, tasseling and silking stages, respectively. The pooled analysis also indicate the superiority of June I FN with respect to plant height (22.0, 182.0, 184.9 and 201.4 cm) at sixth leaf, tasseling, silking and physiological maturity stages respectively.

Planting geometry

Pooled analysis indicate that, among the three planting geometries tried, narrow spaced maize (45 x 20 cm) recorded the tallest plant height (2.11,21.6, 178.4, 181.0 and 196.4 cm) at V_1, V_6, tasseling, silking and physiological maturity, respectively. The shortest plant height (2.08 cm, 19.9 cm, 164.3 cm, 166.5 cm and 182.6 cm) was recorded with wider spaced maize crop (75 x 20 cm).

Interactions

Among the different treatment combinations, July I FN (D_3) and June I FN (D_1) with narrow spacing (45 cm x 20 cm) recorded significantly the taller plants at tasseling

Table 22: Plant height (cm) as influenced by different growing environments and planting geometry

Treatments	Plant height (cm)														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	2.11a	2.01b	2.06a	23.0a	21.0bc	22.0a	180.2a	183.8a	182.0a	183.8a	186.0a	184.9a	203.7a	199.0a	201.4a
D_2: June II fortnight	2.17a	1.96b	2.06a	21.2ab	19.2c	20.2bc	171.1ab	181.2a	177.8a	177.8ab	183.7a	180.7a	193.4ab	199.3a	196.4ab
D_3: July I fortnight	2.04a	2.23a	2.13a	19.5bc	23.8a	21.6ab	168.0bc	186.1a	177.0a	170.2bc	188.9a	179.6a	188.3b	197.3a	192.8ab
D_4: July II fortnight	2.07a	2.20a	2.13a	19.2c	22.8ab	21.0ab	158.8c	169.9b	164.4b	161.1cd	173.2b	167.2b	184.9b	186.6ab	185.7b
D_5:August I fortnight	2.02a	2.16a	2.09a	17.3c	20.6bc	18.9c	145.4d	151.2c	148.3c	149.2d	154.4c	151.8c	166.0c	170.2b	168.1c
Planting geometry (S)															
S_1 – 45 cm x 20 cm	2.09a	2.13a	2.11a	20.8a	22.4a	21.6a	175.3a	182.7a	178.4a	176.4a	185.5a	181.0a	196.0a	196.8a	196.4a
S_2 – 60 cm x 20 cm	2.08a	2.11a	2.09a	20.1a	21.4b	20.8ab	162.2b	171.7b	167.0b	167.2ab	174.8b	171.0b	185.7b	189.4b	187.6b
S_3 – 75 cm x 20 cm	2.07a	2.09a	2.08a	19.2a	20.6b	19.9b	156.7b	169.0b	164.3b	161.6b	171.5b	166.5b	180.1b	185.2b	182.6b
Interaction (D x S)															
D_1S_1	2.12a	2.07ac	2.09a	23.4a	22.7ac	23.0ab	188.5a	192.3ab	190.4ab	192.3a	194.3ab	193.3a	209.2a	203.7a	206.4a
D_1S_2	2.03a	2.00bc	2.02a	23.4a	21.1ce	22.3a	178.8ac	182.4ad	180.6ac	182.4ac	185.0ad	183.7ac	204.1ab	200.7ab	202.4ab
D_1S_3	2.17a	1.97bc	2.07a	22.3a	19.2ef	20.7ac	173.2ad	176.7bd	175.0ad	176.7ad	178.7bd	177.7ad	197.8ac	192.7ac	195.3ac
D_2S_1	2.15a	2.00bc	2.08a	23.2a	19.5ef	21.3ac	180.1ac	187.3ac	183.7ac	183.7ac	189.7ac	186.7ab	199.9ac	205.3a	202.6ab
D_2S_2	2.20a	1.90c	2.05a	20.9ab	19.2ef	20.0ac	173.4ad	180.3bd	176.8ad	176.8ad	182.7bd	179.8ad	192.4ac	198.4ab	195.4ac
D_2S_3	2.17a	1.97bc	2.07a	19.5ab	18.8f	19.2bc	169.3be	176.1bd	172.7bd	172.7ae	178.7bd	175.7ad	188.0ac	194.2ac	191.1ac
D_3S_1	2.08a	2.15ac	2.12a	20.4ab	23.7ab	22.0ac	185.1ab	199.6a	192.4a	185.4ab	202.7a	194.1a	204.1ab	204.0a	204.1a
D_3S_2	2.03a	2.30a	2.17a	19.7ab	23.7ab	21.7ac	161.7cf	182.3ad	172.0bd	164.9bf	185.3ad	175.1ad	182.6bd	195.7ac	189.1ac
D_3S_3	2.00a	2.23ab	2.12a	18.3ab	24.0a	21.1ac	157.3df	176.2bd	166.8cd	160.4cf	178.7bd	169.5be	178.2cd	192.3ac	185.3bc
D_4S_1	2.08a	2.23ab	2.16a	19.6ab	23.7ab	21.6ac	159.3df	170.5cd	164.9cd	166.9de	173.7cd	170.3be	187.1bc	191.3ac	189.2ac
D_4S_2	2.04a	2.13ac	2.09a	19.1ab	23.2ac	21.2ac	153.4ef	164.1de	158.7de	161.0cf	167.3de	164.1ce	185.2bd	184.5bd	184.8c
D_4S_3	2.08a	2.23ab	2.16a	19.0ab	21.7bd	20.3ac	163.8ce	175.2bd	169.5cd	155.5df	178.7bd	167.1be	182.3bd	184.0bd	183.1c
D_5S_1	2.02a	2.20ab	2.11a	17.4b	22.3ac	19.9ac	157.3df	163.6de	160.4de	153.9df	167.0de	160.5df	179.6cd	179.8cd	179.7cd
D_5S_2	2.10a	2.20ab	2.15a	17.3b	20.0df	18.6bc	143.8fg	149.6ef	146.7ef	151.0ef	153.7ef	152.3ef	164.1de	168.0de	166.0de
D_5S_3	1.93a	2.07ac	2.00a	17.1b	19.3ef	18.2c	135.1g	140.5f	137.8f	142.6f	142.7f	142.6f	154.3e	162.7e	158.5e

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

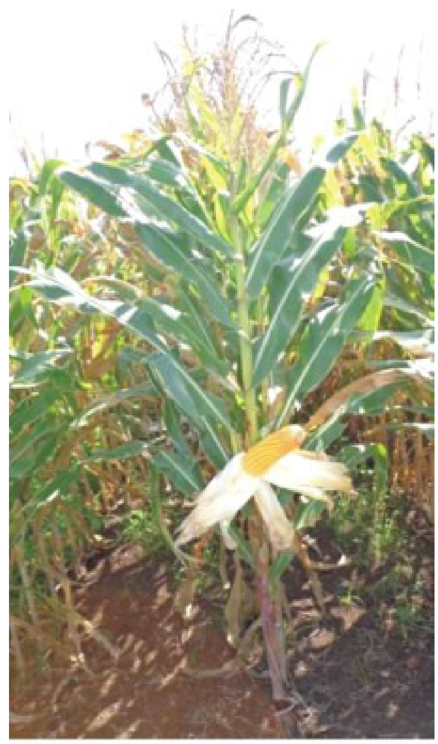
Emergence

Seedling (V_1)

Sixth leaf stage

Tasseling

Silking



Physiological maturity

Plate 3. Different phenological stages of maize

(192.4 cm and 190.4 cm), silking (194.1 cm and 193.3 cm) and at physiological maturity stages, respectively (204.1 cm and 206.4 cm) over other treatment combinations.

4.3.1.2 Leaf area per plant (dm^2)

Leaf area per plant was influenced significantly due to sowing dates and planting geometries at all the stages during both the years as well in pooled analysis (Table 23).

Sowing dates

In general, delayed sowings recorded the smaller leaf area per plant than early sown crops at all the stages during both the years. During 2013, significantly the larger leaf area per plant at V_6 (5.1 and 5.1 dm^2), tasseling (58.3 and 58.1 dm^2), silking (60.9 and 60.3 dm^2) and physiological maturity stage (38.4 and 37.6 dm^2) were recorded correspondingly for June I FN (D_1) and June II FN (D_2) sown crops. Whereas, for 2014 significantly larger leaf area per plant at V_6 (5.0), tasseling (58.1), silking (60.4) and physiological maturity (40.2) was recorded with July I FN (D_3) sown crop. However, the lowest leaf area per plant was recorded in August I FN sown crop at all the phenological stages during both the years.

Planting geometry

Significantly the largest leaf area per plant was recorded with 75 x 20 cm spaced crop over other planting geometries. It recorded 4.8, 53.1, 55.2 and 35.4 dm^2 during 2013 and 5.1, 60.3, 62 and 41.2 dm^2 during 2014 at V_6, tasseling, silking and physiological maturity stages. Similar trend was noticed in case of pooled analysis.

Interactions

In case of pooled analysis, among the different combinations of sowing dates and planting geometries tried, D_1 x S_3 and D_3 x S_3 (June I FN/July I FN with 75 x 20 cm) recorded significantly the larger leaf area. Combination of June I FN / June II FN sowing with wider spacing (75 x 20 cm) recorded larger leaf area at V_6 (5.4 dm^2), tasseling (62.4 and 65.4 dm^2), silking (64.1 and 67.1 dm^2) and physiological maturity stages (41.2 and 43 dm^2).

Table 23: Leaf area per plant (dm^2) as influenced by different growing environments and planting geometry

Treatments	Leaf area per plant (dm^2)											
	Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)												
D_1: June I fortnight	5.1a	4.7a	4.9a	58.3a	55.2ab	56.7a	60.9a	56.7b	58.8a	38.4a	36.8b	37.6a
D_2: June II fortnight	5.1a	4.5ab	4.8a	58.1a	55.0ab	56.6a	60.5a	55.6b	58.0a	37.6a	36.7b	37.2a
D_3: July I fortnight	4.3b	5.0ab	4.6a	47.9b	58.1a	53.0b	50.2d	60.4a	55.3a	31.9b	40.2a	36.1a
D_4: July II fortnight	3.9bc	3.9b	3.9b	42.6b	51.6b	47.1c	44.0b	53.2b	48.6b	28.8b	35.5bc	32.1b
D_5:August I fortnight	3.3c	4.0b	3.7b	33.5c	46.5c	40.0d	34.7c	48.8c	41.8c	28.8b	32.5c	30.6b
Planting geometry (S)												
S_1 – 45 cm x 20 cm	3.9c	3.8c	3.9c	43.2c	43.7c	43.5c	45.1c	45.5c	45.3c	31.5b	29.8c	30.7c
S_2 – 60 cm x 20 cm	4.3b	4.4b	4.3b	47.9b	55.7b	51.8b	49.8b	57.3b	53.5b	32.4b	38.0b	35.2b
S_3 – 75 cm x 20 cm	4.8a	5.1a	4.9a	53.1a	60.3a	56.7a	55.2a	62.0a	58.6a	35.4a	41.2a	38.3a
Interaction (D x S)												
D_1S_1	4.9bc	4.0fh	4.5cd	56.3bd	47.7df	52.0ce	58.8bd	51.2fh	55.0df	37.9bc	31.8fh	34.8df
D_1S_2	5.1bc	4.6cf	4.8bc	57.5bc	54.0bd	55.8bc	60.1bc	54.5df	57.3cd	37.5bd	36.0cf	36.7cd
D_1S_3	5.3ad	5.5ab	5.4a	61.0b	63.8a	62.4a	63.8b	64.4ab	64.1ab	39.8b	42.5ab	41.2ab
D_2S_1	4.8cd	3.8gh	4.3de	51.0ce	45.3ef	48.2eg	53.1de	45.7gi	49.4fh	32.9ef	30.2gi	31.6fg
D_2S_2	4.8cd	4.5cg	4.6cd	55.3be	57.1ab	56.2bc	57.4ce	57.6be	57.5cd	35.8ce	38.0bd	36.9cd
D_2S_3	5.8a	5.1bc	5.4a	68.1a	62.7a	65.4a	71.0a	63.3bc	67.1a	44.2a	41.8ab	43.0a
D_3S_1	3.8f	4.2eg	4.0ef	43.7f	47.2df	45.4fh	45.9f	49.0gh	47.5gi	29.2gh	32.7eh	30.9gh
D_3S_2	4.4de	4.9bd	4.6cd	48.7ef	62.9a	55.8bc	50.9ef	65.4a	58.1cd	32.4eg	43.5a	37.9cd
D_3S_3	4.6cd	5.8a	5.2ab	51.3ce	64.2a	57.7b	53.8ce	66.7a	60.3bc	34.2de	44.6a	39.4dc
D_4S_1	3.2gh	3.5h	3.3gh	33.4g	41.3fg	37.4ij	34.7g	42.6hi	38.6jk	28.6gh	28.4hi	28.5hi
D_4S_2	3.9ef	4.0fh	4.0ef	44.5f	55.1bc	49.8df	46.0f	56.8ce	51.4eg	27.7h	37.9bd	32.8eg
D_4S_3	4.6cd	4.4df	4.5cd	49.8df	58.4ab	54.1bd	51.3ef	60.2ad	55.8ce	30.2fh	40.1ac	35.2de
D_5S_1	2.9h	3.4h	3.2h	31.8g	37.2g	34.5j	33.2g	39.1i	36.1k	28.8gh	26.1i	27.4i
D_5S_2	3.4fh	4.0fh	3.7fg	33.4g	49.6ce	41.5hi	34.7g	52.1eg	43.4ij	28.8gh	34.7dg	31.8fg
D_5S_3	3.6fg	4.8ce	4.2de	35.3g	52.6be	44.0gh	36.3g	55.2df	45.8hi	28.7gh	36.8ce	32.7eg

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

4.3.1.3 Leaf area index (LAI)

Leaf area index also varied significantly due to sowing dates and planting geometries at all the phenophases during both the years (Table 24).

Sowing dates

In general, the LAI reduced with the delayed sowing from June I FN (D_1) to August I FN (D_5). During 2013, significantly higher LAI was recorded with June I FN and June II FN sown crop at V_6 (0.44 and 0.44), tasseling (5.04 and 4.94), silking (5.27 and 5.14) and physiological maturity (3.33 and 3.20), respectively over other sowing dates. The lowest LAI was recorded in August I FN sown crop (0.28, 2.9, 3.0 and 2.50). During 2014, June I FN and July I FN (D_3) sown crops had significantly higher LAI at V_6 (0.40 and 0.42) and tasseling (4.68 and 4.69). The July I FN sown crop had the highest LAI (5.12 and 3.41) at silking and physiological maturity stages, respectively. Pooled analysis indicated that, June I FN, June II FN and July I FN sown crops supported the highest LAI at all the phenophases. Delayed sowing had the lowest LAI at all the phenophases during both the years.

Planting geometry

Among the three planting geometries, narrow spaced maize (45 x 20 cm) recorded higher LAI at all phenophases during both years. During 2013, it was 0.44, 4.80, 5.02 and 3.50 and 0.42, 5.01, 5.06 and 3.31 for 2014 at V_6, tasseling, silking and physiological maturity, respectively. The LAI was lowest in widely spaced maize crop (75 x 20 cm). Similar trend were observed in case of pooled analysis.

Interactions

Combination of June I FN (D_1) sown crop with 45 x 20 cm (S_1) recorded significantly higher LAI at all the phenophases. In case of pooled analysis, D_1 x S_1 recorded 0.50, 5.78, 6.11 and 3.87 at V_6, tasseling, silking and physiological maturity stages, respectively. The lowest LAI was recorded with August I FN (D_5) sown crop with 75 x 20 cm spacing at V_6 (0.28), tasseling (3.01, silking (3.05) and physiological maturity stages (2.18).

Table 24: Leaf area index (LAI) as influenced by different growing environments and planting geometry

Treatments	Leaf area index											
	Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)												
D_1: June I fortnight	0.44a	0.40a	0.42a	5.04a	4.68a	4.86a	5.27a	4.84b	5.05a	3.33a	3.12b	3.23a
D_2: June II fortnight	0.44a	0.38ab	0.41a	4.94a	4.66a	4.80a	5.14a	4.70b	4.92a	3.20a	3.10b	3.15a
D_3: July I fortnight	0.36b	0.42a	0.39a	4.11b	4.69a	4.40b	4.31b	5.12a	4.71a	2.74b	3.41a	3.07a
D_4: July II fortnight	0.33bc	0.34b	0.33b	3.58b	4.62a	4.10b	3.70b	4.49b	4.10b	2.50b	2.99bc	2.75b
D_5:August I fortnight	0.28c	0.34b	0.31b	2.89c	4.15b	3.52c	3.00c	4.12c	3.56c	2.50b	2.75c	2.63b
Planting geometry (S)												
S_1 – 45 cm x 20 cm	0.44a	0.42a	0.43a	4.80a	5.01a	4.91a	5.02a	5.06a	5.04a	3.50a	3.31a	3.41a
S_2 – 60 cm x 20 cm	0.36c	0.37b	0.36c	3.99b	4.50b	4.24b	4.15b	4.77a	4.46b	2.70b	3.17a	2.94b
S_3 – 75 cm x 20 cm	0.32b	0.34c	0.33b	3.54c	4.18c	3.86c	3.68c	4.13b	3.91c	2.36c	2.74b	2.55c
Interaction (D x S)												
D_1S_1	0.55a	0.45a	0.50a	6.25a	5.30a	5.78a	6.53a	5.68ab	6.11a	4.21a	3.53ab	3.87a
D_1S_2	0.42c	0.38bd	0.40cd	4.79c	4.50cd	4.65cd	5.01c	4.54ce	4.78d	3.12c	3.00ce	3.06d
D_1S_3	0.36b	0.37bd	0.36dg	4.06de	4.25de	4.16eh	4.25de	4.30de	4.27e	2.65ef	2.83df	2.74e
D_2S_1	0.53a	0.42ab	0.48ab	5.67d	5.03ac	5.35b	5.89b	5.08ac	5.49ab	3.66b	3.35ac	3.51b
D_2S_2	0.40bc	0.37bd	0.39ce	4.60c	4.75ad	4.68cd	4.78cd	4.80bd	4.79d	2.99cd	3.17bd	3.08d
D_2S_3	0.38bd	0.34ce	0.36dg	4.54cd	4.18de	4.36df	4.73cd	4.22df	4.48de	2.94ce	2.79df	2.86de
D_3S_1	0.42b	0.46a	0.44bc	4.86ce	5.24a	5.05bc	5.10c	5.45a	5.28bc	3.25c	3.63a	3.44bc
D_3S_2	0.36ce	0.41ab	0.39ce	4.06de	4.55bd	4.30dg	4.24de	5.45a	4.84cd	2.70df	3.63a	3.16cd
D_3S_3	0.31ef	0.39bc	0.35dg	3.42f	4.28de	3.85gi	3.59f	4.45ce	4.02ef	2.28gh	2.97ce	2.63ef
D_4S_1	0.35ce	0.38bd	0.37df	3.71ef	5.10ab	4.41de	3.86ef	4.73cd	4.29e	3.18c	3.16bd	3.17cd
D_4S_2	0.33df	0.33ce	0.33eh	3.71ef	4.43de	4.07eh	3.83ef	4.73cd	4.28e	2.30gh	3.16bd	2.73e
D_4S_3	0.30ef	0.29e	0.30gh	3.32f	4.33de	3.83hi	3.42fg	4.01ef	3.72f	2.02hi	2.67ef	2.34fg
D_5S_1	0.33df	0.38bd	0.35dg	3.53ef	4.36de	3.94fi	3.69ef	4.34de	4.02ef	3.20c	2.89de	3.05d
D_5S_2	0.28fg	0.33ce	0.31fh	2.78g	4.24de	3.51ij	2.89gh	4.34de	3.62f	2.40fg	2.89de	2.65e
D_5S_3	0.24g	0.32de	0.28h	2.36g	3.86e	3.11j	2.42h	3.68f	3.05g	1.91i	2.45f	2.18g

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

4.3.2 Dry matter accumulation and its partitioning in different plant parts

4.3.2.1 Dry matter accumulation in leaves (g/plant)

The DMA in leaves was significantly influenced by sowing dates and planting geometry at all the growth stages during both the years and in their pooled analysis (Table 25).

Sowing dates

Among the five sowing dates tried during 2013, June I FN sowing (D_1) recorded significantly higher DMA in leaves at sixth leaf stage (3.82 g), tasseling (50.7 g), silking (53.9 g) and physiological maturity (35.8 g) compared to other sowing dates. Whereas in 2014, July I FN sowing (D_3) recorded significantly higher DMA in leaves (2.92, 49.0, 52.3 and 33.2 g) correspondingly at sixth leaf, tasseling, silking and physiological maturity stages. In case of pooled analysis, June I FN to July I FN sowing, were found on par with each other for the DMA in leaves, but were significantly higher over late sown (July II FN and August I FN) conditions.

Planting geometry

Among the three planting geometries tried, wider spacing of 75 x 20 cm (S_3) recorded significantly higher DMA in leaves at all the stages in both the years as well in pooled analysis. During 2013, 75 x 20 cm recorded 3.44, 43.5, 44.3 and 30.3 g and during 2014, 2.85, 47.5, 48.7 and 31.4 g, respectively for sixth leaf, tasseling, silking and physiological maturity stages. Similar trend was observed in pooled analysis.

Interactions

Pooled data indicate that, combination of early sowing (June I FN) with wider spacing (75 x 20 cm) recorded significantly higher DMA in leaves at seedling, sixth leaf, tasseling, silking and physiological maturity stages (3.52 g,53.4 g,54.9 g and 37.7 g, respectively) over other treatment combinations, which ranged between 2.1 to 3.34 g, 29.5 to 51.0 g for corresponding phenological stages mentioned above.

Table 25: Dry matter accumulation (DMA) in leaf as influenced by different growing environments and planting geometry

Treatments	Dry matter accumulation in leaf (g plant^{-1})											
	Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)												
D_1: June I fortnight	3.82a	2.71ab	3.27a	50.7a	47.8a	49.2a	53.9a	48.3ab	51.1a	35.8a	32.6a	34.2a
D_2: June II fortnight	3.61a	2.72ab	3.17a	45.4b	43.6ab	44.5a	48.1b	44.4b	46.2a	32.3b	29.4ab	30.9ab
D_3: July I fortnight	3.17b	2.92a	3.04a	40.8b	49.0a	44.9a	41.4c	52.3a	46.8a	27.1c	33.2a	30.1b
D_4: July II fortnight	2.77c	2.66b	2.71b	33.8c	38.8bc	36.3b	33.7d	41.5bc	37.6b	23.2d	25.3bc	24.3c
D_5:August I fortnight	2.37d	2.37c	2.37c	26.6d	35.9c	31.3b	26.6c	36.8c	31.7c	21.6d	22.5c	22.0c
Planting geometry (S)												
S_1 – 45 cm x 20 cm	2.86c	2.48c	2.67c	35.6c	38.6c	37.1c	37.2c	40.5c	38.9c	26.5b	26.0c	26.2b
S_2 – 60 cm x 20 cm	3.15b	2.69b	2.92b	39.3b	42.9b	41.1b	40.7b	44.7b	42.7b	27.2b	28.3b	27.7b
S_3 – 75 cm x 20 cm	3.44a	2.85a	3.15a	43.5a	47.5a	45.5a	44.3a	48.7a	46.5a	30.3a	31.4a	30.9a
Interaction (D x S)												
D_1S_1	3.63bd	2.58bd	3.10bd	48.8ac	44.6bd	46.7ad	52.8a	44.4df	48.6bc	34.3bc	30.6bd	32.5b
D_1S_2	3.73bc	2.63ad	3.18ac	49.8ab	45.5bc	47.6ac	53.2a	46.3cf	49.8ab	33.5bd	31.2ad	32.4b
D_1S_3	4.11a	2.84ab	3.52a	53.4a	53.4a	53.4a	55.7a	54.1ac	54.9a	39.5a	35.8a	37.7a
D_2S_1	3.41cd	2.61ad	3.01bd	39.9d	39.3ce	39.6de	43.5bd	39.6eg	41.5ef	29.4cf	26.1df	27.8ce
D_2S_2	3.56bd	2.75ac	3.16ac	43.4bd	43.3bd	43.3ce	46.3b	46.1be	46.2de	32.0be	28.9cd	30.5bd
D_2S_3	3.89ab	2.80ac	3.34ab	52.8a	48.3ab	50.5ab	54.4a	47.6bd	51.0ab	35.5ab	33.2ac	34.4ab
D_3S_1	2.87e	2.83ab	2.85ce	37.3d	44.7bc	41.0ce	37.9de	47.8bd	42.8df	24.8fh	30.3cd	27.5de
D_3S_2	3.27d	2.93ab	3.10bd	41.4cd	49.6ab	45.5bd	41.9bd	53.0ab	47.5bd	27.4eg	33.6ac	30.5bd
D_3S_3	3.37cd	3.00a	3.18ac	43.7bd	52.5a	48.1ac	44.4bc	56.1a	50.2ab	29.0df	35.6ab	32.3bc
D_4S_1	2.28fg	2.28de	2.28gh	26.5f	30.4f	28.5g	26.6f	32.5g	29.5g	23.0gh	19.8g	21.4g
D_4S_2	2.79e	2.73ac	2.76df	35.4de	40.6ce	38.0ef	35.3e	43.3df	39.3f	22.3gh	26.4de	24.3eg
D_4S_3	3.26d	2.96ab	3.11bd	39.6d	45.4bc	42.5ce	39.4ce	48.6ad	44.0cf	24.3fh	29.6cd	27.0df
D_5S_1	2.10g	2.10e	2.10h	25.3f	34.1ef	29.7g	25.5f	38.2fg	31.9g	20.8h	23.3eg	22.0g
D_5S_2	2.42fg	2.42ce	2.42fh	26.5f	35.8ef	31.1g	26.6f	34.9g	30.7g	20.8h	21.3fg	21.0g
D_5S_3	2.58ef	2.58bd	2.58eg	28.1ef	37.9de	33.0fg	27.8f	37.2fg	32.5g	23.4gh	22.8eg	23.1fg

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

4.3.2.2 Dry matter accumulation in stem (g/plant)

The dry matter accumulation in stem was also differed significantly due to sowing dates and planting geometry at all the stages during both the years as well as in their pooled analysis (Table 26).

Sowing dates

During 2013, June I FN sowing (D_1) recorded significantly more DMA in stem (3.5, 58.3, 63.9 and 75.2 g) at sixth leaf, tasseling, silking and physiological maturity stages, respectively. For 2014, July I FN sown crop recorded significantly higher DMA in stem (2.34, 53.9 and 56.8 g) at V_6, tasseling and silking stages, respectively. The lowest DMA in stem was recorded with August I FN (D_5) sown crop in both the years as well in pooled analysis.

Planting geometry

Among the three planting geometries tried, wider (75 x 20 cm) geometry recorded significantly higher DMA in stem for 2013 (3.3, 52.1, 55.9 and 64.8 g) and for 2014 (2.42, 51.2, 54.6 and 79.9 g) correspondingly at sixth leaf, tasseling, silking and physiological maturity stages, respectively. Similar results were noticed in case of pooled analysis.

Interactions

Pooled mean indicate that, combination of D_1 x S_3 (June I FN with 75 x 20 cm) recorded higher DMA in stem (3.2,60.3,64.8 and 81.4 g) over other treatment combinations, which ranged between 2.0 to 2.98 g, 34.2 to 56.0 g, 37.3 to 58.1 g and 51.0 to 76.9 g at sixth leaf, tasseling, silking and physiological maturity stages, respectively.

4.3.2.3 Dry matter accumulation in tassel (g/plant)

The DMA in tassel was significantly differed due to different sowing dates and planting geometry as well in their pooled analysis for taseling, silking and physiological maturity stages (Table 27).

Table 26: Dry matter accumulation (DMA) in stem as influenced by different growing environments and planting geometry

Treatments	Dry matter accumulation in stem											
	Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)												
D_1: June I fortnight	3.50a	2.29ab	2.90a	58.3a	51.6ab	54.9a	63.9a	55.0a	59.4a	75.2a	77.7a	76.4a
D_2: June II fortnight	3.30a	2.17ab	2.70ab	52.8a	48.5ab	50.7a	57.5ab	50.7ab	54.1ab	68.6b	72.6a	70.6ab
D_3: July I fortnight	3.00b	2.34a	2.65ab	50.7b	53.9a	52.3ab	56.8b	62.5a	59.6ab	65.8c	77.4a	68.6b
D_4: July II fortnight	2.70b	2.18ab	2.45b	50.6b	49.7bc	50.1b	56.6b	52.9bc	54.8b	63.9c	76.0a	65.7b
D_5:August I fortnight	2.40c	1.96b	2.17c	43.2c	47.3c	45.3c	48.4c	50.4c	49.4c	54.7d	61.6b	52.7c
Planting geometry (S)												
S_1 – 45 cm x 20 cm	2.70c	1.99c	2.34c	45.9c	46.1c	46.0c	52.8c	49.6c	51.2c	60.1c	66.6c	61.1c
S_2 – 60 cm x 20 cm	2.90b	2.15b	2.54b	51.0b	49.9b	50.4b	56.4b	53.9b	55.1b	66.5b	72.7b	67.0b
S_3 – 75 cm x 20 cm	3.30a	2.42a	2.84a	56.4a	54.6a	55.5a	60.8a	59.4a	60.1a	70.3a	79.9a	72.3a
Interaction (D x S)												
D_1S_1	3.40bd	2.04df	2.70cd	55.1ad	48.7cd	51.9bd	61.7ac	50.4ce	56.1b	74.1a	71.9bd	73.0ac
D_1S_2	3.40ac	2.15ce	2.79bc	56.3ac	48.9bd	52.6bd	63.0ab	51.8cd	57.4b	76.0a	73.9bd	74.9ab
D_1S_3	3.70a	2.69a	3.19a	63.4a	57.2ab	60.3a	66.9a	62.8a	64.8a	75.4a	87.4a	81.4a
D_2S_1	3.10de	1.98df	2.52de	47.3ce	44.4de	45.9cd	59.8bd	46.4dg	53.1bc	64.2bc	66.4df	65.3cd
D_2S_2	3.10de	2.18cd	2.64cd	51.4be	48.8cd	50.1bd	53.9dg	50.9ce	52.4bc	68.5ab	73.2bd	70.8bc
D_2S_3	3.60ab	2.33bc	2.98ab	59.7ab	52.3ad	56.0ab	58.7de	54.8ad	56.8b	73.1a	78.2ac	75.6ab
D_3S_1	2.70fg	2.20cd	2.46de	46.4ef	49.3bd	47.8d	51.9g	57.1cd	54.5c	60.2d	70.7ce	62.7d
D_3S_2	3.00ef	2.33bc	2.65cd	51.4ce	54.6ac	53.0bd	57.6eg	63.4ac	60.5bc	66.7bd	78.6ac	69.6bd
D_3S_3	3.20ce	2.48ab	2.83bc	54.4ce	57.7a	56.0bc	60.9cf	66.9ab	63.9b	70.6bc	82.9ab	73.5ac
D_4S_1	2.20hi	1.79f	2.01g	39.6f	39.0f	39.3e	44.4h	41.5h	42.9d	50.1e	59.5ef	51.5e
D_4S_2	2.70fg	2.19cd	2.46de	52.9de	52.0de	52.5d	59.2fg	55.4df	57.3c	66.8cd	79.5ac	68.8bd
D_4S_3	3.20ce	2.55ab	2.87bc	59.2de	58.1ad	58.7bd	66.3df	61.9bd	64.1b	74.7bc	88.8a	76.9ab
D_5S_1	2.10i	1.9df	2.00g	41.0f	49.3ef	45.2e	46.0h	52.6eh	49.3d	51.8e	64.2df	52.8e
D_5S_2	2.50gh	1.90ef	2.18fg	43.1f	45.0f	44.0e	48.2h	47.9gh	48.1d	54.3e	58.5f	51.0e
D_5S_3	2.60g	2.02df	2.33ef	45.6f	47.7ef	46.7e	51.1h	50.8fh	50.9d	57.8e	62.1df	54.2e

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

Table 27: Dry matter accumulation (DMA) in tassel and cob as influenced by different growing environments and planting geometry

Treatments	Dry matter accumulation in tassel									Dry matter accumulation in cob					
	Tasseling (VT)			Silking			Physiological maturity			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	4.50a	4.20ab	4.33a	4.60a	4.56ab	4.59a	3.7a	3.0c	3.3ab	30.0a	29.0a	29.5a	203.1a	202.2ab	202.7a
D_2: June II fortnight	4.40ab	4.17ab	4.30a	4.50ab	4.54ab	4.50a	3.6ab	3.1bc	3.4ab	29.8a	29.1a	29.4a	198.9a	201.8ab	200.3a
D_3: July I fortnight	4.00bc	4.62a	4.30a	4.00bc	5.02a	4.52a	3.2bc	3.7a	3.5a	24.4ab	29.8a	27.1a	186.6a	211.2a	198.9a
D_4: July II fortnight	3.80c	4.41ab	4.09ab	3.80c	4.79ab	4.30ab	3.3bc	3.5ab	3.4ab	24.1b	24.7b	24.4b	164.3b	183.0bc	173.7b
D_5:August I fortnight	3.60c	3.94b	3.75d	3.60c	4.28d	3.94b	3.1c	3.1bc	3.1b	20.0c	24.3b	22.2b	140.0c	166.0c	153.0b
Planting geometry (S)															
S_1 – 45 cm x 20 cm	3.70b	3.86c	3.79c	3.80b	4.19c	3.98c	3.1b	3.0c	3.0c	23.2c	25.3b	24.2c	160.5c	169.7c	165.1c
S_2 – 60 cm x 20 cm	3.90b	4.25b	4.08b	4.00b	4.62b	4.32b	3.3b	3.3b	3.3b	25.6b	27.3b	26.4b	178.1b	189.3b	183.7b
S_3 – 75 cm x 20 cm	4.50a	4.70a	4.59a	4.50a	5.11a	4.82a	3.7a	3.6a	3.7a	28.2a	29.6a	28.9a	197.2a	219.5a	208.4a
Interaction (D x S)															
D_1S_1	4.10ad	4.20bd	4.13bf	4.10ad	4.55bd	4.33be	3.3ac	2.9ef	3.1cf	29.0bc	29.1ad	29.0bc	196.4bd	185.6bd	191.0de
D_1S_2	4.50ab	4.18bd	4.35ae	4.90a	4.53bd	4.71ac	3.9ab	2.9ef	3.4de	29.6bc	29.5ad	29.6b	200.4bc	187.8bd	194.1cd
D_1S_3	4.80a	4.23bd	4.51ad	4.80a	4.61bd	4.73ac	3.9ab	3.1bf	3.5bd	31.4b	28.4be	29.9b	212.6ab	233.3a	223.0ab
D_2S_1	4.40ad	3.63b	4.00cg	4.40ac	3.94d	4.18cf	3.5ac	2.7f	3.1cf	26.0ce	25.3ce	25.6cd	173.8de	170.2cd	172.0ef
D_2S_2	4.40ac	3.98cd	4.19bf	4.50ac	4.34cd	4.40be	3.6ac	3.0df	3.3de	28.3bd	27.7be	28.0bc	189.4be	202.9ac	196.2cd
D_2S_3	4.50ab	4.91ab	4.69ac	4.50ab	5.36ab	4.94ab	3.6ac	3.7ac	3.7ac	34.9a	34.2a	34.6a	233.4a	232.2a	232.8a
D_3S_1	3.70ad	4.16bd	3.95dg	3.80ad	4.53bd	4.15cf	3.0bc	3.4ae	3.2bf	23.1e	27.1be	25.1cd	170.6e	181.0bd	175.8ef
D_3S_2	3.90ad	4.61ac	4.24bf	3.90ad	5.01ac	4.46bd	3.1ac	3.8ab	3.5be	25.0ce	30.3ac	27.6bc	189.2ce	216.1ab	202.7bd
D_3S_3	4.40ad	5.07a	4.72ab	4.40ac	5.52a	4.96ab	3.5ac	4.0a	3.8ab	25.2bd	31.9ab	28.5b	200.0bd	236.6a	218.3ac
D_4S_1	3.20d	3.46d	3.35g	3.30d	3.75d	3.51f	2.8c	2.7f	2.8f	18.9f	19.3f	19.1f	128.8f	148.7d	138.7h
D_4S_2	3.30cd	4.61ac	3.96dg	3.30cd	5.00ac	4.17cf	2.9c	3.6ad	3.3bf	25.2de	25.8ce	25.5cd	171.8e	177.9cd	174.9ef
D_4S_3	4.80a	5.16a	4.97a	4.80a	5.61a	5.22a	4.1a	4.1a	4.1a	28.2bd	28.9ad	28.5bc	192.3ce	222.4a	207.4bd
D_5S_1	3.20d	3.86cd	3.55fg	3.30d	4.17cd	3.72ef	2.8c	3.2bf	3.0df	19.0f	25.5ce	22.2ef	132.9f	163.1d	148.0gh
D_5S_2	3.50bd	3.85cd	3.68eg	3.50bd	4.20cd	3.87df	3.0c	2.9ef	3.0ef	19.9f	23.0ef	21.5ef	139.5f	162.0d	150.7gh
D_5S_3	4.00ad	4.11bd	4.04bg	4.00ad	4.48bd	4.24be	3.4ac	3.1cf	3.3bf	21.1f	24.5de	22.8de	147.6f	173.0cd	160.3fg

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

Sowing dates

Among the five sowing dates tried, significantly the lowest DMA in tassel was recorded in case of August I FN (D_5) sown crop in both the years as well in pooled data corresponding values of 3.6, 3.6 and 3.1 during 2013 and 3.94, 4.3 and 3.1 during 2014, were recorded at tasseling, silking and physiological maturity stages, respectively. Similar trend was observed in the pooled analysis.

Planting geometry

Among the planting geometries tried, 75 x 20 cm recorded significantly the higher DMA in tassel (4.5, 4.5 and 3.7 g) during 2013. While, in 2014, recorded 4.7, 5.1 and 3.6 g, at tasseling, silking and physiological maturity stages, respectively. Similar trend was noticed in case of pooled analysis.

Interactions

The interaction effects gave interesting combinations in all the three stages (tasseling, silking and physiological maturity) during both the years as well as in pooled mean combination of D_4 x S_3 (July II FN sowing with 75 x 20 cm) recorded significantly higher DMA in tassel for 2013 (4.8, 4.8 and 4.3 g) and for 2014 (5.16, 5.61 and 4.08 g) at tasseling, silking and physiological maturity stages, respectively. Similar trend was observed in case of pooled means.

4.3.2.4 Dry matter accumulation in cob (g/cob)

Dry matter accumulation in cob was influenced significantly due to sowing dates and planting geometry in both the years and in pooled analysis (Table 27).

Sowing dates

During 2013, among the five sowing dates tried June I FN and June II FN sown crop recorded significantly higher DMA in cob at silking (30.0 and 29.8 g) and 203.1 g and 198.9 g at physiological maturity stage, respectively. Similarly, during 2014, the highest DMA in cob (29.8 and 211.2 g) at silking and physiological maturity stages, respectively. However, it was on par with June I FN (29.0 and 202.2 g) and June II FN sown crop (29.1 and 201.8 g). Similar trend was observed in pooled analysis. The lowest DMA in cob was recorded with August I FN sown crop in both the years at both stages.

Planting geometry

During both the years as well in pooled analysis, 75 x 20 cm recorded significantly higher DMA in cob during 2013 (32.8 and 222.4 g) and 2014 (29.56 and 218.22 g) at silking and physiological maturity stage, respectively. However, the lowest DMA in cob was recorded in 45 x 20 cm. Similar trend was observed in pooled analysis.

Interaction

Interaction effects revealed that the combination of June II FN sowing with wider geometry (75 x 20 cm) recorded significantly higher DMA in cob at silking and physiological maturity for both the years as well for pooled analysis. The corresponding values for 2013 and 2014 were 34.9 and 34.2 g at silking and 233.4 and 232.2 g at physiological maturity, respectively. Similar trend was observed incase of pooled analysis.

4.3.2.5 Total dry matter production (g/plant)

Total dry matter production per plant was influenced significantly by sowing dates and planting geometry in both the years and pooled analysis (Table 28 and Plate 4).

Sowing dates

During 2014 June I FN, June II FN and July I FN sowing recorded significantly higher TDM per plant during both the years and pooled analysis at all the phenological stages. However during 2013, June I FN sowing recorded significantly the highest TDM at sixth leaf (7.3 g), tasseling (113.4 g), silking (152.5 g) and physiological maturity (317.7 g). While, in 2014, July I FN sowing (D_3) recorded higher TDM (g/plant) at sixth leaf (5.3), tasseling (107.4 g), silking (143.9 g) and physiological maturity (325.5 g).

Table 28: Total Dry matter accumulation (DMA) per plant (g) as influenced by different growing environments and planting geometry

Treatments	Total dry matter per plant (g)											
	Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)												
D_1: June I fortnight	7.3a	5.0a	6.2a	113.4a	103.6a	108.5a	152.4a	136.8a	144.6a	317.7a	315.5ab	316.6a
D_2: June II fortnight	6.9a	4.9a	5.9a	102.6a	96.3ab	99.4a	139.8ab	128.7ab	134.2a	303.4ab	306.9ab	305.1a
D_3: July I fortnight	6.1b	5.3a	5.7a	95.5b	107.4a	101.5a	126.7bc	149.5a	138.1a	282.7bc	325.5a	304.1a
D_4: July II fortnight	5.5c	4.8ab	5.2b	88.2b	92.9bc	90.5b	118.3c	123.8bc	121.1b	254.7c	287.7b	271.2b
D_5:August I fortnight	4.8d	4.3b	4.5c	73.4c	87.2c	80.3c	98.7d	115.8c	107.2c	219.4d	253.1c	236.3c
Planting geometry (S)												
S_1 – 45 cm x 20 cm	5.5c	4.5c	5.0c	85.2c	88.6c	86.9c	117.0c	119.5c	118.3c	250.1c	265.3c	257.7c
S_2 – 60 cm x 20 cm	6.1b	4.8b	5.5b	94.2b	97.1b	95.6b	126.7b	130.5b	128.6b	275.0b	293.6b	284.3b
S_3 – 75 cm x 20 cm	6.7a	5.3a	6.0a	104.5a	106.8a	105.6a	137.8a	142.8a	140.3a	301.6a	334.4a	318.0a
Interaction (D x S)												
D_1S_1	7.0bd	4.6eg	5.8bd	108.0ad	97.4be	102.7bc	147.6a	128.4bc	138.0bc	308.1bd	291.0df	299.5b
D_1S_2	7.2ac	4.8df	6.0bc	110.5ac	98.5be	104.5ab	150.7a	132.2bd	141.4ac	313.8ac	295.8ce	304.8b
D_1S_3	7.8a	5.6a	6.7a	121.6a	114.8a	118.2a	158.8a	149.9ab	154.3a	331.3ab	359.7af	345.5a
D_2S_1	6.5ce	4.6eg	5.5cd	91.6de	87.3eg	89.5cd	133.7b	115.1dg	124.4de	270.9ef	265.5dg	268.2c
D_2S_2	6.6ce	4.9ce	5.8bd	99.2bc	96.0ce	97.6bd	133.0b	129.0be	131.0ce	293.5ce	308.0bd	300.8b
D_2S_3	7.5ab	5.1ae	6.3ab	117.0ab	105.5ac	111.3ab	152.6a	142.0ac	147.3ab	345.6a	347.3ab	346.4a
D_3S_1	5.6fg	5.0be	5.3de	87.4ef	98.2be	92.8cd	116.7c	136.6bd	126.6de	258.6f	285.4df	272.0cd
D_3S_2	6.2ef	5.3ad	5.7bd	96.7ce	108.9ab	102.8bd	128.5bc	151.7ab	140.1bd	286.4df	332.0ac	309.2b
D_3S_3	6.5ce	5.5ac	6.0bc	102.5ce	115.3a	108.9ab	134.8b	160.4a	147.6ac	303.2ce	359.1a	331.1ab
D_4S_1	4.5ij	4.1g	4.3g	69.4g	72.8h	71.1e	93.2d	97.1h	95.1f	204.7g	230.7g	217.7e
D_4S_2	5.5gh	4.9ce	5.2de	91.6ef	97.2df	94.4d	123.1c	129.5cf	126.3e	263.8f	287.5df	275.6c
D_4S_3	6.4de	5.5ab	6.0bc	103.6ce	108.7bd	106.1bd	138.7b	144.9ac	141.8cd	295.5cf	345.0ab	320.3b
D_5S_1	4.2j	4.0g	4.1g	69.5g	87.2gh	78.4e	93.7d	120.5eh	107.1f	208.3g	253.8eg	231.0e
D_5S_2	4.9hi	4.3fg	4.6fg	73.1g	84.6gh	78.9e	98.3d	110.0gh	104.1f	217.6g	244.7fg	231.2e
D_5S_3	5.2gh	4.6eg	4.9ef	77.6fg	89.7fg	83.7e	104.0d	117.0fh	110.5f	232.2g	261.0eg	246.6de

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

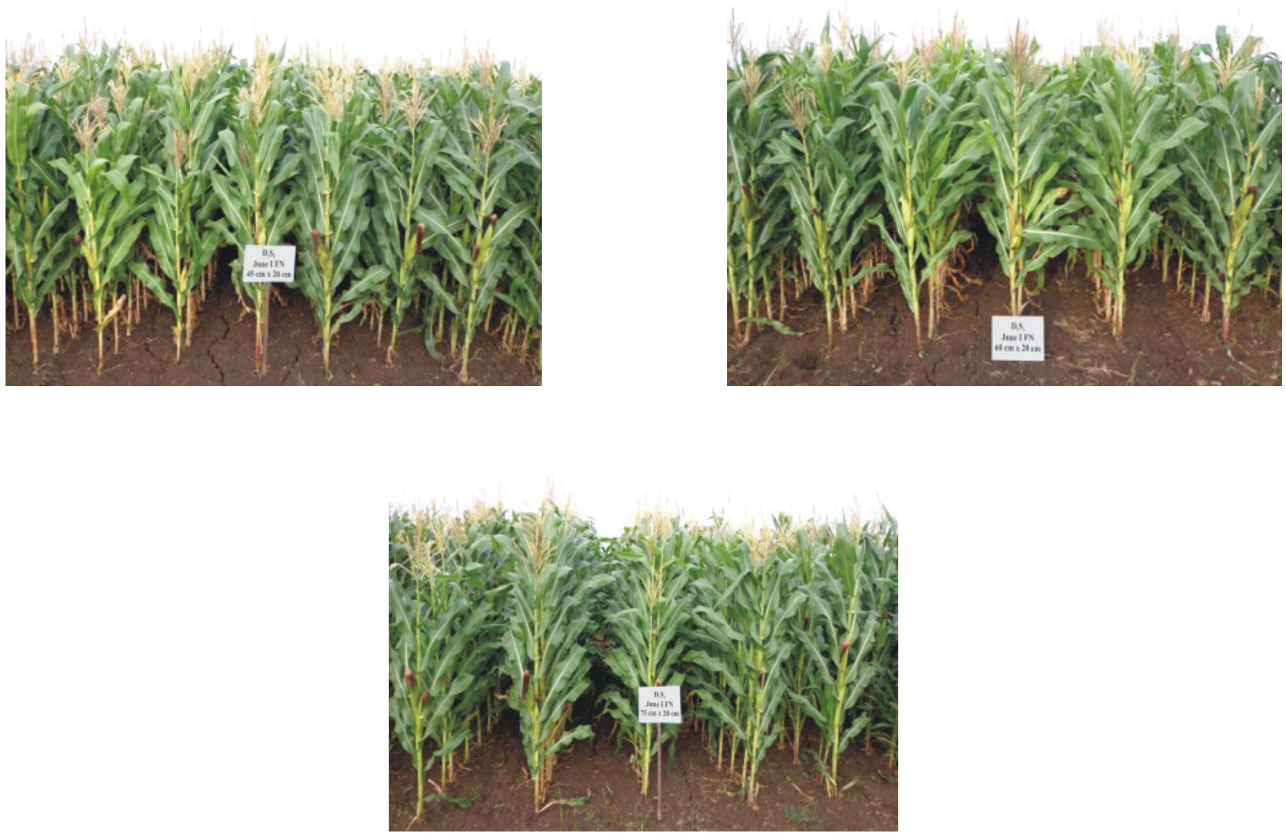


Plate 4. Maize plant stand under different planting geometries

Planting geometry

Among the three planting geometries tried, 75 x 20 cm registered significantly higher TDM (g/plant) in both the years at all the phenological stages. It recorded 6.7 g, 100.1 g, 132.9 g and 296 g during 2013 and 5.3, 103.4, 132.9 and 334.4 g per plant during 2014 at V_6, tassel, silking and physiological maturity, respectively. Pooled mean also followed the same trend.

Interaction

Early sowing during June I FN with 75 x 20 cm gave significantly the higher TDM at all the phenological stages during both the years, except at seedling stage during 2014. This combination (D_1 x S_3) during 2013, recorded 7.80, 121.6, 158.8 g and 331.3 g at V_6, tassel, silking and physiological maturity stages and during 2014, 5.60, 114.8, 359.7 g at V_6, tassel and physiological maturity. However, pooled data clearly indicated the superiority of the D_1 x S_3 treatment combination over other treatment combinations. It recorded 6.7, 118.2, 154.3 and 345.5 g at V_6, tassel, silking and physiological maturity, respectively.

4.3.3 Yield components

4.3.3.1 Cob length (cm)

Cob length was also influenced significantly due to sowing dates and planting geometry (Table 29 and Plate 5).

Sowing dates

Significantly superior cob length was recorded in early sown maize crop during 2013 (June I FN and June II FN) and in 2014 (June I FN, June II FN and July I FN). Similar trend was observed in pooled analysis.

Planting geometry

During both the years as well as pooled analysis indicated the superiority of widely spaced (75 x 20 cm) maize crop with respect to cob length. Higher cob length of 19.5 and 20.1 cm were recorded during 2013 and 2014 respectively. Pooled analysis also 75 x 20 cm recorded significantly higher cob length (19.8 cm) over other spacings.

Table 29: Yield attributes as influenced by different growing environments and planting geometry

Treatment	Cob weight (g)			Grain weight per cob (g)			Cob length (cm)			No. of kernel rows cob^{-1}		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)												
D_1: June I fortnight	223.6a	191.8ab	**207.7a**	189.4a	162.0ab	**175.7a**	20.4a	19.1a	**19.8a**	15.3a	15.2a	**15.3a**
D_2: June II fortnight	217.0a	196.7a	**206.8a**	183.8a	162.9ab	**173.3a**	19.5ab	19.3a	**19.4a**	15.2a	15.1a	**15.1ab**
D_3: July I fortnight	192.7b	215.2a	**203.9a**	166.1b	174.3a	**170.2a**	18.3b	20.1a	**19.2a**	15.0a	15.1a	**15.0ab**
D_4: July II fortnight	177.4bc	168.8bc	**173.1b**	152.9bc	143.7bc	**148.3b**	15.3c	16.2b	**15.7b**	14.9a	14.5ab	**14.7bc**
D_5: August I fortnight	158.7c	155.6c	**157.2c**	137.2c	134.1c	**135.6b**	14.0c	16.2b	**15.1b**	14.4a	14.1b	**14.2c**
Planting geometry (S)												
S_1:45 cm x 20 cm	177.3b	145.1c	**161.2c**	145.4b	118.9c	**132.2c**	15.3c	16.2c	**15.8c**	15.2a	15.3a	**15.2a**
S_2:60 cm x 20 cm	198.7a	181.3b	**190.0b**	171.1a	151.6b	**161.4b**	17.7b	18.2b	**18.0b**	14.8a	14.8a	**14.8b**
S_3:75 cm x 20 cm	205.6a	230.4a	**218.0a**	181.2a	195.6a	**188.4a**	19.5a	20.1a	**19.8a**	14.9a	14.3b	**14.6b**
Date of sowing (D) x Planting geometry (S)												
D_1S_1	214.7ab	160.7e-g	**187.7c-f**	176.0a-e	125.3f-h	**150.7e-g**	17.1ef	17.8cd	**17.5e-g**	15.5a	15.6ab	**15.5a-b**
D_1S_2	224.7ab	176.7d-f	**200.7b-e**	191.0ab	144.0d-f	**167.5c-e**	20.7bc	18.8cd	**19.8cd**	14.9a-c	15.2a-c	**15.1a-d**
D_1S_3	231.3a	238.0ab	**234.7a**	201.3a	216.7a	**209.0a**	23.3a	20.8ab	**22.0a**	15.6a	14.8a-d	**15.2a-c**
D_2S_1	209.9ac	161.3e-g	**185.6d-g**	172.1a-f	134.7e-g	**153.4e-g**	17.7d-f	17.6c-e	**17.6e-g**	15.5a	15.9a	**15.7a**
D_2S_2	219.1ab	201.3cd	**210.2ad**	186.2a-c	165.3cd	**175.8b-d**	18.9c-e	18.7cd	**18.8de**	14.8a-c	15.1a-c	**14.9a-e**
D_2S_3	221.9ab	227.3ac	**224.6ab**	193.1ab	188.7bc	**190.9ab**	21.8ab	21.6a	**21.7ab**	15.2ab	14.4bd	**14.8a-e**
D_3S_1	174.9cd	160.6e-g	**167.8f-h**	143.4f-g	128.5fg	**136.0g**	16.1fg	17.5c-e	**16.8f-h**	15.1ab	15.3a-c	**15.2a-c**
D_3S_2	196.3a-d	224.3bc	**210.3ad**	170.8a-f	185.6bc	**178.2bd**	19.3cd	20.8ab	**20.0b-d**	15.2ab	15.2a-c	**15.2a-c**
D_3S_3	207.0a-c	260.5a	**233.8a**	184.3a-d	208.8ab	**196.5ab**	19.7cd	22.1a	**20.9a-c**	14.7a-c	14.7a-d	**14.7b-f**
D_4S_1	163.1d	126.3gh	**144.7h**	133.8g	99.4h	**116.6h**	12.9hi	13.7g	**13.3j**	15.0ab	15.1a-c	**15.0a-e**
D_4S_2	178.9cd	143.8fh	**161.4gh**	155.6d-g	129.4fg	**142.5fg**	14.9gh	15.7ef	**15.3hi**	14.9a-c	14.7a-d	**14.8de**
D_4S_3	190.1b-d	236.2ab	**213.2a-c**	169.2b-f	202.4ab	**185.8bc**	18.1df	19.1bc	**18.6d-f**	14.9a-c	13.7d	**14.3d-f**
D_5S_1	123.9e	116.4h	**120.2i**	101.6h	106.7gh	**104.2h**	12.6i	14.6fg	**13.6ij**	14.8a-c	14.4bd	**14.6c-f**
D_5S_2	174.7cd	160.4e-g	**167.6f-h**	152.0e-g	133.8e-g	**142.9fg**	14.8gh	17.1d-e	**16.0gh**	14.3bc	14.1c-d	**14.2ef**
D_5S_3	177.7cd	189.9de	**183.8e-g**	158.1c-g	161.6c-e	**159.9d-f**	14.6gh	16.9d-e	**15.8gh**	14.0c	13.7d	**13.9f**

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

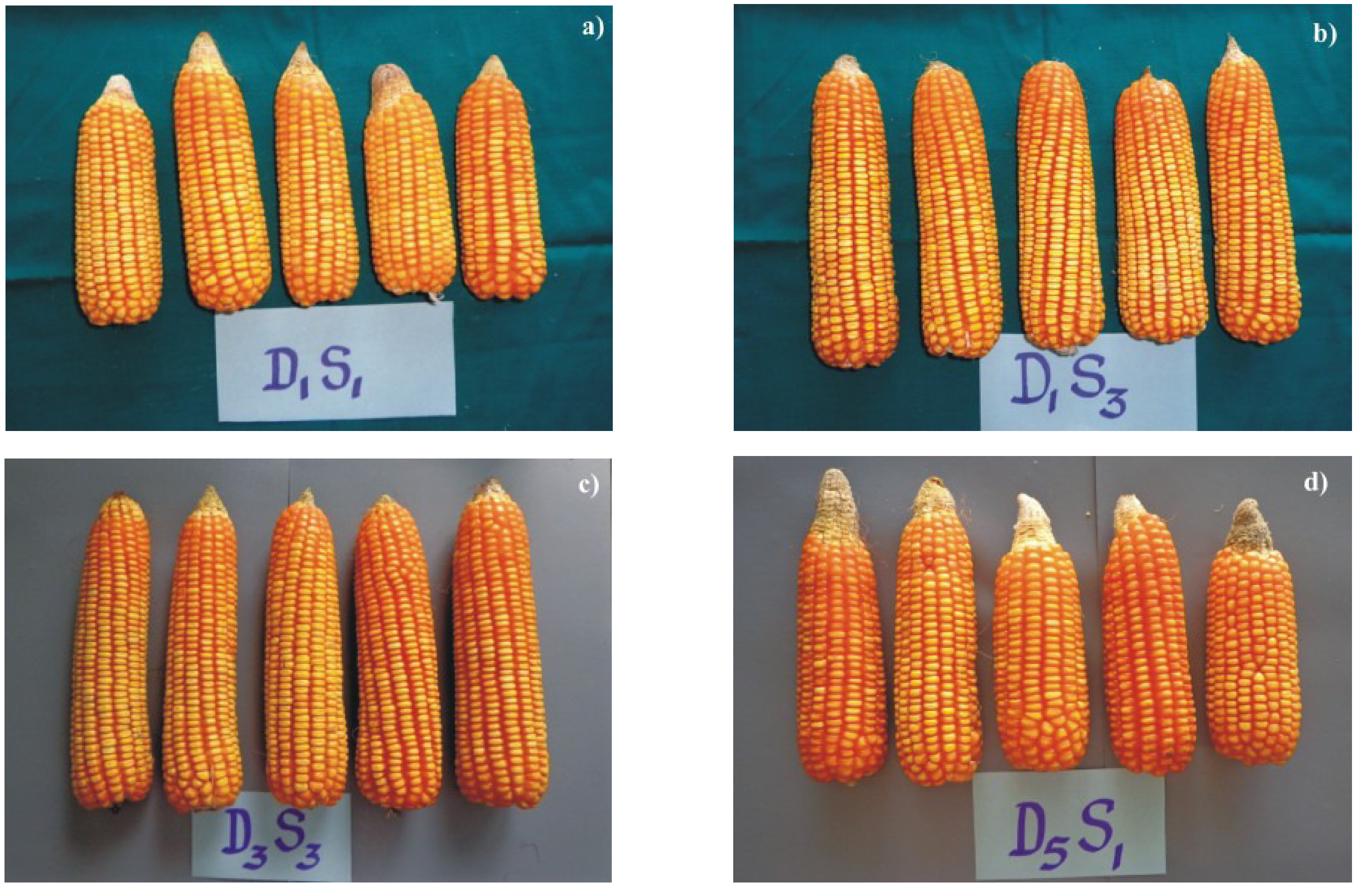


Plate 5. Cob length as influenced by different sowing dates and planting geometries during 2013 (a,b) and 2014 (c.d)

Interactions

Pooled analysis indicate that combination of D_1 (June I FN) with 75 x 20 cm spacing gave significantly superior cob length (22.0 g) over other treatment combinations. However, the shortest cob length (13.6 cm) was noticed in case of August I FN sown maize with narrow spacing (45 x 20 cm).

4.3.3.2 Cob weight (g)

Cob weight was significantly differed due to sowing dates and planting geometry (Table 29).

Sowing dates

Delayed sowings decreased the cob weight during both the years. Significantly higher cob weight per cob during 2013 (223.6 g) and 2014 (215.2 g) were recorded with June I FN and July I FN sowings, respectively. Pooled analysis indicated that June I FN sowing had significantly heavier cobs (207.7 g). But, it was on par with June II FN (206.8 g) and July I FN (203.9 g) sowings. The lowest cob weight (157.2 g) was recorded in August I FN sowing.

Planting geometry

Significantly higher cob weight of 205.6 and 230.4 g was recorded with wider spacing of 75 x 20 cm during 2013 and 2014, respectively. Similar results were found with pooled analysis.

Interactions

Combination of June I FN (D_1) with wider spacing (75 x 20 cm) gave significantly heavier cob weight during 2013 (231.3 g) and in 2014, July I FN sown crop with wider spacing gave superior cob weight (260.5 g). However, pooled analysis clearly indicate that wider spacing of 75 x 20 cm either in June I FN or July I FN gave superior cob weight over other treatment combinations.

4.3.3.3 Number of kernel rows per cob

Sowing dates failed to influence the number of kernels rows per cob significantly during 2013, but had significant effect during 2014 and also in pooled analysis (Table 29).

Sowing dates

Delay in sowing decreased the number of kernel rows per cob during 2014 crop season, as more kernel rows per cob were recorded in June I FN sown crop (15.20). Pooled analysis also revealed significant effect of sowing date on number of kernel rows per cob.

Planting geometry

Interestingly, more number of kernel rows per cob were recorded in case of narrow (45 x 20 cm) spaced maize crop during both the years (15.2 and 15.3 in 2013 and 2014, respectively). However, in 2014 crop season widest row spacing of 75 cm x 20 cm has significantly lesser kernel rows per cob than other two row spacings. Pooled analysis showed that the narrowest row spacing was significantly superior to other two spacing for number of kernel rows per cob.

Interactions

Interaction effects during both the years as well as in pooled analysis showed no definite trend. However, combination of early sown maize with narrow spacing (45 x 20 cm) had the higher number of kernel rows per cob (15.7 with June II FN), whereas lowest number of kernel rows per cob (13.9) were obtained in August I FN (D_5) with 75 cm x 20 cm (S_3).

4.3.3.4 Grain weight per cob (g)

Sowing dates and planting geometry had significant influence on grain weight per cob. Also, the interaction effects were found significant (Table 29)

Sowing dates

Decrease in grain weight per cob with delay in sowing was observed in both the years, as well as in pooled analysis. The pooled analysis indicated that significantly higher grain weight per cob (175.7 g) was recorded in June I FN sown maize, which was at par with June II FN (173.3 g) and July I FN (170.2 g) sowings. The lowest grain weight per cob was recorded in case of August I FN sowing (135.6 g).

Planting geometry

Among the three planting geometries tried, wider spacing of 75 x 20 cm resulted in significantly higher grain weight per cob both during 2013 (181.2 g) and 2014 (195.6 g). Least grain weight per cob (132.2 g) was recorded with 45 x 20 cm spacing. Similar trend was observed in case of pooled analysis.

Interactions

Combination of June I FN with wider spacing of 75 x 20 cm resulted in significantly superior grain weight per cob during both the years as well as in pooled analysis (188.4 g).

4.3.3.5 Hundred grain weight (g)

The hundred grain weight was influenced significantly due to sowing dates and planting geometry and also by their combination (Table 30).

Sowing dates

Early sowings during June I FN to July I FN had higher hundred grain weight (31.3 to 33.3 g during 2013 and 32.2 to 33.0 g during 2014). The most delayed sowing resulted in lowest hundred grain weight in August I FN (29.3 and 29.4 g during 2013 and 2014 respectively). Similar trend was observed in case of pooled analysis.

Planting geometry

Wider spacing of 75 x 20 cm sown produced significantly higher 100-grain weight (34.1 and 35.0 g) during both the years (2013 and 2014, respectively). Pooled analysis also followed the same trend.

Interactions

Pooled analysis indicates that combination of either June I FN (D_1), June II FN (D_2) and July I FN (D_3) with wider spacing (75 x 20 cm) had significantly higher

Table 30: Yield and Yield attributes as influenced by different growing environments and planting geometry

Treatment	Grain yield (kg ha^{-1})			Stover yield (q ha^{-1})			Harvest index			100 seed weight (g)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)												
D_1: June I fortnight	8055a	8110a	**8082a**	100.3a	112.8a	**106.6a**	0.45a	0.42a	**0.43a**	33.3a	32.2a	**32.7a**
D_2: June II fortnight	7254b	8177a	**7716ab**	99.4a	112.3a	**105.8a**	0.43ab	0.42a	**0.42a**	32.8ab	32.4a	**32.6a**
D_3: July I fortnight	6575c	8224a	**7400b**	95.6a	112.7a	**104.2a**	0.41bc	0.42a	**0.42a**	31.3ac	33.0a	**32.1ab**
D_4: July II fortnight	5107d	6678b	**5892c**	77.0b	97.8b	**87.4b**	0.40cd	0.41a	**0.40ab**	30.4bc	30.7ab	**30.6bc**
D_5 :August I fortnight	4662d	5408c	**5035d**	76.7b	96.2b	**86.5b**	0.38d	0.36b	**0.37b**	29.3c	29.4b	**29.3c**
Planting geometry (S)												
S_1:45 cm x 20 cm	6992a	8065a	**7529a**	101.0a	123.2a	**112.1a**	0.41a	0.39b	**0.40b**	29.2c	28.0c	**28.6c**
S_2:60 cm x 20 cm	6475b	7344b	**6909b**	93.0b	107.6b	**100.3b**	0.41a	0.40ab	**0.41ab**	31.1b	31.5b	**31.3b**
S_3:75 cm x 20 cm	5525c	6549c	**6037c**	75.4c	88.2c	**81.8c**	0.42a	0.42a	**0.42a**	34.1a	35.0a	**34.6a**
Date of sowing (D) x Planting geometry (S)												
D_1S_1	8420a	8502a-c	**8461a**	112.0a	126.7ab	**119.3ab**	0.43ac	0.40ad	**0.42bc**	32.4ac	28.3fg	**30.4de**
D_1S_2	8156ab	8480a-c	**8318a**	107.0a	123.1a-c	**115.1ab**	0.43ac	0.41ac	**0.42bc**	32.9ac	32.3bd	**32.6b-d**
D_1S_3	7589bc	7348cd	**7468cd**	82.0ce	88.5fg	**85.3fg**	0.48a	0.45a	**0.47a**	34.6ab	36.0a	**35.3ab**
D_2S_1	7690bc	8784a	**8237ab**	111.9a	131.0a	**121.5a**	0.41bc	0.40ad	**0.40cd**	31.6ac	28.9eg	**30.3de**
D_2S_2	7520bc	8490a-c	**8005a-c**	109.5a	113.1bd	**111.3bc**	0.41bc	0.43ab	**0.42bc**	31.7ac	32.3bd	**32.0cd**
D_2S_3	6552de	7258d	**6905de**	76.7cf	92.7e-g	**84.7fg**	0.46ab	0.44ab	**0.45ab**	35.2a	36.0a	**35.6a**
D_3S_1	7146cd	8740a	**7943a-c**	107.0a	124.7ab	**115.8ab**	0.40c	0.41ac	**0.41cd**	28.1de	29.3dg	**28.7eg**
D_3S_2	6740de	8493a-c	**7617bc**	99.9ab	111.3bd	**105.6cd**	0.40c	0.43ab	**0.42bc**	31.3bd	33.2ac	**32.3cd**
D_3S_3	5838fg	7439b-d	**6639e**	80.0ce	102.0df	**91.0ef**	0.42bc	0.42ac	**0.42bc**	34.5ab	36.4a	**35.4ab**
D_4S_1	6235ef	8608ab	**7421cd**	85.9cd	125.3ab	**105.6cd**	0.42bc	0.41ac	**0.41cd**	26.8e	27.3fg	**27.1fg**
D_4S_2	5175hi	5716e	**5446fg**	79.2cf	91.0fg	**85.1fg**	0.40c	0.39ad	**0.39c-e**	30.1ce	30.0cf	**30.0de**
D_4S_3	3912j	5708e	**4810gh**	65.9f	77.0g	**71.4h**	0.37cd	0.42ac	**0.40cd**	34.3ab	34.9ab	**34.6a-c**
D_5S_1	5472gh	5692e	**5582f**	88.3bc	108.1ce	**98.2de**	0.38cd	0.34d	**0.36e**	26.8e	26.3g	**26.6g**
D_5S_2	4782i	5539e	**5161fg**	69.3ef	99.5df	**84.4fg**	0.41bc	0.36cd	**0.38de**	29.3ce	29.9cf	**29.6d-f**
D_5S_3	3732j	4993e	**4363h**	72.7df	80.9g	**76.8gh**	0.34d	0.38bd	**0.36e**	31.8ac	32.0be	**31.9cd**

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

hundred grain weight (35.3 g, 35.6 g and 35.4 g, respectively) over other treatment combinations.

4.3.4 Yield

4.3.4.1 Grain yield (kg ha^{-1})

Grain yield of maize differed significantly due to sowing dates and planting geometry. Interaction effects were also found significant as presented in Table 30.

Sowing dates

Among the five sowing dates, June I FN (D_1) sown maize registered significantly higher grain yield (8055 kg ha^{-1}) over other sowing dates (7254 to 4662 kg ha^{-1}) in 2013 crop season. Whereas during 2014, July I FN (D_3) sown crop had the highest grain yield (8224 kg ha^{-1}) which was at par with June II FN (8177 kg ha^{-1}) and June I FN sowing (8110 kg ha^{-1}). Pooled analysis suggest the superiority of June I FN sown maize (8082 kg ha^{-1}) which was at par with June II FN sowing (7716 kg ha^{-1}) but significantly superior over remaining these sowing dates in July and August months. The lowest grain yield (5035 kg ha^{-1}) was recorded in August I FN sown maize.

Planting geometry

Among the three planting geometries, 45 x 20 cm (S_1) recorded significantly higher grain yield both during 2013 and 2014 (6992 and 8065 kg ha^{-1}, respectively) than other two planting geometries. The lowest grain yield of 5525 and 6549 kg ha^{-1}, were obtained in 2013 and 2014, respectively with 75 x 20 cm planting geometry. Pooled analysis followed the similar trend.

Interactions

The pooled analysis of interaction effect of sowing dates and planting geometry showed that sowing in June I FN (D_1) either with 45 x 20 cm or 60 x 20 cm geometry resulted in significantly higher grain yield (8461 and 8318 kg ha^{-1}, respectively) over other treatment combinations (4363 to 8237 kg ha^{-1}). While, the lowest grain yield (4363 kg ha^{-1}) was registered with August I FN sown maize with 75 x 20 cm (S_3) spacing.

4.3.4.2 Stover yield (q ha^{-1})

Straw yield of maize also differed significantly due to different sowing dates, planting geometry and the interactions (Table 30).

Sowing dates (D)

Among the five sowing dates tried, June I FN (D_1) sown crop recorded significantly higher straw yield (100.3 and 112.8 q/ha) over other sowing dates during 2013 and 2014, respectively. Pooled data also indicate the superiority of June I FN (106.6 q/ha) over other sowing dates. But, it was on par with June II FN (D_2) and July I FN (D_3) sown crop (99.4 and 95.6 q per ha in 2013 and 112.3 and 112.7 q per ha in 2014). Similar trend was observed in case of pooled analysis.

Planting geometry

Narrower spacing of 45 x 20 cm recorded significantly higher straw yield over other planting geometries during I and II year (101 and 123.2 q/ha, respectively). Similar trend was observed in their pooled data.

Interactions

Among the various treatment combinations tried, June I/II FN with 45 x 20 recorded higher straw yield (119.3 and 121.5 q ha^{-1}) over other treatment combinations in pooled analysis.

4.3.4.3 Harvest index

Harvest index differed significantly for different sowing dates. But, it was not influenced significantly due to planting geometry and interaction effect (Table 30).

Sowing dates (D)

During both the years (2013 and 2014) June I FN sown maize recorded significantly higher harvest index (0.45 and 0.42, respectively) over August I FN sown crop (0.38 and 0.36). However, the harvest indices obtained with June II FN and July I FN sown crop were closer. Pooled analysis also suggests the same trend.

Planting geometry

Harvest indices ranged from 0.41 to 0.42 during 2013 and 0.39 to 0.42 during 2014. In pooled mean it ranged between 0.40 to 0.42. Higher harvest index values were comparatively higher with 75 x 20 cm spacing during both the years and in pooled mean.

Interactions

The interactions effects revealed no larger differences in HI over various treatment combinations.

4.4 Microclimatic variations in maize under different growing environment and planting geometry

4.4.1 Morning and afternoon temperature and relative humidity profiles

To illustrate the micro environment of maize crop, (diurnal) observations on temperature, relative humidity and wind speed within maize canopy at five important crop growth stages *viz*., seedling (V_1), sixth leaf stage (V_6), tasseling, silking and physiological maturity during morning and afternoon were made and results are given as follows (Table 31 to 38)

4.4.1.1 Temperature (^{0}C)

Temperature profiles inside the crop were different from that at top of canopy. Microclimate of maize is largely influenced by temperature within canopy. Therefore, phenophase-wise temperature profiles at three different heights (top, middle and bottom) were studied in both the crop seasons (Table 31 to 34).

Almost similar kind of temperature profile were observed during morning (0700 hrs) in both the years. However, variations were quite visible when compared over different phenophases. Temperature profile during seedling emergence and early vegetative stage were different from the reproductive stage and at maturity. Temperature profiles were lapse *i.e.* decrease with crop height during seedling establishment phase extending first two growth stages (seedling and sixth leaf stages).

Table 31: Canopy temperature profile at 0700 hrs as influenced by different growing environments and planting geometry during 2013

Treatments	Canopy temperature profile														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
Date of sowing (D)															
D_1: June I fortnight	21.6	21.8	21.8	21.0	21.7	21.6	21.0	21.2	20.6	20.0	20.2	19.6	22.1	22.4	21.9
D_2: June II fortnight	22.0	22.3	22.3	20.6	21.2	21.1	20.8	21.0	20.5	21.1	21.3	20.7	22.1	22.4	21.9
D_3: July I fortnight	21.0	21.2	21.2	20.5	21.1	21.0	21.4	21.6	21.1	22.4	22.6	22.0	22.8	23.0	22.6
D_4: July II fortnight	21.0	21.2	21.2	19.6	20.2	20.1	20.2	20.4	19.9	20.3	20.5	20.0	20.8	21.0	20.6
D_5:August I fortnight	21.0	21.2	21.2	19.3	19.9	19.9	22.0	22.3	21.6	19.8	20.0	19.4	20.6	20.8	20.4
Planting geometry (S)															
S_1 – 45 cm x 20 cm	21.1	21.4	21.4	20.0	20.6	20.5	20.9	21.1	20.4	20.5	20.7	20.1	20.2	20.4	20.0
S_2 – 60 cm x 20 cm	21.3	21.6	21.6	20.2	20.8	20.7	21.1	21.3	20.7	20.7	20.9	20.3	21.8	22.0	21.6
S_3 – 75 cm x 20 cm	21.5	21.7	21.7	20.4	21.0	21.0	21.3	21.5	21.0	20.9	21.1	20.6	23.1	23.3	22.9
Interaction (D x S)															
D_1S_1	21.5	21.7	21.7	21.0	21.6	21.5	20.8	21.0	20.4	19.8	20.0	19.4	20.8	21.0	20.6
D_1S_2	21.7	21.9	21.9	21.0	21.7	21.6	21.0	21.2	20.6	20.0	20.2	19.6	22.3	22.5	22.1
D_1S_3	21.7	21.9	21.9	21.1	21.8	21.8	21.1	21.3	20.8	20.1	20.3	19.8	23.4	23.6	23.1
D_2S_1	21.9	22.1	22.1	20.4	21.0	20.9	20.6	20.8	20.2	20.8	21.0	20.4	20.6	20.8	20.4
D_2S_2	22.1	22.3	22.3	20.7	21.3	21.2	20.9	21.1	20.5	21.0	21.2	20.6	22.2	22.4	22.0
D_2S_3	22.2	22.4	22.4	20.7	21.3	21.3	21.0	21.2	20.8	21.6	21.8	21.2	23.7	23.9	23.4
D_3S_1	20.8	21.0	21.0	20.2	20.8	20.7	21.2	21.4	20.8	22.2	22.4	21.7	21.6	21.8	21.4
D_3S_2	21.0	21.2	21.2	20.5	21.1	21.0	21.4	21.6	21.0	22.4	22.6	21.9	22.9	23.1	22.6
D_3S_3	21.1	21.3	21.3	20.8	21.4	21.4	21.6	21.8	21.5	22.6	22.8	22.2	24.0	24.2	23.7
D_4S_1	20.8	21.0	21.0	19.4	20.0	19.9	20.0	20.2	19.6	20.2	20.4	19.8	18.8	19.0	18.6
D_4S_2	21.0	21.2	21.2	19.6	20.2	20.1	20.2	20.4	19.8	20.3	20.5	19.9	21.0	21.2	20.8
D_4S_3	21.3	21.5	21.5	19.7	20.3	20.3	20.4	20.6	20.3	20.5	20.7	20.2	22.6	22.8	22.3
D_5S_1	20.8	21.0	21.0	19.2	19.8	19.7	21.8	22.0	21.3	19.6	19.8	19.2	19.2	19.4	19.0
D_5S_2	21.0	21.2	21.2	19.3	19.9	19.8	22.1	22.3	21.6	19.8	20.0	19.4	20.6	20.8	20.4
D_5S_3	21.1	21.3	21.3	19.5	20.1	20.2	22.3	22.5	21.8	19.9	20.1	19.7	22.0	22.2	21.8

Table 32: Canopy temperature profile at 0700 hrs as influenced by different growing environments and planting geometry during 2014

Treatments	Canopy temperature														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
Date of sowing (D)															
D_1: June I fortnight	22.4	22.9	22.9	21.4	21.9	20.8	21.1	21.5	20.7	21.4	21.9	20.7	22.3	22.6	22.3
D_2: June II fortnight	22.1	22.5	22.5	21.3	21.7	20.6	21.7	22.2	21.3	20.4	20.8	19.8	21.1	21.3	21.1
D_3: July I fortnight	21.5	22.0	22.0	20.7	21.1	20.1	21.3	21.8	20.7	21.1	21.5	20.4	21.0	21.2	21.0
D_4: July II fortnight	20.8	21.3	21.3	21.3	21.8	20.7	21.8	22.2	21.1	21.3	21.7	20.6	21.5	21.7	21.5
D_5:August I fortnight	21.3	21.8	21.8	21.1	21.5	20.5	21.7	22.1	21.0	22.8	23.2	22.0	18.2	18.4	18.2
Planting geometry (S)															
S_1 – 45 cm x 20 cm	21.5	21.9	22.0	21.1	21.5	20.4	21.3	21.7	20.7	21.2	21.7	20.5	20.6	20.8	20.6
S_2 – 60 cm x 20 cm	21.7	22.1	22.1	21.2	21.6	20.5	21.5	22.0	21.0	21.4	21.9	20.8	20.8	21.0	20.8
S_3 – 75 cm x 20 cm	21.7	22.2	22.2	21.2	21.7	20.7	21.7	22.2	21.2	21.5	22.0	20.9	21.1	21.3	21.1
Interaction (D x S)															
D_1S_1	22.2	22.7	22.7	21.4	21.8	20.7	20.9	21.3	20.4	21.2	21.6	20.4	22.0	22.2	22.0
D_1S_2	22.4	22.9	22.9	21.5	21.9	20.8	21.1	21.5	20.6	21.5	21.9	20.8	22.2	22.4	22.2
D_1S_3	22.5	23.0	23.0	21.5	21.9	20.9	21.3	21.7	20.9	21.7	22.1	21.0	22.9	23.1	22.9
D_2S_1	21.9	22.3	22.3	21.2	21.6	20.5	21.4	21.8	20.9	20.2	20.6	19.5	20.9	21.1	20.9
D_2S_2	22.1	22.6	22.6	21.3	21.7	20.6	21.8	22.2	21.3	20.4	20.8	19.8	21.2	21.4	21.2
D_2S_3	22.1	22.6	22.6	21.4	21.8	20.8	22.1	22.5	21.8	20.7	21.1	20.0	21.2	21.4	21.2
D_3S_1	21.4	21.8	21.8	20.6	21.0	20.0	21.0	21.4	20.3	21.0	21.4	20.2	20.8	21.0	20.8
D_3S_2	21.6	22.0	22.0	20.8	21.2	20.1	21.4	21.8	20.7	21.2	21.6	20.5	21.0	21.2	21.0
D_3S_3	21.7	22.1	22.1	20.8	21.2	20.2	21.7	22.1	21.0	21.2	21.6	20.5	21.1	21.3	21.1
D_4S_1	20.8	21.2	21.2	21.2	21.6	20.5	21.8	22.2	21.1	21.3	21.7	20.5	21.2	21.4	21.2
D_4S_2	20.9	21.3	21.3	21.4	21.8	20.7	21.8	22.2	21.1	21.3	21.7	20.6	21.3	21.5	21.3
D_4S_3	20.9	21.3	21.3	21.5	21.9	20.9	21.9	22.3	21.2	21.3	21.7	20.6	21.9	22.1	21.9
D_5S_1	21.3	21.7	21.7	21.0	21.4	20.3	21.6	22.0	20.9	22.6	23.1	21.8	18.1	18.3	18.1
D_5S_2	21.4	21.8	21.8	21.1	21.5	20.4	21.8	22.2	21.1	22.8	23.3	22.1	18.3	18.5	18.3
D_5S_3	21.4	21.8	21.8	21.2	21.6	20.7	21.8	22.2	21.1	22.8	23.3	22.1	18.3	18.5	18.3

Table 33: Canopy temperature profile at 1430 hrs as influenced by different growing environments and planting geometry during 2013

Treatments	Canopy temperature														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
Date of sowing (D)															
D_1: June I fortnight	29.8	29.8	29.8	23.8	24.2	25.7	25.2	25.4	24.4	31.0	31.3	30.0	33.7	32.4	31.6
D_2: June II fortnight	28.9	28.9	29.0	25.8	26.3	27.9	30.5	30.8	29.6	29.7	30.0	28.8	30.2	29.0	28.4
D_3: July I fortnight	28.6	28.6	28.7	24.7	25.1	26.7	26.7	27.0	26.1	30.4	30.7	29.6	33.1	29.7	29.0
D_4: July II fortnight	30.0	30.0	30.1	30.2	30.7	32.6	27.3	27.6	26.7	26.0	26.3	25.5	33.1	29.8	29.5
D_5:August I fortnight	28.5	28.5	28.6	26.9	27.2	28.9	32.3	32.7	31.6	33.4	33.8	32.7	33.4	29.8	29.5
Planting geometry (S)															
S_1 – 45 cm x 20 cm	29.0	29.0	29.1	25.6	26.3	27.8	28.1	28.4	27.3	29.6	30.0	28.8	32.2	29.7	29.1
S_2 – 60 cm x 20 cm	29.2	29.2	29.3	26.4	26.7	28.3	28.5	28.8	27.7	30.0	30.3	29.1	32.6	30.0	29.4
S_3 – 75 cm x 20 cm	29.3	29.3	29.3	26.9	27.2	28.9	28.7	29.0	28.2	30.7	31.0	30.1	33.4	30.7	30.2
Interaction (D x S)															
D_1S_1	29.7	29.7	29.8	23.5	24.1	25.6	25.0	25.3	24.2	30.5	30.8	29.5	32.6	31.3	30.5
D_1S_2	29.8	29.8	29.9	24.0	24.3	25.7	25.2	25.5	24.4	30.3	30.7	29.4	33.8	32.4	31.6
D_1S_3	29.8	29.8	29.9	24.0	24.3	25.7	25.2	25.5	24.6	32.1	32.4	31.2	34.8	33.4	32.6
D_2S_1	28.7	28.7	28.8	25.6	26.3	27.9	30.0	30.3	29.0	28.7	29.0	27.8	30.2	29.0	28.3
D_2S_2	28.7	28.7	28.8	26.0	26.3	27.9	30.6	30.9	29.6	29.7	30.0	28.7	30.2	29.0	28.3
D_2S_3	29.2	29.2	29.3	26.0	26.3	27.9	31.0	31.3	30.3	30.6	30.9	30.0	30.2	29.0	28.5
D_3S_1	28.5	28.5	28.6	23.6	24.2	25.7	26.4	26.7	25.7	30.3	30.6	29.4	33.0	29.7	29.0
D_3S_2	28.6	28.6	28.7	24.2	24.5	26.0	26.7	27.0	26.0	30.2	30.5	29.3	32.8	29.5	28.8
D_3S_3	28.6	28.6	28.7	26.4	26.7	28.3	27.0	27.3	26.7	30.7	31.0	30.0	33.4	30.0	29.3
D_4S_1	29.7	29.7	29.8	29.2	30.0	31.8	27.1	27.4	26.4	25.7	26.0	25.0	32.7	29.4	29.1
D_4S_2	30.2	30.2	30.3	30.4	30.8	32.7	27.4	27.7	26.7	26.1	26.4	25.4	32.9	29.6	29.3
D_4S_3	30.2	30.2	30.3	30.9	31.3	33.2	27.5	27.8	27.0	26.2	26.5	26.0	33.7	30.3	30.1
D_5S_1	28.5	28.5	28.6	26.3	26.6	28.2	31.8	32.1	31.0	33.0	33.4	32.2	32.5	29.0	28.7
D_5S_2	28.5	28.5	28.6	27.2	27.5	29.2	32.5	32.8	31.6	33.4	33.8	32.6	33.1	29.5	29.2
D_5S_3	28.5	28.5	28.6	27.3	27.6	29.3	32.8	33.1	32.2	33.7	34.1	33.2	34.7	31.0	30.8

Table 34: Canopy temperature profile at 1430 hrs as influenced by different growing environments and planting geometry during 2014

Treatments	Canopy temperature														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
Date of sowing (D)															
D_1: June I fortnight	33.0	33.0	33.1	28.3	28.7	30.4	28.7	29.0	27.8	32.9	33.3	31.9	33.5	32.2	31.4
D_2: June II fortnight	31.0	31.0	31.1	24.8	25.1	26.6	30.8	31.1	29.8	27.8	28.1	26.9	35.3	33.9	33.1
D_3: July I fortnight	25.4	25.4	25.5	27.6	27.9	29.6	25.2	25.4	24.5	30.0	30.4	29.2	34.9	31.3	30.6
D_4: July II fortnight	27.0	27.0	27.0	31.8	32.2	34.1	25.5	25.7	24.8	33.3	33.7	32.4	35.2	31.6	31.3
D_5:August I fortnight	35.8	35.8	35.9	27.2	27.6	29.2	29.3	29.6	28.6	32.8	33.2	32.0	32.6	29.1	28.8
Planting geometry (S)															
S_1 – 45 cm x 20 cm	30.2	30.2	30.3	27.6	28.0	29.7	27.7	28.0	26.9	31.1	31.4	30.2	34.0	31.3	30.7
S_2 – 60 cm x 20 cm	30.4	30.4	30.5	27.9	28.2	30.0	27.9	28.2	27.1	31.4	31.8	30.5	34.4	31.7	31.1
S_3 – 75 cm x 20 cm	30.7	30.7	30.8	28.3	28.6	30.4	28.1	28.4	27.3	31.6	31.9	30.7	34.6	31.9	31.2
Interaction (D x S)															
D_1S_1	32.9	32.9	33.0	28.2	28.5	30.2	28.6	28.9	27.7	32.7	33.0	31.6	33.4	32.0	31.2
D_1S_2	33.0	33.0	33.1	28.3	28.7	30.4	28.8	29.1	27.9	32.7	33.0	31.6	33.9	32.5	31.7
D_1S_3	33.1	33.1	33.2	28.6	28.9	30.6	28.8	29.1	27.9	33.4	33.8	32.4	33.4	32.0	31.2
D_2S_1	31.0	31.0	31.1	24.4	24.7	26.2	30.3	30.6	29.3	27.7	28.0	26.8	34.7	33.3	32.5
D_2S_2	31.0	31.0	31.1	24.7	25.0	26.5	30.8	31.1	29.8	27.8	28.1	26.9	35.4	34.0	33.2
D_2S_3	31.0	31.0	31.1	25.2	25.5	27.0	31.4	31.7	30.4	27.9	28.2	27.0	35.9	34.4	33.5
D_3S_1	25.0	25.0	25.1	27.2	27.5	29.2	25.1	25.4	24.4	29.9	30.2	29.1	34.7	31.2	30.4
D_3S_2	25.3	25.3	25.4	27.9	28.2	29.9	25.1	25.4	24.4	30.1	30.4	29.3	34.9	31.4	30.6
D_3S_3	25.9	25.9	26.0	27.8	28.1	29.8	25.2	25.5	24.5	30.2	30.5	29.3	34.9	31.4	30.6
D_4S_1	26.5	26.5	26.6	31.3	31.7	33.6	25.4	25.7	24.7	32.7	33.0	31.8	34.9	31.4	31.0
D_4S_2	27.0	27.0	27.1	31.6	32.0	33.9	25.4	25.7	24.7	33.6	34.0	32.7	35.0	31.5	31.1
D_4S_3	27.4	27.4	27.5	32.4	32.8	34.8	25.5	25.8	24.8	33.6	34.0	32.7	35.6	32.0	31.6
D_5S_1	35.8	35.8	35.9	27.2	27.5	29.2	29.3	29.6	28.5	32.7	33.0	31.8	32.3	28.8	28.5
D_5S_2	35.8	35.8	35.9	27.1	27.4	29.1	29.3	29.6	28.5	33.0	33.3	32.1	32.6	29.1	28.8
D_5S_3	35.9	35.9	36.0	27.5	27.8	29.5	29.4	29.7	28.6	32.9	33.2	32.0	33.1	29.5	29.2

But, at tasseling, silking and physiological maturity higher temperature was noticed in the middle of the canopy height compared to top and bottom levels of the canopy. The increase was to an extent of 0.2 ^{0}C to 0.6 ^{0}C at tasseling and silking and 0.3 to 0.5 ^{0}C at physiological maturity during 2013 and 0.4 ^{0}C to 0.8 ^{0}C at tasseling, 0.5 ^{0}C to 1.2 ^{0}C at silking and 0.3 ^{0}C at physiological maturity during 2014 were observed. Similar trend was noticed in all the sowing dates during both the years.

Planting geometries also influenced the temperature profile inside the crop canopy at all the stages. Narrow spacing of 45 cm x 20 cm, showed lower canopy temperature at all the heights over 60 cm x 20 cm and 75 cm x 20 cm row spacings. Canopy temperature increased with increase in row width.

In the afternoon (1430 hrs) also, temperature profiles within crop canopy were studied at different phenophases and it was noticed that, temperature profiles were lapse during first two stages (seedling and sixth leaf stage). The decrease in temperature with increase in height was to an extent of 0.1 ^{0}C at V_1 and 1.9 ^{0}C at V_6 stage. But, the temperature profiles were quite different at tasseling, silking and physiological maturity. Temperature was more in the middle of the canopy than upper and bottom levels at reproductive stages (tasseling and silking). The decline was more at the bottom and less in the top level of canopy. Temperature in the middle of the canopy recorded 0.2 ^{0}C (at top) to 1.0 ^{0}C (at bottom) at tasseling stage and 0.3 ^{0}C (at top) to 1.3 ^{0}C (at bottom) at silking stage. But, at physiological maturity, temperature increased with increase in crop height. More temperature was recorded in the upper canopy and lowest at the bottom.

Among the planting geometries tried, narrow spaced (45 cm x 20 cm) crop recorded lowest canopy temperature. It increased with increase in row width at all the heights (top, middle and bottom) at all the phenophases during both the years.

4.4.1.2 Relative humidity (%) profiles within crop canopy

The relative humidity profiles were also measured at different phenophases during both the years in the morning as well as in the afternoon. The diurnal variations in the relative humidity profiles (Table 35 to 38).

Table 35: Canopy relative humidity profile at 0700 hrs as influenced by different growing environments and planting geometry during 2013

Treatments	Canopy relative humidity														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
Date of sowing (D)															
D_1: June I fortnight	92	92	92	93	94	94	94	95	96	88	89	90	90	91	89
D_2: June II fortnight	95	94	94	93	94	94	93	94	95	93	94	94	95	96	94
D_3: July I fortnight	94	94	94	92	93	93	94	95	96	92	93	94	78	79	77
D_4: July II fortnight	95	95	95	88	89	89	91	92	93	95	96	97	80	81	79
D_5:August I fortnight	94	94	94	95	96	96	89	90	91	94	95	95	76	77	75
Planting geometry (S)															
S_1 – 45 cm x 20 cm	95	95	95	94	94	95	94	95	96	94	95	96	86	86	85
S_2 – 60 cm x 20 cm	94	94	94	92	93	93	92	93	94	92	93	94	84	85	83
S_3 – 75 cm x 20 cm	93	93	93	91	92	92	91	92	93	91	92	93	82	83	82
Interaction (D x S)															
D_1S_1	94	94	94	94	95	95	96	97	98	89	90	91	92	93	91
D_1S_2	92	92	92	93	93	94	93	94	95	88	89	90	90	91	89
D_1S_3	91	91	91	91	92	92	93	93	94	87	88	89	88	89	87
D_2S_1	96	96	96	94	95	96	95	96	97	94	95	96	97	98	96
D_2S_2	94	94	94	93	94	94	93	93	94	93	94	95	95	96	94
D_2S_3	93	93	93	92	93	93	92	93	93	91	92	93	93	94	92
D_3S_1	95	95	95	93	93	94	95	96	97	93	94	95	79	80	78
D_3S_2	94	94	94	92	93	93	94	94	95	91	92	93	77	78	77
D_3S_3	93	93	93	91	92	92	92	93	94	91	92	93	77	78	76
D_4S_1	96	96	96	89	90	90	93	93	94	97	98	99	82	83	81
D_4S_2	94	94	94	88	89	89	90	91	92	95	96	97	80	81	80
D_4S_3	93	93	93	87	88	88	90	91	92	94	95	95	78	79	77
D_5S_1	96	95	95	97	98	98	90	91	92	95	96	97	77	78	76
D_5S_2	93	93	93	95	96	96	89	89	90	94	95	96	75	76	75
D_5S_3	92	92	92	93	94	94	88	89	90	92	93	93	75	76	74

Table 36: Canopy relative humidity profile at 0700 hrs as influenced by different growing environments and planting geometry during 2014

Treatments	Canopy relative humidity														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
Date of sowing (D)															
D_1: June I fortnight	87	87	87	85	86	86	89	90	90	88	89	89	86	87	85
D_2: June II fortnight	84	84	84	85	86	86	92	93	93	92	93	94	85	86	84
D_3: July I fortnight	89	89	89	93	94	94	91	91	93	90	91	92	76	77	75
D_4: July II fortnight	89	89	89	88	88	89	86	87	88	88	89	90	80	81	79
D_5:August I fortnight	89	88	88	89	90	90	91	92	93	80	81	82	78	79	77
Planting geometry (S)															
S_1 – 45 cm x 20 cm	88	88	88	89	90	90	91	92	93	89	90	91	82	83	82
S_2 – 60 cm x 20 cm	87	87	87	88	89	89	89	90	91	87	88	89	81	82	80
S_3 – 75 cm x 20 cm	87	87	87	87	88	88	89	90	90	87	88	88	80	81	79
Interaction (D x S)															
D_1S_1	87	87	87	85	86	86	90	91	92	88	89	90	88	89	87
D_1S_2	87	87	87	85	86	86	89	90	91	87	88	89	86	87	86
D_1S_3	87	87	87	84	85	85	88	89	89	87	88	88	84	85	83
D_2S_1	84	84	84	86	87	87	93	94	95	95	96	97	86	87	85
D_2S_2	84	84	84	85	86	86	91	92	93	91	92	93	85	86	84
D_2S_3	84	83	83	85	86	85	91	92	92	91	92	92	84	85	83
D_3S_1	89	89	89	94	95	95	92	93	94	91	92	93	78	79	77
D_3S_2	89	89	89	93	94	94	90	91	93	90	91	92	75	76	75
D_3S_3	89	89	89	92	93	93	89	90	91	89	90	91	74	75	74
D_4S_1	90	89	89	88	89	89	86	87	88	88	89	90	81	82	81
D_4S_2	88	88	88	87	88	88	86	87	88	88	89	90	80	80	79
D_4S_3	88	88	88	87	88	88	85	86	87	87	88	89	79	80	78
D_5S_1	89	89	89	90	91	91	92	93	94	81	82	83	79	80	79
D_5S_2	88	88	88	89	90	90	91	92	93	80	81	82	78	79	77
D_5S_3	88	88	88	89	90	89	91	92	92	79	80	81	77	78	77

Table 37: Canopy relative humidity profile at 1430 hrs as influenced by different growing environments and planting geometry during 2013

Treatments	Canopy relative humidity														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
Date of sowing (D)															
D_1: June I fortnight	69	69	69	88	91	92	77	79	83	59	61	64	49	51	53
D_2: June II fortnight	74	74	74	73	76	77	59	61	64	53	55	58	60	63	66
D_3: July I fortnight	75	75	75	72	75	75	71	73	77	57	59	62	59	62	65
D_4: July II fortnight	65	65	65	61	63	64	55	57	60	68	70	73	61	64	67
D_5:August I fortnight	67	67	67	72	74	75	53	54	57	52	53	56	58	61	64
Planting geometry (S)															
S_1 – 45 cm x 20 cm	71	71	71	75	77	78	64	66	69	59	60	64	58	61	64
S_2 – 60 cm x 20 cm	70	70	70	73	76	77	63	65	68	57	59	62	57	60	63
S_3 – 75 cm x 20 cm	69	69	69	72	74	75	62	64	66	57	59	61	57	60	62
Interaction (D x S)															
D_1S_1	69	69	69	88	91	92	77	80	84	59	61	65	50	52	55
D_1S_2	69	69	69	88	91	92	76	79	83	58	60	64	49	51	53
D_1S_3	69	69	69	88	91	91	76	78	82	58	60	63	48	50	52
D_2S_1	74	74	74	74	77	77	60	62	65	54	56	59	61	64	67
D_2S_2	74	74	74	73	75	76	59	61	64	53	55	58	60	62	65
D_2S_3	72	72	72	73	75	76	58	59	62	52	53	56	61	63	66
D_3S_1	75	75	75	74	77	78	72	74	78	57	59	62	59	62	65
D_3S_2	75	75	75	74	76	77	72	74	78	57	59	62	60	62	65
D_3S_3	75	75	75	69	71	72	70	72	75	56	58	61	59	62	64
D_4S_1	68	68	68	63	65	66	56	58	61	68	70	74	62	64	68
D_4S_2	64	64	64	60	62	63	56	58	61	68	70	74	61	63	66
D_4S_3	64	64	64	59	61	62	54	56	58	67	69	72	61	63	66
D_5S_1	69	69	69	73	75	76	54	56	59	53	55	58	59	62	65
D_5S_2	66	66	66	72	74	75	52	54	56	51	52	55	58	61	64
D_5S_3	65	65	65	71	73	74	51	53	55	51	53	55	58	60	62

Table 38: Canopy relative humidity profile at 1430 hrs as influenced by different growing environments and planting geometry during 2014

Treatments	Canopy relative humidity														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
Date of sowing (D)															
D_1: June I fortnight	43	43	43	61	63	64	59	60	65	56	57	62	54	56	59
D_2: June II fortnight	50	50	50	79	81	82	54	55	60	67	68	75	42	44	46
D_3: July I fortnight	82	82	82	66	68	69	78	80	87	55	56	61	34	35	37
D_4: July II fortnight	77	77	77	55	57	57	67	69	75	45	46	50	45	46	49
D_5:August I fortnight	60	60	60	72	74	75	59	60	66	45	46	50	36	37	39
Planting geometry (S)															
S_1 – 45 cm x 20 cm	63	63	63	67	69	70	65	66	72	55	57	61	43	45	47
S_2 – 60 cm x 20 cm	63	63	63	66	69	69	63	64	70	53	54	59	42	43	45
S_3 – 75 cm x 20 cm	62	62	62	66	68	69	62	63	69	52	53	58	41	43	45
Interaction (D x S)															
D_1S_1	43	43	43	62	64	64	61	62	66	58	59	64	56	58	61
D_1S_2	43	43	43	61	63	64	58	59	65	54	55	60	52	55	57
D_1S_3	43	43	43	61	63	64	57	58	64	55	56	61	53	56	58
D_2S_1	50	50	50	79	82	83	55	56	61	69	70	77	42	44	46
D_2S_2	50	50	50	79	82	82	53	54	59	66	68	74	42	43	46
D_2S_3	49	49	49	77	80	81	53	54	59	66	67	74	42	43	46
D_3S_1	82	82	82	66	68	69	79	80	87	56	57	62	34	36	38
D_3S_2	83	83	83	66	68	69	78	80	87	56	57	62	34	35	37
D_3S_3	82	82	82	65	68	68	78	79	87	54	55	60	33	34	36
D_4S_1	78	78	78	57	59	60	68	69	75	47	48	52	46	48	51
D_4S_2	77	77	77	53	55	56	67	68	75	45	45	50	44	45	48
D_4S_3	77	77	77	54	56	57	67	68	75	44	44	49	44	45	48
D_5S_1	60	60	60	72	75	75	63	64	69	47	48	52	36	38	39
D_5S_2	60	60	60	72	74	75	58	59	65	45	46	50	36	38	39
D_5S_3	60	60	60	71	73	74	56	57	63	42	43	47	36	37	39

During morning (0700 hrs), relative humidity profiles were lapse at all the phenophases (except at seedling and physiological maturity) in all the sowing dates and planting geometries. Lapse was to an extent of 1 per cent (V_6), 1 to 2 per cent (tasseling and silking) during 2013 and 1 per cent (V_6) and 1 to 2 per cent (tasseling and silking) during 2014. But, at physiological maturity higher RH was noticed in the middle of the canopy and lower at top and bottom levels.

Planting geometries also influenced the RH profiles at all the stages. Here also lapse in RH profiles were observed at all the phenophases (except at seedling stage and physiological maturity). Narrower planting geometry (45 cm x 20 cm) had considerably higher RH compared to other two wider planting geometries. The RH percentage decreased with increase in row spacing irrespective of growth stage.

In the afternoon (1430 hrs), fluctuations in RH profiles were observed at different phenophases during both the years. However, RH profile remained unchanged during the seedling stage, but differed at other stages in both the years. During both the years RH (%) decreased with height. Thus, RH profiles were always lapse at sixth leaf, tasseling, silking and physiological maturity stages in both of study. Thus, higher RH was observed at the bottom and lower at the top of the crop canopy during almost entire crop growth period.

Among the planting geometries, RH profiles varied. Irrespective of growth stage, the narrower spacing of 45 cm x 20 cm showed considerably higher RH values as compared to other planting geometries with wider spacing (60 cm x 20 cm and 75 cm x 20 cm).

4.4.1.3 Morning and afternoon variations in the mean canopy temperature and relative humidity

4.4.1.3.1 Mean canopy temperature (0700 hrs)

In 2013, mean canopy temperature decreased with delayed sowings during (seedling stage and sixth leaf stages). Later on the canopy temperature increased in crop sown till D_3 during tasseling, silking and physiological maturity, however on crop sown beyond this date the canopy temperature decreased. During 2014 also, canopy temperature decreased with delayed sowings at seedling and sixth leaf stages. It increased during tasseling and silking stage in crops sown beyond D_1. The mean canopy temperature values decreased at with delayed sowing at physiological maturity in all sowing dates except D_5 (Table 39).

The mean of two years indicate that canopy temperature decreased with delayed sowings at seedling (22 – 20.9 ^{0}C), sixth leaf (21.2 – 20.2 ^{0}C) and physiological maturity stages (22.2 – 19.4 ^{0}C), but increased with delayed sowings at tasseling (21 – 21.9 ^{0}C) and silking (20.7 – 21.7 ^{0}C) stages.

Among the three planting geometries tried higher canopy temperature was noticed in widely spaced crop (75 x 20 cm) (21.6, 20.8, 21.5, 21.2 and 22.1 ^{0}C, respectively) than narrower (45 x 20 cm) (21.3, 20.5, 21.1, 20.9 and 20.4 ^{0}C, respectively) at all the stages during both the years.

4.4.1.4.2 Mean canopy temperature

During 2013, at seedling and physiological maturity stage, lower afternoon canopy temperature was observed under delayed sowings. Delayed sowings led to increase in canopy led to increase in canopy temperature during afternoon at sixth leaf (24.2 – 30.7 ^{0}C) stage and tasseling (24.5 – 33.8 ^{0}C) stage. During 2014, it decreased upto D_4 sowings and increased in the later sowings at seedling (33 – 27 ^{0}C) and sixth leaf (28.3 – 27.2 ^{0}C) stages. But at tasseling and physiological maturity (except D_2) and later decreased with delayed sowings (29 – 25.7 ^{0}C and 32.2 – 29.1 ^{0}C, respectively). Irrespective of the phenological stages and years mean canopy temperature increased with increase in row spacing from 45 x 20 cm to 75 x 20 cm (26.9 – 27.5, 28.2 – 28.7, 29.8 – 30.4 and 31.3 – 32.0 ^{0}C, respectively) during sixth leaf, tasseling, silking and physiological maturity stages (Table 40).

4.4.1.4.3 Mean canopy relative humidity (0700 hrs)

During 2013, mean morning canopy RH increased with delayed sowings during initial two growth stages from 92 to 95 per cent. But, decreased at tasseling from 95 to 90 per cent and at physiological maturity from 90 to 76 per cent. During 2014 also,

Table 39: Mean canopy temperature (°C) in the morning (0700 hrs) at different phenophases of maize under different growing environments and planting geometry

Treatments	Mean canopy temperature (°C)														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Date of sowing (D)															
D_1 – June I FN	21.6	22.4	22.0	21.0	21.4	21.2	21.0	21.1	21.0	20.0	21.4	20.7	22.1	22.3	22.2
D_2 – June II FN	22.0	22.1	22.0	20.6	21.3	20.9	20.8	21.7	21.3	21.1	20.4	20.8	22.1	21.1	21.6
D_3 – July I FN	21.0	21.5	21.2	20.5	20.7	20.6	21.4	21.3	21.4	22.4	21.1	21.7	22.8	21.0	21.9
D_4 – July I FN	21.0	20.8	20.9	19.6	21.3	20.4	20.2	21.8	21.0	20.3	21.3	20.8	20.8	21.5	21.1
D_5 – August I FN	21.0	21.3	21.1	19.3	21.1	20.2	22.0	21.7	21.9	19.8	22.8	21.3	20.6	18.2	19.4
Planting geometry (S)															
S_1 – 45 cm x 20 cm	21.1	21.5	21.3	20.0	21.1	20.5	20.9	21.3	21.1	20.5	21.2	20.9	20.2	20.6	20.4
S_2 – 60 cm x 20 cm	21.3	21.7	21.5	20.2	21.2	20.7	21.1	21.5	21.3	20.7	21.4	21.1	21.8	20.8	21.3
S_3 – 75 cm x 20 cm	21.5	21.7	21.6	20.4	21.2	20.8	21.3	21.7	21.5	20.9	21.5	21.2	23.1	21.1	22.1
Interaction (D x S)															
D_1S_1	21.5	22.2	21.9	21.0	21.4	21.2	20.8	20.9	20.8	19.8	21.2	20.5	20.8	22.0	21.4
D_1S_2	21.7	22.4	22.1	21.0	21.5	21.3	21.0	21.1	21.0	20.0	21.5	20.7	22.3	22.2	22.2
D_1S_3	21.7	22.5	22.1	21.1	21.5	21.3	21.1	21.3	21.2	20.1	21.7	20.9	23.4	22.9	23.1
D_2S_1	21.9	21.9	21.9	20.4	21.2	20.8	20.6	21.4	21.0	20.8	20.2	20.5	20.6	20.9	20.7
D_2S_2	22.1	22.1	22.1	20.7	21.3	21.0	20.9	21.8	21.3	21.0	20.4	20.7	22.2	21.2	21.7
D_2S_3	22.2	22.1	22.2	20.7	21.4	21.0	21.0	22.1	21.5	21.6	20.7	21.1	23.7	21.2	22.4
D_3S_1	20.8	21.4	21.1	20.2	20.6	20.4	21.2	21.0	21.1	22.2	21.0	21.6	21.6	20.8	21.2
D_3S_2	21.0	21.6	21.3	20.5	20.8	20.6	21.4	21.4	21.4	22.4	21.2	21.8	22.9	21.0	21.9
D_3S_3	21.1	21.7	21.4	20.8	20.8	20.8	21.6	21.7	21.6	22.6	21.2	21.9	24.0	21.1	22.5
D_4S_1	20.8	20.8	20.8	19.4	21.2	20.3	20.0	21.8	20.9	20.2	21.3	20.7	18.8	21.2	20.0
D_4S_2	21.0	20.9	20.9	19.6	21.4	20.5	20.2	21.8	21.0	20.3	21.3	20.8	21.0	21.3	21.1
D_4S_3	21.3	20.9	21.1	19.7	21.5	20.6	20.4	21.9	21.1	20.5	21.3	20.9	22.6	21.9	22.2
D_5S_1	20.8	21.3	21.0	19.2	21.0	20.1	21.8	21.6	21.7	19.6	22.6	21.1	19.2	18.1	18.7
D_5S_2	21.0	21.4	21.2	19.3	21.1	20.2	22.1	21.8	21.9	19.8	22.8	21.3	20.6	18.3	19.5
D_5S_3	21.1	21.4	21.2	19.5	21.2	20.3	22.3	21.8	22.0	19.9	22.8	21.4	22.0	18.3	20.1

Table 40: Mean canopy temperature (^oC) in the afternoon (1430 hrs) at different phenophases of maize under different growing environments (sowing dates) and planting geometry

Treatments	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Date of sowing (D)															
D_1 – June I FN	28.1	33.0	30.6	24.2	28.3	26.3	24.5	29.0	26.8	30.4	30.7	30.6	32.2	32.2	32.2
D_2 – June II FN	29.2	31.0	30.1	24.2	24.8	24.5	30.9	31.1	31.0	25.8	28.3	27.1	33.8	33.9	33.9
D_3 – July I FN	26.2	25.4	25.8	26.5	27.6	27.0	27.1	25.4	26.3	28.7	30.4	29.5	31.7	31.3	31.5
D_4 – July I FN	27.4	27.0	27.2	26.5	31.8	29.1	27.6	25.7	26.7	26.3	33.7	30.0	31.4	31.6	31.5
D_5 – August I FN	27.8	35.8	31.8	30.7	27.2	29.0	33.8	29.6	31.7	32.8	34.1	33.4	29.1	29.1	29.1
Planting geometry (S)															
S_1 – 45 cm x 20 cm	27.9	30.2	29.1	26.1	27.6	26.9	28.4	28.0	28.2	28.5	31.1	29.8	31.2	31.3	31.3
S_2 – 60 cm x 20 cm	27.7	30.4	29.1	26.5	27.9	27.2	28.9	28.2	28.5	28.8	31.5	30.1	31.5	31.7	31.6
S_3 – 75 cm x 20 cm	27.6	30.7	29.1	26.7	28.3	27.5	29.1	28.4	28.7	29.1	31.7	30.4	32.2	31.9	32.0
Interaction															
D_1S_1	28.2	32.9	30.5	24.2	28.2	26.2	24.3	28.9	26.6	30.2	30.5	30.4	32	32.0	32.0
D_1S_2	28.1	33.0	30.6	24.2	28.3	26.3	24.6	29.1	26.9	30.4	30.8	30.6	32	32.5	32.3
D_1S_3	28.1	33.1	30.6	24.3	28.6	26.4	24.6	29.1	26.9	30.6	30.8	30.7	32.5	32.0	32.3
D_2S_1	29.4	31.0	30.2	24.0	24.4	24.2	30.3	30.6	30.5	25.7	28.0	26.9	33.5	33.3	33.4
D_2S_2	29.2	31.0	30.1	24.2	24.7	24.5	30.9	31.1	31.0	25.8	28.2	27.0	33.5	34.0	33.8
D_2S_3	29.0	31.1	30.1	24.5	25.2	24.8	31.4	31.7	31.6	26	28.8	27.4	34.4	34.4	34.4
D_3S_1	26.4	25.0	25.7	26.2	27.2	26.7	26.7	25.4	26.1	28.3	30.2	29.3	31.1	31.2	31.2
D_3S_2	26.1	25.3	25.7	26.5	27.9	27.2	27.3	25.4	26.4	28.5	30.4	29.5	31.6	31.4	31.5
D_3S_3	26.0	25.9	26.0	26.7	27.8	27.2	27.4	25.5	26.5	29.3	30.5	29.9	32.4	31.4	31.9
D_4S_1	27.6	26.5	27.1	26.2	31.3	28.8	27.4	25.7	26.6	26	33.0	29.5	30.7	31.4	31.1
D_4S_2	27.4	27.0	27.2	26.5	31.6	29.0	27.7	25.7	26.7	26.4	34.0	30.2	31.5	31.5	31.5
D_4S_3	27.1	27.4	27.3	26.8	32.4	29.6	27.8	25.8	26.8	26.6	34.0	30.3	32	32.0	32.0
D_5S_1	28.0	35.8	31.9	30.1	27.2	28.6	33.4	29.6	31.5	32.5	34.0	33.3	28.8	28.8	28.8
D_5S_2	27.8	35.8	31.8	31.0	27.1	29.0	33.8	29.6	31.7	32.8	34.0	33.4	29.1	29.1	29.1
D_5S_3	27.6	35.9	31.8	31.0	27.5	29.2	34.1	29.7	31.9	33	34.2	33.6	29.5	29.5	29.5

canopy RH increased in delayed sowings up to D_3 sowing date (July I FN), at seedling and sixth leaf stages. For remaining stages did not show any specific trend. But at physiological maturity, it decreased with delayed sowing (95 to 76 %) (Table 41).

The mean of two years indicate that canopy relative humidity increased with delayed sowings during seedling (90 to 92 %), sixth leaf (89 to 93 %) and silking (89 to 93 %), but decreased at tasseling (92 to 89 %) and physiological maturity (90 to 77 %).

Among the three planting geometries higher canopy relative humidity (92, 92, 93, 92 and 84 %) was noticed in narrowly spaced crop (45 x 20 cm) than widest spacing (75 x 20 cm) (90, 90, 91, 90 and 81 %) at seedling, sixth leaf, tasseling, silking and physiological maturity, respectively.

4.4.1.4.4 Mean canopy relative humidity (1430 hrs)

During 2013, canopy relative humidity during afternoon hours (1430 hrs), did not show any specific trend at seedling and sixth leaf stages. But, later on decreased with delayed sowing during both the years. The mean of two years also followed same trend, where it decreased from 71 to 59 per cent at tasseling, 60 to 51 per cent at silking and 54 to 49 per cent at physiological maturity (Table 42).

Among the three planting geometries, mean canopy relative humidity during afternoon decreased with increase in row spacing from 67 to 66 % at seedling, 73 to 71 % at sixth leaf stage, 68 to 65 per cent at tasseling, 60 to 58 per cent at silking and 53 to 52 per cent at physiological maturity stage.

4.4.1.4.5 Canopy, leaf and soil surface temperature and their differential values

The microclimate observations in maize during morning and afternoon changes in leaf temperature (T_L), canopy temperature (T_C) and soil surface temperature (Ts), leaf-air temperature differential, canopy-air temperature differential and soil surface temperature-air temperature differential at seedling, sixth leaf stage, tasseling, silking and physiological maturity stages were studied during 2013 and 2014 crop seasons (Table 43 and 54).

Table 41: Mean canopy relative humidity (%) in the morning (07 hrs) at different phenophases of maize under different growing environments during 2013 and 2014 cropping period

Treatments	Mean canopy relative humidity														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking (R_1)			Physiological maturity		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Date of sowing (D)															
D_1: June I fortnight	92	87	90	93	86	89	95	90	92	89	88	89	90	86	88
D_2: June II fortnight	94	84	89	94	86	90	94	93	93	94	93	93	95	85	90
D_3: July I fortnight	94	89	92	92	94	93	95	92	93	93	91	92	78	76	77
D_4: July II fortnight	95	89	92	89	88	89	92	87	89	96	89	93	80	80	80
D_5:August I fortnight	94	88	91	96	90	93	90	92	91	94	81	88	76	78	77
Planting geometry (S)															
S_1 – 45 cm x 20 cm	95	88	92	94	89	92	95	92	93	95	90	92	86	82	84
S_2 – 60 cm x 20 cm	94	87	90	93	89	91	93	90	92	93	88	91	84	81	82
S_3 – 75 cm x 20 cm	93	87	90	91	88	90	92	90	91	92	88	90	82	80	81
Interaction															
D_1S_1	94	87	90	95	86	91	97	91	94	90	89	90	92	88	90
D_1S_2	92	87	90	93	86	89	94	90	92	89	88	89	90	86	88
D_1S_3	91	87	89	92	85	88	93	89	91	88	88	88	88	84	86
D_2S_1	96	84	90	95	87	91	96	94	95	95	96	95	97	86	91
D_2S_2	94	84	89	94	86	90	93	92	93	94	92	93	95	85	90
D_2S_3	93	84	88	92	85	89	93	92	92	92	92	92	93	84	89
D_3S_1	95	89	92	93	95	94	96	93	95	94	92	93	79	78	79
D_3S_2	94	89	92	92	94	93	94	91	93	92	91	92	77	75	76
D_3S_3	93	89	91	91	93	92	93	90	92	92	90	91	77	74	76
D_4S_1	96	89	93	90	89	89	93	87	90	98	89	93	82	81	82
D_4S_2	94	88	91	89	88	88	91	87	89	96	89	93	80	80	80
D_4S_3	93	88	91	88	88	88	91	86	89	95	88	91	78	79	79
D_5S_1	96	89	92	98	91	94	91	93	92	96	82	89	77	79	78
D_5S_2	93	88	91	96	90	93	89	92	91	95	81	88	75	78	77
D_5S_3	92	88	90	94	89	92	89	91	90	93	80	86	75	77	76

Table 42: Mean canopy relative humidity (%) in the afternoon (1430 hrs) at different phenophases of maize under different growing environments (sowing dates) during 2013 and 2014 cropping period

Treatments	Mean canopy relative humidity														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Date of sowing (D)															
D_1 – June I FN	69	43	56	90	63	77	80	62	71	62	59	60	51	56	54
D_2 – June II FN	74	50	62	75	81	78	62	57	59	56	71	64	63	44	54
D_3 – July I FN	75	82	79	74	68	71	75	83	79	60	59	59	62	35	49
D_4 – July I FN	65	77	71	63	56	60	58	71	65	71	48	59	64	47	55
D_5 – August I FN	67	60	63	74	73	74	55	63	59	54	48	51	61	38	49
Planting geometry (S)															
S_1 – 45 cm x 20 cm	71	63	67	77	69	73	67	69	68	61	59	60	61	45	53
S_2 – 60 cm x 20 cm	70	63	66	75	68	72	66	67	67	60	56	58	60	43	52
S_3 – 75 cm x 20 cm	69	62	66	74	67	71	65	66	65	60	55	58	60	43	52
Interaction															
D_1S_1	69	43	56	91	63	77	81	64	72	62	62	62	52	58	55
D_1S_2	69	43	56	90	63	77	80	62	71	61	57	59	51	55	53
D_1S_3	69	43	56	90	63	76	80	61	70	61	58	60	50	56	53
D_2S_1	74	50	62	76	81	79	63	58	61	57	73	65	64	44	54
D_2S_2	74	50	62	75	81	78	62	57	59	56	71	63	62	44	53
D_2S_3	72	49	61	75	79	77	60	57	58	54	70	62	63	44	53
D_3S_1	75	82	78	76	68	72	76	83	79	60	60	60	62	36	49
D_3S_2	75	83	79	76	68	72	75	83	79	60	59	59	62	35	49
D_3S_3	75	82	79	71	67	69	73	83	78	59	57	58	62	34	48
D_4S_1	68	78	73	65	59	62	59	72	65	72	50	61	65	48	57
D_4S_2	64	77	71	62	55	58	59	71	65	71	47	59	64	46	55
D_4S_3	64	77	70	61	56	58	57	71	64	70	46	58	63	46	54
D_5S_1	69	60	65	75	74	74	57	66	62	56	50	53	62	38	50
D_5S_2	66	60	63	74	74	74	54	62	58	53	48	51	61	38	49
D_5S_3	65	60	62	73	73	73	54	60	57	54	45	49	60	37	49

Canopy temperature (^{0}C)

Diurnal variations in canopy temperature at different phenological stages of maize were recorded at 0700 hrs and 1430 hrs. It was observed from the data that the canopy temperature values were low (18.7 to 23.1 ^{0}C) in the morning and high (24.2 to 34.4 ^{0}C) in the afternoon hours of the day (Table 41 & 42).

During morning hours, among the different sowing dates, lower values of canopy temperature were observed with delayed sowings at seedling (22.0 to 20.9 ^{0}C), six canopy (21.2 to 20.2 ^{0}C) and physiological maturity stages (22.2 to 19.4 ^{0}C). But, slightly higher canopy temperature were observed at tasseling (21.0 to 21.9 ^{0}C) and silking (20.7 to 21.7 ^{0}C) with delayed sowings. Among the three planting geometries tried, the canopy temperature values were low (21.3,20.5,21.1,20.9 and 20.4 ^{0}C) in narrowest spaced maize (45 cm x 20 cm) and high (21.6,20.8,21.5,21.2 and 22.1 ^{0}C) in wider spacing (75 cm x 20 cm) at seedling, six leaf, tasseling, silking and physiological maturity, respectively.

Similarly, during afternoon hours, among the different sowing dates, lower values of temperature were observed with delayed sowings at seedling stage (30.6 to 25.8 ^{0}C). But, it increased with delayed sowings at six canopy a stage (24.5 to 29 ^{0}C), tasseling (26.8 to 31.7 ^{0}C) and silking (27.1 to 33.4 ^{0}C). Among the three planting geometries tried, the canopy temperature values increased with increase in row spacing from 45 cm x 20 cm to 75 cm x 20 cm at all the phenological stages except at seedling stage.

Leaf temperature (^{0}C)

Diurnal variations in leaf temperature at different phenological stages of maize were recorded at 0700 hrs and 1430 hrs. It was observed that the leaf temperature values were low (18.3 to 21.3 ^{0}C) in the morning and high (25.6 to 37 ^{0}C) in the afternoon hours of the day.

During morning hours, among the different sowing dates, lower values of leaf temperature were observed with delayed sowings at seedling (20.8 to 19.7 ^{0}C), sixth leaf (20 to 18.6 ^{0}C) and physiological maturity stages (20.5 to 17.9 ^{0}C). But, slightly

Table 43: Air temperature at 0700 hrs as influenced by different growing environments and planting geometry

Treatments	Air temperature														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	21.8	22.8	22.3	21.6	21.6	21.6	21.0	21.4	21.2	20.0	21.2	20.6	21.0	21.8	21.4
D_2: June II fortnight	22.0	22.8	22.4	21.0	21.6	21.3	20.8	22.0	21.4	21.0	20.6	20.8	20.8	22.4	21.6
D_3: July I fortnight	21.0	21.8	21.4	20.8	21.0	20.9	21.4	21.4	21.4	22.4	21.4	21.9	21.8	21.0	21.4
D_4: July II fortnight	21.0	21.2	21.1	20.0	21.6	20.8	20.2	21.0	20.6	20.4	20.8	20.6	19.0	21.4	20.2
D_5:August I fortnight	21.0	21.6	21.3	19.8	21.4	20.6	22.0	22.8	22.4	19.8	23.0	21.4	19.4	18.4	18.9
Planting geometry (S)															
S_1 – 45 cm x 20 cm	21.4	22.0	21.7	20.6	21.4	21.0	21.1	21.7	21.4	20.7	21.4	21.1	20.4	21.0	20.7
S_2 – 60 cm x 20 cm	21.4	22.0	21.7	20.6	21.4	21.0	21.1	21.7	21.4	20.7	21.4	21.1	20.4	21.0	20.7
S_3 – 75 cm x 20 cm	21.4	22.0	21.7	20.6	21.4	21.0	21.1	21.7	21.4	20.7	21.4	21.1	20.4	21.0	20.7
Interaction (D x S)															
D_1S_1	21.8	22.8	22.3	21.6	21.6	21.6	21.0	21.4	21.2	20.0	21.2	20.6	21.0	21.8	21.4
D_1S_2	21.8	22.8	22.3	21.6	21.6	21.6	21.0	21.4	21.2	20.0	21.2	20.6	21.0	21.8	21.4
D_1S_3	21.8	22.8	22.3	21.6	21.6	21.6	21.0	21.4	21.2	20.0	21.2	20.6	21.0	21.8	21.4
D_2S_1	22.0	22.8	22.4	21	21.6	21.3	20.8	22	21.4	21.0	20.6	20.8	20.8	22.4	21.6
D_2S_2	22.0	22.8	22.4	21	21.6	21.3	20.8	22	21.4	21.0	20.6	20.8	20.8	22.4	21.6
D_2S_3	22.0	22.8	22.4	21	21.6	21.3	20.8	22	21.4	21.0	20.6	20.8	20.8	22.4	21.6
D_3S_1	21.0	21.8	21.4	20.8	21.0	20.9	21.4	21.4	21.4	22.4	21.4	21.9	21.8	21.0	21.4
D_3S_2	21.0	21.8	21.4	20.8	21.0	20.9	21.4	21.4	21.4	22.4	21.4	21.9	21.8	21.0	21.4
D_3S_3	21.0	21.8	21.4	20.8	21.0	20.9	21.4	21.4	21.4	22.4	21.4	21.9	21.8	21.0	21.4
D_4S_1	21.0	21.2	21.1	20	21.6	20.8	20.2	21	20.6	20.4	20.8	20.6	19.0	21.4	20.2
D_4S_2	21.0	21.2	21.1	20	21.6	20.8	20.2	21	20.6	20.4	20.8	20.6	19.0	21.4	20.2
D_4S_3	21.0	21.2	21.1	20	21.6	20.8	20.2	21	20.6	20.4	20.8	20.6	19.0	21.4	20.2
D_5S_1	21.0	21.6	21.3	19.8	21.4	20.6	22.0	22.8	22.4	19.8	23	21.4	19.4	18.4	18.9
D_5S_2	21.0	21.6	21.3	19.8	21.4	20.6	22.0	22.8	22.4	19.8	23	21.4	19.4	18.4	18.9
D_5S_3	21.0	21.6	21.3	19.8	21.4	20.6	22.0	22.8	22.4	19.8	23	21.4	19.4	18.4	18.9

Table 44: Air temperature (^{0}C 1430 hrs) as influenced by different growing environments and planting geometry

Treatments	Air temperature														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	28.0	30.0	29.0	24.8	28.0	26.4	25.2	27.7	26.5	25.6	31.2	28.4	29.0	29.2	29.1
D_2: June II fortnight	27.4	28.7	28.1	24.6	26.2	25.4	31.0	31.2	31.1	27.9	28.1	28.0	28.5	31.0	29.8
D_3: July I fortnight	24.7	26.2	25.5	26.4	25.8	26.1	26.1	25.1	25.6	28.0	27.6	27.8	28.7	30.1	29.4
D_4: July II fortnight	25.8	24.6	25.2	25.6	31.2	28.4	25.6	28.8	27.2	26.0	27.2	26.6	28.0	28.5	28.3
D_5:August I fortnight	26.4	28.1	27.3	29.5	26.0	27.8	26.5	28.0	27.3	28.8	29.2	29.0	29.9	28.0	29.0
Planting geometry (S)															
S_1 – 45 cm x 20 cm	26.5	27.5	27.0	26.2	27.4	26.8	26.9	28.2	27.5	27.3	28.7	28.0	28.8	29.4	29.1
S_2 – 60 cm x 20 cm	26.5	27.5	27.0	26.2	27.4	26.8	26.9	28.2	27.5	27.3	28.7	28.0	28.8	29.4	29.1
S_3 – 75 cm x 20 cm	26.5	27.5	27.0	26.2	27.4	26.8	26.9	28.2	27.5	27.3	28.7	28.0	28.8	29.4	29.1
Interaction (D x S)															
D_1S_1	28.0	30.0	29.0	24.8	28.0	26.4	25.2	27.7	26.5	25.6	31.2	28.4	29.0	29.2	29.1
D_1S_2	28.0	30.0	29.0	24.8	28.0	26.4	25.2	27.7	26.5	25.6	31.2	28.4	29.0	29.2	29.1
D_1S_3	28.0	30.0	29.0	24.8	28.0	26.4	25.2	27.7	26.5	25.6	31.2	28.4	29.0	29.2	29.1
D_2S_1	27.4	28.7	28.1	24.6	26.2	25.4	31.0	31.2	31.1	27.9	28.1	28.0	28.5	31.0	29.8
D_2S_2	27.4	28.7	28.1	24.6	26.2	25.4	31.0	31.2	31.1	27.9	28.1	28.0	28.5	31.0	29.8
D_2S_3	27.4	28.7	28.1	24.6	26.2	25.4	31.0	31.2	31.1	27.9	28.1	28.0	28.5	31.0	29.8
D_3S_1	24.7	26.2	25.5	26.4	25.8	26.1	26.1	25.1	25.6	28.0	27.6	27.8	28.7	30.1	29.4
D_3S_2	24.7	26.2	25.5	26.4	25.8	26.1	26.1	25.1	25.6	28.0	27.6	27.8	28.7	30.1	29.4
D_3S_3	24.7	26.2	25.5	26.4	25.8	26.1	26.1	25.1	25.6	28.0	27.6	27.8	28.7	30.1	29.4
D_4S_1	25.8	24.6	25.2	25.6	31.2	28.4	25.6	28.8	27.2	26.0	27.2	26.6	28.0	28.5	28.3
D_4S_2	25.8	24.6	25.2	25.6	31.2	28.4	25.6	28.8	27.2	26.0	27.2	26.6	28.0	28.5	28.3
D_4S_3	25.8	24.6	25.2	25.6	31.2	28.4	25.6	28.8	27.2	26.0	27.2	26.6	28.0	28.5	28.3
D_5S_1	26.4	28.1	27.3	29.5	26.0	27.8	26.5	28	27.3	28.8	29.2	29.0	29.9	28.0	29.0
D_5S_2	26.4	28.1	27.3	29.5	26.0	27.8	26.5	28	27.3	28.8	29.2	29.0	29.9	28.0	29.0
D_5S_3	26.4	28.1	27.3	29.5	26.0	27.8	26.5	28	27.3	28.8	29.2	29.0	29.9	28.0	29.0

Table 45: Leaf temperature (T_L) at 0700 hrs as influenced by different growing environments and planting geometry

Treatments	Leaf temperature (T_L) °C														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	20.3	21.3	20.8	19.6	20.4	20.0	18.9	19.6	19.2	17.8	19.2	18.5	20.4	20.6	20.5
D_2: June II fortnight	20.7	20.9	20.8	19.1	20.2	19.7	18.7	20.2	19.5	18.8	18.3	18.5	20.4	19.4	19.9
D_3: July I fortnight	19.9	20.5	20.2	19.0	18.8	18.9	19.2	19.2	19.2	19.8	18.8	19.3	21.0	19.3	20.1
D_4: July II fortnight	19.8	19.6	19.7	18.2	19.4	18.8	18.2	19.6	18.9	18.0	18.9	18.5	19.1	19.7	19.4
D_5:August I fortnight	19.7	20.1	19.9	18.0	19.2	18.6	19.8	19.5	19.7	17.6	20.3	18.9	18.9	16.8	17.9
Planting geometry (S)															
S_1 – 45 cm x 20 cm	19.9	20.3	20.1	18.6	19.5	19.1	18.8	19.4	19.1	18.2	19.0	18.6	18.6	18.9	18.8
S_2 – 60 cm x 20 cm	20.1	20.5	20.3	18.8	19.6	19.2	19.0	19.6	19.3	18.4	19.1	18.7	20.0	19.1	19.6
S_3 – 75 cm x 20 cm	20.2	20.5	20.4	18.9	19.7	19.3	19.1	19.8	19.5	18.6	19.2	18.9	21.3	19.4	20.3
Interaction (D x S)															
D_1S_1	20.2	21.1	20.7	19.5	20.3	19.9	18.7	19.4	19.1	17.6	18.9	18.3	19.1	20.2	19.7
D_1S_2	20.4	21.3	20.9	19.6	20.4	20.0	18.9	19.6	19.2	17.8	19.2	18.5	20.5	20.4	20.4
D_1S_3	20.4	21.4	20.9	19.7	20.4	20.0	19.0	19.8	19.4	17.9	19.4	18.6	21.5	21.0	21.3
D_2S_1	20.6	20.8	20.7	18.9	20.1	19.5	18.5	19.9	19.2	18.5	18.1	18.3	18.9	19.2	19.1
D_2S_2	20.8	21.0	20.9	19.2	20.2	19.7	18.8	20.2	19.5	18.7	18.2	18.5	20.4	19.5	19.9
D_2S_3	20.8	21.0	20.9	19.2	20.3	19.8	18.9	20.5	19.7	19.2	18.5	18.9	21.8	19.5	20.6
D_3S_1	19.8	20.3	20.0	18.8	18.7	18.7	19.1	18.9	19.0	19.6	18.7	19.1	19.9	19.1	19.5
D_3S_2	19.9	20.5	20.2	19.0	18.9	19.0	19.2	19.2	19.2	19.8	18.8	19.3	21.0	19.3	20.2
D_3S_3	20.0	20.6	20.3	19.3	18.9	19.1	19.4	19.5	19.5	20.0	18.8	19.4	22.0	19.4	20.7
D_4S_1	19.5	19.5	19.5	18.0	19.3	18.7	18.0	19.6	18.8	17.9	18.9	18.4	17.3	19.5	18.4
D_4S_2	19.7	19.6	19.7	18.2	19.4	18.8	18.2	19.6	18.9	18.0	18.9	18.4	19.3	19.6	19.4
D_4S_3	20.0	19.6	19.8	18.3	19.5	18.9	18.4	19.7	19.0	18.1	18.9	18.5	20.8	20.1	20.4
D_5S_1	19.5	20.0	19.8	17.9	19.1	18.5	19.6	19.4	19.5	17.4	20.1	18.8	17.7	16.7	17.2
D_5S_2	19.7	20.1	19.9	18.0	19.2	18.6	19.9	19.6	19.7	17.6	20.3	19.0	18.9	16.8	17.9
D_5S_3	19.8	20.1	20.0	18.1	19.3	18.7	20.0	19.6	19.8	17.7	20.3	19.0	20.2	16.8	18.5

Table 46: Leaf temperature at 1430 hrs as influenced by different growing environments and planting geometry

Treatments	Leaf temperature														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	31.8	37.7	34.7	25.5	29.8	27.7	26.1	28.1	27.1	31.9	32.2	32.1	33.1	33.4	33.3
D_2: June II fortnight	29.7	37.9	33.8	25.6	27.5	26.5	35.4	32.4	33.9	30.2	30.5	30.3	34.4	33.6	34.0
D_3: July I fortnight	27.6	27.4	27.5	29.3	31.1	30.2	26.4	28.4	27.4	30.9	30.4	30.6	33.0	33.1	33.0
D_4: July II fortnight	28.6	27.4	28.0	27.7	32.1	29.9	26.8	30.4	28.6	32.3	32.0	32.2	35.6	37.6	36.6
D_5:August I fortnight	29.0	36.3	32.7	32.1	27.3	29.7	29.3	31.4	30.4	30.8	31.4	31.1	31.6	30.3	30.9
Planting geometry (S)															
S_1 – 45 cm x 20 cm	29.6	32.9	31.2	27.5	29.0	28.3	28.0	29.5	28.8	30.7	30.3	30.5	34.0	33.6	33.8
S_2 – 60 cm x 20 cm	29.4	33.2	31.3	28.2	29.5	28.8	28.9	30.3	29.6	31.3	31.2	31.3	33.4	33.9	33.6
S_3 – 75 cm x 20 cm	29.0	34.0	31.5	28.4	30.1	29.3	29.5	30.5	30.0	31.6	32.4	32.0	33.2	33.4	33.3
Interaction (D x S)															
D_1S_1	32.0	36.9	34.4	25.1	29.6	27.4	25.4	28.0	26.7	31.4	31.2	31.3	33.8	33.4	33.6
D_1S_2	31.8	37.3	34.6	25.5	29.7	27.6	26.0	28.1	27.1	32.1	32.4	32.3	32.8	33.5	33.2
D_1S_3	31.5	39.0	35.3	26.0	30.1	28.0	26.9	28.2	27.6	32.3	33.1	32.7	32.6	33.4	33.0
D_2S_1	29.9	37.3	33.6	24.2	26.9	25.6	34.6	31.2	32.9	29.6	29.4	29.5	34.6	32.3	33.5
D_2S_2	29.8	38.0	33.9	26.2	27.6	26.9	35.4	32.8	34.1	30.2	30.4	30.3	34.3	35.5	34.9
D_2S_3	29.4	38.5	34.0	26.3	28.0	27.2	36.3	33.1	34.7	30.8	31.6	31.2	34.2	33.1	33.7
D_3S_1	27.8	27.1	27.5	29.1	30.2	29.7	25.9	27.4	26.7	30.5	29.4	30.0	33.1	32.8	33.0
D_3S_2	27.6	27.1	27.4	29.4	30.9	30.2	26.4	28.2	27.3	31.0	30.3	30.7	33.0	33.9	33.5
D_3S_3	27.4	28.0	27.7	29.4	32.2	30.8	26.8	29.5	28.2	31.2	31.4	31.3	32.8	32.6	32.7
D_4S_1	29.0	26.8	27.9	27.2	31.4	29.3	26.0	29.6	27.8	31.6	31.0	31.3	35.8	36.9	36.4
D_4S_2	28.8	27.3	28.1	27.8	32.0	29.9	27.2	30.4	28.8	32.5	31.5	32.0	35.6	38.3	37.0
D_4S_3	28.0	28.2	28.1	28.1	32.8	30.5	27.3	31.2	29.3	32.7	33.6	33.2	35.4	37.5	36.5
D_5S_1	29.2	36.4	32.8	31.8	27.1	29.5	28.3	31.4	29.9	30.6	30.4	30.5	32.5	32.4	32.5
D_5S_2	29.0	36.3	32.7	32.2	27.2	29.7	29.7	32.2	31.0	30.9	31.4	31.2	31.2	28.2	29.7
D_5S_3	28.8	36.3	32.6	32.3	27.5	29.9	30.0	30.5	30.3	31.0	32.4	31.7	31.0	30.2	30.6

higher leaf temperature were observed at tasseling (19.2 to 19.7 ^{0}C) and silking (18.5 to 19.3 ^{0}C) with delayed sowings. Among the three planting geometries tried, the leaf temperature values were low (20.1, 19.1, 19.1, 18.6 and 18.8 ^{0}C) in narrow spaced maize (45 cm x 20 cm) and high (20.4, 19.3, 19.5, 19.2 and 20.3 ^{0}C) in wider spacing (75 cm x 20 cm) at seedling, sixth leaf, tasseling, silking and physiological maturity stages, respectively. In general, it was observed that leaf temperature was more during early vegetative stages (seedling and sixth leaf) than later stages (tasseling, silking and physiological maturity) of maize.

Similarly, during afternoon hours, among the different sowing dates tried, lower values of temperature were observed with delayed sowings at seedling stage (34.7 to 28.0 ^{0}C). But, it increased with delayed sowings at sixth leaf a stage. At remaining stages it did not show any specific trend. Among the three planting geometries tried, the leaf temperature values increased with increase in row spacing from 45 cm x 20 cm to 75 cm x 20 cm.

iii) Soil surface temperature (^{0}C)

Diurnal variations in soil surface temperature at different phenological stages of maize were recorded at 0700 hrs and 1430 hrs. It was observed from the data that the soil surface temperature values were low (17.7 to 22.2 ^{0}C) in the morning and high (25.1 to 38.9 ^{0}C) in the afternoon hours of the day (Table 47 & 48).

During morning hours, among the different sowing dates tried, lower values of soil surface temperature were observed with delayed sowings at seedling (22.1 to 20.9 ^{0}C), sixth leaf (20.9 to 19.5 ^{0}C) and physiological maturity stages (21.1 to 18.4 ^{0}C). But, slightly higher soil surface temperature were noticed at tasseling (19.7 to 20.1 ^{0}C) and silking (18.6 to 19.1 ^{0}C) with delayed sowings. Among the three planting geometries tried, the soil surface temperature values were low (21.3,20.0, 19.5, 18.8 and 19.3 ^{0}C) in narrow spaced maize (45 cm x 20 cm) and high (21.6,20.2, 19.9, 19.1 and 20.9 ^{0}C) in wider spacing (75 cm x 20 cm) at seedling, sixth leaf, tasseling, silking and physiological maturity stages, respectively. In general, it was observed that soil surface temperature was more during early vegetative stages (seedling and sixth leaf) than later stages (tasseling, silking and physiological maturity) of maize.

Table 47: Soil Surface temperature (Ts) at 0700 hrs as influenced by different growing environments and planting geometry

Treatments	Soil surface temperature (Ts) °C														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	21.3	22.8	22.1	20.3	21.6	20.9	19.2	20.1	19.7	17.9	19.6	18.8	20.9	21.3	21.1
D_2: June II fortnight	21.8	22.4	22.1	19.8	21.4	20.6	19.1	20.7	19.9	19.0	18.6	18.8	20.9	20.1	20.5
D_3: July I fortnight	20.9	21.9	21.4	19.7	20.0	19.8	19.6	19.6	19.6	20.0	19.0	19.5	21.5	20.0	20.7
D_4: July II fortnight	20.7	21.0	20.9	18.8	20.6	19.7	18.5	20.0	19.3	18.2	19.1	18.6	19.6	20.4	20.0
D_5:August I fortnight	20.7	21.5	21.1	18.6	20.3	19.5	20.2	19.9	20.1	17.8	20.5	19.1	19.4	17.4	18.4
Planting geometry (S)															
S_1 – 45 cm x 20 cm	20.9	21.8	21.3	19.3	20.7	20.0	19.2	19.9	19.5	18.4	19.2	18.8	19.0	19.6	19.3
S_2 – 60 cm x 20 cm	21.1	21.9	21.5	19.5	20.8	20.1	19.4	20.1	19.7	18.6	19.4	19.0	20.5	19.8	20.2
S_3 – 75 cm x 20 cm	21.2	22.0	21.6	19.6	20.9	20.2	19.5	20.2	19.9	18.8	19.5	19.1	21.8	20.1	20.9
Interaction (D x S)															
D_1S_1	21.2	22.6	21.9	20.2	21.5	20.8	19.1	19.9	19.5	17.8	19.3	18.6	19.6	20.9	20.3
D_1S_2	21.4	22.8	22.1	20.3	21.6	20.9	19.3	20.1	19.7	18.0	19.6	18.8	21.0	21.1	21.1
D_1S_3	21.4	22.9	22.2	20.4	21.6	21.0	19.4	20.3	19.8	18.1	19.8	18.9	22.0	21.8	21.9
D_2S_1	21.6	22.2	21.9	19.6	21.3	20.5	18.9	20.4	19.6	18.7	18.4	18.6	19.4	19.9	19.7
D_2S_2	21.8	22.5	22.2	19.9	21.4	20.7	19.2	20.7	20.0	18.9	18.6	18.7	20.9	20.2	20.5
D_2S_3	21.9	22.5	22.2	19.9	21.5	20.7	19.3	21.0	20.1	19.4	18.9	19.1	22.3	20.2	21.2
D_3S_1	20.7	21.7	21.2	19.4	19.9	19.6	19.4	19.3	19.4	19.8	18.9	19.3	20.4	19.8	20.1
D_3S_2	20.9	21.9	21.4	19.7	20.0	19.9	19.6	19.6	19.6	20.0	19.0	19.5	21.6	20.0	20.8
D_3S_3	21.0	22.0	21.5	20.0	20.0	20.0	19.8	19.9	19.8	20.2	19.0	19.6	22.6	20.1	21.3
D_4S_1	20.5	20.9	20.7	18.7	20.4	19.5	18.4	20.0	19.2	18.1	19.1	18.6	17.7	20.2	19.0
D_4S_2	20.7	21.0	20.9	18.9	20.6	19.7	18.5	20.0	19.3	18.1	19.1	18.6	19.8	20.3	20.0
D_4S_3	21.0	21.0	21.0	19.0	20.7	19.8	18.7	20.1	19.4	18.3	19.1	18.7	21.3	20.8	21.1
D_5S_1	20.5	21.4	21.0	18.5	20.2	19.4	20.0	19.8	19.9	17.8	20.3	19.1	18.1	17.3	17.7
D_5S_2	20.7	21.5	21.1	18.6	20.3	19.5	20.3	20.0	20.1	17.8	20.5	19.2	19.4	17.4	18.4
D_5S_3	20.8	21.5	21.2	18.8	20.4	19.6	20.4	20.0	20.2	17.9	20.5	19.2	20.7	17.4	19.1

Table 48: Soil surface temperature at 1430 hrs as influenced by different growing environments and planting geometry

Treatments	Soil surface temperature														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	34.1	38.8	36.5	30.3	32.9	31.6	29.4	28.4	28.9	34.9	28.1	31.5	34.5	35.0	34.8
D_2: June II fortnight	34.0	40.2	37.1	29.7	28.9	29.3	37.0	30.4	33.7	30.3	26.9	28.6	35.1	39.4	37.3
D_3: July I fortnight	32.8	28.2	30.5	34.0	38.9	36.4	27.2	24.9	26.1	33.6	31.8	32.7	35.3	34.6	34.9
D_4: July II fortnight	33.3	28.6	31.0	32.7	42.5	37.6	30.1	25.7	27.9	33.3	32.5	32.9	36.4	36.4	36.4
D_5:August I fortnight	32.7	41.8	37.3	36.4	30.3	33.4	35.4	30.8	33.1	34.1	34.1	34.1	34.5	33.3	33.9
Planting geometry (S)															
S_1 – 45 cm x 20 cm	32.8	34.8	33.8	31.5	34.0	32.7	31.0	27.0	29.0	32.6	29.9	31.3	33.8	34.3	34.1
S_2 – 60 cm x 20 cm	33.5	35.6	34.5	32.5	34.5	33.5	31.8	27.8	29.8	33.3	30.7	32.0	35.2	36.1	35.7
S_3 – 75 cm x 20 cm	33.8	36.1	35.0	33.9	35.6	34.8	32.6	29.3	31.0	33.8	31.4	32.6	36.4	36.8	36.6
Interaction (D x S)															
D_1S_1	33.9	38.3	36.1	29.8	32.1	31.0	28.8	28.0	28.4	34.4	27.8	31.1	32.7	32.9	32.8
D_1S_2	34.1	39.0	36.6	30.1	33.0	31.5	29.2	28.4	28.8	35.0	28.0	31.5	34.2	35.4	34.8
D_1S_3	34.3	39.1	36.7	31.0	33.7	32.3	30.2	28.8	29.5	35.4	28.5	32.0	36.5	36.8	36.7
D_2S_1	33.7	39.8	36.8	28.8	28.5	28.6	36.0	28.5	32.3	29.2	26.8	28.0	33.2	38.9	36.1
D_2S_2	34.1	40.2	37.2	29.2	28.7	29.0	37.2	30.3	33.8	30.7	26.8	28.8	35.6	39.2	37.4
D_2S_3	34.2	40.5	37.4	31.2	29.6	30.4	37.8	32.5	35.2	30.9	27.2	29.1	36.5	40.2	38.4
D_3S_1	32.2	27.2	29.7	32.1	38.6	35.4	26.6	23.6	25.1	33.3	30.4	31.9	33.6	32.6	33.1
D_3S_2	32.9	28.2	30.6	33.4	38.6	36.0	27.1	24.7	25.9	33.4	31.9	32.7	35.2	35.5	35.4
D_3S_3	33.2	29.1	31.2	36.4	39.5	38.0	27.9	26.5	27.2	34.0	33.2	33.6	37.0	35.6	36.3
D_4S_1	32.1	27.6	29.9	31.5	41.0	36.3	29.0	25.0	27.0	32.4	31.8	32.1	35.6	35.5	35.6
D_4S_2	33.4	28.3	30.9	32.8	42.5	37.7	30.1	25.8	28.0	33.4	32.6	33.0	36.6	36.4	36.5
D_4S_3	34.5	29.8	32.2	33.8	44.0	38.9	31.2	26.4	28.8	34.1	33.1	33.6	37.0	37.2	37.1
D_5S_1	32.2	41.2	36.7	35.2	29.7	32.5	34.5	29.8	32.2	33.6	32.8	33.2	33.8	31.7	32.8
D_5S_2	33.0	42.1	37.6	36.8	29.9	33.4	35.5	30.0	32.8	34.2	34.4	34.3	34.6	33.9	34.3
D_5S_3	33.0	42.2	37.6	37.2	31.4	34.3	36.1	32.5	34.3	34.5	35.0	34.8	35.2	34.3	34.8

Similarly, during afternoon hours, among the different sowing dates tried, lower values of temperature were observed with delayed sowings at seedling stage (36.5 to 30.5 ^{0}C). But, it increased with delayed sowings at sixth leaf a stage (29.3 to 37.6) and silking (28.6 to 34.1 ^{0}C). At remaining stages it did not show any specific trend. Among the three planting geometries tried, the soil surface temperature values increased with increase in row spacing from 45 cm x 20 cm to 75 cm x 20 cm.

iv) Diurnal changes of canopy-air temperature differential at different phenological stages of maize

The canopy –air temperature differential values during morning hours, were negative at all the stages (except at physiological maturity) indicating that the canopy temperature remained cooler than air during morning hours (0700 hrs). But, the values became positive during afternoon hours (1430 hrs) indicating the higher canopy temperature of maize than air during afternoon hours of the day (Table 49 & 50).

Among the different sowing dates tried, the values ranged from 0 to -0.5,-0.1 to -0.5,0 to -0.7 and -0.3 to 0.3 ^{0}C during morning hours (0700 hrs) and 0.3 to 4.7,-1.2 to 1.5,-0.7 to 4.7 and -0.6 to 4.6 ^{0}C during afternoon hours (1430 hrs) at seedling, sixth leaf, tasseling and silking stages, respectively. Among the three planting geometries tried, in the 45 cm x 20 cm planting geometry, differential values were higher during morning hours indicating cooler canopy temperature than widely spaced maize. Also, during afternoon hours (1430 hrs) cooler canopy temperature values were observed in 45 cm x 20 cm than 75 cm x 20 cm spaced maize.

v) Diurnal changes of leaf-air temperature differential

The data pertaining to diurnal changes in leaf-air temperature differential as influenced by different sowing dates and planting geometry are presented in (Table 51 and 52).

The leaf–air temperature differential values during morning hours, were negative at all the stages indicating that the leaf temperature remained cooler than air during morning hours (0700 hrs). But, the values became positive during afternoon hours (1430 hrs) indicating the higher leaf temperature of maize than air during afternoon hours of the day.

Table 49: Canopy- Air temperature differential (ΔTC) at 0700 hrs as influenced by different growing environments and planting geometry

Treatments	Canopy- Air temperature differential (ΔTC) °C														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	-0.2	-0.4	-0.3	-0.6	-0.2	-0.4	-0.1	-0.3	-0.2	0.0	0.2	0.1	1.1	0.5	0.8
D_2: June II fortnight	0.0	-0.8	-0.4	-0.4	-0.3	-0.4	0.0	-0.3	-0.1	0.1	-0.2	0.0	1.3	-1.3	0.0
D_3: July I fortnight	-0.1	-0.3	-0.2	-0.3	-0.3	-0.3	0.0	-0.1	0.0	0.0	-0.3	-0.2	1.0	-0.1	0.5
D_4: July II fortnight	0.0	-0.4	-0.2	-0.4	-0.3	-0.4	0.0	0.8	0.4	-0.1	0.5	0.2	1.8	0.1	0.9
D_5:August I fortnight	-0.1	-0.3	-0.2	-0.5	-0.3	-0.4	0.0	-1.1	-0.5	0.0	-0.2	-0.1	1.2	-0.2	0.5
Planting geometry (S)															
S_1 – 45 cm x 20 cm	-0.2	-0.5	-0.4	-0.6	-0.4	-0.5	-0.2	-0.4	-0.3	-0.2	-0.2	-0.2	-0.2	-0.4	-0.3
S_2 – 60 cm x 20 cm	0.0	-0.4	-0.2	-0.4	-0.3	-0.3	0.0	-0.2	-0.1	0.0	0.0	0.0	1.4	-0.2	0.6
S_3 – 75 cm x 20 cm	0.1	-0.3	-0.1	-0.3	-0.2	-0.2	0.2	0.0	0.1	0.2	0.1	0.2	2.7	0.1	1.4
Interaction (D x S)															
D_1S_1	-0.3	-0.6	-0.4	-0.6	-0.2	-0.4	-0.2	-0.5	-0.4	-0.2	0.0	-0.1	-0.2	0.2	0.0
D_1S_2	-0.1	-0.4	-0.2	-0.6	-0.1	-0.3	0.0	-0.3	-0.2	0.0	0.3	0.1	1.3	0.4	0.8
D_1S_3	-0.1	-0.3	-0.2	-0.5	-0.1	-0.3	0.1	-0.1	0.0	0.1	0.5	0.3	2.4	1.1	1.7
D_2S_1	-0.1	-0.9	-0.5	-0.6	-0.4	-0.5	-0.2	-0.6	-0.4	-0.2	-0.4	-0.3	-0.2	-1.5	-0.9
D_2S_2	0.1	-0.7	-0.3	-0.3	-0.3	-0.3	0.1	-0.2	-0.1	0.0	-0.2	-0.1	1.4	-1.2	0.1
D_2S_3	0.2	-0.7	-0.2	-0.3	-0.2	-0.3	0.2	0.1	0.1	0.6	0.1	0.3	2.9	-1.2	0.8
D_3S_1	-0.2	-0.4	-0.3	-0.6	-0.4	-0.5	-0.2	-0.4	-0.3	-0.2	-0.4	-0.3	-0.2	-0.2	-0.2
D_3S_2	0.0	-0.2	-0.1	-0.3	-0.2	-0.3	0.0	0.0	0.0	0.0	-0.2	-0.1	1.1	0.0	0.5
D_3S_3	0.1	-0.1	0.0	0.0	-0.2	-0.1	0.2	0.3	0.2	0.2	-0.2	0.0	2.2	0.1	1.1
D_4S_1	-0.2	-0.4	-0.3	-0.6	-0.4	-0.5	-0.2	0.8	0.3	-0.2	0.5	0.1	-0.2	-0.2	-0.2
D_4S_2	0.0	-0.3	-0.2	-0.4	-0.2	-0.3	0.0	0.8	0.4	-0.1	0.5	0.2	2.0	-0.1	0.9
D_4S_3	0.3	-0.3	0.0	-0.3	-0.1	-0.2	0.2	0.9	0.5	0.1	0.5	0.3	3.6	0.5	2.0
D_5S_1	-0.2	-0.3	-0.3	-0.6	-0.4	-0.5	-0.2	-1.2	-0.7	-0.2	-0.4	-0.3	-0.2	-0.3	-0.2
D_5S_2	0.0	-0.2	-0.1	-0.5	-0.3	-0.4	0.1	-1.0	-0.5	0.0	-0.2	-0.1	1.2	-0.1	0.6
D_5S_3	0.1	-0.2	-0.1	-0.3	-0.2	-0.3	0.3	-1.0	-0.4	0.1	-0.2	0.0	2.6	-0.1	1.2

Table 50: Canopy- Air temperature differential (∆TC) at 1430 hrs as influenced by different growing environments and planting geometry

Treatments	Canopy- Air temperature differential														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	0.1	3.0	1.6	-0.6	0.3	-0.1	-0.7	1.3	0.3	4.8	-0.5	2.2	3.2	3.0	3.1
D_2: June II fortnight	1.8	2.3	2.1	-0.4	-1.4	-0.9	-0.1	-0.1	-0.1	-2.1	0.2	-0.9	5.3	2.9	4.1
D_3: July I fortnight	1.5	-0.8	0.3	0.1	1.8	0.9	1.0	0.3	0.7	0.7	2.8	1.7	3.0	1.2	2.1
D_4: July II fortnight	1.6	2.4	2.0	0.9	0.6	0.7	2.0	-3.1	-0.5	0.3	6.5	3.4	3.4	3.1	3.3
D_5:August I fortnight	1.4	7.7	4.6	1.2	1.2	1.2	7.3	1.6	4.5	4.0	4.9	4.4	-0.8	1.1	0.2
Planting geometry (S)															
S_1 – 45 cm x 20 cm	1.5	2.7	2.1	0.0	0.2	0.1	1.5	-0.1	0.7	1.3	2.5	1.9	2.4	2.0	2.2
S_2 – 60 cm x 20 cm	1.3	2.9	2.1	0.3	0.5	0.4	2.0	0.0	1.0	1.5	2.8	2.2	2.7	2.3	2.5
S_3 – 75 cm x 20 cm	1.1	3.2	2.1	0.5	0.8	0.7	2.2	0.2	1.2	1.8	3.0	2.4	3.3	2.5	2.9
Interaction (D x S)															
D_1S_1	0.2	2.9	1.5	-0.6	0.2	-0.2	-0.9	1.2	0.2	4.6	-0.7	2.0	3.0	2.8	2.9
D_1S_2	0.1	3.0	1.6	-0.6	0.3	-0.1	-0.6	1.4	0.4	4.8	-0.4	2.2	3.0	3.3	3.2
D_1S_3	0.1	3.1	1.6	-0.5	0.6	0.0	-0.6	1.4	0.4	5.0	-0.4	2.3	3.5	2.8	3.2
D_2S_1	2.0	2.3	2.2	-0.6	-1.8	-1.2	-0.7	-0.6	-0.6	-2.2	-0.1	-1.2	5.0	2.3	3.7
D_2S_2	1.8	2.3	2.1	-0.4	-1.5	-1.0	-0.1	-0.1	-0.1	-2.1	0.1	-1.0	5.0	3.0	4.0
D_2S_3	1.6	2.4	2.0	-0.1	-1.0	-0.6	0.4	0.5	0.4	-1.9	0.7	-0.6	5.9	3.4	4.7
D_3S_1	1.7	-1.2	0.3	-0.2	1.4	0.6	0.6	0.3	0.4	0.3	2.6	1.5	2.4	1.1	1.8
D_3S_2	1.4	-0.9	0.3	0.1	2.1	1.1	1.2	0.3	0.7	0.5	2.8	1.7	2.9	1.3	2.1
D_3S_3	1.3	-0.3	0.5	0.3	2.0	1.1	1.3	0.4	0.8	1.3	2.9	2.1	3.7	1.3	2.5
D_4S_1	1.8	1.9	1.9	0.6	0.1	0.4	1.8	-3.1	-0.7	0.0	5.8	2.9	2.7	2.9	2.8
D_4S_2	1.6	2.4	2.0	0.9	0.4	0.6	2.1	-3.1	-0.5	0.4	6.8	3.6	3.5	3.0	3.3
D_4S_3	1.3	2.8	2.1	1.2	1.2	1.2	2.2	-3.0	-0.4	0.6	6.8	3.7	4.0	3.5	3.8
D_5S_1	1.6	7.7	4.7	0.6	1.2	0.9	6.9	1.6	4.3	3.7	4.8	4.3	-1.1	0.8	-0.1
D_5S_2	1.4	7.7	4.6	1.5	1.1	1.3	7.3	1.6	4.5	4.0	4.8	4.4	-0.8	1.1	0.2
D_5S_3	1.2	7.8	4.5	1.5	1.5	1.5	7.6	1.7	4.7	4.2	5.0	4.6	-0.4	1.5	0.6

Table 51: Leaf- Air temperature differential (ΔTL) at 0700 hrs as influenced by different growing environments and planting geometry

Treatments	Leaf - Air temperature differential														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	-1.5	-1.5	-1.5	-2.0	-1.2	-1.6	-2.1	-1.8	-2.0	-2.2	-2.0	-2.1	-0.6	-1.2	-0.9
D_2: June II fortnight	-1.3	-1.9	-1.6	-1.9	-1.4	-1.6	-2.1	-1.8	-1.9	-2.2	-2.3	-2.3	-0.4	-3.0	-1.7
D_3: July I fortnight	-1.1	-1.3	-1.2	-1.8	-2.2	-2.0	-2.2	-2.2	-2.2	-2.6	-2.6	-2.6	-0.8	-1.7	-1.3
D_4: July II fortnight	-1.2	-1.6	-1.4	-1.8	-2.2	-2.0	-2.0	-1.4	-1.7	-2.4	-1.9	-2.1	0.1	-1.7	-0.8
D_5:August I fortnight	-1.3	-1.5	-1.4	-1.8	-2.2	-2.0	-2.2	-3.3	-2.7	-2.2	-2.7	-2.5	-0.5	-1.6	-1.0
Planting geometry (S)															
S_1 – 45 cm x 20 cm	-1.4	-1.7	-1.6	-2.0	-1.9	-2.0	-2.3	-2.3	-2.3	-2.5	-2.4	-2.5	-1.8	-2.1	-1.9
S_2 – 60 cm x 20 cm	-1.3	-1.5	-1.4	-1.8	-1.8	-1.8	-2.1	-2.1	-2.1	-2.3	-2.3	-2.3	-0.4	-1.9	-1.1
S_3 – 75 cm x 20 cm	-1.1	-1.5	-1.3	-1.7	-1.8	-1.7	-1.9	-1.9	-1.9	-2.1	-2.2	-2.2	0.9	-1.6	-0.4
Interaction (D x S)															
D_1S_1	-1.6	-1.7	-1.6	-2.1	-1.3	-1.7	-2.3	-2.0	-2.1	-2.4	-2.3	-2.3	-1.9	-1.6	-1.7
D_1S_2	-1.4	-1.5	-1.4	-2.0	-1.2	-1.6	-2.1	-1.8	-2.0	-2.2	-2.0	-2.1	-0.5	-1.4	-1.0
D_1S_3	-1.4	-1.4	-1.4	-1.9	-1.2	-1.6	-2.0	-1.6	-1.8	-2.1	-1.8	-2.0	0.5	-0.8	-0.1
D_2S_1	-1.4	-2.0	-1.7	-2.1	-1.5	-1.8	-2.3	-2.1	-2.2	-2.5	-2.5	-2.5	-1.9	-3.2	-2.5
D_2S_2	-1.2	-1.8	-1.5	-1.8	-1.4	-1.6	-2.0	-1.8	-1.9	-2.3	-2.4	-2.3	-0.4	-2.9	-1.7
D_2S_3	-1.2	-1.8	-1.5	-1.8	-1.3	-1.5	-1.9	-1.5	-1.7	-1.8	-2.1	-1.9	1.0	-2.9	-1.0
D_3S_1	-1.2	-1.5	-1.4	-2.0	-2.3	-2.2	-2.3	-2.5	-2.4	-2.8	-2.7	-2.8	-1.9	-1.9	-1.9
D_3S_2	-1.1	-1.3	-1.2	-1.8	-2.1	-1.9	-2.2	-2.2	-2.2	-2.6	-2.6	-2.6	-0.8	-1.7	-1.2
D_3S_3	-1.0	-1.2	-1.1	-1.5	-2.1	-1.8	-2.0	-1.9	-1.9	-2.4	-2.6	-2.5	0.2	-1.6	-0.7
D_4S_1	-1.5	-1.7	-1.6	-2.0	-2.3	-2.1	-2.2	-1.4	-1.8	-2.5	-1.9	-2.2	-1.7	-1.9	-1.8
D_4S_2	-1.3	-1.6	-1.4	-1.8	-2.2	-2.0	-2.0	-1.4	-1.7	-2.4	-1.9	-2.2	0.3	-1.8	-0.8
D_4S_3	-1.0	-1.6	-1.3	-1.7	-2.1	-1.9	-1.8	-1.3	-1.6	-2.3	-1.9	-2.1	1.8	-1.3	0.2
D_5S_1	-1.5	-1.6	-1.5	-1.9	-2.3	-2.1	-2.4	-3.4	-2.9	-2.4	-2.9	-2.6	-1.7	-1.7	-1.7
D_5S_2	-1.3	-1.5	-1.4	-1.8	-2.2	-2.0	-2.1	-3.2	-2.7	-2.2	-2.7	-2.4	-0.5	-1.6	-1.0
D_5S_3	-1.2	-1.5	-1.3	-1.7	-2.1	-1.9	-2.0	-3.2	-2.6	-2.1	-2.7	-2.4	0.8	-1.6	-0.4

Table 52: Leaf- Air temperature differential (ΔTL) at 1430 hrs as influenced by different growing environments and planting geometry

Treatments	Leaf- Air temperature differential														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	3.8	7.7	5.7	0.7	1.8	1.3	0.9	0.4	0.7	6.3	1.0	3.7	4.1	4.2	4.2
D_2: June II fortnight	2.3	9.2	5.8	1.0	1.3	1.1	4.4	1.2	2.8	2.3	2.4	2.3	5.9	2.6	4.3
D_3: July I fortnight	2.9	1.2	2.1	2.9	5.3	4.1	0.3	3.3	1.8	2.9	2.8	2.8	4.3	3.0	3.6
D_4: July II fortnight	2.8	2.8	2.8	2.1	0.9	1.5	1.2	1.6	1.4	6.3	4.8	5.6	7.6	9.1	8.3
D_5:August I fortnight	2.6	8.2	5.4	2.6	1.3	1.9	2.8	3.4	3.1	2.0	2.2	2.1	1.7	2.3	2.0
Planting geometry (S)															
S_1 – 45 cm x 20 cm	3.1	5.4	4.2	1.3	1.6	1.5	1.2	1.4	1.3	3.5	1.6	2.6	5.1	4.2	4.7
S_2 – 60 cm x 20 cm	2.9	5.7	4.3	2.0	2.0	2.0	2.1	2.2	2.1	4.1	2.5	3.3	4.6	4.5	4.5
S_3 – 75 cm x 20 cm	2.6	6.5	4.5	2.2	2.7	2.5	2.6	2.3	2.5	4.3	3.8	4.1	4.4	4.0	4.2
Interaction (D x S)															
D_1S_1	4.0	6.9	5.4	0.3	1.6	1.0	0.2	0.3	0.3	5.8	0.0	2.9	4.8	4.2	4.5
D_1S_2	3.8	7.3	5.6	0.7	1.7	1.2	0.8	0.4	0.6	6.5	1.2	3.9	3.8	4.3	4.1
D_1S_3	3.5	9.0	6.3	1.2	2.1	1.6	1.7	0.5	1.1	6.7	1.9	4.3	3.6	4.2	3.9
D_2S_1	2.5	8.6	5.6	-0.4	0.7	0.1	3.6	0.0	1.8	1.7	1.3	1.5	6.1	1.3	3.7
D_2S_2	2.4	9.3	5.9	1.6	1.4	1.5	4.4	1.6	3.0	2.3	2.3	2.3	5.8	4.5	5.2
D_2S_3	2.0	9.8	5.9	1.7	1.8	1.8	5.3	1.9	3.6	2.9	3.5	3.2	5.7	2.1	3.9
D_3S_1	3.1	0.9	2.0	2.7	4.4	3.6	-0.2	2.3	1.1	2.5	1.8	2.2	4.4	2.7	3.6
D_3S_2	2.9	0.9	1.9	3.0	5.1	4.1	0.3	3.1	1.7	3.0	2.7	2.9	4.3	3.8	4.1
D_3S_3	2.7	1.8	2.3	3.0	6.4	4.7	0.7	4.4	2.6	3.2	3.8	3.5	4.1	2.5	3.3
D_4S_1	3.2	2.2	2.7	1.6	0.2	0.9	0.4	0.8	0.6	5.6	3.8	4.7	7.8	8.4	8.1
D_4S_2	3.0	2.7	2.9	2.2	0.8	1.5	1.6	1.6	1.6	6.5	4.3	5.4	7.6	9.8	8.7
D_4S_3	2.2	3.6	2.9	2.5	1.6	2.1	1.7	2.4	2.1	6.7	6.4	6.6	7.4	9.0	8.2
D_5S_1	2.8	8.3	5.6	2.3	1.1	1.7	1.8	3.4	2.6	1.8	1.2	1.5	2.6	4.4	3.5
D_5S_2	2.6	8.2	5.4	2.7	1.2	2.0	3.2	4.2	3.7	2.1	2.2	2.2	1.3	0.2	0.8
D_5S_3	2.4	8.2	5.3	2.8	1.5	2.2	3.5	2.5	3.0	2.2	3.2	2.7	1.1	2.2	1.7

Among the different sowing dates tried, the values ranged from -1.2 to -2.0,-1.6 to-2.0,-1.7 to -2.7,-2.1 to -2.6 and -0.8 to -1.7 ^{0}C during morning hours (0700 hrs) and 2.1 to 5.8, 1.1 to 4.1,0.7 to 3.1,2.1 to 5.6, 2 to 8.3 ^{0}C during afternoon hours (1430 hrs) at seedling, sixth leaf, tasseling, silking and physiological maturity stages, respectively. Among the three planting geometries tried, in the 45 cm x 20 cm planting geometry, differential values were higher during morning hours indicating more cooler leaf temperature than widely spaced maize. Also, during afternoon hours (1430 hrs) cooler leaf temperature values were observed in 45 cm x 20 cm than 75 cm x 20 cm spaced maize.

vi) Diurnal changes of soil surface temperature-air temperature differential at different phenological stages of maize

The data pertaining to diurnal changes in soil surface-air temperature differential as influenced by different sowing dates and planting geometry are presented in (Table 53 & 54).

The soil surface –air temperature differential values during morning hours, were negative at all the stages indicating that the soil surface temperature remained cooler than air during morning hours (0700 hrs). But, the values became positive during afternoon hours (1430 hrs) indicating the higher soil surface temperature of maize than air during afternoon hours of the day.

Among the different sowing dates tried, the values ranged from 0.1 to -0.5,-0.6 to -1.3,-1.3 to -2.5,-1.7 to -2.6 and -1.9 to 0.9 ^{0}C during morning hours (0700 hrs) and 4.3 to 10.4,3.2 to 11.9,-0.5 to 7.1, 0.0 to 7.0 and 3.7 to 8.9 ^{0}C during afternoon hours (1430 hrs) at seedling, sixth leaf, tasseling, silking and physiological maturity stages, respectively. Among the three planting geometries tried, in the 45 cm x 20 cm planting geometry, differential values were higher during morning hours indicating cooler soil surface temperature than widely spaced maize. Also, during afternoon hours (1430 hrs) cooler soil surface temperature values were observed in 45 cm x 20 cm than 75 cm x 20 cm spaced maize.

Table 53: Soil surface temperature- Air temperature differential (ΔTs) at 0700 hrs as influenced by different growing environments and planting geometry

Treatments	Soil surface temperature- Air temperature differential (ΔTs)														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	-0.5	0.0	-0.2	-1.3	0.0	-0.7	-1.8	-1.3	-1.5	-2.1	-1.6	-1.8	-0.1	-0.5	-0.3
D_2: June II fortnight	-0.2	-0.4	-0.3	-1.2	-0.2	-0.7	-1.7	-1.3	-1.5	-2.0	-2.0	-2.0	0.1	-2.3	-1.1
D_3: July I fortnight	-0.1	0.1	0.0	-1.1	-1.0	-1.1	-1.8	-1.8	-1.8	-2.4	-2.4	-2.4	-0.3	-1.0	-0.7
D_4: July II fortnight	-0.3	-0.2	-0.2	-1.2	-1.0	-1.1	-1.7	-1.0	-1.3	-2.2	-1.7	-2.0	0.6	-1.0	-0.2
D_5:August I fortnight	-0.3	-0.1	-0.2	-1.2	-1.1	-1.1	-1.8	-2.9	-2.3	-2.0	-2.5	-2.3	0.0	-1.0	-0.5
Planting geometry (S)															
S_1 – 45 cm x 20 cm	-0.4	-0.3	-0.4	-1.4	-0.8	-1.1	-1.9	-1.9	-1.9	-2.3	-2.2	-2.2	-1.4	-1.4	-1.4
S_2 – 60 cm x 20 cm	-0.2	-0.1	-0.2	-1.2	-0.6	-0.9	-1.7	-1.6	-1.7	-2.2	-2.0	-2.1	0.1	-1.2	-0.5
S_3 – 75 cm x 20 cm	-0.1	-0.1	-0.1	-1.1	-0.6	-0.8	-1.6	-1.5	-1.5	-2.0	-1.9	-1.9	1.4	-0.9	0.2
Interaction (D x S)															
D_1S_1	-0.6	-0.2	-0.4	-1.4	-0.1	-0.8	-1.9	-1.5	-1.7	-2.2	-1.9	-2.0	-1.4	-0.9	-1.1
D_1S_2	-0.4	0.0	-0.2	-1.3	0.0	-0.7	-1.7	-1.3	-1.5	-2.0	-1.6	-1.8	0.0	-0.7	-0.3
D_1S_3	-0.4	0.1	-0.1	-1.2	0.0	-0.6	-1.6	-1.1	-1.4	-1.9	-1.4	-1.7	1.0	0.0	0.5
D_2S_1	-0.4	-0.6	-0.5	-1.4	-0.3	-0.8	-1.9	-1.6	-1.8	-2.3	-2.2	-2.2	-1.4	-2.5	-1.9
D_2S_2	-0.2	-0.3	-0.2	-1.1	-0.2	-0.6	-1.6	-1.3	-1.4	-2.1	-2.0	-2.1	0.1	-2.2	-1.1
D_2S_3	-0.1	-0.3	-0.2	-1.1	-0.1	-0.6	-1.5	-1.0	-1.3	-1.6	-1.7	-1.7	1.5	-2.2	-0.4
D_3S_1	-0.3	-0.1	-0.2	-1.4	-1.1	-1.3	-2.0	-2.1	-2.0	-2.6	-2.5	-2.6	-1.4	-1.2	-1.3
D_3S_2	-0.1	0.1	0.0	-1.1	-1.0	-1.0	-1.8	-1.8	-1.8	-2.4	-2.4	-2.4	-0.2	-1.0	-0.6
D_3S_3	0.0	0.2	0.1	-0.8	-1.0	-0.9	-1.6	-1.5	-1.6	-2.2	-2.4	-2.3	0.8	-0.9	-0.1
D_4S_1	-0.5	-0.3	-0.4	-1.3	-1.2	-1.3	-1.8	-1.0	-1.4	-2.3	-1.7	-2.0	-1.3	-1.2	-1.2
D_4S_2	-0.3	-0.2	-0.2	-1.1	-1.0	-1.1	-1.7	-1.0	-1.3	-2.3	-1.7	-2.0	0.8	-1.1	-0.2
D_4S_3	0.0	-0.2	-0.1	-1.0	-0.9	-1.0	-1.5	-0.9	-1.2	-2.1	-1.7	-1.9	2.3	-0.6	0.9
D_5S_1	-0.5	-0.2	-0.3	-1.3	-1.2	-1.2	-2.0	-3.0	-2.5	-2.0	-2.7	-2.3	-1.3	-1.1	-1.2
D_5S_2	-0.3	-0.1	-0.2	-1.2	-1.1	-1.1	-1.7	-2.8	-2.3	-2.0	-2.5	-2.2	0.0	-1.0	-0.5
D_5S_3	-0.2	-0.1	-0.1	-1.0	-1.0	-1.0	-1.6	-2.8	-2.2	-1.9	-2.5	-2.2	1.3	-1.0	0.2

Table 54: Soil surface- Air temperature differential (ΔTs) at 1430 hrs as influenced by different growing environments and planting geometry

Treatments	Soil surface- Air temperature differential														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)															
D_1: June I fortnight	6.1	8.8	7.5	5.5	4.9	5.2	4.2	0.7	2.5	9.3	-3.1	3.1	5.5	5.8	5.7
D_2: June II fortnight	6.6	11.5	9.0	5.1	2.7	3.9	6.0	-0.8	2.6	2.4	-1.2	0.6	6.6	8.4	7.5
D_3: July I fortnight	8.1	2.0	5.0	7.6	13.1	10.3	1.1	-0.2	0.5	5.6	4.2	4.9	6.6	4.5	5.5
D_4: July II fortnight	7.5	4.0	5.8	7.1	11.3	9.2	4.5	-3.1	0.7	7.3	5.3	6.3	8.4	7.9	8.1
D_5:August I fortnight	6.3	13.7	10.0	6.9	4.3	5.6	8.9	2.8	5.8	5.3	4.9	5.1	4.6	5.3	5.0
Planting geometry (S)															
S_1 – 45 cm x 20 cm	6.4	7.3	6.8	5.3	6.5	5.9	4.1	-1.2	1.5	5.3	1.3	3.3	5.0	5.0	5.0
S_2 – 60 cm x 20 cm	7.0	8.0	7.5	6.3	7.1	6.7	4.9	-0.3	2.3	6.1	2.1	4.1	6.4	6.7	6.6
S_3 – 75 cm x 20 cm	7.4	8.6	8.0	7.7	8.2	8.0	5.8	1.2	3.5	6.5	2.7	4.6	7.6	7.5	7.5
Interaction (D x S)															
D_1S_1	5.9	8.3	7.1	5.0	4.1	4.6	3.6	0.3	2.0	8.8	-3.4	2.7	3.7	3.7	3.7
D_1S_2	6.1	9.0	7.6	5.3	5.0	5.1	4.0	0.7	2.4	9.4	-3.2	3.1	5.2	6.2	5.7
D_1S_3	6.3	9.1	7.7	6.2	5.7	5.9	5.0	1.1	3.1	9.8	-2.7	3.6	7.5	7.6	7.6
D_2S_1	6.3	11.1	8.7	4.2	2.3	3.2	5.0	-2.7	1.2	1.3	-1.3	0.0	4.7	7.9	6.3
D_2S_2	6.7	11.5	9.1	4.6	2.5	3.6	6.2	-0.9	2.7	2.8	-1.3	0.8	7.1	8.2	7.7
D_2S_3	6.8	11.8	9.3	6.6	3.4	5.0	6.8	1.3	4.1	3.0	-0.9	1.1	8.0	9.2	8.6
D_3S_1	7.5	1.0	4.3	5.7	12.8	9.3	0.5	-1.5	-0.5	5.3	2.8	4.1	4.9	2.5	3.7
D_3S_2	8.2	2.0	5.1	7.0	12.8	9.9	1.0	-0.4	0.3	5.4	4.3	4.9	6.5	5.4	6.0
D_3S_3	8.5	2.9	5.7	10.0	13.7	11.9	1.8	1.4	1.6	6.0	5.6	5.8	8.3	5.5	6.9
D_4S_1	6.3	3.0	4.7	5.9	9.8	7.9	3.4	-3.8	-0.2	6.4	4.6	5.5	7.6	7.0	7.3
D_4S_2	7.6	3.7	5.7	7.2	11.3	9.3	4.5	-3.0	0.8	7.4	5.4	6.4	8.6	7.9	8.3
D_4S_3	8.7	5.2	7.0	8.2	12.8	10.5	5.6	-2.4	1.6	8.1	5.9	7.0	9.0	8.7	8.9
D_5S_1	5.8	13.1	9.5	5.7	3.7	4.7	8.0	1.8	4.9	4.8	3.6	4.2	3.9	3.7	3.8
D_5S_2	6.6	14.0	10.3	7.3	3.9	5.6	9.0	2.0	5.5	5.4	5.2	5.3	4.7	5.9	5.3
D_5S_3	6.6	14.1	10.4	7.7	5.4	6.6	9.6	4.5	7.1	5.7	5.8	5.8	5.3	6.3	5.8

4.4.1.5 Soil temperature profile studies at different depths

Soil temperature plays a very important role in the microclimate of crop. It influences the growth and development of maize crop. Hence, the diurnal variation in soil temperature at two depths *viz.*, 5 and 15 cm as influenced by sowing dates and planting geometry were studied and presented in (Table 55 to 58).

Mean of two years indicated that during morning hours of the day (0700 hrs), soil temperature at 5 cm depth declined with delayed sowings from June I FN (D_1) to August I FN (D_5) sowing at all the stages (except at tasseling and silking). It declined from 23.9 to 22.8 ^{0}C at seedling stage and 22.4 to 20.8 ^{0}C at sixth leaf stage. But, raised at tasseling (20.6 to 21.1 ^{0}C) and at silking stages (19.6 to 20.4 ^{0}C).

Also, it was observed that among the three planting geometries, soil temperature at 5 cm depth increased with increase in spacing at all the phenological stages (23 – 23.3, 21.4 – 21.6, 20.5 – 20.9, 19.7 – 20, 20.5 – 22.2 ^{0}C, respectively). Similarly, combination of early sowing with wider spacing recorded higher soil temperatures at 5 cm depth over other treatment combinations.

At 15 cm depth also, the mean of two years showed a gradual decline in soil temperature with delayed sowings (25.3 – 24.1, 23.5 – 21.9 and 23.2 – 20.3 ^{0}C, respectively) during seedling, sixth leaf and physiological maturity stages but increased during tasseling (21.3 – 21.7) and silking (20.2 – 20.6 ^{0}C). Among the three planting geometries tried, wider spacing of 75 x 20 cm (S_3) recorded a higher soil temperature (24.7, 22.7, 21.5, 20.6 and 23.1 ^{0}C, respectively) compared to narrow spacing (24.4, 22.4, 21.1, 20.3 and 21.3 ^{0}C, respectively). Similar trend was observed at all the phenological stages. The soil temperature at 15 cm was higher than 5 cm depth indicating the soil heat flux from lower to surface layer during night hours.

During afternoon hours of the day (1430 hrs) the soil temperature at 5 and 15 cm depths did not show any specific trend among the sowing dates. But, at both the depths (5 and 15 cm), soil temperature increased with increase in row spacing (wider planting geometry). However, the data indicate that soil temperature at 5 cm depth was greater compared to 15 cm depth indicating heat flux from surface to lower (15 cm) depth. Thus, the soil temperature during afternoon hours of the day (1430 hrs) decreased with increase in soil depth.

Table 55: Soil temperature (^{o}C) at 5 cm depth in the morning (0700 hrs) as influenced by different growing environments and planting geometry

Treatments	Soil temperature (^{o}C) at 5 cm depth in the morning (0700 hrs)														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Date of sowing (D)															
D_1: June I fortnight	23.0	24.6	23.8	21.7	23.1	22.4	20.2	21.1	20.6	18.8	20.4	19.6	22.1	22.5	22.3
D_2: June II fortnight	23.5	24.2	23.9	21.2	22.9	22.0	20.1	21.7	20.9	19.8	19.5	19.7	22.1	21.3	21.7
D_3: July I fortnight	22.6	23.6	23.1	21.1	21.4	21.2	20.6	20.6	20.6	20.9	19.8	20.4	22.8	21.2	22.0
D_4: July II fortnight	22.4	22.6	22.5	20.1	22.0	21.1	19.5	21.0	20.2	19.0	20.0	19.5	20.8	21.7	21.2
D_5:August I fortnight	22.3	23.2	22.8	19.9	21.7	20.8	21.2	20.9	21.1	18.6	21.4	20.0	20.6	18.4	19.5
Planting geometry (S)															
S_1 – 45 cm x 20 cm	22.6	23.5	23.0	20.6	22.1	21.4	20.1	20.8	20.5	19.3	20.1	19.7	20.2	20.8	20.5
S_2 – 60 cm x 20 cm	22.8	23.7	23.3	20.8	22.3	21.5	20.3	21.1	20.7	19.4	20.2	19.8	21.8	21.0	21.4
S_3 – 75 cm x 20 cm	22.9	23.7	23.3	21.0	22.3	21.6	20.5	21.3	20.9	19.6	20.3	20.0	23.1	21.3	22.2
Interaction (D x S)															
D_1S_1	22.9	24.4	23.7	21.6	23.0	22.3	20.0	20.9	20.5	18.6	20.2	19.4	20.8	22.2	21.5
D_1S_2	23.1	24.6	23.9	21.7	23.1	22.4	20.2	21.1	20.7	18.8	20.5	19.6	22.3	22.4	22.3
D_1S_3	23.1	24.7	23.9	21.8	23.1	22.5	20.3	21.3	20.8	18.9	20.7	19.8	23.4	23.1	23.2
D_2S_1	23.3	24.0	23.7	21.0	22.8	21.9	19.8	21.4	20.6	19.5	19.3	19.4	20.6	21.1	20.8
D_2S_2	23.5	24.3	23.9	21.3	22.9	22.1	20.1	21.8	21.0	19.7	19.4	19.6	22.2	21.4	21.8
D_2S_3	23.6	24.3	24.0	21.3	23.0	22.1	20.2	22.1	21.2	20.3	19.7	20.0	23.7	21.4	22.5
D_3S_1	22.4	23.5	22.9	20.8	21.2	21.0	20.4	20.2	20.3	20.7	19.7	20.2	21.6	21.0	21.3
D_3S_2	22.6	23.7	23.1	21.1	21.4	21.3	20.6	20.6	20.6	20.9	19.9	20.4	22.9	21.2	22.0
D_3S_3	22.7	23.8	23.2	21.4	21.4	21.4	20.8	20.9	20.8	21.1	19.9	20.5	23.9	21.3	22.6
D_4S_1	22.2	22.6	22.4	20.0	21.8	20.9	19.3	21.0	20.1	18.9	20.0	19.4	18.8	21.4	20.1
D_4S_2	22.4	22.7	22.5	20.2	22.1	21.1	19.5	21.0	20.2	19.0	20.0	19.5	21.0	21.5	21.2
D_4S_3	22.7	22.7	22.7	20.3	22.2	21.2	19.7	21.1	20.4	19.1	20.0	19.6	22.6	22.1	22.3
D_5S_1	22.2	23.1	22.6	19.8	21.6	20.7	21.0	20.8	20.9	18.6	21.3	19.9	19.2	18.3	18.7
D_5S_2	22.4	23.2	22.8	19.9	21.7	20.8	21.3	21.0	21.1	18.6	21.4	20.0	20.6	18.5	19.5
D_5S_3	22.5	23.2	22.8	20.1	21.8	21.0	21.5	21.0	21.2	18.7	21.4	20.1	22.0	18.5	20.2

Table 56: Soil temperature (°C) at 15 cm depth in the morning (0700 hrs) as influenced by different growing environments and planting geometry

Treatments	Soil temperature (°C) at 15 cm depth in the morning (0700 hrs)														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Date of sowing (D)															
D_1: June I fortnight	24.4	26.1	25.3	22.8	24.2	23.5	20.8	21.7	21.3	19.3	21.1	20.2	23.0	23.5	23.2
D_2: June II fortnight	24.9	25.7	25.3	22.2	24.1	23.1	20.7	22.4	21.5	20.4	20.1	20.2	23.0	22.1	22.6
D_3: July I fortnight	23.9	25.1	24.5	22.1	22.4	22.3	21.2	21.2	21.2	21.5	20.4	21.0	23.7	22.0	22.9
D_4: July II fortnight	23.8	24.0	23.9	21.2	23.1	22.1	20.1	21.6	20.8	19.6	20.6	20.1	21.6	22.5	22.1
D_5:August I fortnight	23.7	24.6	24.1	20.9	22.8	21.9	21.9	21.5	21.7	19.2	22.0	20.6	21.4	19.2	20.3
Planting geometry (S)															
S_1 – 45 cm x 20 cm	23.9	24.9	24.4	21.7	23.2	22.4	20.7	21.5	21.1	19.8	20.7	20.3	21.0	21.6	21.3
S_2 – 60 cm x 20 cm	24.2	25.1	24.6	21.9	23.4	22.6	21.0	21.7	21.3	20.0	20.9	20.4	22.6	21.8	22.2
S_3 – 75 cm x 20 cm	24.3	25.2	24.7	22.0	23.4	22.7	21.1	21.9	21.5	20.2	20.9	20.6	24.0	22.1	23.1
Interaction (D x S)															
D_1S_1	24.3	25.9	25.1	22.7	24.2	23.4	20.6	21.5	21.1	19.2	20.8	20.0	21.6	23.1	22.3
D_1S_2	24.5	26.1	25.3	22.8	24.3	23.5	20.8	21.7	21.3	19.3	21.1	20.2	23.2	23.3	23.2
D_1S_3	24.7	26.5	25.6	23.1	24.5	23.8	21.2	22.2	21.7	19.7	21.5	20.6	24.5	24.2	24.4
D_2S_1	24.7	25.4	25.1	22.0	23.9	23.0	20.4	22.0	21.2	20.1	19.8	20.0	21.4	21.9	21.7
D_2S_2	24.9	25.8	25.4	22.3	24.1	23.2	20.7	22.4	21.6	20.3	20.0	20.2	23.1	22.2	22.6
D_2S_3	25.3	26.0	25.7	22.6	24.4	23.5	21.1	23.0	22.1	21.1	20.6	20.9	24.9	22.5	23.7
D_3S_1	23.7	24.9	24.3	21.8	22.3	22.1	21.0	20.8	20.9	21.3	20.3	20.8	22.4	21.8	22.1
D_3S_2	24.0	25.1	24.5	22.1	22.5	22.3	21.2	21.2	21.2	21.5	20.5	21.0	23.8	22.0	22.9
D_3S_3	24.4	25.6	25.0	22.7	22.7	22.7	21.7	21.8	21.7	22.0	20.7	21.4	25.2	22.4	23.8
D_4S_1	23.5	23.9	23.7	21.0	22.9	22.0	19.9	21.6	20.7	19.4	20.6	20.0	19.6	22.2	20.9
D_4S_2	23.7	24.0	23.9	21.2	23.2	22.2	20.1	21.6	20.8	19.5	20.6	20.1	21.8	22.3	22.1
D_4S_3	24.4	24.4	24.4	21.5	23.5	22.5	20.5	22.0	21.2	20.0	20.8	20.4	23.9	23.4	23.6
D_5S_1	23.5	24.5	24.0	20.8	22.7	21.7	21.6	21.4	21.5	19.2	21.9	20.5	20.0	19.2	19.6
D_5S_2	23.7	24.6	24.2	20.9	22.8	21.9	21.9	21.6	21.8	19.2	22.1	20.6	21.4	19.5	20.4
D_5S_3	24.4	25.2	24.8	21.6	23.5	22.5	22.6	22.1	22.3	19.7	22.6	21.1	23.4	19.7	21.5

Table 57: Soil temperature (^oC) at 5 cm depth in the afternoon (1430 hrs) as influenced by different growing environments and planting geometry

Treatments	Soil temperature (^oC)														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Date of sowing (D)															
D_1: June I fortnight	31.7	36.1	33.9	27.9	30.3	29.1	26.5	25.7	26.1	31.4	25.3	28.4	31.4	31.9	31.6
D_2: June II fortnight	31.6	37.4	34.5	27.4	26.6	27.0	33.3	27.4	30.3	27.2	24.2	25.7	31.9	35.9	33.9
D_3: July I fortnight	30.5	26.2	28.3	31.2	35.8	33.5	24.5	22.4	23.5	30.2	28.7	29.4	32.1	31.5	31.8
D_4: July II fortnight	31.0	26.6	28.8	30.1	39.1	34.6	27.1	23.2	25.1	30.0	29.3	29.6	33.1	33.1	33.1
D_5:August I fortnight	30.4	38.9	34.7	33.5	27.9	30.7	31.8	27.7	29.8	30.7	30.7	30.7	31.4	30.3	30.9
Planting geometry (S)															
S_1 – 45 cm x 20 cm	30.5	32.4	31.5	29.0	31.3	30.1	27.9	24.4	26.1	29.3	26.9	28.1	30.7	31.2	31.0
S_2 – 60 cm x 20 cm	31.2	33.1	32.1	29.9	31.8	30.8	28.6	25.1	26.8	30.0	27.7	28.8	32.1	32.8	32.5
S_3 – 75 cm x 20 cm	31.5	33.6	32.5	31.2	32.8	32.0	29.4	26.4	27.9	30.4	28.3	29.3	33.2	33.5	33.3
Interaction (D x S)															
D_1S_1	31.5	35.6	33.6	27.4	29.5	28.5	25.9	25.8	25.8	31.0	25.0	28.0	29.8	29.9	29.8
D_1S_2	31.7	36.3	34.0	27.7	30.3	29.0	26.3	25.6	25.9	31.5	25.2	28.4	31.1	32.2	31.7
D_1S_3	31.9	36.4	34.1	28.5	31.0	29.7	27.2	25.9	26.6	31.9	25.7	28.8	33.2	33.5	33.4
D_2S_1	31.3	37.0	34.2	26.5	26.2	26.3	32.4	25.7	29.0	26.3	24.1	25.2	30.2	35.4	32.8
D_2S_2	31.7	37.4	34.5	26.9	26.4	26.6	33.5	27.3	30.4	27.6	24.1	25.9	32.4	35.7	34.0
D_2S_3	31.8	37.7	34.7	28.7	27.2	28.0	34.0	29.3	31.6	27.8	24.5	26.1	33.2	36.6	34.9
D_3S_1	29.9	25.3	27.6	29.5	35.5	32.5	23.9	21.2	22.6	30.0	27.4	28.7	30.6	29.7	30.1
D_3S_2	30.6	26.2	28.4	30.7	35.5	33.1	24.4	22.2	23.3	30.1	28.7	29.4	32.0	32.3	32.2
D_3S_3	30.9	27.1	29.0	33.5	36.3	34.9	25.1	23.9	24.5	30.6	29.9	30.2	33.7	32.4	33.0
D_4S_1	29.9	25.7	27.8	29.0	37.7	33.4	26.1	22.5	24.3	29.2	28.6	28.9	32.4	32.3	32.4
D_4S_2	31.1	26.3	28.7	30.2	39.1	34.6	27.1	23.2	25.2	30.1	29.3	29.7	33.3	33.1	33.2
D_4S_3	32.1	27.7	29.9	31.1	40.5	35.8	28.1	23.8	25.9	30.7	29.8	30.2	33.7	33.9	33.8
D_5S_1	29.9	38.3	34.1	32.4	27.3	29.9	31.1	26.8	28.9	30.2	29.5	29.9	30.8	28.8	29.8
D_5S_2	30.7	39.2	34.9	33.9	27.5	30.7	32.0	27.0	29.5	30.8	31.0	30.9	31.5	30.8	31.2
D_5S_3	30.7	39.2	35.0	34.2	28.9	31.6	32.5	29.3	30.9	31.1	31.5	31.3	32.0	31.2	31.6

Table 58: Soil temperature (°C) at15 cm depth in the afternoon (1430 hrs) as influenced by different growing environments and planting geometry

Treatments	Soil temperature (°C) at15 cm depth in the afternoon (1430 hrs)														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Date of sowing (D)															
D_1: June I fortnight	30.1	34.3	32.2	26.5	28.8	27.6	24.1	23.4	23.8	28.6	23.0	25.8	28.9	29.3	29.1
D_2: June II fortnight	30.0	35.5	32.8	26.0	25.3	25.6	30.3	24.9	27.6	24.8	22.1	23.4	29.4	33.0	31.2
D_3: July I fortnight	28.9	24.9	26.9	29.7	34.0	31.8	22.3	20.4	21.3	27.5	26.1	26.8	29.5	28.9	29.2
D_4: July II fortnight	29.5	25.2	27.3	28.6	37.1	32.9	24.7	21.1	22.9	27.3	26.6	26.9	30.5	30.4	30.5
D_5:August I fortnight	28.9	37.0	32.9	31.8	26.5	29.2	29.0	25.2	27.1	27.9	27.9	27.9	28.9	27.9	28.4
Planting geometry (S)															
S_1 – 45 cm x 20 cm	29.0	30.8	29.9	27.5	29.7	28.6	25.4	22.2	23.8	26.7	24.5	25.6	28.3	28.7	28.5
S_2 – 60 cm x 20 cm	29.6	31.4	30.5	28.4	30.2	29.3	26.1	22.8	24.4	27.3	25.2	26.2	29.5	30.2	29.9
S_3 – 75 cm x 20 cm	29.9	31.9	30.9	29.6	31.1	30.4	26.7	24.0	25.4	27.7	25.7	26.7	30.5	30.8	30.7
Interaction (D x S)															
D_1S_1	30.0	33.8	31.9	26.0	28.1	27.1	23.6	23.4	23.5	28.2	22.8	25.5	27.4	27.5	27.5
D_1S_2	30.1	34.5	32.3	26.3	28.8	27.6	23.9	23.3	23.6	28.7	22.9	25.8	28.6	29.6	29.1
D_1S_3	30.3	34.5	32.4	27.1	29.4	28.3	24.7	23.6	24.2	29.0	23.3	26.2	30.6	30.8	30.7
D_2S_1	29.8	35.2	32.5	25.2	24.9	25.0	29.5	23.3	26.4	23.9	21.9	22.9	27.8	32.6	30.2
D_2S_2	30.1	35.5	32.8	25.5	25.1	25.3	30.5	24.8	27.6	25.1	21.9	23.5	29.8	32.8	31.3
D_2S_3	30.2	35.8	33.0	27.3	25.9	26.6	31.0	26.6	28.8	25.3	22.3	23.8	30.6	33.7	32.1
D_3S_1	28.4	24.0	26.2	28.1	33.7	30.9	21.8	19.3	20.6	27.3	24.9	26.1	28.1	27.3	27.7
D_3S_2	29.1	24.9	27.0	29.2	33.7	31.5	22.2	20.2	21.2	27.4	26.1	26.7	29.5	29.7	29.6
D_3S_3	29.3	25.7	27.5	31.8	34.5	33.2	22.9	21.7	22.3	27.8	27.2	27.5	31.0	29.8	30.4
D_4S_1	28.4	24.4	26.4	27.5	35.8	31.7	23.8	20.5	22.1	26.5	26.0	26.3	29.8	29.7	29.8
D_4S_2	29.5	25.0	27.3	28.7	37.1	32.9	24.7	21.1	22.9	27.4	26.7	27.0	30.6	30.5	30.6
D_4S_3	30.5	26.3	28.4	29.5	38.5	34.0	25.6	21.6	23.6	27.9	27.1	27.5	31.0	31.1	31.1
D_5S_1	28.4	36.4	32.4	30.8	26.0	28.4	28.3	24.4	26.3	27.5	26.9	27.2	28.3	26.5	27.4
D_5S_2	29.2	37.2	33.2	32.2	26.1	29.1	29.1	24.6	26.8	28.0	28.2	28.1	29.0	28.4	28.7
D_5S_3	29.2	37.3	33.2	32.5	27.4	30.0	29.6	26.6	28.1	28.3	28.7	28.5	29.5	28.7	29.1

4.4.1.6 Soil moisture content (%) at different depth

Soil moisture content (%) at 0-15 cm, 15-30 cm and 30-45 cm depths was studied at different phenological stages during both the years for different sowing dates and planting geometries (Table 59 to 61).

Soil moisture content (%) at 0-15 cm during different phenophases did not show any specific trend. However, the mean of two years indicated that, it ranged from 20.1 to 25.1 per cent at seedling stage (V_1), 21.3 to 32.4 per cent at sixth leaf stage (V_6), 23.3 to 32.9 per cent at tasseling, 19.5 to 33.3 per cent at silking and 20.4 to 28.9 per cent at physiological maturity was observed. Among the three planting geometries tried, narrow spacing (45 x 20 cm) had higher soil moisture content at 0-15 cm depth over other planting geometries tried at sixth leaf stage (27.8 %), tasseling (31.3 %), silking (29.2 %) and physiological maturity (26.6 %).

At 15-30 cm depth, the mean of two years indicated that, at 15-30 cm depth soil moisture ranged from 22.3 to 27.9 per cent at seedling stage (V_1), 24.1 to 36.6 per cent at sixth leaf stage (V_6), 21.8 to 37.2 per cent at tasseling, 21.5 to 36.6 per cent at silking and 24.0 to 31.7 per cent at physiological maturity was observed. Among the three planting geometries tried, narrow spacing (45 x 20 cm) had higher soil moisture content at 15-30 cm depth over other planting geometries tried at sixth leaf stage (31.4 %), tasseling (34.3 %), silking (32 %) and physiological maturity (29.2 %). Similar kind of soil moisture pattern was observed in 30-45 cm soil depth.

4.5 Economics

4.5.1 Gross return (` $ha^{-1}$), net returns (` ha^{-1}) and B:C ratio as influenced by sowing dates and planting geometry

Variation in gross return, net return and B:C ratio were computed for different sowing dates and planting geometry during both crop season and pooled data (Table 62)

During 2013, among the sowing dates, June I fortnight sowing recorded significantly higher gross return (` 93010 $ha^{-1}$), net returns (` 63618 ha^{-1}) and B:C ratio (3.16). It was followed by June II fortnight sowing (` 84308, ` 54915 and 2.87, respectively). The lowest monetary benefits were obtained in August I fortnight sowing

Table 59: Soil moisture (%) at 0-15 cm depth as influenced by different growing environments and planting geometry

Treatments	Soil moisture at 0-15 cm depth (%)														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Date of sowing (D)															
D_1: June I fortnight	22.8	18.6	**20.7**	29.5	20.3	**24.9**	29.0	29.5	**29.3**	30.4	30.4	**30.4**	24.8	27.1	**26.0**
D_2: June II fortnight	23.2	18.8	**21.0**	28.9	22.1	**25.5**	27.9	30.5	**29.2**	27.7	28.9	**28.3**	26.2	26.1	**26.2**
D_3: July I fortnight	23.6	22.3	**23.0**	28.4	33.4	**30.9**	27.8	33.6	**30.7**	29.1	28.4	**28.8**	26.8	27.9	**27.4**
D_4: July II fortnight	23.9	25.6	**24.8**	23.3	27.6	**25.5**	29.6	28.7	**29.2**	27.5	26.6	**27.1**	22.4	22.5	**22.4**
D_5:August I fortnight	22.7	23.5	**23.1**	20.6	25.2	**22.9**	27.1	24.3	**25.7**	19.7	22.2	**21.0**	21.1	24.1	**22.6**
Planting geometry (S)															
S_1 – 45 cm x 20 cm	22.2	20.9	**21.6**	28.2	27.4	**27.8**	30.5	32.0	**31.3**	29.0	29.2	**29.1**	25.6	27.5	**26.6**
S_2 – 60 cm x 20 cm	23.6	21.6	**22.6**	26.0	25.8	**25.9**	28.5	29.8	**29.1**	27.0	27.3	**27.2**	24.5	25.7	**25.1**
S_3 – 75 cm x 20 cm	23.9	22.7	**23.3**	24.2	24.0	**24.1**	25.9	26.2	**26.0**	24.6	25.3	**25.0**	22.7	23.4	**23.1**
Interaction (D x S)															
D_1S_1	22.0	18.2	**20.1**	31.2	21.2	**26.2**	32.0	32.4	**32.2**	34.0	32.6	**33.3**	26.6	29.6	**28.1**
D_1S_2	23.2	18.6	**20.9**	29.6	20.6	**25.1**	28.6	29.6	**29.1**	31.2	30.2	**30.7**	25.6	27.6	**26.6**
D_1S_3	23.3	19.0	**21.2**	27.6	19.2	**23.4**	26.5	26.6	**26.6**	26.0	28.4	**27.2**	22.2	24.2	**23.2**
D_2S_1	22.6	18.2	**20.4**	32.2	23.6	**27.9**	30.0	33.3	**31.7**	29.6	30.3	**30.0**	27.3	28.5	**27.9**
D_2S_2	23.3	18.1	**20.7**	28.2	21.8	**25.0**	28.6	30.4	**29.5**	27.2	28.8	**28.0**	26.4	26.5	**26.5**
D_2S_3	23.6	20.0	**21.8**	26.2	20.8	**23.5**	25.2	27.8	**26.5**	26.2	27.6	**26.9**	25.0	23.2	**24.1**
D_3S_1	22.0	20.9	**21.5**	30.2	34.5	**32.4**	29.6	36.2	**32.9**	32.2	30.2	**31.2**	28.4	29.3	**28.9**
D_3S_2	24.2	22.3	**23.3**	28.6	33.6	**31.1**	28.1	34.6	**31.4**	29.6	28.9	**29.3**	26.8	28.0	**27.4**
D_3S_3	24.6	23.7	**24.2**	26.4	32.0	**29.2**	25.6	30.0	**27.8**	25.6	26.0	**25.8**	25.2	26.5	**25.9**
D_4S_1	23.6	25.2	**24.4**	25.5	30.0	**27.8**	32.6	31.5	**32.1**	28.6	28.4	**28.5**	24.2	25.1	**24.7**
D_4S_2	24.0	25.6	**24.8**	23.5	27.6	**25.6**	29.6	29.2	**29.4**	27.6	26.8	**27.2**	22.7	21.8	**22.3**
D_4S_3	24.2	26.0	**25.1**	21.0	25.2	**23.1**	26.7	25.3	**26.0**	26.3	24.6	**25.5**	20.3	20.6	**20.4**
D_5S_1	21.0	22.2	**21.6**	22.0	27.5	**24.8**	28.5	26.5	**27.5**	20.6	24.6	**22.6**	21.3	25.2	**23.3**
D_5S_2	23.2	23.6	**23.4**	20.3	25.2	**22.8**	27.4	25.2	**26.3**	19.6	22.0	**20.8**	21.0	24.4	**22.7**
D_5S_3	24.0	24.8	**24.4**	19.6	23.0	**21.3**	25.3	21.3	**23.3**	19.0	20.0	**19.5**	21.0	22.6	**21.8**

Table 60: Soil moisture (%) at 15-30 cm depth as influenced by different growing environments and planting geometry

Treatments	Soil moisture at 15-30 cm depth (%)														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Date of sowing (D)															
D_1: June I fortnight	25.6	20.5	**23.0**	33.3	23.0	**28.1**	32.8	33.4	**33.1**	33.4	33.4	**33.4**	27.3	29.8	**28.6**
D_2: June II fortnight	25.9	20.6	**23.3**	32.6	24.9	**28.8**	31.6	34.5	**33.0**	30.4	31.8	**31.1**	28.9	28.7	**28.8**
D_3: July I fortnight	26.4	24.5	**25.5**	32.1	37.7	**34.9**	31.4	38.0	**34.7**	32.0	31.2	**31.6**	29.5	30.7	**30.1**
D_4: July II fortnight	26.8	28.2	**27.5**	26.4	31.2	**28.8**	33.5	32.4	**32.9**	30.3	29.3	**29.8**	24.6	24.8	**24.7**
D_5:August I fortnight	25.5	25.9	**25.7**	23.3	28.5	**25.9**	21.2	27.5	**24.3**	21.7	24.4	**23.1**	23.2	26.5	**24.8**
Planting geometry (S)															
S_1 – 45 cm x 20 cm	24.9	23.0	**24.0**	31.9	30.9	**31.4**	32.5	36.1	**34.3**	31.9	32.1	**32.0**	28.1	30.3	**29.2**
S_2 – 60 cm x 20 cm	26.4	23.8	**25.1**	29.4	29.1	**29.3**	30.3	33.7	**32.0**	29.7	30.1	**29.9**	27.0	28.2	**27.6**
S_3 – 75 cm x 20 cm	26.8	25.0	**25.9**	27.3	27.2	**27.2**	27.4	29.6	**28.5**	27.1	27.9	**27.5**	25.0	25.8	**25.4**
Interaction (D x S)															
D_1S_1	24.6	20.0	**22.3**	35.3	24.0	**29.6**	36.2	36.6	**36.4**	37.4	35.9	**36.6**	29.3	32.6	**30.9**
D_1S_2	26.0	20.5	**23.2**	33.4	23.3	**28.4**	32.3	33.4	**32.9**	34.3	33.2	**33.8**	28.2	30.4	**29.3**
D_1S_3	26.1	20.9	**23.5**	31.2	21.7	**26.4**	29.9	30.1	**30.0**	28.6	31.2	**29.9**	24.4	26.6	**25.5**
D_2S_1	25.3	20.0	**22.7**	36.4	26.7	**31.5**	33.9	37.6	**35.8**	32.6	33.3	**32.9**	30.0	31.4	**30.7**
D_2S_2	26.1	19.9	**23.0**	31.9	24.6	**28.3**	32.3	34.4	**33.3**	29.9	31.7	**30.8**	29.0	29.2	**29.1**
D_2S_3	26.4	22.0	**24.2**	29.6	23.5	**26.6**	28.5	31.4	**29.9**	28.8	30.4	**29.6**	27.5	25.5	**26.5**
D_3S_1	24.6	23.0	**23.8**	34.1	39.0	**36.6**	33.4	40.9	**37.2**	35.4	33.2	**34.3**	31.2	32.2	**31.7**
D_3S_2	27.1	24.5	**25.8**	32.3	38.0	**35.1**	31.8	39.1	**35.4**	32.6	31.8	**32.2**	29.5	30.8	**30.1**
D_3S_3	27.6	26.1	**26.8**	29.8	36.2	**33.0**	28.9	33.9	**31.4**	28.2	28.6	**28.4**	27.7	29.2	**28.4**
D_4S_1	26.4	27.7	**27.1**	28.8	33.9	**31.4**	36.8	35.6	**36.2**	31.5	31.2	**31.4**	26.6	27.6	**27.1**
D_4S_2	26.9	28.2	**27.5**	26.6	31.2	**28.9**	33.4	33.0	**33.2**	30.4	29.5	**29.9**	25.0	24.0	**24.5**
D_4S_3	27.1	28.6	**27.9**	23.7	28.5	**26.1**	30.2	28.6	**29.4**	28.9	27.1	**28.0**	22.3	22.7	**22.5**
D_5S_1	23.5	24.4	**24.0**	24.9	31.1	**28.0**	22.4	29.9	**26.2**	22.7	27.1	**24.9**	23.4	27.7	**25.6**
D_5S_2	26.0	26.0	**26.0**	22.9	28.5	**25.7**	21.6	28.5	**25.0**	21.6	24.2	**22.9**	23.1	26.8	**25.0**
D_5S_3	26.9	27.3	**27.1**	22.1	26.0	**24.1**	19.5	24.1	**21.8**	20.9	22.0	**21.5**	23.1	24.9	**24.0**

Table 61: Soil moisture (%) at 30-45 cm depth as influenced by different growing environments and planting geometry

Treatments	Soil moisture at 30-45 cm depth (%)														
	Seedling (V_1)			Six leaf (V_6)			Tasseling (vT)			Silking			Physiological maturity		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Date of sowing (D)															
D_1: June I fortnight	26.3	20.7	**23.5**	34.0	23.4	**28.7**	33.5	34.0	**33.8**	34.1	34.1	**34.1**	26.7	29.2	**28.0**
D_2: June II fortnight	26.7	20.8	**23.8**	33.3	25.4	**29.4**	32.2	35.2	**33.7**	31.0	32.4	**31.7**	28.3	28.1	**28.2**
D_3: July I fortnight	27.2	24.8	**26.0**	32.7	38.5	**35.6**	32.0	38.7	**35.4**	32.7	31.8	**32.3**	28.9	30.1	**29.5**
D_4: July II fortnight	27.6	28.4	**28.0**	26.9	31.8	**29.4**	34.2	33.0	**33.6**	30.9	29.8	**30.4**	24.1	24.3	**24.2**
D_5:August I fortnight	26.2	26.1	**26.2**	23.8	29.1	**26.4**	21.6	28.0	**24.8**	22.1	24.9	**23.5**	22.7	25.9	**24.3**
Planting geometry (S)															
S_1 – 45 cm x 20 cm	25.7	23.3	**24.5**	32.5	31.5	**32.0**	33.2	36.9	**35.0**	32.5	32.8	**32.7**	27.6	29.7	**28.6**
S_2 – 60 cm x 20 cm	27.2	24.0	**25.6**	30.0	29.7	**29.9**	30.9	34.3	**32.6**	30.3	30.7	**30.5**	26.4	27.7	**27.0**
S_3 – 75 cm x 20 cm	27.6	25.2	**26.4**	27.8	27.7	**27.8**	28.0	30.2	**29.1**	27.6	28.4	**28.0**	24.5	25.2	**24.9**
Interaction (D x S)															
D_1S_1	25.4	20.2	**22.8**	36.0	24.4	**30.2**	36.9	37.3	**37.1**	38.1	36.6	**37.4**	28.7	31.9	**30.3**
D_1S_2	26.8	20.7	**23.7**	34.1	23.7	**28.9**	33.0	34.1	**33.5**	35.0	33.9	**34.4**	27.6	29.8	**28.7**
D_1S_3	26.9	21.1	**24.0**	31.8	22.1	**27.0**	30.5	30.7	**30.6**	29.2	31.9	**30.5**	23.9	26.1	**25.0**
D_2S_1	26.1	20.2	**23.1**	37.1	27.2	**32.2**	34.6	38.4	**36.5**	33.2	34.0	**33.6**	29.4	30.7	**30.1**
D_2S_2	26.9	20.1	**23.5**	32.5	25.1	**28.8**	33.0	35.0	**34.0**	30.5	32.3	**31.4**	28.5	28.6	**28.5**
D_2S_3	27.2	22.2	**24.7**	30.2	24.0	**27.1**	29.0	32.0	**30.5**	29.4	31.0	**30.2**	27.0	25.0	**26.0**
D_3S_1	25.4	23.2	**24.3**	34.8	39.8	**37.3**	34.1	41.7	**37.9**	36.1	33.9	**35.0**	30.6	31.6	**31.1**
D_3S_2	27.9	24.8	**26.3**	33.0	38.7	**35.8**	32.4	39.9	**36.1**	33.2	32.4	**32.8**	28.9	30.2	**29.5**
D_3S_3	28.4	26.3	**27.4**	30.4	36.9	**33.7**	29.5	34.6	**32.0**	28.7	29.2	**28.9**	27.2	28.6	**27.9**
D_4S_1	27.2	28.0	**27.6**	29.4	34.6	**32.0**	37.6	36.3	**36.9**	32.1	31.9	**32.0**	26.1	27.1	**26.6**
D_4S_2	27.7	28.4	**28.1**	27.1	31.8	**29.4**	34.1	33.7	**33.9**	31.0	30.1	**30.5**	24.5	23.5	**24.0**
D_4S_3	27.9	28.9	**28.4**	24.2	29.0	**26.6**	30.8	29.2	**30.0**	29.5	27.6	**28.6**	21.8	22.2	**22.0**
D_5S_1	24.2	24.7	**24.4**	25.4	31.7	**28.5**	22.8	30.5	**26.7**	23.1	27.6	**25.4**	23.0	27.2	**25.1**
D_5S_2	26.8	26.2	**26.5**	23.4	29.0	**26.2**	22.0	29.0	**25.5**	22.0	24.7	**23.3**	22.6	26.3	**24.5**
D_5S_3	27.7	27.6	**27.6**	22.6	26.5	**24.6**	19.9	24.6	**22.2**	21.3	22.4	**21.9**	22.6	24.4	**23.5**

Table 62: Economics as influenced by different growing environments and planting geometry

Treatment	Cost of cultivation (Rs ha^{-1})			Gross returns (Rs ha^{-1})			Net returns (Rs ha^{-1})			B:C ratio		
	2013	2014	Mean	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Date of sowing (D)												
D_1: June I fortnight	29393	30940	30166	93010a	95975a	94493a	63618a	65035a	64326a	3.16a	3.10a	3.13a
D_2: June II fortnight	29393	30940	30166	84308b	96686a	90497ab	54915b	65746a	60331ab	2.87b	3.12a	2.99ab
D_3: July I fortnight	29393	30940	30166	76748c	97225a	86986b	47355c	66286a	56820b	2.61c	3.14a	2.87b
D_4: July II fortnight	29393	30940	30166	59777d	79321b	69549c	30384d	48381b	39383c	2.02d	2.55b	2.28c
D_5:August I fortnight	29393	30940	30166	54955d	65261c	60108d	25562d	34321c	29942d	1.86d	2.11c	1.98d
Planting geometry (S)												
S_1:45 cm x 20 cm	31295	32942	32118	81580a	96109a	88845a	50286a	63167a	56726a	2.61a	2.92a	2.76a
S_2:60 cm x 20 cm	29187	30723	29955	75505b	87236b	81370b	46318b	56513b	51416b	2.59a	2.84a	2.71a
S_3:75 cm x 20 cm	27696	29154	28425	64194c	77336c	70765c	36497c	48182c	42339c	2.32b	2.65b	2.49b
Interaction (D x S)												
D_1S_1	31295	32942	32118	97651a	101124ab	99388a	66356a	68182ac	67269a	3.12ab	3.07a	3.10ab
D_1S_2	29187	30723	29955	94502ab	100664ab	97583a	65315ab	69941ac	67628a	3.24a	3.28a	3.26a
D_1S_3	27696	29154	28425	86878c	86136c	86507bc	59181bc	56982bc	58082bd	3.14a	2.95a	3.05ac
D_2S_1	31295	32942	32118	89772bc	104483a	97127a	58477bc	71541a	65009ab	2.87bc	3.17a	3.02ac
D_2S_2	29187	30723	29955	87789bc	100170ab	93979ab	58602bc	69447ac	64025ab	3.01ab	3.26a	3.13ab
D_2S_3	27696	29154	28425	75364e	85405c	80384cd	47667de	56251c	51959de	2.72c	2.93a	2.83ce
D_3S_1	31295	32942	32118	83598cd	103624a	93611ab	52303cd	70682ab	61493ac	2.67cd	3.15a	2.91be
D_3S_2	29187	30723	29955	78790de	100103ab	89447b	49603d	69380ac	59492bc	2.70cd	3.26a	2.98bd
D_3S_3	27696	29154	28425	67855fg	87949bc	77902d	40158f	58795ac	49477e	2.45de	3.02a	2.73de
D_4S_1	31295	32942	32118	72487ef	102211a	87349bc	41192ef	69269ac	55230ce	2.32ef	3.10a	2.71e
D_4S_2	29187	30723	29955	60640hi	68343d	64492e	31454g	37620d	34537f	2.08fg	2.22b	2.15f
D_4S_3	27696	29154	28425	46202j	67410d	56806fg	18506h	38256d	28381fg	1.67hi	2.31b	1.99fg
D_5S_1	31295	32942	32118	64394gh	69102d	66748e	33099g	36160d	34630f	2.06g	2.10b	2.08fg
D_5S_2	29187	30723	29955	55802i	66901d	61351ef	26615g	36178d	31396f	1.91gh	2.18b	2.04fg
D_5S_3	27696	29154	28425	44669j	59779d	52224g	16973h	30625d	23799g	1.61i	2.05b	1.83g

Price of produce (per kg): 2013 grain: Rs 10.80 straw (dry): Rs 0.60 2014 grain: Rs 11.00 straw (dry) : Rs 0.60
Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

(` 54955, ` 25562 and 1.86, respectively). Among the three planting geometries tried, during 2013, 45 cm x 20 cm geometry recorded significantly higher gross return (` 81580 $ha^{-1}$), net returns (` 50586 ha^{-1}) and B:C ratio (2.61) compared to 60 cm x 20 cm (` 75505, ` 46318 and 2.59, respectively) and the lowest returns were observed in 75 cm x 20 cm (` 64194, ` 36497 and 2.32, respectively). Among the treatment combinations, June I FN with 45 cm x 20 cm gave significantly higher monetary benefits interms of gross returns and net returns (` 97651 and ` 66356 ha^{-1}, respectively) over other treatment combinations.

During 2014, among the sowing dates, July I fortnight sowing recorded significantly higher gross return (` 97225 $ha^{-1}$), net returns (` 66286 ha^{-1}) and B:C ratio (3.14). It was followed by June II fortnight sowing (` 96686, ` 65746 and 3.12, respectively). The lowest monetary benefits were obtained in August I fortnight sowing (` 65261, ` 34321 and 2.11, respectively). Among the three planting geometries, during 2014, 45 cm x 20 cm geometry recorded significantly higher gross return (` 96109 $ha^{-1}$), net returns (` 63167 ha^{-1}) and B:C ratio (2.92) followed by 60 cm x 20 cm (` 87236, ` 56513 and 2.84, respectively) and the lowest returns were observed in 75 cm x 20 cm (` 77336, ` 48182 and 2.65, respectively). Among the treatment combinations, June II FN with 45 cm x 20 cm gave significantly higher monetary benefits interms of gross returns and net returns (` 104483 and ` 71541 ha^{-1}, respectively) over other treatment combinations.

In pooled mean, among the different sowing dates tried, June I FN sowing (D_1) proved its superiority interms of monetary benefits over other sowing dates. It recorded the highest gross returns (` 94493 $ha^{-1}$), net returns (` 64326 ha^{-1}) and B:C ratio (3.13). The lowest monetary benefits were obtained in delayed sowing *i.e.* August I FN (` 60108, ` 29942 and 1.98, respectively). Among the three planting geometries tried, 45 cm x 20 cm geometry recorded significantly higher gross return (` 88845 $ha^{-1}$), net returns (` 56726 ha^{-1}) and B:C ratio (2.76) compared to 60 cm x 20 cm (` 81370, ` 51416 and 2.71, respectively) and the lowest returns were observed in 75 cm x 20 cm (` 76765, ` 42339 and 2.49, respectively).

Among the treatment combinations, June I FN with 45 cm x 20 cm gave significantly higher gross returns (` 99388 $ha^{-1}$) however significantly higher net returns and B:C ratio (` 67628 and 3.26, respectively) were obtained with June I FN sowing with 60 cm x 20 cm planting geometry.

4.6 Correlation studies

4.6.1 Correlation between growth, yield parameters, agrometeorological indices and grain yield

During 2013, grain yield of maize had highly significant positive correlation with LAI during silking (0.88**), days to physiological maturity (0.92**), plant height at physiological maturity (0.87**), GDD at physiological maturity (0.95**), HUE during physiological maturity (0.72**), LAR during silking (0.95**) and APAR (%) during silking (0.86**). Whereas, grain yield showed negative correlatation with LTR during silking (-0.95**). During 2014, grain yield of maize had highly significant positive correlation with LAI at silking (0.74**), days to physiological maturity (0.82**), plant height at physiological maturity (0.91**), GDD during physiological maturity (0.85**) and per cent APAR at silking (0.72**) (Table 63).

For pooled mean also, grain yield had highly significant positive correlation with LAI at silking (0.87**), days to physiological maturity (0.90**), GDD at physiological maturity (0.93**), HUE at physiological maturity (0.63*), LAR at silking (0.81**) and APAR (%) at silking (0.85**). Whereas the grain yield had negative correlation with LTR at silking (-0.81**).

4.6.2 Relationship between weather parameters and grain yield of maize

Correlation studies between weather parameters prevailed at different crop growth stages and grain yield of maize were studied during 2013 and 2014 (Table 64).

During 2013, grain yield of maize had a negative association with maximum temperature during all phenophases (except sowing to seedling emergence) *viz*., seedling emergence to sixth leaf (-0.54), sixth leaf to tasseling (-0.77), tasseling to silk (-0.20), silk to milk (-0.46) and milk to physiological maturity (-0.69). But, it had a positive association with minimum temperature during all the phenophases (except sixth leaf to tasseling) *viz*., sowing to seedling emergence (0.61), seedling emergence to sixth leaf (0.89*), tasseling to silk (0.39), silk to milk (0.69) and milk to physiological

Table 63: Correlation between growth, yield parameters, agrometeorological indices with grain yield of maize

	2013	2014	Pooled
Grain yield (kg/ha)	-	-	-
Grain weight per cob (g)	0.42	-0.09	0.11
Cob length (cm)	0.48	0.20	0.35
LAI at silking	0.88**	0.74**	0.87**
Days to physiological maturity	0.92**	0.82**	0.90**
Plant height at physiological maturity(cm)	0.87**	0.91**	0.90**
Growing degree days for physiological maturity (^{o}C d)	0.95**	0.85**	0.93**
Heat use efficiency at physiological maturity	0.72**	0.49	0.63*
Light transmission ratio during silking (%)	-0.95**	-0.51	-0.81**
Light absorption ratio during silking (%)	0.95**	0.51	0.81**
Per cent APAR during silking	0.86**	0.72**	0.85**

*, ** = Significant at 5% and 1% level

Table 64: Correlation between weather parameters during different phenophases with grain yield of maize

	2013					2014				
	T_{max}	T_{min}	RH-I	RH-II	Rainfall	T_{max}	T_{min}	RH-I	RH-II	Rainfall
Sowing to emergence	0.62	0.61	-0.30	-0.72	-0.29	0.67	0.63	-0.53	-0.31	-0.46
Emergence to six leaf	-0.54	0.89*	0.57	0.45	0.50	0.25	0.88*	-0.48	-0.22	-0.002
Six leaf to tasseling	-0.77	-0.19	0.07	0.76	0.19	-0.85	0.69	0.92*	0.83	0.77
Tasseling to silking	-0.20	0.39	-0.57	0.43	0.19	-0.59	0.58	0.90*	0.47	-0.14
Silking to milk	-0.46	0.69	0.65	0.72	0.72	-0.83	0.61	0.87	0.88*	0.54
Milk to physiological maturity	-0.69	0.88*	0.88	0.97**	0.33	0.66	0.92*	0.88	0.76	0.19

*, ** = Significant at 5% and 1% level

Tmax : maximum temperature Tmin : minimum temperature RH-I : morning relative humidity RH-II : afternoon relative humidity maturity (0.88**).Grain yield had a positive association with morning relative humidity during seedling emergence to sixth leaf (0.57), sixth leaf to tasseling (0.07), silk to milk (0.65) and milk to physiological maturity (0.88). But negatively correlated during sowing to seedling emergence (-0.30) and tasseling to silk (-0.57).

Similarly, grain yield had a positive association with afternoon relative humidity during seedling emergence to sixth leaf (0.45), sixth leaf to tasseling (0.76), tasseling to silk (0.43), silk to milk (0.72) and milk to physiological maturity (0.97**). But negatively correlated during sowing to seedling emergence (-0.72). Also, it had positive association with rainfall during seedling emergence to sixth leaf (0.50), sixth leaf to tasseling (0.19), tasseling to silk (0.19), silk to milk (0.72) and milk to physiological maturity (0.33). But negatively correlated during sowing to seedling emergence (-0.29).

For the year 2014, grain yield of maize had a positive association with maximum temperature during sowing to seedling emergence (0.67),emergence to sixth leaf (0.25) and milk to physiological maturity (0.66) but, it had negative association with maximum temperature during sixth leaf to tasseling (-0.85), tasseling to silk (-0.59) and silk to milk (-0.83). It had a positive association with minimum temperature during all the phenophases *viz*., sowing to seedling emergence (0.63), seedling emergence to sixth leaf (0.88*), sixth leaf to tasseling (0.69), tasseling to silk (0.58), silk to milk (0.61) and milk to physiological maturity (0.92**).Grain yield had a positive association with morning relative humidity during sixth leaf to tasseling (0.92**), tasseling to silk (0.90**), silk to milk (0.87) and milk to physiological maturity (0.88). But, negatively correlated during sowing to seedling emergence (-0.53) and seedling emergence to sixth leaf (-0.48). Similarly, grain yield had a positive association with afternoon relative humidity during sixth leaf to tasseling (0.83), tasseling to silk (0.47), silk to milk (0.88*) and milk to physiological maturity (0.76). But, negatively correlated during sowing to seedling emergence (-0.31) and seedling emergence to sixth leaf (-0.22).Rainfall also had a positive association with yield during sixth leaf to tasseling (0.77), silk to milk (0.54) and milk to physiological maturity (0.19) and it was negatively correlated during sowing to emergence (-0.46) and emergence to sixth leaf (-0.002).

5. DISCUSSION

The critical agrometeorological variables associated with agricultural production are precipitation, air temperature, solar radiation, wind and relative humidity. They influence the crop growth and development throughout the life cycle. Interrelations between the above said climatic factors and crops' behaviour are an important part of agro-meteorological study. The primary influence of temperature is on growth duration. Lower temperature increase the length of time that the crop can intercept radiation. Under favourable growing conditions, biomass accumulation is directly proportional to the amount of radiation intercepted and for a given harvest index, grain yield is directly proportional to biomass. Consequently, high maize yield is associated with low temperature and high solar radiation. The yield potential of maize cultivars with 18 leaves growing in tropical environments is lower than in temperate environments, despite high levels of solar radiation. In the tropics, high temperature is the dominant influence markedly decreasing the duration of crop growth (Muchow *et al.*, 1990).

The crop growth response is influenced largely by the micro-climate environment in the crop. Micro-climate in the crop varies from top of the canopy to the soil surface and affects crop development and yield. Various environmental factors influencing growth are interception of photosynthetically active radiation, air and leaf temperature, relative humidity, prevailing wind speed, CO2 concentration and soil moisture availability. Temperature and light play a key role in influencing crop production. The occurrence of different phenological events during crop growth period in relation to temperature can be estimated by using accumulated heat units or growing degree days (GDD) (Gouri *et al.*, 2005).

The variation in planting dates and plant geometry, row spacing and plant density modifies the microclimate to which the plants are exposed and it is responsible for biomass production and ultimately the yield. Therefore, it is necessary to understand the knowledge of plant environment interaction for increasing yield of crop. Optimum time of sowing is one of the important factors which provide score for better utilization of natural resources by the crop during its crop to take full advantage of favourable weather conditions during growing season.Planting date was reported to affect the growth and yield of maize significantly.

In northern transitional zone of Karnataka maize is better suited to use the natural resources available more efficiently. Maize yields are higher when sown with the onset of monsoon. However, during recent years after the onset of monsoon, occurrence of intermittent dry spells causes delayed crop sowing leading to poor growth and yield in maize. Planting pattern is another agronomic practice that optimizes the use of natural resources. The increase in planting density will increase the light interception and radiation use efficiency and thereby bringing improvement in dry matter accumulation and yield of maize. The grain yield as a function of increased light interception during reproductive phase of crop as a result of narrow row spacing of crop, the plant population/unit land area play an important role in higher RUE and subsequently the increment in grain yield. Phenological development of crop closely follows the changes in weather conditions occurring during crop growing period. The planting geometry and sowing time had a direct bearing on congenial in the crop microclimate which directly influences the plant growth and development and efficient resource utilization.

5.1 Influence of various weather parameters on crop phenology, growth and development

5.1.1 Mean maximum and minimum temperature (^{0}C)

During 2013, the mean maximum and mean minimum temperatures in early sowing (June I FN D_1) were 27.4 and 20.6 ^{0}C at sowing to seedling emergence, 26.7 and 20.6 ^{0}C from seedling emergence to sixth leaf stage, 25.5 and 20.2 ^{0}C from sixth leaf to tasseling, 25.9 and 20.0 ^{0}C from tasseling to silking, 28.5 and 19.9 ^{0}C from silking to milk and 27.5 and 20.0 ^{0}C from milk to physiological maturity stage. Both maximum and minimum temperatures decreased with delayed sowings (except for D_5 - August I FN) from sowing to sixth leaf stage. In the later phases of crop growth *i.e.*, sixth leaf to tasseling, maximum temperature increased with delayed sowings, whereas, it failed any specific trend in latter phenophases except from milk to physiological maturity, where it increased with delayed sowings (except in August I FN sowing). Minimum temperature also had no specific trend but it increased in crop sown till D_3 (July I FN) and later it decreased. During milk to physiological maturity phase, it decreased with delayed sowings (Table 4-5).

During 2014, June I FN (D_1) sowings experienced maximum and minimum temperatures of 28.7 and 21.2 ^{0}C at sowing to seedling emergence, 30.8 and 21.0 ^{0}C at seedling emergence to sixth leaf stage, 25.7 to 20.8 ^{0}C at sixth leaf to tasseling, 27.4 and 20.4 ^{0}C at tasseling to silking, 27.0 and 20.4 ^{0}C at silking to milk and 28.9 and 20.1 ^{0}C at milk to physiological maturity stages. Maximum temperature increased with delayed sowings during sixth leaf to tasseling, silking to milk and milk to physiological maturity stages, whereas, minimum temperature decreased with delayed sowings during the above mentioned stages. High temperature during tasseling and silking stage adversely affected the fertilization, grain filling and yield in delayed sowings. These observations are in accordance with Lenka (1998).

During 2013, the early vegetative stages of maize in delayed sowings were exposed to higher values of mean maximum temperature.While, in 2014, the early sowing experienced higher values of maximum temperatures. On the other hand, for both the years the delayed sowings experienced higher maximum temperatures during grain development to maturity. For both the years, minimum temperature did not vary during early vegetative stage of maize. But, the delayed sowings experienced a slightly lower mean minimum temperature during grain development and physiological maturity stages which affected the grain yield.

5.1.2 Morning and afternoon Relative humidity (%)

During 2013, both morning and afternoon relative humidity increased with delayed sowings from sowing to seedling emergence. But, it increased upto D_3 and later decreased with delayed sowings from seedling emergence to silking phase, but they decreased with delayed sowings during milk to physiological maturity. During 2014, morning relative humidity decreased with delay in sowings at all the phenological phase except during sowing to sixth leaf stage, whereas afternoon relative humidity decreased with delayed sowings at sixth leaf to physiological maturity stage.

5.1.3 Rainfall (mm) received by maize during different phenophases under different growing environments (sowing dates) for 2013 and 2014

June I FN sowing (D_1)

During 2013, the maize crop received 13.2 mm (Sowing to seedling emergence), 72.0 mm (Seedling emergence to sixth leaf), 206.0 mm (sixth leaf to tasseling), 13.0

mm (tasseling to silking), 106.0 mm (silking to milk) and 41.4 mm (milk to physiological maturity). Thus, a total amount of 451.6 mm was received from sowing to physiological maturity with 51 rainy days. Similarly, during 2014, the maize crop received rainfall of 15.8 mm (sowing to seedling emergence), 3.5 mm (seedling emergence to sixth leaf), 309.6 mm (sixth leaf to tasseling), 2.4 mm (tasseling to silking), 106.4 (silking to milk) and 104.6 mm (milk to physiological maturity). Thus, a total amount of 542.3 mm was received from sowing to physiological maturity with 48 rainy days (Table 6 and Fig. 3).

June II FN (D_2)

During 2013, the maize crop had rainfall of 18.6 mm (sowing to seedling emergence), 180.4 mm (seedling emergence to sixth leaf), 76.0 mm (sixth leaf to tasseling), 6.0 mm (tasseling to silking), 123.0 mm (silking to milk) and 64.8 mm (milk to physiological maturity). Thus, a total amount of 468.8 mm was received from sowing to physiological maturity with 46 rainy days. Similarly, during 2014, the maize crop received no rainfall from sowing to seedling emergence, 39.2 mm (seedling emergence to sixth leaf), 285.2 mm (sixth leaf to tasseling), 48.4 mm (tasseling to silking), 51.8 mm (silking to milk) and 115.6 mm (milk to physiological maturity). Thus, a total amount of 540.2 mm was received from sowing to physiological maturity with 48 rainy days.

July I FN sowing (D_3)

During 2013, the maize crop received rains amounting to 12.4 mm (sowing to seedling emergence), 193.0 mm (seedling emergence to sixth leaf), 71.8 mm (sixth leaf to tasseling), 69.6 mm (tasseling to silking), 23.4 mm (silking to milk) and 74.6 mm (milk to physiological maturity). Thus, a total rainfall amount of 444.8 mm was received from sowing to physiological maturity with 38 rainy days. During 2014, the maize crop received rainfall of 7.4 mm (sowing to seedling emergence), 257.2 mm (seedling emergence to sixth leaf), 153.0 mm (sixth leaf to tasseling), 5.6 mm (tasseling to silking), 95.4 mm (silking to milk) and 103.4 mm (milk to physiological maturity) of rain fall. Thus, a total amount of 622.0 mm was received from sowing to physiological maturity with 52 rainy days.

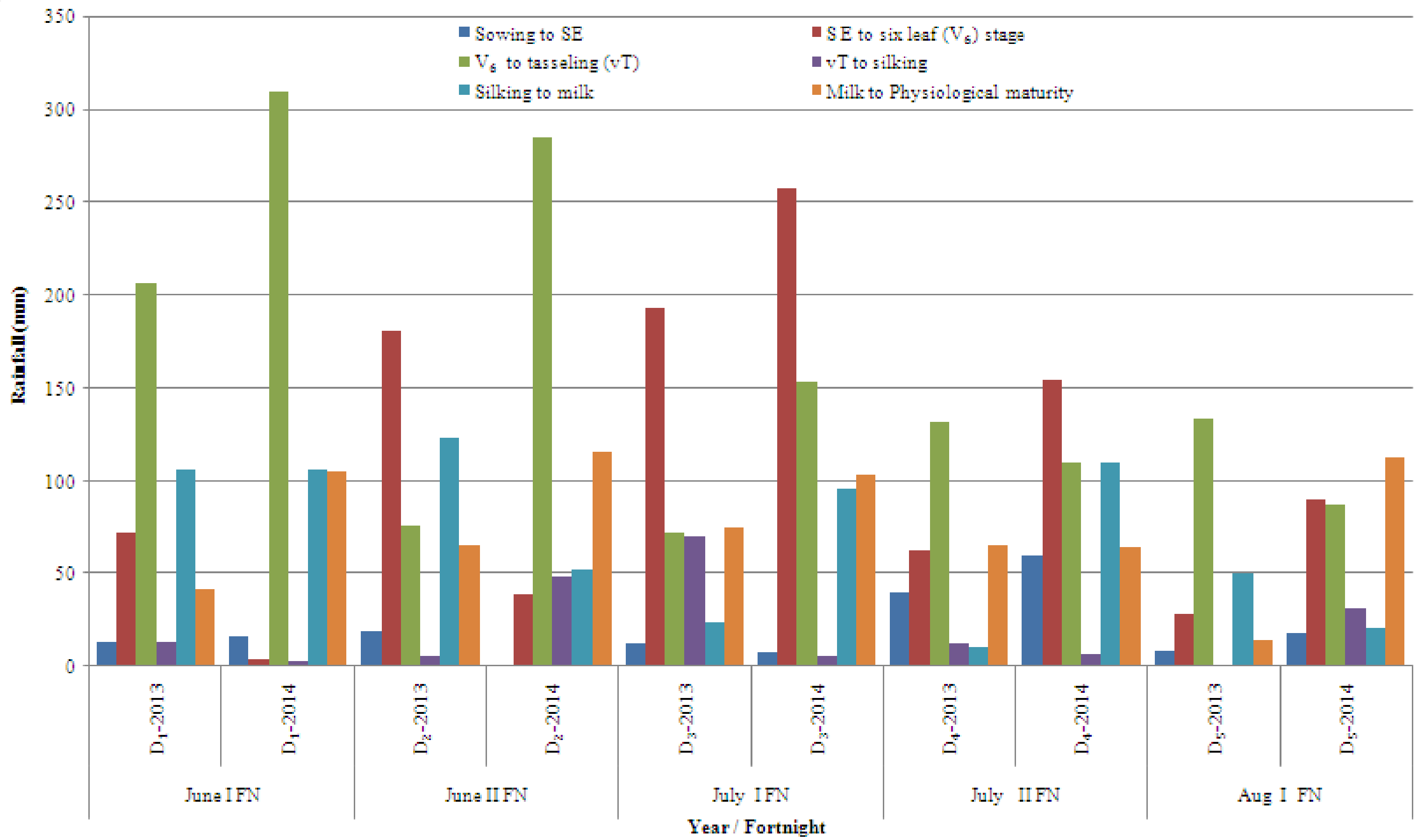


Fig. 3: Rainfall (mm) received during different phenophases under different growing environments for 2013 and 2014

July II FN sowing (D_4)

During 2013, the maize crop had 39.4 mm of rainfall (sowing to seedling emergence), 62.4 mm (seedling emergence to sixth leaf), 131.6 mm (sixth leaf to tasseling), 12.4 mm (tasseling to silking), 10.4 mm (silking to milk) and 65.2 mm (milk to physiological maturity). Thus, a total of 321.4 mm rainfall was received from sowing to physiological maturity with 28 rainy days. Whereas, during 2014, the maize crop received rains of 59.4 mm (sowing to seedling emergence), 154.4 mm (seedling emergence to sixth leaf), 110 mm (sixth leaf to tasseling), 6.2 mm (tasseling to silking), 109.4 mm (silking to milk) and 64.0 mm (milk to physiological maturity). Thus, a total amount of 503.4 mm was received from sowing to physiological maturity with 40 rainy days.

August I FN sowing (D_5)

During 2013, the maize crop received rains amounting to 8.8 mm (sowing to seedling emergence), 28.2 mm (seedling emergence to sixth leaf), 133.0 mm (sixth leaf to tasseling), 0 mm (tasseling to silking), 50.6 mm (silking to milk) and 14.6 mm (milk to physiological maturity). Thus, a total amount of 235.2 mm was received from sowing to physiological maturity with 24 rainy days. In 2014, the crop had rainfall of 17.8 mm (sowing to seedling emergence), 89.6 mm (seedling emergence to sixth leaf), 86.6 mm (sixth leaf to tasseling), 30.8 mm (tasseling to silking), 20.8 mm (silking to milk) and 112.2 mm (milk to physiological maturity). Thus, a total amount of 357.8 mm was received from sowing to physiological maturity with 29 rainy days.

The overall rainfall distribution for both the years for different sowing dates, indicated that during 2013, higher amount of rainfall (468.8 mm) occurred during the cropping period in June II FN sown crop (D_2), followed by June I FN (D_1) sowing (451.6 mm), July I FN (D_3) sowing (444.8 mm) and lowest (235.2 mm) for August I FN sowing (D_5). Whereas, in 2014 crop season, the highest amount of rainfall (622 mm) was received in July I FN sown crop (D_3), followed by June I FN (D_1) sowing (542.3 mm) and June II FN (D_2) sown crop (540.2 mm) and July II FN (D_4) 503.4 mm. Again, the lowest amount of rainfall (357.8 mm) was received by August I FN sown crop (D_5)

5.1.4 Wind speed (kmph)

Compared to normal wind speed (7.2 to 8.0 kmph), higher wind speed prevailed from 23rd SMW to 31st SMW, during both 2013 (10.1 to 14.4 kmph) and 2014 (10 – 15 kmph) cropping period (Table 3). Thereafter, it continuously declined upto the end of cropping period. In comparison with the 27 years average values (7.5 kmph), the wind speed value for the entire cropping period were higher for both 2013 (8.5 kmph) and 2014 crop season (8.3 kmph).

5.1.5 Light and photosynthetically active radiation (PAR)

5.1.5.1 Light transmission ratio (LTR) and light absorption ratio (LAR)

Influence of sowing dates

In early sown crop (June I FN), LTR was to an extent of 8.09, 6.69 and 20.39 per cent at tasseling, silking and physiological maturity stage, respectively and it increased with delayed sowing at all the phenological stages (Table 11). Conversely, higher values of LAR (91.85, 93.31 and 79.61 per cent, respectively) were observed (Table 12). The lowest LAR (89.52, 91.01 and 71.03 %) and higher LTR (10.48, 8.99 and 28.97 %, respectively) values were observed in most delayed sowing (August I FN). This might have been due to attainment of higher values of LAI in early sown crop than delayed sowings and also due to fast development of canopy cover in early sowings. Maximization of light interception derived from early canopy cover resulted in decrease in light transmittance through the canopy. Thus, less radiation reached the soil surface which had smothering effect on weed growth. These results are in line with that of Mc Lachlan *et al.* (1993), Teasdale (1995); and Thimmegowda (2012).

Influence of planting geometry (planting density)

Among the planting geometries, wider spacing (S_3) recorded significantly more LTR over other spacings in both crop seasons at all the phenological stages. In case of pooled analysis per cent LTR for S_3 (75 x 20 cm) was to an extent of 81.90 per cent at sixth leaf, 11.06 per cent (tasseling), 8.72 per cent (silking) and 28.24 per cent (physiological maturity).

S_1 (45 cm x 20 cm) recorded significantly the higher light absorption ratio (LAR) at all the phenological stages except at seedling stage during both the years and in pooled analysis. During 2013, LAR was to an extent of 28.3 per cent, 91.6 per cent, 92.7 per cent and 77.7 per cent.During 2014, it was to an extent of 28.6 per cent, 93.5 per cent, 93.9 per cent and 84.6 per cent at sixth leaf, tasseling, silking and physiological maturity stages. The lowest LAR was observed in case of wider spacing of 75 cm x 20 cm (S_3) in both the years.

5.1.5.2 Photosynthetically active radiation (PAR)

Influence of sowing dates

The accumulation of biomass by crops results from the amount of incident photosynthetically active radiation (PAR) intercepted by the canopy and from the efficiency with which the intercepted PAR is converted into dry matter (Table 19, 20 and 21)

i) Per cent Transmitted PAR (TPAR %)

During 2013, per cent transmitted PAR increased with delay in sowing at all the phenological stages (except at physiological maturity). Among the five sowing dates tried early sowing during I FN of June (D_1) recorded the lowest per cent of transmitted PAR. It recorded 71.9, 5.8, 4.4 and 21.4 per cent of transmitted PAR at sixth leaf, taseling, silking and physiological maturity. But, the trend differed during 2014, where July I FN (D_3) sown crop recorded the lowest per cent of transmitted PAR during tasseling and silking (9.5 and 7.7 % respectively). However, the pooled data indicated that the lowest per cent of transmitted PAR was recorded in the early sown (June I FN and June II FN) crops at all the stages. The per cent transmitted PAR decreased progressively during crop growth from seedling to silking due to increased leaf area index and canopy cover with progressive crop growth stages. But, % TPAR again slightly increased up to physiological maturity as leaves senesced and leaf angle distribution changed with more penetration of light through the canopy. These findings are in conformity with Gallo and Daughtry (1986).

ii) Per cent intercepted PAR (IPAR %)

During 2013, among the five sowing dates, June I FN (D_1) recorded the highest IPAR (28.1, 94.2, 95.6 and 79 %) at V_6, tasseling, silking and physiological maturity stages, respectively. Whereas, July I FN (S_3) sown crop recorded the highest IPAR (90.5 and 92.3 %) at tasseling and silking stages in 2014. In pooled analysis the highest IPAR (24.0, 91.4, 93.9 and 77.1 %) were recorded in June I FN (D_1) sown crop at V_6, tasseling, silking and physiological maturity stages, respectively. In general, late plantings will result in high crop growth rates during the vegetative period because of high RUE and IPAR %, but conversely results in low crop growth rates during grain filling because of low RUE and low incident radiation. The inverse holds true for early plantings Cirilo and Andrade (1994). In addition, Maddonni, *et al.,* (1998) found that in late plantings, both solar radiation and temperature decline during grain filling. Thereby, lowered solar radiation resulted in grain growth in excess of biomass production, indicating a possible source limitation. Similar findings were observed by Cirilo and Andrade (1994). The amount of incident radiation and the proportion of this radiation that is intercepted by the crop directly determine crop growth rate. Delay in planting date determined important reductions in the amount of incident radiation accumulated from emergence to silking, because it hastened development.

iii) Per cent absorbed PAR (APAR %)

Per cent APAR was influenced by sowing dates and decreased with delay in sowing. During 2013, the highest percentage of APAR was recorded in June I FN (D_1) sown crop to an extent of 25.8, 91.6, 92.9 and 74.7 per cent at V_6, tasseling, silking and physiological and maturity, respectively. But during 2014, July I FN (D_3) sown crop recorded the highest per cent APAR (86.8 and 90.1 %) at tasseling and silking stage, respectively. However, the pooled analysis clearly indicated the superiority of June I FN sown crop with respect to higher percentage of APAR (21.8, 87.9, 90.2 and 72.0 %) at V_6, tasseling, silking and physiological maturity stages, respectively.

Influence of planting geometry (planting density) on Photosynthetically active radiation (PAR) (Table 19 to 21)

i. Per cent Transmitted PAR (TPAR %)

Among the three planting geometries tried, the lowest per cent transmitted PAR was recorded with narrow planting geometry (45 cm x 20 cm) crop at all the phenological stages. It recorded 85.4, 69.1, 6.4, 5.4 and 16.6 per cent during 2014 at three leaf (V3), sixth leaf (V_6), tasseling, silking and physiological maturity stages, respectively. Thus, early canopy cover reduces light transmittance through the canopy. These observations are in line with Mc Lachlan *et al.* (1993).

ii. Per cent intercepted PAR (IPAR %) (Table)

During 2013, 45 cm x 20 cm (S_1) recorded 14.6, 30.9, 93.6, 94.6 and 83.4 per cent intercepted PAR during V3, V_6, tasseling, silking and physiological maturity stages, respectively. During 2014, it (45 cm x 20 cm) recorded 12.5,24.6, 91.0,94.8 and 88.8 per cent IPAR for respective stages. Similar trend was noticed in case of pooled analysis. Increasing plant densities and decreasing row spacing improve light interception and therefore grain yield. Increased plant population leads to a greater leaf area index (LAI) at silking, which increases interception of photosynthetically active radiation. Similar results were reported by Tollenaar and Aguilera, 1992; Stewart *et al.*, 2003. Also, at higher densities, possessing leaves with an upright angle and a smaller surface area, higher up in the canopy, allows for more efficient light interception and penetration which consequently results in higher photosynthetic rates specifically at leaves located in the lower portion of the canopy (Yao and Shaw, 1964; Duncan *et al.*, 1967; Williams *et al.*, 1968; Duncan, 1971; Scarsbrook and Doss 1973). Thus, Planting geometry influenced the distribution of radiation in the canopy as well as the total amount of incident radiation intercepted by a crop. Solar radiation interception by the crop is greater with narrow rows and incident radiation in soil is greater in wider geometry. Early canopy cover not only maximizes light interception (Williams *et al.*, 1965; and Ottman and Welch, 1989), it also decreases evaporation from the soil surface (Karlen and Camp, 1992). The results also indicated that higher IPAR implies that at higher plant population density more efficient photosynthesis occurs due to mutual shading of leaves in the canopy.

But, increasing row width had a positive influence on radiation penetration but decreased total radiation interception by the crop. The lower yield of 75 cm x 20 cm can be explained in view of poor primarily radiation interception by the canopy as a whole offsetting any advantage gained by intercepting a greater proportion of radiation with the lower leaves. Similar findings were recorded by Ottman and Welch (1989).

iii. Per cent Absorbed PAR (APAR %)

During 2013, among the three planting geometries, the highest percentage of APAR was recorded in 45 cm x 20 cm (S_1) spaced crop due to higher LAI (Fig. 4). It was to an extent of 13.8, 29.1, 89.6, 90.7 and 78.8 per cent. For 2014, it was to an extent of 12, 23, 87.3, 91.4 and 81.6 per cent during three leaf (V3), sixth leaf (V_6), tasseling, silking and physiological maturity stage, respectively. Similar trend was observed in pooled analysis. The lowest per cent of APAR (8.4, 15.0, 77.8, 82.1 and 57.7 %) at V3, V_6, tasseling, silking and physiological maturity stages, respectively was recorded with wider planting geometry (75 x 20 cm) crop due to lower LAI. These results are in conformity with Tollennar and Bruulsema (1988), they reported that the grain yield and absorbed solar radiation increased with plant population up to 100000 plants ha^{-1}. It was also observed that the presence of vertically oriented maize leaves, within the upper portion of the canopy in narrow spaced crop (45 cm x 20 cm) with high population density, resulted in a reduction of the canopy light extinction coefficient, increased light penetration to the lower portion of the canopy, therby resulting in more uniform and higher photosynthetic rates within the canopy.

5.1.5.3 Growing degree days (GDD)

Among the five sowing dates, except for seedling emergence (V_6), June I FN sown crop recorded more number of GDD (378.4, 815.8, 890.4 and 1593.0 ^{0}C day) to attain sixth leaf tasseling, silking and physiological maturity stages, respectively. The number of GDD taken to attain different phenological stages decreased with delay in sowings (Fig. 5). The lowest number of GDD (302.8, 692.3, 787.8 and 1402.0 ^{0}C day) were recorded in August I FN (D_5) sown crop to attain sixth leaf, tasseling, silking and physiological maturity stages, respectively. Thus, the delayed sowing resulted in lesser GDD because of fall in ambient temperature and water stress experienced by delayed

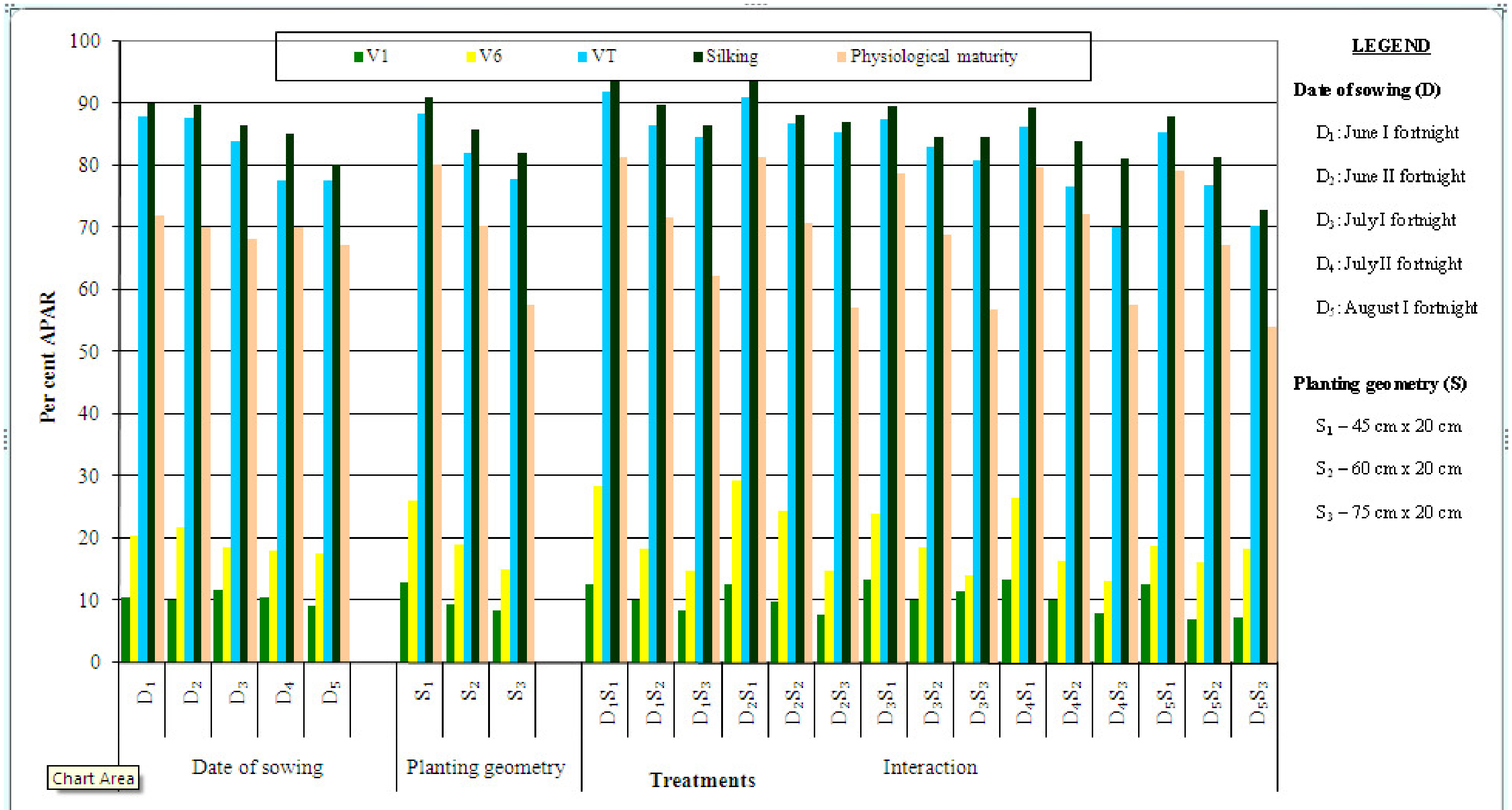


Fig. 4: Per cent APAR as influenced by different growing environments and planting geometry

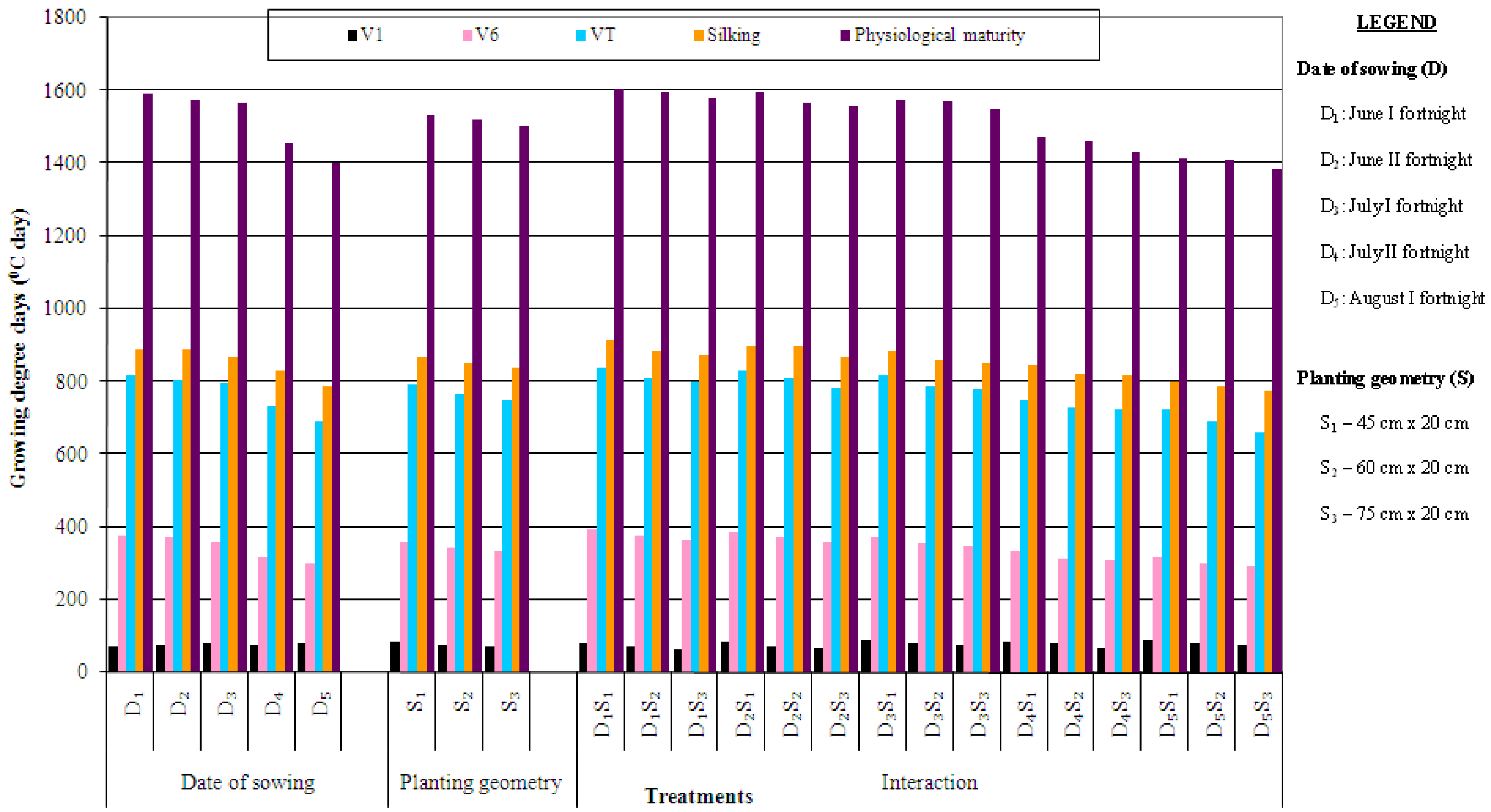


Fig. 5: Growing degree days (^{0}C day) as influenced by different growing environments and planting geometry

sown maize lead to reduced growing period. These findings are in accordance Badu-Apraku *et al.* (1983), Nielsen *et al.* (2002) and Hemalatha (2013).

Among the three planting geometries tried, 45 x 20 cm spacing (S_1) recorded more number of accumulated heat units to attain all phenological stages from seedling emergence to physiological maturity during both the years. Similar trend was observed in pooled analysis, where, S_1 (45 x 20 cm) recorded higher number of heat units (84.5, 360.3, 792.3, 868.6 and 1532.5 ^{0}C day) over 60 x 20 cm (78.1,344.0,765.0,851.3 and 1521.1 ^{0}C day) and 75 cm x 20 cm (70.3,334.2,749.4,837.3 and 1501.7 ^{0}C day) to attain seedling emergence, sixth leaf stage, tasseling, silking and physiological maturity stages, respectively.

5.1.5.4 Phenothermal Index (PTI, ^{0}C days day^{-1})

Among sowing dates, in pooled mean of 2013 and 2014, June I fortnight (D_1) sown maize recorded significantly higher phenothermal index (14.23, 13.74, 13.70 and 13.86) to complete sixth leaf stage, tasseling, silking and physiological maturity stages, respectively compared to other sowing dates (delayed). These results confirms the findings of Amgain (2011) and Gouri *et al.* (2013). Among the three planting geometries tried, 45 x 20 cm (S_1) recorded higher values of PTI (13.23, 13.74, 13.65 and 13.79) compared to wider planting geometries of 60 cm x 20 cm and 75 cm x 20 cm. But, the differences were very small.

5.1.5.4 Heat Use Efficiency (HUE)

June I FN (D_1) recorded significantly higher HUE (1.22, 1.49 and 1.82 g m^{-2}/ ^{0}C day) at tasseling, silking and physiological maturity stages, respectively compared to fortnightly delayed sowings. These results confirms the findings of Amgain (2011),Girijesh *et al.* (2011) and Thimmegowda *et al.* (2013). Among the planting geometries also, 45 cm x 20 cm (S_1) recorded significantly higher HUE (1.24, 1.52 and 1.96 g m^{-2}/ ^{0}C day) at tasseling, silking and physiological maturity stages, respectively compared to wider planting geometries (60 cm x 20 cm and 75 cm x 20 cm).

5.1.6 Phenology, growth, yield and its parameters

5.1.6.1 Maize phenology

The number of days taken by maize crop for completion of each phenophase varied with the date of sowing. The crop had a maturity period ranging from 104.1 to 118.0 days and 102 to 117 days in 2013 and 2014, respectively. The mean of two years showed that the number of days taken to physiological maturity was highest (115 days) with the earliest sowing (June I FN - D_1) and consistently reduced with subsequently delayed sowings. Except at seedling stage, the number of days taken to different phenological stages decreased with successive fortnightly delay in sowing. The advancement was to an extent of 4 days for sixth leaf stage, 10 days for tasseling, 8.5 days for silking and 12 days for physiological maturity (Table 7).

The reduction in duration of crop phenophases under delayed sowings might be due to higher maximum temperatures during early vegetative growth and faster development of maize crop which led to hastened crop growth and early attainment of physiological maturity in maize. The duration of grain filling period decreased with increasing temperature and shorter grain filling period which can be associated with lower grain yield in delayed sowings. These findings are in accordance with Hunter *et al.* (1977) and Badu-Apraku *et al.* (1983). Thus these results supports the hypothesis that shorter the reproductive and grain development phase, the poorer will be the grain yield. These results are in line with Lenka (1998), Berzsenyi, *et al.* (1998) and Thimmegowda (2012).

5.1.6.2 Growth, yield and its attributes

Pooled analysis revealed the superiority of June I FN sown maize (8082 kg ha^{-1}), which was at par with June II FN sowing (7716 kg ha^{-1}) (Fig. 6), but significantly superior over other delayed sowing in July I FN (7400 kg ha^{-1}), July II FN (5892 kg ha^{-1}) and the lowest in August I FN (5035 kg ha^{-1}). The reduction in grain yield of maize was to an extent of 4.5, 8.4, 27.1 and 37.7 per cent with fortnightly delay in sowing. It could mainly be attributed to lower values of growth and yield components under delayed sowings. Early sown maize, had better growth and yield because the vegetative and reproductive period of its development encountered favour between their

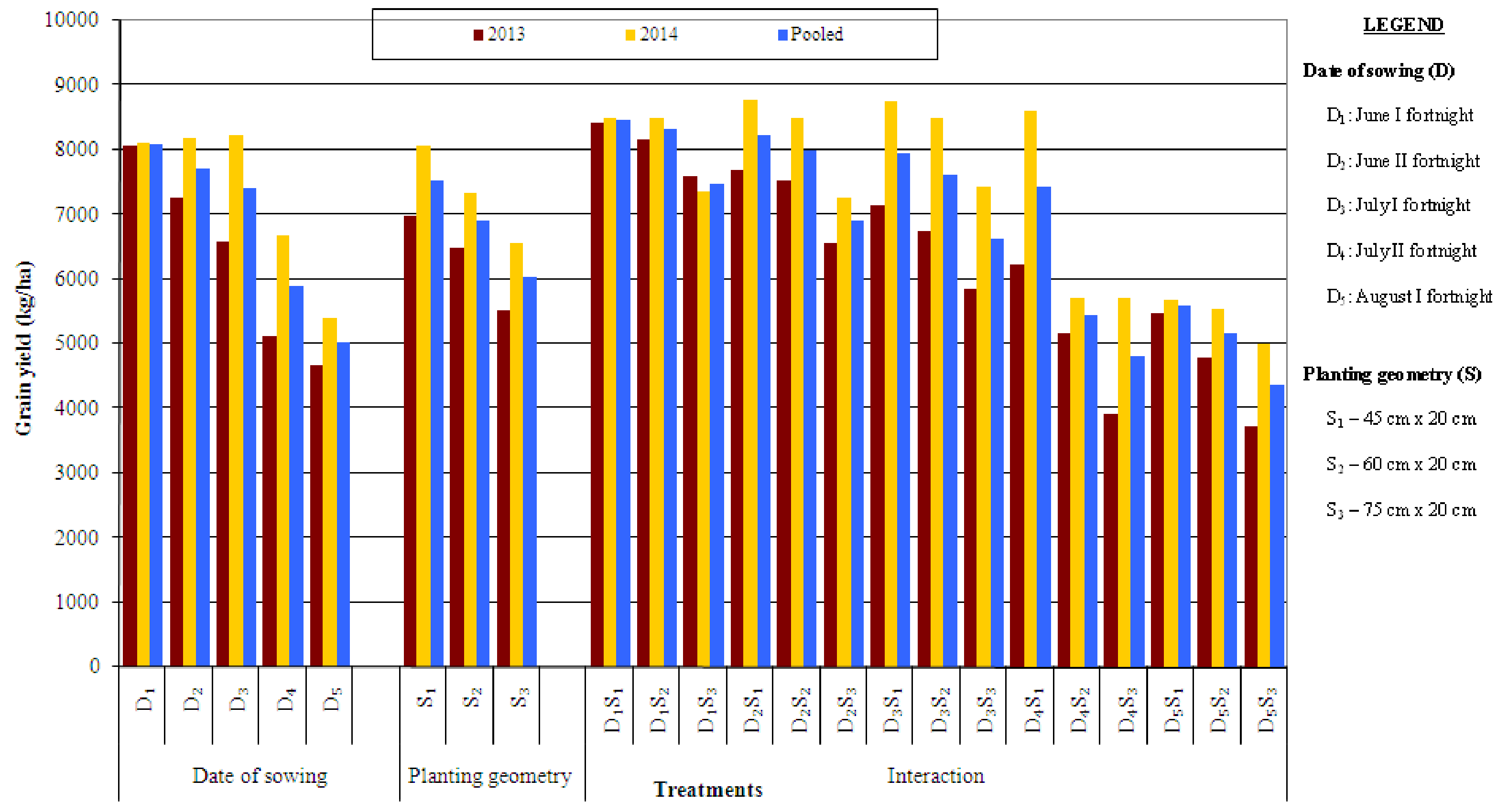


Fig. 6: Grain yield (kg/ha) as influenced by different growing environments and planting geometry

season when moisture stress is less likely a favourable weather condition. These results are inconformity with the findings of Khola *et al.* (1999), Jayasree *et al.* (2008) and Thimmegowda (2012).

The higher grain yield (8082 kg ha^{-1}) of June I FN sowing (early) compared to delayed sowings was mainly attributed to superior values of growth (leaf area index and dry matter production) and yield attributes (cob weight, grain weight per cob, cob length, no. of kernel rows per cob, harvest index and hundred seed weight). Low temperatures during grain filling in late plantings limited seed growth as well as crop photosynthesis. Thus, the ratio between final seed number and dry matter at silking dropped dramatically for the late plantings, indicating a predominance of vegetative growth over reproductive growth. Also which might be due to more biotic stresses (pest and disease incidence) in late sown crop thus resulting lower photosynthetic rate and total dry matter production (Table 22 to 30).

In general, the lower LAI values were recorded with delayed sowing from June I FN (D_1) to August I FN (D_5). LAI values decreased from 4.86 to 3.52, 5.05 to 3.56 and 3.23 to 2.63 at tasseling, silking and physiological maturity stages, respectively. Delayed sowing recorded the lowest LAI at all the phenophases (Fig. 7). The dry matter partitioning to cob at physiological maturity was higher (202.7 g plant^{-1}) and result in better yield. The 100-grain weight (g) significantly decreased from 32.7 g to 29.3 g with every fortnight delay in sowing dates. This was mainly because of reduced grain filling period under late sown conditions due to increase in temperature. But, cooler climate prevailed during grain filling period in early sown crops coupled with better soil moisture and prolonged grain filling period might have lead to accumulation of higher translocates to seeds, in turn higher grain weight. The results are in line with the findings of Hunter *et al.* (1977) and Badu-Aparku *et al.* (1983).

In addition, superior cob weight (207.7), grain weight per cob (175.7 g), cob length (19.8 cm), no. of kernel rows per cob (15.3), hundred seed weight (32.7 g) and harvest index (0.43) were recorded in early sown (June I FN) crop and consistently decreased with subsequent fortnightly delayed sowings up to August I FN sowing, which recorded the lowest values for the above mentioned characters. Similar findings were reported by Otegui and Melon (1997), that delayed sowings are generally

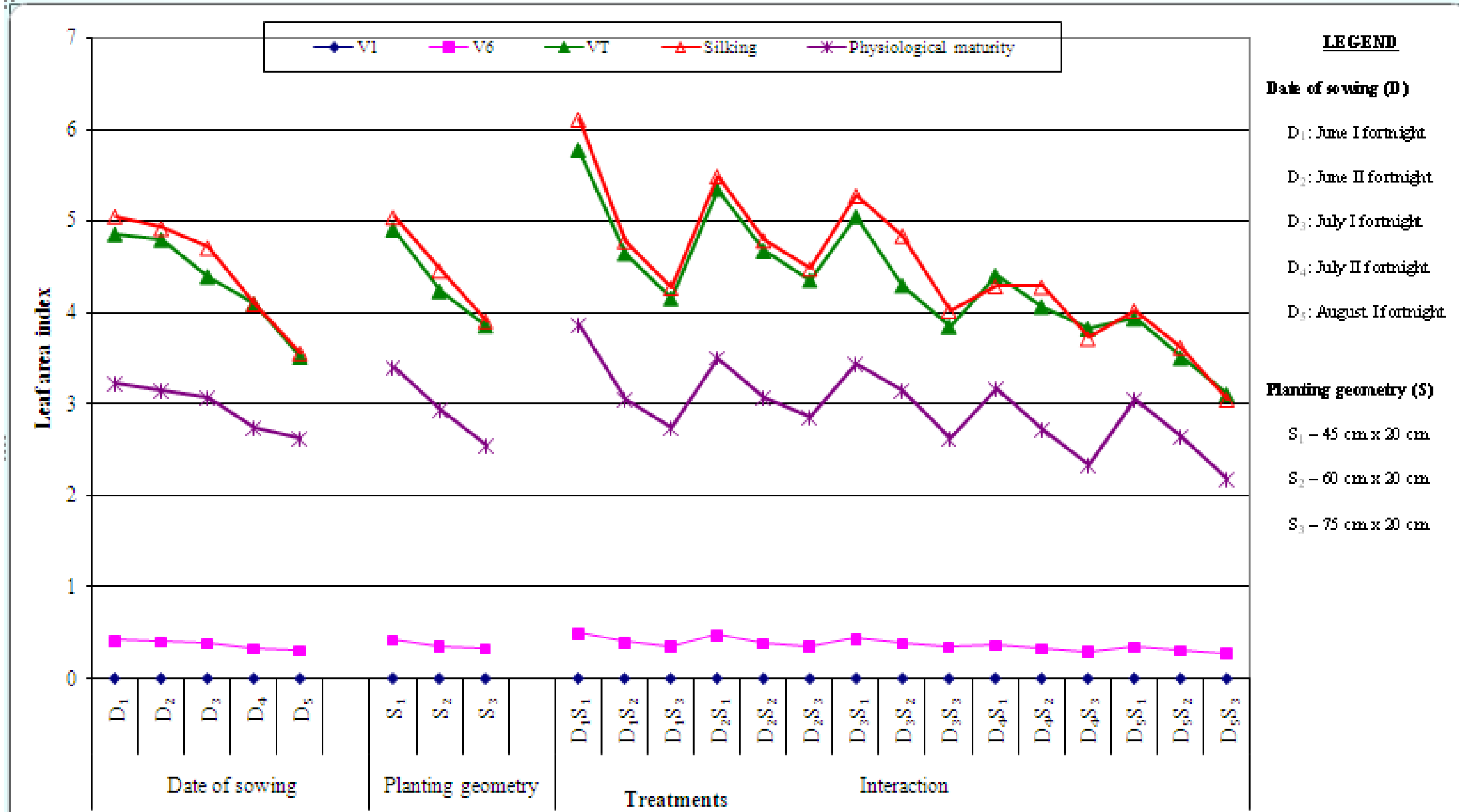


Fig. 7: Leaf area index as influenced by different growing environments and planting geometry

accompanied by increased temperatures during the growing season, which accelerate crop development and decrease accumulated solar radiation, resulting in less biomass production, seed set and grain yield. Also, these results are in line with Thimmegowda (2012).

5.1.7 Influence of planting geometry /planting density

Maize grain yield is also influenced by plant spacing. Decades of row spacing research has been conducted, with greater maize yield produced by narrowing rows in desirable production environments and widening rows in more stressful environments. Row spacing is important in crop canopy structure. A better canopy structure can result in better solar radiation interception. (Karlen and Camp, 1985; Andrade *et al.*, 2002; Sharratt and McWilliams, 2005)

5.1.7.1 Maize phenology

Among the three planting geometries tried during 2013 and 2014, 45 cm x 20 cm (S_1) took more number of days to attain seedling emergence (6.1 and 6.1 days), sixth leaf stage (29.3 and 25.7 days), tasseling (59.5 and 56.1 days), silking (65.3 and 62.1 days) and physiological maturity (111.7 and 110.4 days) stages, respectively compared to 60 cm x 20 cm (S_2) and 75 x 20 cm (S_3). The tasseling period increased with increase in sowing density. A positive relation exists between number of days to flowering and yield (Table 7). These findings are in accordance with Sangoi and Salvador (1998) and Gokmen *et al.* (2001).

5.1.7.2 Growth, yield and yield attributes of maize

Among the three planting geometries tried, 45 x 20 cm (S_1) recorded significantly higher grain yield (7529 kg ha^{-1}) compared to 60 cm x 20 cm (S_2 6909 kg ha^{-1}) and (6037 kg ha^{-1}). The reduction in grain yield with increase in spacing was to an extent of 8.2 per cent with 60 cm x 20 cm and 19.8 per cent with 75 cm x 20 cm compared to 45 cm x 20 cm. It was mainly attributed to more total dry matter production per unit area and probably because of the cumulative effect of more number of plants accommodated per unit area in higher population densities (Fig. 8). Because,

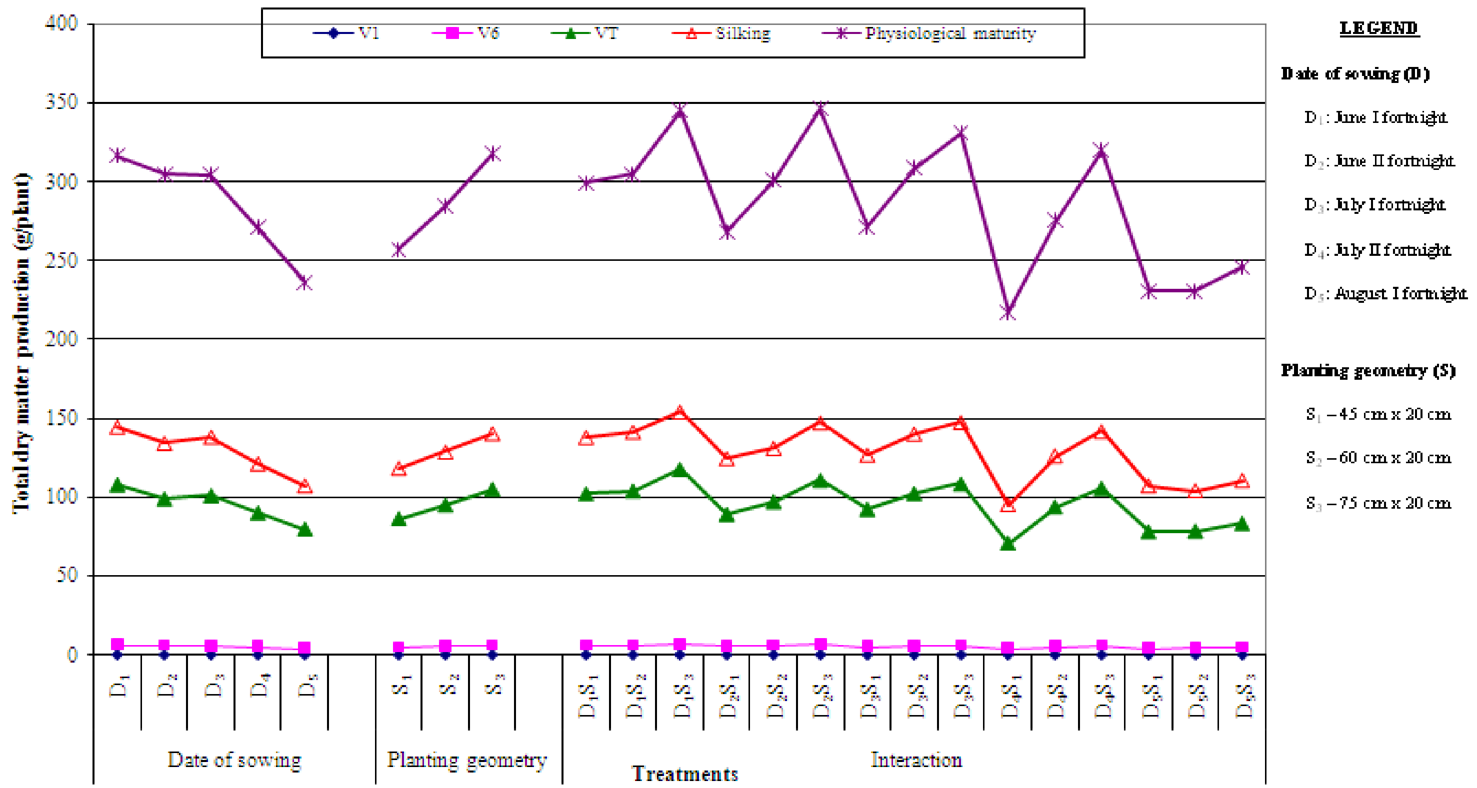


Fig. 8: Total dry matter production (g/plant) as influenced by different growing environments and planting geometry

population density was to an extent of 11.11 plants per square metre in 45 cm x 20 cm which was comparatively higher than in 60 cm x 20 cm (8.33) and 75 cm x 20 cm (6.66). Similar findings have earlier been reported by Gollar and Patil (2000), Agasibagil (2006), Wasnik *et al* (2012), Bisht *et al.* (2012)

In general, the higher LAI values were recorded with narrow spaced crop at all the phenological stages. LAI values decreased from 0.43 to 0.33, 4.91 to 3.86 and 5.04 to 3.91 at sixth leaf, tasseling, silking and physiological maturity stages, respectively from 45 cm x 20 cm to 75 cm x 20 cm planting geometry. 75 cm x 20 cm recorded the lowest LAI at all the phenophases. The maximum LAI values of 45 cm x 20 cm, might have resulted in higher radiation use efficiency and higher synthesis of metabolites leading to higher total dry matter production at grain filling and maturity and in turn higher grain yield per unit area. These results are in line with Karlen *et al.* (1985) who recorded dry matter yield increase of 4 Mg ha^{-1} by elevating plant density from 6.7 to 13.5 plants m^{-2}. These results are in accordance with Cox (1996) who reported a 40 % increase in LAI at high plant population from mid-vegetative to early grain fill even though per plant biomass has been reported to decrease 40 to 60 % at high plant population (Maddonni and Otegui, 1996).

Conversely, superior cob weight (218 g), grain weight per cob (188.4 g), cob length (19.8 cm), harvest index (0.42) and 100 grain weight (34.6 g) were recorded in widest (75 cm x 20 cm) planting geometry and consistently decreased with decrease in row spacing (or increase in plant density) up to 45 cm x 20 cm, which recorded the lowest values for the above mentioned characters. These results are in conformity with Maddonni and Otegui (2004) and Fulton (1970). Yield attributes of maize, were significantly higher at lower planting density (75 cm x 20 cm), which might be due to reduced competition for various growth resources especially light, moisture and nutrients. These results are in line with Zakkam *et al.* (2012), Bangarwa *et al.* (1989a). Although all yield attributing characters were higher at lower population (75 cm x 20 cm), the increased value of these characters under lower population failed to supersede the gains of higher plant population (45 cm x 20 cm) interms of higher grain yield. Lower plant population could not compensate the large plant population per unit area for these characters. It was observed that the presence of vertically oriented maize leaves, within the upper portion of the canopy in high density planting (narrow spaced), resulted in a reduction of the canopy light extinction coefficient, increased light penetration to the lower portion of the canopy and more uniform photosynthetic rates within the canopy.

5.1.8 Interactions of sowing time and planting geometry

Sowing date and plant geometry are very important parameters in crop production. The optimum sowing date and plant geometry paves the way for better use of time, light, temperature, precipitation and other factors. Plant density is of particular importance in maize, because it does not have tillering capacity to adjust to variation in plant stand.

There was a significant interaction between row spacing and planting date with respect to grain yield. In the pooled analysis, the interaction effect of sowing dates and planting geometry shown that sowing in June I FN (D_1) either with 45 x 20 cm or 60 x 20 cm spacing recorded significantly higher grain yield (8461 and 8318 kg ha^{-1}, respectively) over other treatment combinations (8237 to 4363 kg ha^{-1}). While, the lowest grain yield (4363 kg ha^{-1}) was registered with August I FN sown maize with 75 x 20 cm (S_3) spacing. The advantage of having narrow rows was higher when maize was sown earlier in the growing season. The yield edge promoted by the use of narrow rows may be related to a higher interception of solar radiation and greater radiation use efficiency (Sangoi *et al.*, 2001).

During 2013 combination of D_1 (June I FN) with S_1 (45 x 20 cm) recorded the highest number of accumulated GDD to attain sixth leaf stage (412), tasseling (853.5), silking (721.7) and physiological maturity (1609.3). During 2014 combination of D_3 x S_1 recorded the highest number of accumulated GDD to attain V_6 stage (405.8) and physiological maturity (1630). But, D_2 (June II FN) with S_1 (45 x 20 cm) recorded the highest number of accumulated heat units to attain tasseling (830.8). Combination of D_1 x S_1 recorded the highest number of heat units (904.9) to attain silking. Whereas, pooled analysis clearly indicated that combination of June I FN sowing with narrow spacing (45 x 20 cm) recorded the highest number of accumulated heat units to attain V_6 (393), tasseling (838.2), silking (913.3) and physiological maturity (1604.1).

Pooled mean indicate that, treatment combination of delayed sowing with wider spacing attained different phenological stages in less number of days. They took 23 days, 49.3 days, 55.8 days, 102.7 days to attain sixth leaf stage, tasseling, silking and physiological maturity stages compared to other treatment combinations (24 to 31 day, 54.2 to 61.7 days, 62.2 to 66.7 days and 105.3 to 115.7 days for respective phenological stages).

The combination of early sowing (June I FN) with narrow row spacing (45 cm x 20 cm) recorded higher values of heat use efficiency at tasseling (1.45 g m^{-2}/ ^{0}C day), silking (1.79 g m^{-2}/ ^{0}C day) and physiological maturity (2.21 g m^{-2}/ ^{0}C day) stages compared to other treatment combinations.

Combination of June I FN (D_1) sown crop with 45 x 20 cm (S_1) recorded significantly higher LAI at all the phenophases. In case of pooled analysis, D_1 x S_1 recorded 0.50, 5.78, 6.11 and 3.87 at V_6, tasseling, silking and physiological maturity stages, respectively. The lowest LAI was recorded with August I FN (D_5) sown crop with 75 x 20 cm spacing at V_6 (0.28), tasseling (3.01, silking (3.05) and physiological maturity stages (2.18).

Combination of late sowing with wider spacing (75 x 20 cm) recorded significantly more light transmission ratio at all the phenological stages except at seedling stage and sixth leaf stages for both the years and in pooled analysis. LTR for August I FN sowing with 75 x 20 cm (S_3) during tasseling, silking and physiological maturity was to an extent of 11.52, 10.59 and 34.10 per cent respectively. Similarly for 2014, it was to an extent of 13.25, 10.67 and 30.49 per cent, respectively. Similar trend was observed in pooled analysis. In pooled mean, combination of August I FN (D_5) with wider spacing (75 x 20 cm) recorded the lowest LAR at sixth leaf stage (17.4), tasseling (87.6), silking (89.4) and physiological maturity stages (67.7). However, early sown maize crop with narrow spacing of 45 x 20 cm recorded higher LAR in the above mentioned stages for both the years as well as in pooled analysis.

Pooled data indicate that combination of June I FN sowing with 45 x 20 cm spacing recorded the lowest per cent transmitted PAR (68.2, 4.6, 2.4 and 13.2) at V_6, tasseling, silking and physiological maturity stages respectively. The per cent TPAR increased with other combinations. During 2013, except at V3 stage, combination of June I FN (D_1) with 45 x 20 cm spacing (S_1) recorded the highest percentage of APAR (37.1, 94.3, 95.1 and 80.8 %) at V_6, tasseling, silking and physiological maturity and June II FN (D_2) sown crop recorded the highest percentage of absorbed PAR (92.9 and 83.2 %) at silking and physiological maturity stages, respectively. The pooled data clearly indicated that the combination of June I FN (D_1) with 45 x 20 cm planting geometry, recorded the highest percentage of absorbed PAR (29.4, 92, 93.6 and 81.4 %) at V_6, tasseling, silking and physiological maturity stages, respectively.

Combination of June I FN sowing with 45 x 20 cm recorded the highest percentage of intercepted PAR (IPAR). In case of pooled analysis,D_1 x S_1, recorded 31.8, 95.4, 97.6 and 86.8 per cent of IPAR at V_6, tasseling, silking and physiological maturity stages, respectively.

Pooled analysis of two years indicate that D_1 x S_1 recorded significantly higher (64.4, 1141, 1533 and 3328 g TDM /m^2) at V_6, tassel, silking and physiological maturity stages, respectively. Several researchers in past had noted that dry matter production in maize is related more closely to the utilization of solar radiation than to its interception (Daughtry *et al.*, 1983; Tollenaar and Bruulsema, 1988 and Westgate *et al.*, 1997). The influence of planting date and plant geometry on maize grain yield may be more related to IPAR and LAI. In past also increases in LAI had been found to be associated with increased IPAR and grain yield. Similar finding were reported earlier by Casini, 2012, Peykarestan and Seify (2012), Moosavi (2012) and Mokhtarpour *et al.* (2013).

5.2 Microclimatic variations

The microclimate of a crop is largely influenced by air temperature within and above canopy. Temperature within canopy has direct influence on physiological processes such as photosynthesis, transpiration and respiration. It also determines the thermal environment within crop canopy (Table 31-42).

5.2.1 Diurnal variations in the mean canopy temperature and relative humidity at different phenological stages of maize under different growing environments (sowing dates) and planting geometry

i. Mean canopy temperature

During 2013, the morning (0700 hrs) mean canopy temperature decreased with delayed sowings at both seedling stage and sixth leaf stages. But, it increased upto D_3 (July I FN) and later decreased at tasseling, silking and physiological maturity. During 2014 also, canopy temperature decreased with delayed sowings at seedling and sixth leaf stages. It increased with delayed sowing at silking stage (except at D_1) and decreased with delayed sowing at physiological maturity (Except at D_5). The mean of two years indicate that canopy temperature during morning hours (0700 hrs) decreased with delayed sowings at seedling, sixth leaf and physiological maturity stages, but increased with delayed sowings at tasseling and silking stages. Also, during 2013, at seedling stage and physiological maturity stages, lower afternoon canopy temperature was observed with delayed sowings. It increased with delayed sowings for sixth leaf stage and tasseling stages. During 2014 it decreased upto D_4 sowings and increased in the later sowings at seedling and sixth leaf stages. But at tasseling and physiological maturity it increased upto D_2 and later decreased with delayed sowings.

During, both morning and afternoon hours of the day, among the three planting geometries tried higher canopy temperature was noticed in widely spaced crop (75 x 20 cm) than narrower (45 x 20 cm) at all the stages during both the years. Irrespective of the phenological stages and years mean canopy temperature increased with increase in row spacing from 45 x 20 cm to 75 x 20 cm. These results confirms the findings of Jaya *et al.* (2001).

ii. Mean canopy relative humidity (%)

The mean of two years indicate that morning canopy relative humidity increased with delayed sowings at seedling (90 to 92 %), sixth leaf (89 to 93 %) and silking (89 to 93 %). But decreased with delayed sowings at tasseling (92 to 89 %) and physiological maturity stage (90 to 77 %). Mean afternoon RH (%), decreased with delayed sowing at tasseling, silking and physiological maturity stages during both the years. It decreased from 71 to 59 per cent at tasseling, 60 to 51 per cent at silking and 54 to 49 per cent at physiological maturity stage in delayed sowings.

Among the three planting geometries, in the morning hours (0700 hrs), higher canopy RH was noticed in narrow spaced crop (45 x 20 cm) than wider (75 x 20 cm) at all the stages during both the years. Whereas, mean canopy RH during afternoon hours decreased with increase in row spacing from 67 to 66 % at seedling, 73 to 71 % at sixth leaf stage, 68 to 65 per cent at tasseling, 60 to 58 per cent at silking and 53 to 52 per cent at physiological maturity stage.

5.2.2 Temperature and relative humidity profiles

Basic understanding of the micrometeorological variable profiles and their relationships within the canopy surface is an essential step to quantify and evaluate the heat and water vapor exchange processes between the atmosphere and canopy. A number of factors influence the microclimate including the height of crop canopy, density of leaves, gas exchange activity of the leaves, conditions at the soil surface and wind conditions above the canopy. Therefore, to illustrate the microclimate of maize crop, observations (diurnal) on temperature and relative humidity within maize canopy at five important stages *viz.*, seedling (V_1), sixth leaf stage (V_6), tasseling (VT), silking (Ro) and physiological maturity were made and results are discussed as below.

i. Temperature (^{0}C)

Temperature profiles inside the crop were different from that of above canopy. Microclimate of maize is largely influenced by temperature within canopy. Phenophase-wise temperature profiles at three different canopy heights (top, middle and bottom) were studied in both the crop seasons and presented in Table 31 to 38

In general, the temperature profiles shown that, in the morning hours (0700 hrs) crop canopy was cooler compared to outside irrespective of treatment. This might be due to radiational cooling of ground surface during night. During morning hours (0700 hrs), for both the years, similar kind of temperature profile were observed. But, the variations were noticed at different phenophases of the crop due to increase in height of the crop and leaf area. Temperature profile during seedling emergence and early vegetative stage were different from those at reproductive and maturity. Temperature profiles were lapse during seedling (V_1) and sixth leaf (V_6) stages. But, at tasseling, silking and physiological maturity higher temperature were noticed in the middle of the canopy height compared to top and bottom levels of the canopy. The increase was to an extent of 0.2 ^{0}C to 0.6 ^{0}C at tasseling and silking and 0.3 to 0.5 ^{0}C at physiological maturity during 2013 and 0.4 ^{0}C to 0.8 ^{0}C at tasseling, 0.5 ^{0}C to 1.2 ^{0}C at silking and 0.3 ^{0}C at physiological maturity during 2014 were observed. Similar trend were noticed in all the sowing dates during both the years.

In the afternoon (1430 hrs) also, temperature profiles within crop canopy were studied at different phenophases and it was noticed that the temperature profiles were lapse during first two stages (seedling and sixth leaf stage). The decrease in temperature with increase in height was to an extent of 0.1 ^{0}C at seedling (V_1) and 1.9 ^{0}C at sixth leaf stage (V_6). This might be due to more penetration of solar radiation to ground surface because of vertical sunrays to the surface due less canopy cover during early vegetative stages. But, the temperature profiles were quite different at tasseling, silking and physiological maturity. Temperature was more in the middle of the canopy than upper and bottom levels during reproductive stages (tasseling and silking). The decline was more at the bottom and less in the top level of canopy. Temperature in the middle of the canopy recorded 0.2 ^{0}C (at top) to 1.0 ^{0}C (at bottom) more at tasseling stage and 0.3 ^{0}C (at top) to 1.3 ^{0}C (at bottom) at silking stage. But, at physiological maturity, temperature increased with increase in crop height. More temperature was recorded in the upper canopy and lowest at the bottom. The drier leaves acts as radiation absorbing agent.

Planting geometries also influenced the temperature profile inside the crop canopy at all the stages during morning hours. Narrow spacing of 45 cm x 20 cm, recorded the lowest canopy temperature at all the heights over 60 cm x 20 cm and 75 cm x 20 cm row spacings. Canopy temperature increased with increase in row width in all the heights (top, middle and bottom) of canopy at all the phenological stages during both the years. Similar results were obtained by Graser *et al.* (1987) in sorghum.

Early in the season, soil was bare at the beginning (seedling stage) and partly shaded afterward. When the leaf area was little at seedling and sixth leaf stages, much of the solar radiation reached the soil surface where the greatest heating of air occurred. Hence, early in the season there was a gradual progression of decreasing air temperature with increasing height of the canopy. As the leaf area of maize increased (at tasseling and silking), there was an increased fraction of solar energy absorbed by leaves because here canopy shields the soil surface and encloses air layer between soil surface and crop canopy. Solar energy absorbed by the leaves resulted in heating of air. As a result, the height of the maximum air temperature moved above the soil surface in to the middle of the leaf canopy. These results are inconformity with the findings of Nathan (2007) and Sinclair and Weiss (2010).

During afternoon hours of the day canopy temperature in wider rows was more than in narrow rows. This implies that there was a build up of heat in the lowest layer nearest to soil surface in the wider rows, wide row plants heated up by sun and retained that heat for more time. Therefore inversion in lower canopy in widely spaced crop was observed due to leaves being exposed to sun rays. Shading effect cause low canopy temperature in narrow spaced maize.

ii. Relative humidity profiles within crop canopy

The relative humidity profiles were also measured at different phenophases during both the years in the morning as well as in the afternoon. The diurnal variations in the relative humidity profiles are presented in .

The profiles of relative humidity indicate that relative humidity was higher in the crop canopy than above the crop canopy. The relative humidity profiles were lapse inside the crop canopy throughout the day in all the treatments. During morning hours (0700 hrs), relative humidity profiles were lapse at all the phenophases (except at seedling and physiological maturity) in all the sowing dates and planting geometries. Lapse was to an extent of 1 per cent (sixth leaf), 1 to 2 per cent (tasseling and silking) during 2013 and 1 per cent (sixth leaf) and 1 to 2 per cent (tasseling and silking) during 2014. But, at physiological maturity higher relative humidity was noticed in the middle of the canopy and decreased at upper and bottom levels. In the afternoon hours (1430 hrs) also, fluctuations in relative humidity profiles were observed at different phenophases during both the years. However, relative humidity profile was unchanged during the seedling stage, but differed at other stages in both the years. During both the years relative humidity (%) decreased with height at all stages. Relative humidity profiles were lapse (decrease with height) at sixth leaf, tasseling, silking and physiological maturity stages during both the years. Higher relative humidity (%) was observed at the bottom and lower RH (%) at the top of the crop canopy.

Planting geometries also influenced the relative humidity profiles at all the stages. Here also lapse in relative humidity profiles were observed at all the phenological stages (except at seedling stage and physiological maturity). Narrower planting geometry (45 cm x 20 cm) recorded considerably higher relative humidity profiles compared to other two planting geometries (60 cm x 20 cm and 75 cm x 20 cm). The relative humidity decreased with increase in row spacing at all the phenological stages in both the years.

The relative humidity (%) also increased with depth in the crop canopy (due to increase in water vapour content with depth in to the canopy).Water vapour will be added to air by transpiration of the leaves and evaporation from the soil surface. Since, both processes occurred throughout the growing season of maize crop, there was a increased water vapour for the entire vertical profile from the above leaf canopy through the leaf canopy to the soil surface. Relative humidity profiles demonstrated a decrease from lower to upper canopy level showing inversion. Higher RH in the lower canopy might have implied that the water that evaporated from lower leaves not lost due to dense vegetation barrier also evaporation from soil surface was suppressed. These observations confirms the conclusions of Stigter *et al.* (1976), Sinclair and Weiss, 2010. and Teshfuney *et al.* (2013).

Knowledge of vertical profiles contributes to understanding variations in canopy structure of maize crop under Results showed differences of micrometeorological variables between the wide and narrow spacings. In wide planting geometry, lapse conditions extended from lower level (LP) to the upper level of the canopy and inversion was apparent at the top of the canopy. The main difference observed on the wide rows was the temperature inversion at the top of the canopy during the midday hours. The higher air flow observed in the wide rows compared to narrow rows was the reason for the extension of temperature inversion. The sparse maize canopy of the wider planting geometry had more drying power of the air in response to atmospheric evaporative demand compared to narrow planting geometry. Variation in air flow in wide and narrow planting geometry creates different gradients in humidity and evapotranspiration processes.

Micrometeorological studies within canopy are encourage to take advantage to understand that the equilibrium layer above the maize canopy. Results from this study verified the effect of wind on water vapor removal decreased downward as wind flow transfers within the canopy. This has an influence on the resistance of the boundary layer and canopy and soil surface resistance. Furthermore, vertical profile measurements will also assist to establish relationships between ET, soil water content.

5.2.3 Diurnal changes of canopy- air temperature, leaf- air temperature and soil surface temperature - air temperature differential studies during different phenological stages of maize

a) Canopy-air temperature (∆TC) differential at different phenological stages of maize

The canopy –air temperature differential values during morning hours, were negative at all the stages (except at physiological maturity) indicating that the canopy temperature remained cooler than air during morning hours (0700 hrs) (Table 49-50). But, the values became positive during afternoon hours (1430 hrs) indicating the higher canopy temperature of maize than air during afternoon hours of the day. Thus, the canopy was cooler than air during morning hours. While, the warmer than air during afternoon hours due to greater radiation intensity and absorption resulting in partial stomatal closure and less evaporative cooling. These finding are in line with Sivakumar and Viramani (1984).

Among the different sowing dates tried, the values ranged from 0 to -0.5,-0.1 to -0.5,0 to -0.7 and -0.3 to 0.3 ^{0}C during morning hours (0700 hrs) and 0.3 to 4.7,-1.2 to 1.5,-0.7 to 4.7 and -0.6 to 4.6 ^{0}C during afternoon hours (1430 hrs) at seedling, sixth leaf, tasseling and silking stages, respectively. ∆ TC values were lower during early crop growth period and higher in later crop growth period because of higher activity of leaves during early crop growth period and less activity of functional leaves due to ageing during later crop growth period resulting in to increased ΔTC.

Among the three planting geometries tried, in the 45 cm x 20 cm planting geometry, differential values were higher during morning hours indicating cooler canopy temperature than widely spaced maize. Also, during afternoon hours (1430 hrs) cooler canopy temperature values were observed in 45 cm x 20 cm than 75 cm x 20 cm spaced maize. This might be due to higher soil moisture content in 45 cm x 20 cm planting geometry and more evaporative cooling.

b) Leaf-air temperature differential (ΔTL)

The leaf –air temperature differential (ΔTL) values during morning hours, were negative at all the stages indicating that the leaf temperature remained cooler than air during morning hours (0700 hrs). But, the values became positive during afternoon hours (1430 hrs) indicating the higher leaf temperature of maize than air during afternoon hours of the day (Table 51 and 52). This might be due to higher solar radiation intensity absorption by leaves and air temperature and leaves were warmer than air due to increase in radiation load creating leaf water deficit. Consequently, transpiration decreases and leaf temperature increases resulting in partial stomatal closure and lesser evaporative cooling. Similar findings were recorded by Sivakumar and Viramani (1984) and Sivakumar (1986).

Among the different sowing dates tried, the values ranged from -1.2 to -2.0,-1.6 to-2.0,-1.7 to -2.7, -2.1 to -2.6 and -0.8 to -1.7 ^{0}C during morning hours (0700 hrs) and 2.1 to 5.8, 1.1 to 4.1, 0.7 to 3.1, 2.1 to 5.6, 2 to 8.3 ^{0}C during afternoon hours (1430 hrs) at seedling, sixth leaf, tasseling, silking and physiological maturity stages, respectively. ΔTL values were lower during early crop growth period and higher in later crop growth period because of higher activity of leaves during early crop growth period and less activity during later crop growth period due to ageing of leaves resulting in to increased ΔTL.

Among the three planting geometries tried, in the 45 cm x 20 cm planting geometry, differential values were higher during morning hours indicating more cooler leaf temperature than widely spaced maize. Also, during afternoon hours (1430 hrs) cooler leaf temperature values were observed in 45 cm x 20 cm than 75 cm x 20 cm spaced maize. This might be due to increase in LAI, leaf water potential, stomatal conductance and evapotranspiration resulting in more evaporative cooling and consequently decrease in leaf temperature. Leaf-air temperature differential decreased with increase in soil moisture content. These findings are in line with Sivakumar and Virmani (1984).

c) Soil surface temperature-air temperature differential

The data pertaining to diurnal changes in soil surface-air temperature differential as influenced by different sowing dates and planting geometry are presented in Table 53 and 54

The soil surface –air temperature differential values during morning hours, were negative at all the stages indicating that the soil surface temperature remained cooler than air during morning hours (0700 hrs) because at night with no incoming solar radiation, there will be more outgoing radiation than incoming one creating a negative value for net radiation. Under these circumstances the surface cools due to a loss of energy. Soil sensible heat flux was low and negative indicating that soil surface temperature was low, creating an energy sink at soil surface. Therefore, the soil surface during morning hours was cooler than air. These observations are in line with observation of Rao (2006) and Zeggaf *et al.* (2007). But, the values became positive during afternoon hours (1430 hrs) indicating the higher soil surface temperature of maize than air during afternoon hours of the day.

Among the different sowing dates tried, the values ranged from 0.1 to -0.5,-0.6 to -1.3,-1.3 to -2.5,-1.7 to -2.6 and -1.9 to 0.9 ^{0}C during morning hours (0700 hrs) and 4.3 to 10.4, 3.2 to 11.9,-0.5 to 7.1, 0.0 to 7.0 and 3.7 to 8.9 ^{0}C during afternoon hours (1430 hrs) at seedling, sixth leaf, tasseling, silking and physiological maturity stages, respectively. Among the three planting geometries tried, in the 45 cm x 20 cm planting geometry, differential values were higher during morning hours indicating cooler soil surface temperature than widely spaced maize. Also, during afternoon hours (1430 hrs) cooler soil surface temperature values were observed in 45 cm x 20 cm than 75 cm x 20 cm spaced maize.

5.2.4 Soil temperature profile studies at different depths under different sowing dates and planting geometry

Influence of sowing dates

Mean of two years indicated that during morning hours of the day (0700 hrs), soil temperature at 5 cm depth declined with delayed sowings from June I FN (D_1) to August I FN (D_5) sowing at all the stages (except at tasseling and silking). It declined from 23.9 to 22.8 ^{0}C at seedling stage and 22.4 to 20.8 ^{0}C at sixth leaf stage. But, raised from 20.6 to 21.1 ^{0}C at tasseling and 19.6 to 20.4 ^{0}C at silking stages. At 15 cm depth also, the mean of two years showed a gradual decline in temperature with delayed sowings at all the stages except at tasseling and silking. The soil temperature at 15 cm was higher than at 5 cm depth indicating the soil heat flux from lower to surface layer during night hours. During afternoon hours of the day (1430 hrs) the soil temperature at 5 and 15 cm depths did not show any specific trend among the sowing dates (Table 55 – 58).

Influence of planting geometry

During morning hours (0700 hrs), it was observed that among the three planting geometries tried, soil temperature at 5 cm and 15 cm depth increased with increase in spacing at all the phenological stages. Wider spacing of 75 x 20 cm (S_3) recorded a higher soil temperature compared to narrow spacing. The soil temperature at 15 cm was higher than 5 cm depth indicating the soil heat flux from lower to surface layer during night hours.

During afternoon hours (1430 hrs), at both the depths (5 and 15 cm), soil temperature increased with increase in row spacing (wider planting geometry). These findings are in line with Sharratt (1993). The soil temperature at 5 cm depth was greater compared to 15 cm depth indicating heat flux from surface to lower (15 cm) depth. Thus, the soil temperature during afternoon hours of the day (2.30 cm) decreased with increase in soil depth.

Increased soil temperature in wider planting geometry (75 cm x 20 cm), accelerated the rates of leaf tip appearance and full leaf expansion, enabling the crop to more rapidly attain maximum green leaf area index. This enabled a better synchrony between time of peak radiation interception and peak radiation incidence. At a time decreasing photoperiod, this enabled crops grown in warmer soil to intercept more radiation and to accumulate more biomass per plant. These results are in accordance with Stone *et al.* (1999). A combination of a low soil temperature and high soil water content can cause poor maize stand establishment.

5.2.5 Soil moisture content (%)

Soil moisture content (%) at 0-15 cm during different phenophases did not show any specific trend. However, the mean of two years indicated that, it ranged from 20.1 to 25.1 per cent at seedling stage (V_1), 21.3 to 32.4 per cent at sixth leaf stage (V_6), 23.3 to 32.9 per cent at tasseling, 19.5 to 33.3 per cent at silking and 20.4 to 28.9 per cent at physiological maturity was observed. At 15-30 cm depth, the mean of two years indicated that, at 15-30 cm depth soil moisture ranged from 22.3 to 27.9 per cent at seedling stage (V_1), 24.1 to 36.6 per cent at sixth leaf stage (V_6), 21.8 to 37.2 per cent at tasseling, 21.5 to 36.6 per cent at silking and 24.0 to 31.7 per cent at physiological maturity (Tables 59 to 61).

In general, the presence of excess moisture in the rhizosphere negatively affected maize at every growth stage. For both the years the maize crop under delayed sown condition experienced an excess moisture condition in their early developmental stages. However, excess soil moisture during early seedling to tasseling stage affect severely, because of complete deprivation of oxygen in rhizosphere (anoxia) the root respiration switches from aerobic to anaerobic. And also caused nutrient stress due to leaching of nutrients from rhizosphere due to presence of free water in which roots are immersed. These findings are in accordance with Zaidi *et al.* (2004).

Among the three planting geometries, narrow spacing (45 x 20 cm) had higher soil moisture content over other planting geometries tried at sixth leaf stage (27.8 % and 31.4 %), tasseling (31.3 % and 34.3 %), silking (29.2 % and 32 %) and physiological maturity (26.6 % and 29.2 %) at 0-15 cm and 15-30 cm depth, respectively. Similar kind of soil moisture pattern was observed in 30-45 cm soil depth. Both leaf-air temperature and canopy –air temperature differential decreased with increase in soil moisture content in 45 cm x 20 cm planting geometry.

The quicker shading of soil surface during early part of the season resulted in less water being lost by evaporation. It was especially important under favorable soil surface moisture conditions because it allowed maize plants to maximize photosynthesis and the proportion of water that is used in growth processes rather than evaporated from the soil. Ultimately, the earlier crop cover provided by smaller row widths was instrumental in enhancing soil protection, diminishing water runoff and soil erosion. Similar findings were observed by Karlen and Camp (1985), Lauer (2009) and Sangoi *et al.* (1998)

Production under ideal environments can also support narrow row spacing (45 cm x 20 cm). Under ideal conditions, soil was generally moist and narrow rows resulted in more equidistant plant spacing, increased leaf area and early-season interception of solar radiation and increased soil shading which might have resulted in reduced evaporative water loss. Transpiration may increase due to more leaf area being exposed to radiation; however, better plant distribution maximizes photosynthesis and offsets transpirational water loss.

5.3 Economics

5.3.1 Gross return (` $ha^{-1}$), net returns (` $ha^{-1)}$ and B:C ratio as influenced by sowing dates and planting geometry

During 2013, among the sowing dates, June I fortnight sowing recorded significantly higher gross return (` 93010 $ha^{-1}$), net returns (` 63618 ha^{-1}) and B:C ratio (3.16). It was followed by June II fortnight sowing (` 84308, ` 54915 and 2.87, respectively). The lowest monetary benefits were obtained in August I fortnight sowing (` 54955, ` 25562 and 1.86, respectively). Among the three planting geometries tried, during 2013, 45 cm x 20 cm geometry recorded significantly higher gross return (` 81580 $ha^{-1}$), net returns (` 50586 ha^{-1}) and B:C ratio (2.61) followed by 60 cm x 20 cm (` 75505, ` 46318 and 2.59, respectively) and the lowest returns were observed in 75 cm x 20 cm (` 64194, ` 36497 and 2.32, respectively). Among the treatment combinations, June I FN with 45 cm x 20 cm gave significantly higher monetary benefits interms of gross returns and net returns (` 97651 and ` 66356 ha^{-1}, respectively) over other treatment combinations (Table 62).

During 2014, among the sowing dates, July I fortnight sowing recorded significantly higher gross return (` 97225 $ha^{-1}$), net returns (` 66286 ha^{-1}) and B:C ratio (3.14). It was followed by June II fortnight sowing (` 96686, ` 65746 and 3.12, respectively). The lowest monetary benefits were obtained in August I fortnight sowing (` 65261, ` 34321 and 2.11, respectively). Among the three planting geometries tried, during 2014, 45 cm x 20 cm geometry recorded significantly higher gross return (` 96109 $ha^{-1}$), net returns (` 63167 ha^{-1}) and B:C ratio (2.92) compared to 60 cm x 20 cm (` 87236, ` 56513 and 2.84, respectively) and the lowest returns were observed in 75 cm x 20 cm (` 77336, ` 48182 and 2.65, respectively). Among the treatment combinations, June II FN with 45 cm x 20 cm gave significantly higher monetary benefits interms of gross returns and net returns (` 104483 and ` 71541 ha^{-1}, respectively) over other treatment combinations.

In pooled mean, among the different sowing dates tried, June I FN sowing (D_1) proved its superiority interms of monetary benefits over other sowing dates. It recorded the highest gross returns (` 94493 $ha^{-1}$), net returns (` 64326 ha^{-1}) and B:C ratio (3.13). The lowest monetary benefits were obtained in delayed sowing *i.e.* August I FN (` 60108, ` 29942 and 1.98, respectively). These finding are in conformity with Khola *et al.* (1999).

Among the three planting geometries, 45 cm x 20 cm geometry recorded significantly higher gross return (` 88845 $ha^{-1}$), net returns (` 56726 ha^{-1}) and B:C ratio (2.76) compared to 60 cm x 20 cm (` 81370, ` 51416 and 2.71, respectively) and the lowest returns were observed in 75 cm x 20 cm (` 76765, ` 42339 and 2.49, respectively). Among the treatment combinations, June I FN with 45 cm x 20 cm gave higher gross returns (` 99388 $ha^{-1}$) and significantly higher net returns and B:C ratio (` 67628 and 3.26, respectively) were obtained with June I FN sowing with 60 cm x 20 cm planting geometry. These results confirm the findings of Bangarwa *et al.* (1989), Gollar and Patil (2000) and Bisht *et al.* (2012).

5.4 Correlation studies

5.4.1 Correlation between growth, yield parameters, agrometeorological indices and grain yield of maize

During 2013, grain yield of maize had highly significant positive correlation with LAI during silking (0.88**), days to physiological maturity (0.92**), plant height during physiological maturity (0.87**), GDD during physiological maturity (0.95**), HUE during physiological maturity (0.72**), Light absorption ratio during silking (0.95**) and per cent APAR during silking (0.86**). But, grain yield was negatively correlated with Light transmission ratio during silking (-0.95**). During 2014, grain yield of maize had highly significant positive correlation with LAI during silking (0.74**), days to physiological maturity (0.82**), plant height during physiological maturity (0.91**), GDD during physiological maturity (0.85**) and per cent APAR during silking (0.72**). But, grain yield was negatively correlated with Light transmission ratio during silking (-0.51).For pooled mean also, grain yield had highly significant positive correlation with LAI during silking (0.87**), days to physiological maturity (0.90**), plant height during physiological maturity (0.90**), GDD during physiological maturity (0.93**), HUE during physiological maturity (0.63**), Light absorption ratio during silking (0.81**) and per cent APAR during silking (0.85**). But, grain yield was negatively correlated with Light transmission ratio during silking (-0.81**) (Table 63).

5.4.2 Relationship between weather parameters

During 2013, grain yield of maize had a negative association with maximum temperature during all the phenophases (except sowing to seedling emergence) *viz.*, seedling emergence to sixth leaf (-0.54), sixth leaf to tasseling (-0.77), tasseling to silk (-0.20), silk to milk (-0.46) and milk to physiological maturity (-0.69). But, it had a positive association with minimum temperature during all the phenophases (except sixth leaf to tasseling) *viz.*, sowing to seedling emergence (0.61), seedling emergence to sixth leaf (0.89*), tasseling to silk (0.39), silk to milk (0.69) and milk to physiological maturity (0.88**).Grain yield had a positive association with morning relative humidity during seedling emergence to sixth leaf (0.57), sixth leaf to tasseling (0.07), silk to milk (0.65) and milk to physiological maturity (0.88). But negatively correlated during sowing to seedling emergence (-0.30) and tasseling to silk (-0.57). Similarly, grain yield had a positive association with afternoon relative humidity during seedling emergence to sixth leaf (0.45), sixth leaf to tasseling (0.76), tasseling to silk (0.43), silk to milk (0.72) and milk to physiological maturity (0.97**). But negatively correlated during sowing to seedling emergence (-0.72). Also, it had positive association with rainfall during seedling emergence to sixth leaf (0.50), sixth leaf to tasseling (0.19), tasseling to silk (0.19), silk to milk (0.72) and milk to physiological maturity (0.33). But negatively correlated during sowing to seedling emergence (-0.29) (Table 64). These results are inconformity with the findings of Leelarani *et al.* (2013).

For the year 2014, grain yield of maize had a positive association with maximum temperature during sowing to seedling emergence (0.67), emergence to sixth leaf (0.25) and milk to physiological maturity (0.66) but, it had negative association with maximum temperature during sixth leaf to tasseling (-0.85), tasseling to silk (-0.59) and silk to milk (-0.83). It had a positive association with minimum temperature during all the phenophases *viz.*, sowing to seedling emergence (0.63), seedling emergence to sixth leaf (0.88*), sixth leaf to tasseling (0.69), tasseling to silk (0.58), silk to milk (0.61) and milk to physiological maturity (0.92**).Grain yield had a positive association with morning relative humidity during sixth leaf to tasseling (0.92**), tasseling to silk (0.90**), silk to milk (0.87) and milk to physiological maturity (0.88). But, negatively correlated during sowing to seedling emergence (-0.53) and seedling emergence to sixth leaf (-0.48). Similarly, grain yield had a positive association with afternoon relative humidity during sixth leaf to tasseling (0.83), tasseling to silk (0.47), silk to milk (0.88*) and milk to physiological maturity (0.76). But, negatively correlated during sowing to seedling emergence (-0.31) and seedling emergence to sixth leaf (-0.22).Rainfall also had a positive association with yield during sixth leaf to tasseling (0.77), silk to milk (0.54) and milk to physiological maturity (0.19) and it was negatively correlated during sowing to emergence (-0.46) and emergence to sixth leaf (-0.002). These results are in line with the findings of Huda et al (1976) and Leelarani *et al.* (2013).

Results of practical utility

Based on the results obtained from two year investigation during *kharif* season of 2013 and 2014 with a rainfall of 539.4 mm and 704.3 mm, respectively with maximum temperature ranging between 27.7 ^{0}C to 28.4 ^{0}C and minimum temperature of 18.4 ^{0}C to 18.9 ^{0}C during cropping period from 23rd SMW to 49th SMW, the following results have the practical utility

1. Among the various weather parameters, mean maximum temperature during all phenological stages had a negative association with grain yield of maize during both the years of study. But, the relative humidity (both morning and afternoon) and rainfall (except tasseling to silking stage) had a positive association with grain yield during both the years of study.

2. Among the microclimatic parameters, canopy temperature, soil temperature and leaf temperature, increased with increase in row spacing from 45 x 20 cm to 75 x 20 cm.. Early sowing during June I fortnight with narrow planting geometry (45 cm x 20 cm) resulted in higher light absorption ratio, per cent APAR and per cent IPAR.

3. Sowing of maize during June I or II fortnight resulted in higher grain yield (8082 and 7716 kg ha^{-1}), straw yield (106.6 and 105.8 q ha^{-1}), gross returns (` 94493 and ` 90497 ha^{-1}), net return (` 64326 and ` 60331 ha^{-1}) and B : C ratio (3.13 and 2.99).

4. Sowing of maize with 45 cm x 20 cm planting geometry resulted in higher grain yield (7529 kg ha^{-1}), straw yield (112.1 q ha^{-1}), gross returns (` 88845 ha$^{-1}$), net return (` 56726 ha^{-1}) and B : C ratio (2.76).

5. Sowing of maize during June I fortnight either with 45 cm x 20 or 60 cm x 20 cm planting geometry resulted in higher maize grain yield (8461 and 8318 kg ha^{-1}), gross returns (` 99388 and ` 97583 ha^{-1}), net returns (` 67269 and 67628 ha^{-1}) and B : C ratio (3.10 and 3.26), respectively.

Future line of work

- The relationship of microclimatic parameters with biotic (pest and diseases) and abiotic stress under different sowing windows and planting geometry needs to be studied.
- Hybrids with wider range of maturity/ duration need to be tested for microclimatic responses with wider sowing windows (dates) and higher population densities.
- Nutrient and moisture uptake pattern by maize under different growing environments and densities need to be studied.

6. SUMMARY AND CONCLUSIONS

The field experiment on 'Crop-weather relations in maize (*Zea mays* L.) under different sowing windows and planting geometry in northern transition zone of Karnataka' was carried out at the Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad, during *kharif* season of 2013 and 2014. The treatments consisted of five sowing dates *viz.*, June I fortnight (D_1), June II fortnight (D_2), July I fortnight (D_3), July II fortnight (D_4) and August I fortnight (D_5), as main plots and three planting geometries *viz.*, 45 cm x 20 cm,60 cm x 20 cm and 75 cm x 20 cm in sub plots laid out in split plot design and replicated thrice. The results of the investigation are summarized as below

6.1 Crop weather relations during 2013 and 2014 cropping period

During 2013, the early vegetative stages of maize in delayed sowings were exposed to higher values of mean maximum temperature. While, higher mean temperature values were experienced in the early vegetative stage of maize in early sowing in 2014. In both the years the delayed sowings experienced higher maximum temperatures between grain development to maturity. Minimum temperature did not vary during early vegetative stage of maize. But, the delayed sowings experienced a slightly lower mean minimum temperature during grain development and physiological maturity stages which affected the grain yield.

During 2013, both morning and afternoon relative humidity increased with delayed sowings during sowing to seedling emergence (upto July I FN) and for later sowings decreased with delayed sowings from seedling emergence to physiological maturity. During 2014, morning relative humidity decreased with delay in sowings at all the phenological stages except during sowing to sixth leaf stage, whereas afternoon relative humidity decreased with delayed sowings from sixth leaf to physiological maturity stage.

The overall rainfall distribution for both the years for different sowing dates, indicated that, during 2013, maximum amount of rainfall (468.8 mm) for the cropping period was received by June II FN sown crop (D_2), followed by June I FN (D_1) sowing (451.6 mm), July I FN (D_3) sowing (444.8 mm) and lowest (235.2 mm) for August I FN sowing (D_5).Whereas, in 2014, the highest amount of rainfall (622 mm) was received by July I FN sown crop (D_3), followed by June I FN (D_1) sowing (542.3 mm) and June II FN (D_2) sown crop (540.2 mm) and July II FN (D_4) 503.4 mm. The lowest amount of rainfall (357.8 mm) was received by August I FN sown crop (D_5). In comparison with the 27 years average values (7.5 kmph), the wind speed value for the entire cropping period was higher for both 2013 (8.5 kmph) and 2014 (8.3 kmph).

6.2 Micrometeorological studies

The mean of two years data indicated that canopy temperature during morning hours (0700 hrs) and afternoon hours (1430 hrs) decreased with delayed sowings. Among the three planting geometries, higher canopy temperature were noticed in widely spaced crop (75 x 20 cm) than narrower (45 x 20 cm) at all the stages during both the years. Irrespective of the phenological stages and crop season mean canopy temperature increased with increase in row spacing from 45 cm x 20 cm to 75 x 20 cm.

Mean afternoon RH (%), decreased with delayed sowing (from June I FN to August I FN) during tasseling, silking and physiological maturity stages during both the years. It decreased from 71 to 59 per cent at tasseling, 60 to 51 per cent at silking and 54 to 49 per cent at physiological maturity stage in delayed sowings. Among the three planting geometries, higher canopy RH was noticed in narrow spaced crop (45 cm x 20 cm) than wider (75 cm x 20 cm) at all the stages during both the years.

Mean of two years soil temperature, indicated that during morning and afternoon hours values of the day at 5 cm and 15 cm depth declined with delayed sowings from June I FN (D_1) to August I FN (D_5) sowing at all the stages (except at tasseling and silking). Among the three planting geometries, soil temperature at 5 cm and 15 cm depth increased with increase in spacing at all the phenological stages. Wider spacing of 75 cm x 20 cm (S_3) recorded a higher soil temperature compared to narrow spacing (45 cm x 20 cm). The soil temperature during morning hours, at 5 cm were lower than 15 cm depth, while reverse trend was observed during afternoon hours of the day.

The leaf –air temperature differential (ΔTL) values during morning hours (0700 hrs), were negative at all the stages indicating that the leaf temperature remained cooler than air. But, the values became positive during afternoon hours (1430 hrs) indicating the higher leaf temperature of maize canopy than ambient during afternoon hours of the day. ∆TL values were lower during early crop growth stages and higher in later crop growth stages. Among the three planting geometries tried, differential values were higher in the 45 cm x 20 cm planting geometry, indicating more cooler leaf temperature than widely spaced maize.

The canopy –air temperature differential values during morning hours (0700 hrs), were negative at all the stages (except at physiological maturity) indicating that the canopy temperature remained cooler than ambient. But, the values became positive during afternoon hours (1430 hrs) indicating the higher canopy temperature of maize than air during afternoon hours of the day. ∆ TC values were lower during early crop growth period and higher in later crop growth period. Among the three planting geometries, differential values were higher in the 45 cm x 20 cm planting geometry, indicating cooler canopy temperature than widely spaced maize.

The soil surface –air temperature differential values during morning hours (0700 hrs), were negative at all the stages indicating that the soil surface temperature remained cooler than air. But, the values became positive during afternoon hours (1430 hrs) indicating the higher soil surface temperature of maize canopy than air during afternoon hours of the day. Among the three planting geometries tried, in the 45 cm x 20 cm planting geometry, differential values were higher, indicating cooler soil surface temperature than widely spaced maize.

Light transmission ratio (LTR %) increased with delayed sowing at all the phenological stages. Conversely, higher values of Light Absorption Ratio were observed in early sowings compared to delayed sowing. Among the planting geometries, 45 cm x 20 cm (S_1) recorded higher LAR values than wider planting geometries. Similarly, Absorbed and intercepted PAR (%) decreased with delayed sowings and higher percentage was observed in early sown crops. Among the geometries tried, 45 cm x 20 cm (S_1) recorded higher per cent APAR and IPAR values than wider planting geometries.

Influence of sowing dates on phenology, growth, yield and yield attributes

The number of days taken by the maize for completion of each phenophase varied with the date of sowing. The mean of two years showed that the number of days taken to physiological maturity was highest (115 days) with the earliest sowing *i.e.* June I FN (D_1) and consistently reduced with subsequently delayed sowing.

June I FN (D_1) sown crop had more number of accumulated GDD to attain sixth leaf tasseling, silking and physiological maturity stages (378.4,815.8,890.4 and 1593.0 ^{0}C day), respectively. The number of GDD taken to attain different phenological stages decreased with delay in sowings. The lowest number of accumulated GDD were recorded by August I FN (D_5) sown crop to attain sixth leaf, tasseling, silking and physiological maturity stages (302.8,692.3,787.8 and 1402.0 ^{0}C day), respectively.

June I fortnight (D_1) sown maize recorded significantly higher phenothermal index to complete sixth leaf stage, tasseling, silking and physiological maturity stage (14.23, 13.74, 13.70 and 13.86), respectively compared to other delayed sowing dates. It also, recorded significantly higher HUE at tasseling, silking and physiological maturity stages (1.22, 1.49 and 1.82 g m^{-2}/ ^{0}C day), respectively compared to fortnightly delayed sowings.

June I FN sown maize was superior with respect to grain yield (8082 kg ha^{-1}), which was on par with June II FN sowing (7716 kg ha^{-1}). But significantly superior over other delayed sowing in July I FN (7400 kg ha^{-1}), July II FN (5892 kg ha^{-1}) and the lowest being in August I FN (5035 kg ha^{-1}). The reduction in grain yield of maize was to an extent of 4.5, 8.4, 27.1 and 37.7 per cent with subsequent fortnightly delay in sowing.

The lower LAI values were recorded with delayed sowing from June I FN (D_1) to August I FN (D_5). LAI decreased from 4.86 to 3.52; 5.05 to 3.56 and 3.23 to 2.63 at tasseling, silking and physiological maturity stages, respectively. Delayed sowing recorded the lowest LAI at all the phenophases. Superior cob weight (207.7), grain weight per cob (175.7 g), cob length (19.8 cm), no. of kernel rows per cob (15.3), hundred seed weight (32.7 g) and harvest index (0.43) were recorded in early sown

(June I FN) crop which consistently decreased with subsequent fortnightly delayed sowings up to August I FN sowing, which recorded the lowest values for all yield characters.

Influence of planting geometry phenology, growth, yield and yield attributes

Among the three planting geometries, 45 cm x 20 cm (S_1) took more number of days to attain sixth leaf stage (27.5 days), tasseling (65.3 days), silking (63.7 days) and physiological maturity (111.1 days) stages, respectively compared to wider planting geometries *viz.*, 60 cm x 20 cm (S_2) and 75 x 20 cm (S_3).

Sowing with 45 cm x 20 cm (S_1) geometry recorded more number of accumulated GDD to attain all phenological stages from seedling emergence to physiological maturity. It also recorded higher values of PTI (13.23, 13.74, 13.65 and 13.79) and higher HUE (1.24, 1.52 and 1.96 g m^{-2}/ ^{0}C day) at tasseling, silking and physiological maturity stages, respectively compared to wider planting geometries (60 cm x 20 cm and 75 cm x 20 cm).

The yield and yield attributes were recorded significantly higher with 45 cm x 20 cm (S_1) with grain yield (7529 kg ha^{-1}) compared to 60 cm x 20 cm (6909 kg ha^{-1}) and (6037 kg ha^{-1}). The reduction in grain yield with increase in spacing was to an extent of 8.2 per cent with 60 cm x 20 cm and 19.8 per cent with 75 cm x 20 cm compared to 45 cm x 20 cm.

The highest LAI values were recorded in narrow spaced crop at 45 cm x 20 cm geometry, at all the phenological stages decreased from 0.43 to 0.33, 4.91 to 3.86 and 5.04 to 3.91 at sixth leaf, tasseling, silking and physiological maturity stages, respectively compared to wider geometry of 75 cm x 20 cm.Widest geometry of 75 cm x 20 cm recorded the lowest LAI at all the phenophases. Conversely, superior cob weight (218 g), grain weight per cob (188.4 g), cob length (19.8 cm), harvest index (42 %) and hundred seed weight (34.6 g) were recorded in widest (75 cm x 20 cm) planting geometry and consistently decreasing with decrease in row spacing up to 45 cm x 20 cm, which recorded the lowest values for the above mentioned yield components.

Interaction effect of sowing time and planting geometry

The interaction effect of sowing dates and planting geometry shown that sowing in June I FN (D_1) either with 45 cm x 20 cm or 60 cm x 20 cm spacing recorded significantly higher grain yield (8461 and 8318 kg ha^{-1}, respectively) over remaining sowing date and planting geometry combinations (8237 to 4363 kg ha^{-1}). While, the lowest grain yield (4363 kg ha^{-1}) was registered with August I FN sown maize with 75 x 20 cm (S_3) spacing. The combination of June I FN sowing with narrow spacing (45 x 20 cm) (D_1 x S_1) recorded the highest number of accumulated heat units to attain six th leaf (393 GDD), tasseling (838.2 GDD), silking (913.3 GDD) and physiological maturity (1604.1 GDD).Delayed sowing with wider spacing attained various phenological stages in less number of days. They took 23 days, 49.3 days, 55.8 days, 102.7 days to attain sixth leaf stage, tasseling, silking and physiological maturity stages compared to other treatment combinations (24 to 31 day, 54.2 to 61.7 days, 62.2 to 66.7 days and 105.3 to 115.7 days for respective phenological stages). Also, higher heat use efficiency at tasseling (1.45 g m^{-2}/ ^{0}C day), silking (1.79 g m^{-2}/ ^{0}C day) and physiological maturity (2.21 g m^{-2}/ ^{0}C day) stages was recorded with this combination as compared to other treatment combinations.

Combination of June I FN (D_1) sown crop with 45 cm x 20 cm (S_1) recorded significantly higher LAI at all the phenophases. D_1 x S_1 recorded 0.50, 5.78, 6.11 and 3.87 at V_6, tasseling, silking and physiological maturity stages, respectively. The lowest LAI was recorded with August I FN (D_5) sown crop with 75 x 20 cm spacing. Early sown maize crop with narrow spacing of 45 x 20 cm had higher LAR during all phenological stages. The lowest per cent transmitted PAR (68.2, 4.6, 2.4 and 13.2) at V_6, tasseling, silking and physiological maturity stages respectively. The highest percentage of absorbed PAR (29.4, 92, 93.6 and 81.4) and intercepted PAR (31.8, 95.4, 97.6 and 86.8 %) during respective phenophases.

6.3 Economics

Among the different sowing dates tried, June I FN sowing (D_1) proved its superiority in terms of monetary benefits over other sowing dates. It recorded the highest gross returns (` 94493 ha$^{-1}$), net returns (` 64326 ha^{-1}) and B:C ratio (3.13).

The lowest monetary benefits were obtained in delayed sowing *i.e.* August I FN (` 60108, ` 29942 and 1.98, respectively). Among the three planting geometries tried, 45 cm x 20 cm geometry recorded higher gross return (` 88845 $ha^{-1}$), net returns (` 56726 ha^{-1}) and B:C ratio (2.76) compared to 60 cm x 20 cm (` 81370, ` 51416 and 2.71, respectively) and the lowest returns were observed in 75 cm x 20 cm (` 76765, ` 42339 and 2.49, respectively). Among the treatment combinations, June I FN with 45 cm x 20 cm gave higher gross returns (` 99388 $ha^{-1}$), while higher net returns and B:C ratio (` 67628 and 3.26, respectively) were obtained with June I FN sowing with 60 cm x 20 cm planting geometry.

6.4 Correlation between growth, yield parameters, agrometeorological indices and grain yield of maize

Grain yield had highly significant positive correlation with, LAI during silking (0.87**), days to physiological maturity (0.90**), plant height during physiological maturity (0.90**), GDD during physiological maturity (0.93**), HUE during physiological maturity (0.63**), Light absorption ratio during silking (0.81**) and per cent APAR during silking (0.85**). But, grain yield was negatively correlated with Light transmission ratio during silking (-0.81**).

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Appendix I: Prices of inputs and outputs

Sl. No.	Particulars	Unit	Price (`)	
			2013-14	2014-15
A. Inputs				
I	**Seeds**			
1	Super 900-M (*Dekalb*)	kg	190.00	190.00
II	**Fertilizers**			
1	Urea	kg	6.00	6.00
2	Di ammonium phosphate	kg	24.70	25.54
3	Muriate of potash	kg	17.60	17.60
4	Zinc sulphate	kg	47.00	47.00
5	FYM	tonnes	1000.00	1000.00
6	Chlorpyriphos	litre	320.00	350.00
7	Atrataf	kg	360.00	400.00
8	Phorate	kg	65.00	70.00
9	Furadon	kg	85.00	100.00
III	**Labour wages**			
1	Man	per day	157	157
2	Woman	per day	157	157
3	Bullock pair	per day	600	650
4	Deep ploughing	per hour	500	500
5	Harrowing	per hour	500	500
6	Rotovator	per hour	900	1000
B. Outputs				
1	Maize grain	100 kg	1080	1100
2	Maize stover	100 kg	60	60

Source : MARS, UAS, Dharwad for the year 2013 and 2014

Appendix II: Daily weather data during the cropping period (2013 and 2014)

June	Rainfall (mm)		Maximum temperature (^0C)		Minimum temperature (^0C)	
	2013	2014	2013	2014	2013	2014
01-Jun	22.2	0.0	32.9	34.7	18.1	21.9
02-Jun	0.0	0.0	27.0	33.8	21.2	22.5
03-Jun	0.0	4.2	29.0	33.5	21.4	20.5
04-Jun	0.0	0.0	27.8	30.9	19.9	22.2
05-Jun	0.0	0.0	30.0	32.8	20.9	21.1
06-Jun	0.0	0.0	31.8	32.9	22.2	23.1
07-Jun	0.6	5.4	32.5	32.5	22.0	21.1
08-Jun	0.4	0.0	28.8	34.0	20.5	23.1
09-Jun	0.8	0.0	27.6	32.0	19.9	22.4
10-Jun	1.0	0.0	25.6	30.0	20.3	20.9
11-Jun	3.0	0.2	26.8	29.7	20.5	22.0
12-Jun	0.6	1.6	27.0	29.6	21.6	22.0
13-Jun	4.4	0.0	28.0	30.8	21.0	21.7
14-Jun	4.4	1.2	25.7	30.4	20.0	21.4
15-Jun	0.6	0.0	26.5	30.6	21.4	21.9
16-Jun	3.8	0.0	27.1	30.3	20.5	21.7
17-Jun	4.6	0.0	27.2	31.1	21.2	20.9
18-Jun	4.0	2.4	26.5	29.1	20.2	21.3
19-Jun	1.2	9.4	26.5	26.6	20.3	21.0
20-Jun	0.0	4.0	28.2	26.5	20.6	21.2
21-Jun	2.2	0.9	27.1	28.5	20.5	22.0
22-Jun	1.2	0.0	28.8	29.4	20.9	22.0
23-Jun	0.0	0.0	29.0	30.0	21.4	21.6
24-Jun	0.0	0.0	28.0	30.8	21.1	21.5
25-Jun	5.0	0.0	27.0	30.8	20.3	20.6
26-Jun	5.2	0.0	26.1	30.5	21.0	20.1
27-Jun	7.0	0.0	25.5	32.1	21.1	20.4
28-Jun	0.4	0.0	28.7	32.4	20.6	21.4
29-Jun	0.6	0.0	28.6	33.0	20.5	21.3
30-Jun	2.2	0.0	28.8	32.1	20.4	21.0
Total/Avg	**75.4**	**29.3**	**28.0**	**31.0**	**20.7**	**21.5**

Contd…

July	Rainfall (mm)		Maximum temperature (^{0}C)		Minimum temperature (^{0}C)	
	2013	**2014**	**2013**	**2014**	**2013**	**2014**
01-Jul	4.4	0.0	26.4	32.5	20.1	20.5
02-Jul	2.4	0.0	25.1	32.7	20.6	21.2
03-Jul	4.2	0.0	25.2	31.3	20.2	20.2
04-Jul	1.2	0.8	24.4	29.5	21.5	19.6
05-Jul	0.8	0.0	28.2	28.7	20.9	21.1
06-Jul	5.6	0.6	28.9	30.3	20.0	21.3
07-Jul	0.4	0.0	27.4	30.0	20.6	21.4
08-Jul	1.6	1.2	27.4	30.4	20.2	21.0
09-Jul	0.0	0.6	26.5	29.3	20.4	20.8
10-Jul	1.2	4.4	27.0	28.0	20.3	20.5
11-Jul	11.8	0.4	26.0	27.4	20.4	20.0
12-Jul	5.6	0.8	23.1	25.7	20.0	20.1
13-Jul	4.4	6.0	22.8	25.1	20.4	20.4
14-Jul	3.4	1.4	26.0	26.2	20.2	20.8
15-Jul	1.4	4.8	26.9	25.8	20.1	20.5
16-Jul	1.2	11.8	26.8	23.5	20.9	21.4
17-Jul	0.0	6.4	27.0	25.0	21.0	21.2
18-Jul	2.0	3.8	26.5	26.1	20.5	21.1
19-Jul	1.2	11.0	26.1	26.8	21.0	21.2
20-Jul	7.2	4.8	24.7	25.1	20.6	20.6
21-Jul	11.6	3.2	24.5	24.8	20.4	21.0
22-Jul	13.6	7.8	24.0	26.1	20.6	21.1
23-Jul	16.0	31.0	23.9	24.8	19.9	20.8
24-Jul	15.0	26.4	22.8	22.9	20.2	20.6
25-Jul	11.6	20.4	23.0	25.2	20.6	20.2
26-Jul	17.4	10.6	24.0	25.7	19.6	20.9
27-Jul	16.0	1.8	23.9	27.7	20.5	21.0
28-Jul	7.6	0.2	25.4	27.0	20.1	21.0
29-Jul	2.0	3.2	24.6	27.8	19.7	20.9
30-Jul	1.2.0	3.0	25.2	24.1	20.1	21.1
31-Jul	5.8.0	75.8	24.6	23.6	20.5	20.9
Total/Avg	**173.4**	**242.2**	**25.4**	**26.9**	**20.4**	**20.8**

Contd…

August	Rainfall (mm)		Maximum temperature (^{0}C)		Minimum temperature (^{0}C)	
	2013	**2014**	**2013**	**2014**	**2013**	**2014**
01-Aug	21.2	8.2	22.7	24.6	20.3	21.2
02-Aug	9.2	1.2	24.7	26.1	19.6	21.2
03-Aug	15.2	1.6	24.9	26.5	20.1	21.1
04-Aug	3.0	6.0	25.8	26.8	20.5	20.6
05-Aug	4.0	6.8	27.0	24.8	19.7	20.5
06-Aug	12.4	11.0	28.0	24.0	19.7	20.7
07-Aug	1.2	3.4	27.4	24.8	20.4	20.5
08-Aug	0.4	10.4	27.4	24.8	20.1	20.8
09-Aug	0.2	1.4	26.7	25.8	19.9	20.8
10-Aug	2.2	3.0	26.3	26.8	19.6	20.6
11-Aug	2.0	17.0	26.8	25.0	20.0	20.4
12-Aug	0.0	0.8	27.8	27.1	20.1	20.9
13-Aug	2.4	0.0	27.4	27.9	20.6	20.1
14-Aug	0.6	0.0	25.5	26.4	20.2	19.9
15-Aug	0.0	0.0	26.0	27.5	21.0	20.2
16-Aug	0.0	0.4	27.7	27.7	20.4	20.5
17-Aug	5.8	1.2	25.9	27.7	20.3	20.5
18-Aug	1.8	2.6	25.2	28.1	20.7	19.8
19-Aug	1.4	3.8	26.4	29.3	20.2	21.0
20-Aug	2.8	3.4	26.0	28.6	20.0	21.3
21-Aug	0.2	36.6	26.5	30.4	20.4	19.6
22-Aug	2.8	1.2	26.1	31.2	19.9	19.6
23-Aug	4.0	2.6	25.6	30.2	19.9	21.3
24-Aug	0.8	3.2	25.2	30.0	18.7	20.6
25-Aug	0.6	0.4	27.8	28.1	19.0	21.0
26-Aug	0.4	4.4	26.6	27.5	18.8	19.9
27-Aug	0.4	1.6	28.5	26.0	19.6	20.0
28-Aug	0.0	8.6	28.8	23.0	19.3	18.9
29-Aug	2.2	9.8	27.0	23.0	19.1	19.5
30-Aug	0.0	3.6	28.4	25.0	18.9	20.6
31-Aug	0.0	4.2	30.0	26.8	18.6	20.8
Total/Avg	**76**	**150.2**	**26.8**	**26.9**	**19.8**	**20.4**

Contd…

September	Rainfall (mm)		Maximum temperature (^0C)		Minimum temperature (^0C)	
	2013	2014	2013	2014	2013	2014
01-Sep	0.0	2.0	31.0	24.5	19.9	20.5
02-Sep	5.4	2.6	32.0	25.5	19.5	20.2
03-Sep	0.6	1.4	31.1	26.0	21.3	20.5
04-Sep	0.0	8.2	29.5	26.8	20.1	20.7
05-Sep	0.0	4.2	29.0	25.1	19.8	20.6
06-Sep	1.2	2.0	27.9	25.8	19.4	20.7
07-Sep	0.8	3.6	27.7	25.4	19.5	20.0
08-Sep	2.8	0.0	27.7	25.5	20.3	20.1
09-Sep	4.0	0.0	27.0	27.0	19.6	19.6
10-Sep	23.6	0.0	26.8	27.6	20.7	20.0
11-Sep	3.0	0.0	26.1	27.6	21.4	19.6
12-Sep	3.2	0.0	27.5	28.1	20.9	20.0
13-Sep	7.2	0.0	29.0	28.1	21.0	20.4
14-Sep	50.6	0.0	29.0	27.6	21.0	19.9
15-Sep	8.6	0.0	28.9	29.4	20.9	20.3
16-Sep	0.8	0.0	28.5	29.2	20.9	20.0
17-Sep	3.2	0.0	28.0	27.4	20.9	20.3
18-Sep	0.6	0.0	28.6	28.8	21.0	20.0
19-Sep	0.0	0.0	27.3	26.4	21.0	20.1
20-Sep	5.2	6.2	27.5	28.9	20.1	19.3
21-Sep	0.2	0.0	25.0	27.0	20.9	19.8
22-Sep	0.0	0.0	28.1	27.2	19.8	19.1
23-Sep	6.2	0.0	25.6	30.2	19.0	20.8
24-Sep	1.4	43.0	27.0	30.5	19.9	22.0
25-Sep	0.4	15.4	26.8	31.0	19.7	20.6
26-Sep	3.8	0.0	26.1	30.2	19.9	21.7
27-Sep	0.6	0.0	27.4	31.4	19.9	20.0
28-Sep	0.0	11.6	25.4	29.7	19.6	19.9
29-Sep	0.2	0.0	26.6	30.9	19.2	21.0
30-Sep	0.0	0.0	26.0	30.0	20.0	20.8
Total/Avg	**133.6**	**98.2**	**27.7**	**28.1**	**20.2**	**20.3**

Contd…

October	Rainfall (mm)		Maximum temperature (^{0}C)		Minimum temperature (^{0}C)	
	2013	**2014**	**2013**	**2014**	**2013**	**2014**
01-Oct	0.0	19.2	27.9	28.0	19.9	19.0
02-Oct	0.0	0.0	29.3	29.6	20.2	19.1
03-Oct	0.6	0.0	28.0	30.6	19.5	20.6
04-Oct	0.2	0.0	26.7	31.8	20.3	20.0
05-Oct	0.6	0.0	26.5	31.5	19.6	20.5
06-Oct	8.8	5.6	25.4	31.4	20.0	19.6
07-Oct	0.0	12.0	28.5	30.5	20.4	19.4
08-Oct	0.0	2.6	29.7	29.1	19.9	20.8
09-Oct	0.0	0.0	30.0	29.2	19.3	20.5
10-Oct	0.0	0.0	29.2	29.8	19.3	20.8
11-Oct	0.0	0.0	28.8	30.7	18.8	21.0
12-Oct	0.0	0.0	28.5	30.3	18.9	20.5
13-Oct	0.0	0.0	29.0	30.1	19.9	19.1
14-Oct	0.0	0.0	29.5	30.1	19.5	20.1
15-Oct	0.0	0.0	30.0	31.0	20.4	19.1
16-Oct	17.6	0.0	30.4	31.5	21.0	18.8
17-Oct	0.0	0.0	27.7	31.4	20.4	19.1
18-Oct	0.0	0.0	31.0	31.2	19.8	19.4
19-Oct	0.0	0.6	30.9	31.0	18.3	18.6
20-Oct	0.0	0.0	31.5	31.0	17.8	20.9
21-Oct	0.0	0.0	30.8	31.0	18.2	20.0
22-Oct	0.0	0.0	31.0	30.5	20.4	18.8
23-Oct	13.0	0.0	27.9	30.8	20.2	18.2
24-Oct	19.4	0.0	28.5	30.1	19.8	19.1
25-Oct	0.6	14.6	28.0	29.0	20.5	19.4
26-Oct	1.2	43.4	29.0	22.6	19.6	17.8
27-Oct	12.0	5.0	25.5	24.7	20.5	19.3
28-Oct	1.4	0.4	25.0	25.8	19.2	18.2
29-Oct	0.0	0.0	28.5	27.6	19.4	15.8
30-Oct	0.0	0.0	29.5	28.5	17.6	14.5
31-Oct	0.0	0.0	29.1	29.1	15.8	13.8
Total/Avg	**75.4**	**84.2**	**28.8**	**29.7**	**19.5**	**19.1**

Contd…

November	Rainfall (mm)		Maximum temperature (^{0}C)		Minimum temperature (^{0}C)	
	2013	**2014**	**2013**	**2014**	**2013**	**2014**
01-Nov	0.0	0.0	28.7	28.6	16.5	14.7
02-Nov	0.0	0.0	29.1	28.8	18.2	16.0
03-Nov	0.0	0.0	30.0	30.0	18.7	15.4
04-Nov	0.0	0.0	30.1	30.1	18.0	15.3
05-Nov	0.0	0.0	30.0	30.1	18.3	15.2
06-Nov	0.0	0.0	28.0	30.4	16.5	16.3
07-Nov	0.0	0.0	29.0	30.1	16.3	16.0
08-Nov	0.0	0.0	29.0	30.0	16.1	14.5
09-Nov	0.0	0.0	29.0	28.9	15.7	14.1
10-Nov	0.0	0.0	28.7	29.5	14.4	16.9
11-Nov	0.0	0.0	28.0	30.0	13.7	19.0
12-Nov	0.0	0.0	27.9	30.1	12.5	17.7
13-Nov	0.0	0.0	28.6	30.4	13.3	19.7
14-Nov	0.0	25.4	29.0	28.5	12.4	19.4
15-Nov	0.0	23.2	28.1	24.6	12.0	18.7
16-Nov	0.0	0.2	27.2	26.9	10.5	17.3
17-Nov	0.0	0.0	27.7	28.5	18.4	14.7
18-Nov	0.0	0.0	27.5	29.1	19.1	15.6
19-Nov	0.0	0.0	27.1	29.1	17.0	15.3
20-Nov	0.0	0.0	29.7	29.6	15.3	17.6
21-Nov	0.0	0.0	30.0	28.3	12.5	15.6
22-Nov	0.0	0.0	29.6	28.2	11.5	15.5
23-Nov	0.0	0.0	29.7	29.2	14.5	15.4
24-Nov	0.0	0.0	29.9	29.6	16.7	14.7
25-Nov	0.0	0.0	29.7	28.4	19.2	14.7
26-Nov	0.0	0.0	29.8	28.0	18.5	12.1
27-Nov	0.0	0.0	30.3	28.1	18.9	11.9
28-Nov	0.0	0.0	29.2	29.3	15.1	11.8
29-Nov	0.0	0.0	29.0	28.5	15.3	12.3
30-Nov	2.2	0.0	28.9	28.9	17.9	12.3
Total/Avg	**2.2**	**48.8**	**29.0**	**29.0**	**15.7**	**15.6**

Contd…

December	Rainfall (mm)		Maximum temperature (^0C)		Minimum temperature (^0C)	
	2013	**2014**	**2013**	**2014**	**2013**	**2014**
01-Dec	0.0	0.0	29.8	28.6	19.5	14.9
02-Dec	0.0	0.0	30.4	28.7	17.6	14.5
03-Dec	0.0	0.0	30.1	28.9	17.0	13.4
04-Dec	0.0	0.0	29.6	28.8	15.6	13.7
05-Dec	0.0	0.0	30.0	30.1	13.2	12.8
06-Dec	0.0	0.0	28.4	28.3	13.6	11.3
07-Dec	0.0	0.0	27.0	27.7	10.6	12.9
08-Dec	0.0	0.0	26.9	28.8	11.1	15.4
09-Dec	0.0	0.0	27.8	29.6	11.7	16.6
10-Dec	0.0	0.0	28.3	29.9	10.1	16.8
11-Dec	0.0	0.0	28.9	30.0	10.2	17.9
12-Dec	0.0	0.0	28.5	26.0	11.3	19.2
13-Dec	0.0	24.6	28.5	26.8	13.1	17.9
14-Dec	0.0	0.0	27.6	25.6	13.3	17.6
15-Dec	0.0	1.6	29.0	28.1	13.2	18.9
16-Dec	0.0	0.0	30.0	29.2	10.8	18.2
17-Dec	0.0	0.0	28.9	27.5	9.7	15.0
18-Dec	0.0	0.0	27.7	26.5	10.0	13.0
19-Dec	0.0	0.0	27.2	26.1	11.5	15.9
20-Dec	0.0	0.0	27.1	27.6	10.7	15.8
21-Dec	0.0	0.0	29.0	25.3	11.5	13.2
22-Dec	0.0	0.0	29.8	26.6	13.1	11.6
23-Dec	0.0	0.0	28.4	26.8	11.7	11.3
24-Dec	0.0	0.0	27.5	26.5	12.5	12.7
25-Dec	0.0	0.0	26.9	27.5	12.8	13.2
26-Dec	0.0	0.0	28.5	26.6	12.6	11.8
27-Dec	0.0	0.0	28.1	27.0	12.3	10.4
28-Dec	0.0	0.0	28.0	26.8	12.9	10.8
29-Dec	0.0	0.0	28.8	26.7	14.0	13.2
30-Dec	0.0	0.0	28.6	29.1	14.0	15.0
31-Dec	0.0	0.0	28.1	29.1	12.0	15.7
Total/Avg	**0**	**26.2**	**28.5**	**27.7**	**12.5**	**14.5**

CROP-WEATHER RELATIONS IN MAIZE (*Zea mays* L.) UNDER DIFFERENT SOWING WINDOWS AND PLANTING GEOMETRY IN NORTHERN TRANSITION ZONE OF KARNATAKA

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ABSTRACT

The field experiment was carried out at the Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad, during *kharif* season of 2013 and 2014. The treatments consisted of five sowing dates *viz.*, June I FN (D_1), June II FN (D_2), July I FN (D_3), July II FN (D_4) and August I FN (D_5), as main plots and three planting geometries *viz.*, 45 x 20 cm, 60 x 20 cm and 75 x 20 cm in sub plots laid out in split plot design and replicated thrice.

Sowing of maize during June I or II fortnight resulted in higher grain yield (8082 and 7716 kg ha^{-1}), straw yield (106.6 and 105.8 q ha^{-1}), gross returns (` 94493 and ` 90497 ha^{-1}), net return (` 64326 and ` 60331 ha^{-1}) and B:C ratio (3.13 and 2.99). Sowing of maize with 45 cm x 20 cm planting geometry resulted in higher grain yield (7529 kg ha^{-1}), straw yield (112.1 q ha^{-1}), gross returns (` 88845 $ha^{-1}$), net return (` 56726 ha^{-1}) and B:C ratio (2.76). Combination of June I FN (D_1) sowing either with 45 x 20 cm or 60 x 20 cm spacing recorded significantly higher grain yield (8461 and 8318 kg ha^{-1}, respectively).

Among the various weather parameters, mean maximum temperature during all phenological stages had a negative association with grain yield of maize. The relative humidity (both morning and afternoon) and rainfall (except tasseling to silking stage) had a positive association with grain yield. Among the microclimatic parameters, canopy temperature, soil temperature and leaf temperature, increased with increase in row spacing from 45 x 20 cm to 75 x 20 cm. Early sowing during June I fortnight with narrow planting geometry (45 x 20 cm) resulted in higher light absorption ratio, per cent APAR and per cent IPAR.