Crop weather relationship studies in finger millet (*Eleusine coracana* (L.) Gaertn) in central zone of Kerala

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(2017-11-135)

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Crop weather relationship studies in finger millet (*Eleusine coracana* (L.) Gaertn) in central zone of Kerala"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara

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CERTIFICATE

Certified that this thesis entitled **“Crop weather relationship studies in finger millet (*Eleusine coracana* (L.) Gaertn) in central zone of Kerala”** is a bonafide record of research work done independently by **Ms. Anunayana T. John (2017-11-135)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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We, the undersigned members of the advisory committee of **Ms. Anunayana T. John (2017-11-135)**, a candidate for the degree of **Master of Science in Agriculture** with major field in Agricultural Meteorology, agree that this thesis entitled **"Crop weather relationship studies in finger millet (*Eleusine coracana* (L.) Gaertn) in central zone of Kerala"** may be submitted by **Ms. Anunayana T. John** in partial fulfillment of the requirement for the degree.

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Anunayana T. John

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INTRODUCTION

1. INTRODUCTION

Agriculture can be considered as the feeding sector of the whole world which has been introduced by 9500 BC. In India, agriculture is the backbone of its economy which maintain the balance of all other sectors like food, nutritional, livelihood and financial securities. Any kinds of fluctuations in the agricultural sector can produce an impact to the whole economy. More than half of the Indian population are engaged in the agricultural sector either directly or indirectly for their livelihood. India is a rich source of biological diversity which holds the first position in production of fruits like banana, mango etc., vegetables like chickpea, okra, spices like chili pepper, ginger, and some of the fibrous crops.

Weather play a major role in planning agricultural activities. Since agriculture are very sensitive to weather conditions, agro meteorological information is essential in crop production planning. Weather and climatic information are very much essential for making appropriate decisions on land use and management, selecting crop varieties and crop production practices such as irrigation, pest and disease control. Weather parameters like temperature, humidity, sunshine, wind and rainfall play a major role in controlling most of all the key biological processes in plants, like photosynthesis, respiration and transpiration. Thus, plant growth, development and yield are very much dependent on weather conditions prevailing during their growth period.

Climate is facing abrupt changes now a days. As per the World Meteorological Organisation, “Climate change is not a prediction now. It is happening, everywhere to everyone”. Since it is an assured phenomenon, we have to be more aware regarding its impacts on the biosphere. Climate change generates a lot of changes all over the globe. It can be direct as well as indirect that can affect the atmosphere, hydrosphere, cryosphere, biosphere and lithosphere. In order to cope up with such situations, certain adaptation and mitigation measures should be taken to lessen the impacts of climate change.

Drought is a period of below-average precipitation in a given region, results in prolonged shortage in water supply. Drought occurred in 2016 in Kerala was the worst one to have hit the state since 115 years. A deficiency of 33.7% rain is experienced in Kerala during the South West Monsoon of 2016 (Purohit and Kaur, 2017). So in order to cope up with such situations, we should adopt the crops with less water requirement such as millets. Finger millet, locally known as *Ragi* is an important food crop next to rice, wheat and maize The crop is native to Africa. The main protein fraction (eleusinin) has high biological value with high amount of amino acids which is lacking in the diet of millions of poor people. Finger millet straw is reported to be more nutritious than pearl millet, wheat and sorghum since it is rich in nutrients and minerals. Finger millet diets can digest at a slower rate that helps to provide energy to the consumers throughout the day. Therefore economically weaker and physically hard working people prefer the finger millet which is also the cheapest one. Finger millet is also popular among farmers because it is adaptable, resilient and yields well on marginal land without irrigation (Shinggu and Gani, 2012). The crop is best suited to those areas having an annual rainfall of 700-1200 mm. During grain ripening stages, finger millet prefers a dry spell period and it does not tolerate heavy rainfall. It grows well in the altitudes of 1000-2000m with average temperature of 27^{o}C (*Kissan kerala, 2018*). Finger-millet is called as Climate Change Compliant Crop (CCCC) because it is capable to withstand three stresses such as warming stress, water stress and nutrition stress. These attributes combine to make finger millet a suitable crop for ensuring food security in drought prone areas of the countries under projected climate change scenarios.

Globally, agriculture sector is diminishing due to the non-availability of land. The growth rate followed by the agriculture during the beginning of reforms which could account for more than 30 per cent of GDP is now following a decelerating trend after mid-1990s. So the prime focus should be given on improving the productivity of the land, which can be done by maintaining optimum plant population. This can be attained by choosing the best planting method suitable for each crop at different weather conditions.

Since the weather plays a major role in the whole cultivation process, utilizing the optimum weather effectively at each stage of crop growth could produce better results. Exposure to the optimum crop growing environment such as temperature, humidity, light etc. could help the crop to exploit the genetic potentiality of a variety as it provides. So sowing at optimum time can helps the plant to get exposed to the required environment like attaining the Growing Degree Days (GDD), effective utilization of rainfall, humidity etc. throughout its growing period. So sowing time can be considered as one of the most important non-monetary inputs which influences the yield as well as yield attributing characters of a crop (Singh *et al.,* 2014).

So the work mainly focus on determining the optimum sowing date for the finger millet crop in the rainfed condition from May to July and also identification of best planting method among the three types of methods which are broadcasting, dibbling and transplanting. This could help the finger millet to cultivate at the optimum date with suitable planting method to attain its maximum potential in central zone of Kerala.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

As the climate change consequences follows an increasing trend, it is necessary to adopt cultivation of crops with less water requirement such as millets to avoid drought effects. Finger millet is an important crop next to rice, wheat and maize which is also called as Climate Change Compliant Crop (CCCC). The main aim of this work is to find out the interaction effect of date of sowing and planting methods on growth and yield attributes of finger millet. This helps to identify the ideal date of sowing and best planting method that would encourage the successful cultivation of finger millet in central zone of Kerala. This review of literature covers:

1. Significance of finger millet cultivation
2. Effect of weather parameters on growth and yield of finger millet
3. Effect of dates of planting on growth and yield of finger millet
4. Effect of planting methods on growth and yield of finger millet
5. Micrometeorological parameters
6. Growth indices
7. Influence of weather and planting methods on the incidences of weeds

The literature review in this chapter is a solid background to undertake the research in the influence of weather parameters and planting methods and their interaction effects on crop yields.

2.1. SIGNIFICANCE OF FINGER MILLET CULTIVATION

Considering the phenology of Finger millet, it is small seeded grass, self-pollinated, robust, tufted and tillered annual cereal crop (Michaelraj & Shanmugam, 2013). The major quality of thefinger millet crop is its tolerance capacity. It can able to withstand three types of stresses like warming stress, water stress and nutrition stress. So finger millet is called as Climate Change Compliant Crop (CCCC) (Ferry, 2014). This promotes the cultivation of finger millet concentrating towards the drought occurring areas.

The nutritional values of finger milet is very high compared to most of the other cereals. With regard to protein (6-8%) and fat (1-2%) it is comparable to rice and while with respect to mineral and micronutrient contents it is superior to rice and wheat. Calcium content is very high (344 mg/100g) and also it is a rich source of dietary fiber (15-20%) and phenolic compounds (0.3–3%). The major amino acids present in this minor millets are isoleucine, leucine, methionine and phenyl alanine which are deficient in other starchy meals. It is also known for several health benefits such as anti-diabetic, antitumerogenic, atherosclerogenic effects, antioxidant, which are mainly attributed due to its polyphenol and dietary fiber contents (Gull *et al*., 2014).

Rurinda *et al.* (2014) conducted a comparative assessment of emergence, yield and financial benefits of maize, finger millet and sorghum through field experiments by planting at different dates and variable soil nutrient managements. The study shows that compared to high fertilization rate, financial returns from finger millet were more attractive for the low fertilization rates. The maize yield was greater compared with finger millet yields. But finger millet had higher calcium content and also the grains can be stored for up to five years. This reveals the importance of finger millet as compared to other crops which is also a better substitute for the present climate change scenarios.

2.2. EFFECT OF WEATHER PARAMETERS ON GROWTH AND YIELD OF FINGER MILLET

According to Bisht *et al.* (1984), development of blast disease in finger millet is more favoured by the climatic conditions that prevailed from 15th July with average minimum and maximum atmospheric temperature of around 20^{0} and 30^{0}C respectively and relative humidity of around >80^{0}C. But at the same time the study shows that eventhough weather was ideal for both the plant growth and disease incidence by the pathogen, the loss through disease will be compensated by the high yield obtained by the sowing of susceptible varieties during second fortnight of July to first fortnight of August.

Ong and Monteith (1985) in his work on response of pearl millet to light and temperature have shown that the growth rate is directly proportional to the solar radiation which is intercepted per day and the development rate is proportional to the accumulation of degree days above a base temperature of 10 °C in pearl millet.

Mohammed, Clark, and Ong (1988) conducted a study on the Genotypic differences in the temperature responses of tropical crops, especially groundnut and pearl millet, showed that genotypic differences in tropical crops for the temperature response can be understood through obtaining their base temperature and they also reported the base temperature for germination of pearl millet which should be 135 °C and optimum temperature of 29-36-3 °C is required.

Krishnamoorthy (1996) in his work on agronomic manipulations to improve the productivity to late sown finger millet under dry land conditions stated that delayed sowing will result in the less biomass accumulation which results in less yield. Crop sown at optimum sowing time will provide the opportunity for longer growth period with abundant day length and light, temperature and relative humidity. But in late sown crops less rainfall cause reduction in the soil moisture in the field which may affect the grain yield potential.

Mangant *et al*. (1999) studies on the biology of pearl millet reveals that since pearl millet is largely a quantitative short-day plant which flowers early under a 12-h photoperiod condition. But if it is delayed by 14- to 16-h photoperiods, these can lead to changes in yield and height of pearl millet relative to day length.

Gupta *et al*. (2000) conducted a systematic study to estimate the productivity of rice influenced by agro meteorological variables such as rainfall, number of rainy days and length of rainy season in Jabalpur. The studies shows that rainfall parameters like amount, length of rainy season and number of rainy days shows significant correlation with rice yields. The study also suggest that efficient rice yields in rainfed rice can be obtained through the use of surplus rainwater to overcome the moisture stress during reproductive phase or selection of short duration varieties to minimize moisture stress risk during grain filling stage.

An experiment conducted by Abeysiriwardena *et al*. (2002) to assess the impact of high temperature at very high and low humidity levels and normal temperature at normal and low humidity levels on surface temperature of spikelets and grain sterility in rice at heading stage under controlled environment. The study reveals that a combination of high temperature (30^{0}C night/ 35^{0}C day) and high humidity (85-90%) induced complete grain sterility in rice.

Anil kumar *et al.,* (2003) conducted a study on the diseases of finger millet reveals that dissemination and disease build up by a polycyclic air borne pathogens like P. grisea is considerably depend on the effect of interaction of host variety with weather, pathogenic strains and the time factor.

Morita *et al*. (2005) in his study on the grain growth and endosperm cell size under high night temperatures in rice (*Oryza sativa* L.) revealed a negative correlation of grain yield with high temperature at flowering and grain filling due to spikelet sterility and a shorter grain filling period. The increased night-time temperature of 22/34^{0}C highly suppressed the grain weight compared with high daytime temperature of 34/22 ^{0}C and the control (22/22^{0}C).

Maqsood and Ali (2007) worked on the effects of environmental stress on the growth, radiation use efficiency and yield of finger millet. They had conducted the study on two finger millet landraces TZM-01 and TZA-01 in green houses under irrigated and droughted conditions. The study suggests that drought had reduced the leaf area, seed weight, dry matter accumulation, radiation use efficiency and yield of finger millet. Highest grain yield (4.88 t ha^{-1}) was recorded under irrigated crops, while the lowest grain yield (1.92 t ha^{-1}) was recorded in droughted plants.

Effect of high temperarature and low temperature on the growth and yield of rice was studied by Wahid *et al*. (2007). He identified the rice growth stages which are more temperature sensitive. The study shows that low and high temperature during both vegetative and reproductive stages may lead to poor tillering, productiveless tillers and poor seed setting in rice.

Nagaraja *et al.* (2010) conducted a study on the impact of weather parameters on the incidence of finger millet blast. Through the critical evaluation of 520 accessions of finger millet for blast resistance under the prevailing weather conditions, they observed that when the temperature increased up to 27.0°C from 23.9°C and rainfall decreased to 83.4 mm from 303 mm, the occurrence of neck blast and finger blast decreased considerably especially during the flowering stage.

The influence of low temperatures stress on growth and yield of rice was studied by Murthy and Rao (2010) and he showed that early sowing resulted in significantly higher yield followed by normal sowing. This may be due to the strong positive correlation between minimum temperatures at flowering and yield in comparison with minimum temperatures from PI to 50% flowering and 50%flowering to maturity stages in rice.

A crop simulation study was done using process-based crop model SARRA-H by Sultan *et al.* (2013) to assess climate change impacts on millet yields in the West Africa. More than 7000 simulations of millet yields for 35 stations across West Africa and under very different future climate conditions were done by incorporating precipitation anomalies (−20% to 20%) and temperature anomalies (+0 to+6◦C). The result shows that 31 out of 35 stations shows a negative impact on yields, up to−41% for +6◦C/−20% rainfall. While in future climate conditions the increasingly adverse role of higher temperatures lead to reduction in crop yields, irrespective of rainfall changes. Photoperiod-sensitive cultivars are more resilient to climate change by counteracting temperature increase on shortening cultivar duration.

The study conducted by Kuthe *et al.* in 2015 on the impact of meteorological parameters on rice production at Navasari, showed that rainfall is the main component which governs the other weather parameters. Rainfall has significant role in germination and initial growth, which is found to be affected by the onset of monsoon. Optimum environment for the proliferation of insect and pest growth can be created by the joint effect of rainfall and temperature on relative humidity.

A study conducted by Zhang *et al.* (2016) in changes in extreme temperatures and their impacts on rice yields in southern China from 1981 to 2009 revealed that GDD plays a major role in the yield production of rice. Increase in GDD (Growing degree day) improves the rice yield by 5.83%, 1.71%, 8.73% and 3.49% for early rice, late rice and single rice in western part, and single rice in other parts of the middle and lower reaches of Yangtze River respectively, while at the same time increase in HDD (High temperature degree day) decrease the grain yield by 0.14%, 0.32%, 0.34% and 0.14%. Decrease in CDD (Cold degree day) led to an increase in grain yield by 1.61%, 0.26%, 0.16% and 0.01% and a yield reduction of 0.96%, 0.13%, 9.34% and 6.02% was also found due to the decreased solar radiation.

2.3. EFFECT OF DATE OF PLANTING ON GROWTH AND YIELD OF FINGER MILLET

Reddy and Reddy (1986) conducted a study on the rice which shows that compared to the delayed transplanted rice cultivars, early-transplanted rice had better yields. Nellore variety shows considerable reduction in the growth rate with delay in date of planting along with the increase in total number of days taken for production. Early-transplanted crops also shows high harvest index than later transplanted crops.

Maiti and Soto (1990) conducted a study on the effect of four Sowing dates on growth, development and yield potentials of 15 pearl millet cultivars (*Pennisetum americanum* L. Leeke) during autumn-winter seasons in Mexico. The varieties were introduced from the ICRISAT which were sown in the field in randomized block design with four sowing dates on July 29, August 15, August 27, and September 9. Sowing dates are having significant effect on all the parameters considered especially the growth stage duration (GS1, GS2 and GS3) and yield. Higher grain yield is observed in July sown crops compared to others due to the longer photoperiod (>13 h), higher temperature and significant day and night temperature variations which gets declined by delayed sowing.

The work done by Sukhadia *et al.* (1992) in productivity and water use efficiency of rainy season crops under different dates of sowing revealed that delayed sowing can reduce the moisture use efficiency as compared to the effective usage of water by crops under normal sowing through their profuse vegetative growth.

Hanna and Wright (1995) conducted a study on planting date, rust, and cultivar maturity effects on agronomic characteristics of pearl millet. They observed the effects of planting date on three hybrids differing for maturity and rust resistance. The studies shows that date of planting was significant for both height and yield with June plantings having lower yields than May plantings.

A study was conducted by Mahmood *et al*. (1995) to determine the effect of transplanting date and irrigation on rice yield by fixing three dates of transplanting and three irrigation treatments on rice yield and recorded different yield and agronomic characters. The result shows significant decrease in yield and yield related traits with late transplanting. This decrease in yield was observed due to water shortage during flowering which led to increased spikelet sterility.

Wilson *et al*. (1995) who studied on the pearl millet grain yield loss from rust infection states that maximum of this yield reduction was attributed to rust susceptibility. Rust infection is considerably depend on the weather prevailing in the environment as the inoculum becomes more prevalent later in the season.

Khakwani *et al*. (2006) conducted a study on the agronomic and morphological parameters of rice crop as affected by dates of planting. The study was done with six planting dates as treatments which was divided into two groups as early and late. The results shows that better yield has been attained in early transplanted crops, while late transplanted plants failed to produce increased yield due to heavy stem borer infestation.

Maas *et al.* (2007) conducted a study on effect of planting date on grain yield and height of finger millet in the Southeastern coastal plain of United States. The study was done in three years which are 2001 (near normal rainfalls), 2002 (early season drought year) and 2006 (long drought year with good initial soil moisture). The planting dates were 12 April, 31 May, 18 June, 28 June, 12 July, 19 July and 2 August for 2001, 16 April, 29 April, 13 May, 28 May, 10, June, 24 June, 8 July and 22 July for 2002 and 12 April, 26 April, 10 May, 24 May, 7 June, 21 June, 5 July, 20 July and 31 July for 2006. A general reduction in yield from early to later dates in 2001 and no significant trends in drought years was observed. But in case of drought conditions, early plantings yield well. The result also shows that height is influenced by day length with longer days producing taller plants. So it shows a significant decline for the last two dates across all years.

Nagaraja and Jagadish (2007) conducted a study to determine the ideal sowing time for finger millet to avoid from the finger millet blast. Experiment has been carried out for 15 years during the *kharif* season at fortnightly intervals starting from the second fortnight of June to second fortnight of September. The study reveals that the weather conditions prevailing from second fortnight of July is favourable for the incidence of blast as well as for enhanced plant growth which could give better yield in spite of blast attack. The study concludes that the ideal sowing time during *kharif* season can be considered as the second fortnight of July for medium to late maturing varieties which could be extended up to first fortnight of August for early maturing varieties.

Performance of finger millet varieties on different sowing dates has been studied by Nagaraju and Kumar in 2009. The study had conducted by sowing at three different times comprises of normal (15th July-10th August), delayed (10 to 25 August) and late (25th August to 31st September). According to their study, grain yield was highest at normal sowing followed by delayed and late sowing. The study also reveals that normal sowing produced significantly taller plants with higher dry matter production and number of productive tillers compared to the remaining sowing times. The late sown crop shows reduction in finger length and number of fingers per ear head which is due to inadequate vegetative growth, curtailed growing season and forced maturity.

Akbar *et al*. (2010) done an experiment to evaluate the effect of six different sowing dates (31st May, 10th June, 20th June, 30th June, 10th July and 20th July) on yield and yield components of direct seeded fine rice. Considering the various yield parameters like 1000 kernel weight, tillers per m^2 and number of kernels per panicle, all of them shows significant response with different dates of sowing. June 20th sown crop shows maximum number of productive tillers per m^{-2}, kernel per panicle, 1000-kernel weight and paddy yield.

Two field experiments were conducted during 2009 and 2010 cropping seasons at the experimental farm of the Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria in the Northern Guinea Savanna ecology of Nigeria to study the effect of planting method, sowing date and spacing on the growth and productivity of finger millet. From the study, planting finger millet by dibbling and planting the crop on the 25th June and 9th July at a spacing of 10 and 15 cm gave heavier unthreshed panicles with consequent higher grain yield (Shinggu and Gani, 2012).

A study was undertaken at Navsari, India (20.95°N 72.93°E, elevation of 10 m above Sea level) during summer season 2010 to work out effect of different land configuration and dates of sowing on pearlmillet. The results gained confirm that ridges and furrow along with early sowing date during summer season is beneficial to obtain higher net returns from pearlmillet crop. Sowing pearlmillet during last week of January or first week of February increases the yield as well as net returns from the crop. Pearlmillet sown on 5 February (3.24 t ha^{-1}) gave significantly highest grain yield followed by 25 January (3.04 t ha^{-1}) sowing, while 15 February sowing gave significantly lowest yield. Highest net returns of Rs.15541 ha^{-1} with B:C ratio of 2.03 were obtained with 5 February sowing treatment, followed by 25 January sowing treatment with Rs.13971 ha^{-1} and 1.93 B:C ratio respectively(Desmukh *et al*., 2013)

An experiment was conducted by Khalifa *et al.* (2014) in split-split plot design with main plot treatments are kept as three sowing dates (20th April, 1st May and 10th May), sub plot treatments has been fixed with seeding rates and three rice varieties with four replications to assess the influence of sowing dates and seed rates on selected rice cultivars. The characters under study were maximum tillering, panicle initiation, heading dates, leaf area index, chlorophyll content, 1000-grain weight, panicle length, number of panicles per hill and grain yield. The result shows that early sown crops attained the highest values in case of all characters under study.

During the *kharif* season of 2014, a field experiment was conducted by Maurya *et al*. (2015) at the research farm of School of Forestry & Environment, Sam Higginbottom Institute of Agriculture Technology and Sciences, Allahabad to find out the effect of different sowing dates on performance of Pearl millet (*Pennisetum glaucum* L.) varieties under Allahabad condition. The results revealed that treatment on the variety Ganga kaveri-22 planted on 23rd July was recorded highest plant height (177.21 cm), plant dry weight (78.25 g), grain yield (3.579 t ha^{-1}) and stover yield (10.225 t ha^{-1}).

An experiment was laid out at Allahabad by Ali *et al.* (2015) to analyze the response of different rice cultivars to different dates of transplanting. The results shows that the plants planted during mid-July showed the highest yield when the prevailing temperature at that time was 35^0C. The first week of August during which the temperature recorded was 30^0C shown the lowest grain yield which concludes that late planting is not favourable for rice production.

2.4. EFFECT OF PLANTING METHODS ON GROWTH AND YIELD OF FINGER MILLET

Experiments conducted by Roy *et al*. (2002) to understand the growth and yield attributes of finger millet as influenced by plant population and different levels of nitrogen and phosphorus shown that wider spacing of 25 cm × 10 cm attained the highest total dry matter production (287.3 g m^{-2}) as compared with closer spacing of 25 cm x 6 cm of finger millet. He also inferred that length of finger per earhead was maximum under 25 cm × 10 cm spacing compared to 25 cm × 8 cm and 25 cm × 6 cm during *kharif* season on lateritic soil.

Considering the yield parameters, Shengfu (2002) reported that under SRI system an yield of 12.5 t ha^{-1} with 33.3 cm x 33.3 cm spacing and 11.25 t ha^{-1} with 40 x 40 cm spacing was obtained which was 21.3 and 12.3 percent higher than traditional rice cultivation (10.02 t ha^{-1}).

Bhuva *et al.* (2006) reported that panicles m^{-2}, panicle weight, 1000- grain weight and filled grains per panicle were better with SRI treatment compared to other methods.

Experiments conducted by Krishna *et al.* (2006) on Influence of SRI cultivation on seed yield quality in short duration rice variety suggested that in SRI method, duration of 50 percent flowering to maturity was less in which the plants attained physiological maturity by 4-5 days earlier compared to traditional method.

Porpavi *et al.* (2006) in his work for the evaluation of varietals performance under SRI stated that under SRI system in rice, the crop duration with 14 days old seedlings was reduced by 5 to 6 days in comparison with the conventional method for 25 days old seedlings.

Rao *et al.* (2006) in his study of System of Rice Intensification (SRI) versus traditional method of rice cultivation noticed that under SRI system of rice cultivation, panicles per m^2, spikelets per panicle and grain yield were superior compared to traditional method of rice cultivation.

Compared to drum line and broadcast method of sowing, SRI method of crop establishment shows highest number of effective tillers per m^2, panicle per m^2 (306.5), panicle weight (5.4 g), test weight (23.92 g) and grain yield (5.47 t ha^{-1}) (Saha and Bharti, 2006).

In SRI system of rice cultivation which provide optimum spacing of plants, the treatment combination of 14 days old seedling, wider spacing of 25 cm x 25 cm, limited irrigation of 2 cm with incorporation of weeds and disturbing the soil through SRI weeding in between the phenophase of panicle initiation to flowering and flowering to maturity stage, a significant increase in the crop growth rate, relative growth rate and net assimilation rate was observed. (Vijaykumar *et al.,* 2006).

Tenywa *et al.* (1999) worked on the prospects and constraints of finger millet production in Eastern Uganda and founds out the appropriate planting method for better yield. The field experiment was conducted with row planting at a spacing of 30cm x 6cm which was done using a tin with a hole at the base to allow uniform dropping of seed in lines and broadcasting based on farmers' own practice. The study also shows that there was no significant effect of planting method on plant height up to flowering, but by physiological maturity, plant height increased up by tenfold in row planting over broadcasting. In case of yield also, row planting was consistently higher than broadcasting ($P<0.05$) for all plant population densities. The response to nutritional management was also better in row-planted crop than the broadcast one.

Krishnaji *et al.* (2008) in his work on the effect of SRI practice on the yield attributes, yield and water productivity of rice stated that under SRI cultivation technique, more number of productive tillers per m^2, grains per panicle^{1} and higher test weight with lesser number of unfilled grains, that ultimately results an increase of 12.5 percent in yield compared to the yield obtained in normal practices of transplanting (4.95 t ha^{-1}).

Singh *et al.* (2008) in his study on the agronomic evaluation of different methods of Rice establishment under medium land situation of Jharkhand revealed that various yield attributing characters like effective tillers per m^2 (306), number of fertile grains per panicle^{1} (98.3), 1000- grain weight (24.76 g) and grain yield (5.02 t ha^{-1}) shows the maximum value in SRI method of cultivation compared to conventional transplanting, broadcasting and line sowing method.

The experiment conducted by Thavaprakash *et al.* (2008) revealed that a spacing of 50 x 50 cm shows the highest number of tillers per hill (>60) in rice ADT which was followed by a spacing of 40 x 40 cm (>50), 30 x 30cm (>35) and 25 x 25 cm spacing (>25) compared to the conventional system of planting (<20) with narrow spacing. The study also suggests that this may be due to effective utilization of available resources such as space, foraging area of root system, better root spread, more light interception etc. for the plants cultivated with wider spacing.

Kalaraju *et al.* (2011) in his work on the effect of methods of planting on growth and yield of finger millet genotypes under organic farming reported that higher dry matter accumulation was recorded in different parts of finger millet in square planting compared to line planting. He also reported that maximum number of productive tillers was observed in finger millet under square planting of 30 cm × 30 cm spacing during *kharif* season.

The work done by Kumar (2011) in System of crop intensification in finger millet reported that compared to 20 cm × 20 cm spacing, a spacing of 15 cm × 15 cm shows the highest dry matter production in finger millet. But he also states that the 20 cm × 20 cm spacing in finger millet recorded the maximum number of productive tillers compared to the 15 cm × 15 cm spacing during *kharif* season under irrigated conditions on clay loam soils of Coimbatore. He also states that finger length was maximum in 30 cm × 30 cm over 20 cm × 20 cm and 25 cm × 25 cm spacing. The spacing of 20 cm × 20 cm showed significantly higher number of grains per ear head over 25 cm × 25 cm and 30 cm × 30 cm during *kharif* season on clay loam soils.

Rajesh (2011) in his work on the system of crop intensification in finger millet states that highest 1000- grain weight (2.87 g) was observed under 25 cm × 25 cm spacing in finger millet.

The study conducted by Shinggu and Gani (2012) in savanna ecology of Nigeria with different plant spacing reported that closer inter-row spacing produced a higher number of panicles and higher grain yield at 15 cm inter-row space compared to the 20 cm spacing of plant population.

Ahiwale *et al.* (2013) reported that ear heads produced in finger millet was of significantly higher weight in transplanting method of spacing 20 cm x 15 cm compared to the line sowing of seeds at 20 cm spacing during the onset of monsoon and line sowing of pre-germinated seeds at 20 cm spacing after onset of monsoon except Awanti which is the practice followed by the farmers by throwing seedlings randomly in the fields. He also reports that transplanting obtained the highest grain weight per ear head (2.19 g) and straw weight per m^2.

Experiment conducted by Navale (2013) stated that in foxtail millet varieties, effect of spacing and method of planting on panicle weight exhibited significant differences due to spacing and planting methods during *kharif* season. A spacing of 30 cm x 15 cm recorded significantly highest panicle weight (4.15 g) compared to the spacing of 30 cm x 10 cm which recorded the lowest panicle weight (3.64 g).

Experiment done by Suresh (2013) revealed that among different crop establishment methods, paired row transplanting one side in 30 cm x 10 cm, 60 cm apart one side recorded significantly higher length of ear head (22.69 cm) which was similar with transplanting in single row with distance of 45 cm x 10 cm. Lower ear head length (21.17 cm) was observed in direct sowing in single row with distance of 45 cm x 10 cm.

Maobe *et al*. (2014) conducted an experiment to determine the effects of Plant Density on growth and Grain Yields of Finger Millet (*Eleusine coracana*) under High Potential conditions of Southwest Kenya reported that higher yields of finger millet is obtained from a cultivation with optimum spacing of 30x10 cm with a plant population of 333,333 plants which produced more grains per ha compared to a wider spacing of 40x10 cm or a narrow spacing of 20x10 cm.

The study conducted by Ram *et al.* (2014) also reported that highest plant height (116.3 cm) was obtained under 25 cm x 25 cm spacing in transplanted rice during *kharif* season.

Anitha (2015) reported that transplanting of 25 days old seedlings at 15 cm × 10 cm @ 2-3 seedlings per hill attained the highest plant height compared to transplanting of 15 days old seedlings at 20 cm × 20 cm spacing with single seedling per hill. The study also shows that lowest values of plant height was observed in transplanting of 18 days old seedlings at 30 cm × 30 cm with single seedling per hill. Considering the dry matter production, highest value was recorded in transplanting of 25 days old seedlings at 15 cm × 10 cm @ 2-3 seedlings per hill, while the lowest dry matter production of finger millet was reported in transplanting of 18 days old seedlings at 30 cm × 30 cm with single seedling per hill. She also reported that highest number of productive tillers m^{-2} was reported in transplanting of 15 days old seedlings at 20 cm × 20 cm with single seedling per hill and the lowest was recorded in transplanting of 18 days old seedlings planted at 30 cm × 30 cm with single seedling per hill).

Pradhan *et al*. (2015) conducted a field experiment during the rainy (*kharif*) season 2010 and 2011 at S.G. College of Agriculture and Research Station, Jagdalpur with 6 establishment methods in horizontal plots and 4 nitrogen levels in vertical plots in strip-plot design on sandy-loam soil. Manual transplanted finger millet being statistically on par with seed drill sown finger millet with brown manuring, showed significantly higher values of growth and yield attributes as well as higher effective tillers per m^2, finger length, grains per finger during both the years.

The studies conducted by Dereje *et al.* (2016) to identify the *i*nfluence of row spacing and seed rate on yield components of finger millet at Ethiopia also reveals that, a significant effect of spacing on the plant height of finger millet was observed and it was maximum (92.97 cm) with 50 cm spacing followed by 40 cm row spacing (91.84 cm). Least value of plant height was recorded with finger millet sown at 30 cm spacing which was 84.52 cm.

According to Sarawale *et al.* (2016), transplanted plants of spacing 20 cm x 10 cm and awanti, a traditional method of finger millet cultivation in which seedling are uprooted from nursery and planted by throwing it randomly shows the highest plant height as compared to line sowing and broadcasting of seeds of finger millet.

Nayak *et al.* (2003) and Bhatta *et al.* (2017) suggested that under different crop establishment method, a significant difference was observed especially in system of crop intensification, a higher crop growth rate was found. This may be due to the effect of wider spacing which promotes profuse growth leading to higher dry matter accumulation.

The field experiment conducted *by* Korir *et al.* (2018) revealed the effect of spacing and fertilizer levels on growth and yields of Finger Millet (*Eleusine coracana*) variety P224. They adopted three plant spacing of (i) 40x10 cm, (ii) 30x10 cm and (iii) 20x10 cm and the results shows that significant effect of spacing on number of tillers was observed. Closer spacing of 20 cm x10 cm showed significantly lower tillering compared to the wider spacing of 30 cm x10 cm and 40 cm x10 cm. This can be due to the high interplant competition for nutrients and competition for photo-synthetically active radiation in narrower spacing. But at the same time higher plant population at the closer spacing of 20x10 cm provided more number of heads per plant compared to wider spacing of 30x10cm and 40x10cm which led to significantly higher grain yield compared to the wider spacing of 30x10cm and 40x10cm.

2.5. MICROMETEOROLOGICAL PARAMETERS

Fulton, J.M. (1970) conducted experiments including variables of soil moisture, plant populations and row spacing in four consecutive seasons. The study reports that at a point 40 cm below the soil surface, when the soil moisture tension was in excess of five bars, the yield was reduced considerably. When the moisture stress was coincide with tassel emergence stage, substantial yield reduction occurred. The study suggest that highest yields were obtained where high soil moisture levels (minimum available soil moisture 25% at 40 cm) were combined with high population (54,362 plants ha^{-1}) and narrow (50 cm) rows.

Norwood (2001) conducted an experiment to estimate the effect of Planting date, hybrid maturity, and plant population on soil water depletion, water use efficiency (WUE) and yield of dry land corn from 1996 through 1999. Results suggests that depletion of soil water increased with hybrid maturity. The lower portion of the soil profile will be depleted out of water due to the removal by higher plant populations. Highest yields and WUEs were achieved with the later planting date, combined with later-maturing hybrids and higher plant populations.

Dalley *et al*. (2006) conducted a study with the Glyphosate-resistant corn which was grown in 38- and 76-cm row spacing at two locations in 2001 to determine the effect of weed competition and row spacing on soil moisture. They reported that soil moisture was considerably reduced by season-long weed interference compared with the weed free controls. Even though grain yield was not affected by row spacing it has noticeable effect on the soil moisture. Plants grown under 76-cm row spacing shows higher soil moisture, suggesting that corn in 38-cm row spacing may have been able to access soil moisture more effectively.

Ghanbari *et al*. (2010) conducted a study on Effect of maize (*Zea mays* L.) - cowpea (*Vigna unguiculata* L.) intercropping on light distribution, soil temperature and soil moisture in arid environment. The study reports that Intercropping system had significant effects on soil temperature and soil moisture ($P<0.01$). Sole maize cropping reports highest soil temperature, while lowest temperature were observed in sole cowpea. In case of soil moisture, highest value was recorded for sole cowpea and lowest soil moisture was recorded for sole maize.

2.6. GROWTH INDICES

The study on the response of growth and grain yield in paddy rice to cool water at different growth stages conducted by Shimono *et al.* (2002) reported that CGR was initially found to be increasing and decreasing during later stages of the rice crop

Avasthe *et al.* (2012) reports that during the *kharif* season the highest harvest index was recorded under square planting of 20 cm × 20 cm spacing on clay loam soils while Nain *et al.* (2012) reported that on sandy clay soils, highest harvest index in rice was recorded under square planting of 25 cm × 25 cm during *kharif* season. Ram *et al*. (2014) confirms the statement through the experiment carried out during *kharif* season that states square planting of rice with a spacing of 25 cm × 25 cm gave the highest harvest index.

Anitha (2015) observed that T5 (transplanting of 15 days old seedlings at 20 cm × 20 cm with single seedling hill-1) attains the highest harvest index of finger millet which was comparable with T2 (transplanting of 12 days old seedlings at 20 cm × 20 cm spacing with single seedling per hill) and T8 (transplanting of 18 days old seedlings at 20 cm × 20 cm spacing with single seedling per hill). T1 (ANGRAU package i.e., transplanting of 25 days old seedlings at 15 cm × 10 cm @ 2-3 seedlings per hill), records the least harvest index of finger millet with which was comparatively lower than all other treatments under study.

Mani and Noori (2015) done a study to determine the effect of sowing date and plant density on growth analysis parameters of cowpeas. The study reports that a decrease in net assimilation rate (NAR) and relative growth rate (RGR) was observed as the age of the plant progressed in cow pea.

2.7. INFLUENCE OF WEATHER AND PLANTING METHODS ON THE INCIDENCES OF WEEDS

Wax and Pendleton (1968) conducted field studies over a 2-year period at Urbana, Illinois, to evaluate soybean (*Glycine max* (L.) Merr., var. Harosoy 63 and Wayne) and the effect of row spacing, variety, weed control methods, and 2,3,5-triiodobenzoic acid (here in after referred to as TIBA) on weed yields. Result shows that soybean yield increased and weed yield decreased as row spacing was decreased. Cultivation controlled broadleaf weeds at all row spacing.

Felton (1976) conducted an experiment to determine the reduction in yield attributes due to the weed competition by growing soyabean in 25, 50, 75 and 100 cm rows and within row densities of 10, 20 and 40 plants per per m^2. The results shows no effect of weeds on yield when the crops are grown in 25 cm rows, but a decrease of 20 per cent is identified with 50 cm rows, 26 percent with 75 cm rows and 37 per cent with 100 cm rows.

Samra and Dhillon (1988) conducted a study in wheat and reported that grain yield was obtained maximum in paired row planting (40.6 q/ha) which was closely followed by the crossed row planting (40.4 q/ha). They suggest that this may be due to the suppression and control of weeds in paired and crossed row planting which reduced the weed effect on the yield.

Application of Integrated weed management system requires detailed information on crop-weed interactions along with the impact of the relative competitive ability of the crop during various phases of development on weed growth. So Tollenaar *et al.* (1994) conducted an experiment to quantify effects of plant density on weed interference in maize (*Zea mays* L.) throughout the growing season. Experiments were carried out for 3 years during 1990, 1991, and 1992 at the Elora Research Station, London with Maize grown at three planting densities (4, 7, and 10 plants per m^2) under three weed pressures. This study reveals that increasing maize plant density from 4 to 10 plants per m^2 reduced weed biomass by up to 50%. So the study suggests that by increasing plant density, competitiveness of maize with weeds can be effectively reduced.

Buhler and Gunsolus (1996) conducted field research at Rosemount, MN, in three years which are 1989, 1990, and 1991 to determine the effect of preplant tillage and soybean planting date on weed populations and effectiveness of mechanical weed control operations. The study shows that reduction in weed density as well as yield losses from weeds are possible by delaying soybean planting from mid-May to early-June.

Integrated weed management (IWM) constitutes the combined package of narrower corn row widths, higher crop densities, and inter row cultivation. Murphy *et al.* (1996) conducted a three-year study to test whether these factors affected corn growth, development and grain yield at final harvest, and weed biomass when weeds were late-emerging (after the three-leaf stage of corn). The results shows that corn leaf area index (LAI) are significantly Increased by increasing corn density from 7 to 10 plants per m^2 or decreasing row width from 75 to 50 cm and this led to reduction in photosynthetic photon flux density (PPFD) which should be available for a mixture of weed species located below the corn canopy for their growth. So this concludes that narrower rows and higher corn density significantly reduced biomass of late-emerging weeds.

Rasmussen (2004) conducted a study on the effect of sowing date, stale seedbed, row width and mechanical weed control on weeds and yields of organic winter wheat with treatments were taken as sowing time (normal or late sowing) and false seedbed, row width (12 and 24 cm) and weed control method [untreated; mechanical weed control (weed harrowing at 12 cm supplemented with inter-row hoeing at 24 cm); and herbicide weed control]. The result obtained were concluded as greatest weed biomass which were obtained in midsummer on plots sown at the normal sowing time compared with delayed sowing.

Shinggu *et al*. (2009) conducted a study on the influence of spacing and seed rate on weed suppression in finger millet at Nigeria. The study was done through cultivating finger millet with five different inter row spacing (10, 15, 20, 25 and 30 cm) and five seed rates (10, 15, 20, 25, and 30 kg/ ha). The study reveals that both the spacing and seed rate had significant effect on suppressing weeds in which a negative impact on weed biomass and positive impact on finger millet yield and biomass was observed from the cultivation with higher seed rate and narrow spacing.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The study on “Crop weather relationship studies in finger millet (*Eleusine coracana* (L.) Gaertn) in central zone of Kerala” was carried out during 2018-2019 at the Department of Agricultural Meteorology, College of Horticulture, Vellanikkara.

3.1 DETAILS OF THE EXPERIMENT

3.1.1. Location of experiment

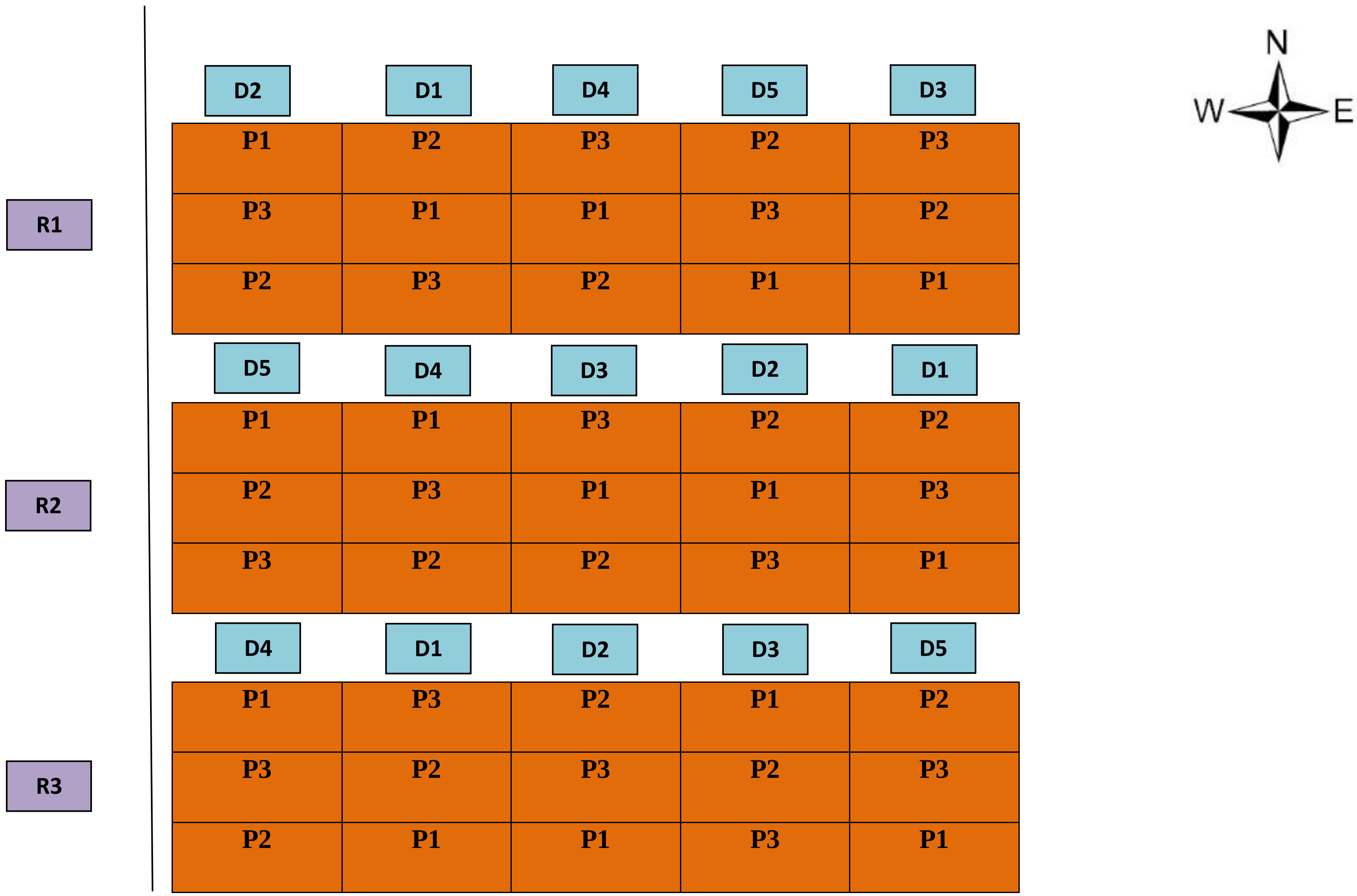
The field experiments were conducted during May 2018 to November 2018 at Instructional farm, Kerala Agricultural University, Thrissur. The station is located at 10^0 32’ N latitude and 76^0 20’ E longitudes at an altitude of 22m above mean sea level.

3.1.2. Soil Characters

The soil texture of the experimental field was sandy loam. Table 3.1 shows the physical properties of soil.

Table 3.1. Mechanical composition of soil of the experimental field

Sl. No	**Particulars**	**Value**
1	Coarse sand (%)	27.6
2	Fine sand (%)	24.2
3	Silt (%)	22.2
4	Clay (%)	26



D1 – May 15th D2 – June 1st D3 – June 15th D4 – July 1st D5 – July 15th planting
P1 – Broadcasting, P2 – Line sowing/Dibbling, P3 - Transplanting

Fig. 3.1. Lay out of the experimental plot in split plot design

3.1.3 **Climate**

The experimental area is a typical warm humid tropical region. Both southwest and northeast monsoons provide rain to the area. The location experienced a mean maximum temperature of 31.1 ^{0}C and a mean minimum temperature of 22.7 ^{0}C during the experimental period. The maximum rainfall was obtained during the month of August which was recorded to be 629 mm. the average sunshine received during experiment was 3.9 hrs/ day. The mean forenoon relative humidity was 92.5% and the mean afternoon relative humidity was 71.7%. The average wind speed was 1.9 kmh^{-1}. Table 3.2 represents the details of the weekly weather parameters during the experiment.

3.1.4 **Season of the experiment**

The field experiment was conducted from May 2017 to November 2017 during *kharif* season.

3.2 EXPERIMENTAL MATERIALS AND METHODS

3.2.1 **Variety**

The variety used for the field experiment study was GPU-28 which is a famous variety in Karnataka and Tamil Nadu. These variety are categorized as medium duration varieties having duration of 110-115 days.

The GPU-28 variety is developed during 1990 by the Project Coordination cell for All India Coordinated Small Millets Improvement Project and it is released for cultivation mainly in Karnataka and Tamil Nadu region. GPU-28 has been considered as the resistant variety for neck and finger blast.

Table 3.2 Weekly weather parameters during the period of experiment 2018

Week No.	Tmax (ºC)	Tmin (ºC)	RH I (%)	RH II (%)	VPD I (mm Hg)	VPD II (mm Hg)	WS (km hr^{-1})	BSS (hrs)	RF (mm)	RD (days)	EVP (mm)
20	33.23	22.57	91.43	63.71	23.24	23.29	1.40	4.93	74.90	2.00	2.83
21	32.44	22.26	90.00	71.57	23.21	23.97	1.60	3.47	113.40	4.00	3.01
22	30.43	24.07	92.71	81.00	23.63	24.07	1.48	2.10	194.50	4.00	2.83
23	30.29	23.56	96.00	81.57	23.59	23.84	1.86	1.71	230.70	5.00	2.00
24	29.36	23.54	97.00	82.29	23.37	23.76	1.73	1.27	236.00	5.00	2.27
25	28.34	22.53	96.00	86.86	21.87	22.37	1.44	1.64	142.70	6.00	2.07
26	30.19	22.69	95.43	76.43	22.43	22.73	1.23	2.99	98.00	5.00	2.40
27	31.46	22.81	93.71	93.71	22.61	22.14	2.04	3.49	65.50	2.00	3.16
28	28.01	21.70	97.86	97.86	21.47	23.77	1.51	0.33	304.20	7.00	2.54
29	28.80	22.09	95.00	86.43	21.79	22.96	1.51	0.09	256.10	6.00	1.94
30	29.54	23.11	96.29	76.71	23.13	22.77	1.76	0.99	110.50	5.00	2.50
31	29.93	23.09	96.43	75.71	23.10	22.79	1.37	1.51	103.60	5.00	2.46
32	28.70	22.04	97.29	84.00	22.29	23.16	1.46	0.41	208.60	7.00	2.04
33	27.10	21.67	96.29	89.43	21.53	21.76	2.19	0.44	629.00	7.00	1.46

Tmax – Maximum temperature
Tmin – Minimum temperature
RH I – Forenoon relative humidity
RH II – Afternoon relative humidity
BSS – Bright sunshine hours

VPD I – Forenoon vapour pressure deficit
VPDII – Afternoon vapour pressure deficit
WS – Wind speed
RF - Rainfall
RD – Rainy days
Epan – Pan evaporation

34	30.60	22.17	94.86	69.71	21.87	21.64	1.94	6.07	12.90	1.00	2.96
35	30.21	22.73	94.29	67.86	22.44	21.19	1.72	2.87	32.60	4.00	2.69
36	31.56	21.99	91.71	59.14	21.86	19.90	2.09	9.57	0.50	0.00	3.53
37	31.91	22.33	90.29	60.57	21.93	20.39	1.51	7.61	0.00	0.00	3.76
38	32.50	22.40	91.71	57.29	22.09	20.30	1.64	7.63	0.90	0.00	3.13
39	33.57	22.46	91.43	62.71	22.30	24.82	1.57	4.96	27.60	2.00	3.09
40	33.23	22.63	88.14	67.14	22.13	23.29	3.30	4.86	131.00	4.00	3.04
41	32.49	24.00	95.43	70.43	23.27	23.54	1.33	5.01	65.70	2.00	2.79
42	31.96	23.17	95.71	69.71	22.34	22.27	1.17	4.81	146.50	5.00	2.80
43	33.33	22.33	79.14	44.86	18.91	16.77	2.61	7.81	39.80	1.00	3.53
44	32.76	23.79	84.57	54.43	21.27	19.37	4.04	6.13	1.00	0.00	3.33
45	33.66	22.83	81.14	49.14	19.76	17.96	2.97	7.17	0.00	0.00	3.61
46	32.71	23.37	88.71	56.71	21.40	20.13	2.10	6.47	4.10	2.00	2.60

3.2.2. Design and Layout

The experimental design used was split plot design with five dates of planting (from 15th May to 15th July) as the main plot treatments and three different planting methods like broadcasting, line sowing/dibbling and transplanting as sub plot treatments. It was replicated three times. Fig. 3.1 shows the field layout. The field was divided into 45 plots of 3x2 m^2 size each. A spacing of 25x15 cm was maintained.

3.2.3. Treatments

The treatments included were five planting dates starting from 15th May to 15th July at 15 days interval and three different planting methods broadcasting, line sowing/dibbling and transplanting. These are given in the following Table 3.3.

Table 3.3. Treatments used in the experiment

MAIN PLOT	**SUB PLOT**
Date of planting	**Planting method**
15th May	Broadcasting
	Line sowing/dibbling
	Transplanting
1st June	Broadcasting
	Line sowing/dibbling
	Transplanting
15th June	Broadcasting
	Line sowing/dibbling
	Transplanting
1st July	Broadcasting
	Line sowing/dibbling
	Transplanting
15th July	Broadcasting
	Line sowing/dibbling
	Transplanting

Plate I. General view of the experimental field

Plate II. Preparation of beds and sowing

Plate III. Manuring

Plate IV. Field after installation of net

Plate V. Spraying of pesticides

Plate VI. Harvesting of finger millet

3.3 CROP MANAGEMENT

3.3.1. Nursery Management

Except for transplanting, the broadcasting and line sowing were done directly to the field. Nursery preparation has been done prior to transplanting which were made eighteen days previous to each date of transplanting. 2-3 seedlings were transplanted per hill in the field. Provision for adequate irrigation and drainage were made. Plant protection measures were also undertaken.

3.3.2. Land Preparation and planting

According to the packages of practices recommended (KAU, 2016) for finger millet, experimental field was cleared, ploughed well and puddled. As per the layout, plots were prepared. The subplots were built as the raised beds where the seeds were sown. Nursery beds were also prepared on one side of the field as per the recommendations.

3.3.3. Application of Manures and Fertilizers

During land preparation, farm yard manure was applied in the field at the rate of 5000 kg ha^{-1}. The nutrients like nitrogen, phosphorous and potassium are applied at appropriate rates (N:P:K = 22.5:22.5:22.5 kg ha^{-1}) in the form of urea, rajphos and muriate of potash as the basal dose. Top dressing was done with nitrogen @ 22.5 kg ha^{-1} within 21 days after sowing or transplanting.

3.3.4. After Cultivation

Weeds were a serious issue in the field which was controlled by hand weeding. Hand weeding was done three weeks after sowing and transplanting. Recommended plant protection measures were given to control pests and diseases. The yellowing of the field is suppressed by the application of Triple 19 (19:19:19) @ 5gm/litre. Spraying with folicur @1.5 ml $litre^{-1}$ was done when the crops start to show the symptoms of blast. In order to protect the crop from attack by the birds, the whole field is covered with net which is installed within the 12^{th} week after sowing and transplanting.

3.4. OBSERVATIONS

In order to record several biometric as well as physiological observations, plants were selected randomly from the field in each replication for each treatment from a unit area after leaving the border plants. The observations were recorded during various phenological stages of the finger millet which is grown with different planting methods.

3.4.1**. Biometric characters**

3.4.1.1. Plant height

Plant height measurements were done at fortnightly intervals. The measurements were taken using a scale from the bottom of the culm to the tip of the largest leaf or the ear head from 5 plants and expressed in cm.

3.4.1.2. Number of ear heads per unit area

The total number of ear heads per unit area was counted for each subplot at the time of harvest.

3.4.1.3. Number of fingers per ear head

Number of fingers per ear head were counted randomly from five plants at the time of harvest.

3.4.1.4. Finger length (cm)

The finger length for every fingers of each ear head from the five randomly selected plants were measured using a scale at the time of harvest.

3.4.1.5. Thousand grain weight

At the time of the harvest, one thousand grains were counted from the cleaned dried produce collected from each subplot and the weight was recorded in grams.

3.4.1.6. Grain yield

The produce from each plot was sun dried at first for 15 days after harvest, which is then threshed, properly winnowed, weighed and expressed as kg ha $^{-1}$.

3.4.1.7. Straw yield

The straw from each plot were dried uniformly for 15 days after harvest, weighed and expressed in kg ha $^{-1}$.

3.4.1.8. Harvest index (HI)

Harvest index is an indices which can be considered as a measure of reproductive efficiency. It is calculated by using grain yield and straw yield which will be expressed in percentage. HI was calculated by using the formula:

$$HI = \frac{Grain\ yield}{Biological\ yield}\ x\ 100$$

3.4.1.3. Dry matter production

Biomass production or dry matter accumulation was estimated by taking observation of the plants at 15 days interval after transplanting. Two healthy plants were randomly selected from the field and uprooted from each experimental sub plot. Then it is cleaned and dried in sun followed by oven drying at a temperature of 80^0C to a constant weight. The weight was taken and recorded in grams per plant.

3.4.2. Phenological observations

3.4.2.1. Number of days for panicle initiation

Number of days taken from sowing to panicle initiation were counted and recorded in days.

3.4.2.2. Number of days for first visible flag leaf

Number of days taken for the crop from sowing to first visible flag leaf was noted and recorded in days for each date of planting.

3.4.2.3. Number of days for 50% flowering

Number of days taken for the crop from sowing to 50% flowering was noted and recorded in days for each date of planting.

3.4.2.4. Number of days for milk stage

Number of days taken by the crop from sowing to milk stage were counted and recorded in days for each date of planting.

3.4.2.5. Number of days for dough stage

Number of days taken for the crop from sowing to dough stage were counted and recorded in days for each planting.

3.4.2.6. Number of days for physiological maturity

Number of days taken for the crop from sowing to physiological maturity were counted and expressed in days.

3.4.3 Micrometeorological observations

3.4.3.1. Soil temperature (^{0}C)

The soil temperature observations were taken by using a digital soil thermometer of 30 cm in length. The thermometer is placed at a depth of 5cm, 15cm and 30cm in depth made in the experimental plots for a few minutes until the reading become constant. Observations are taken for two times per day in the morning and the afternoon and the values were recorded.

3.4.3.2. Soil moisture (%)

The soil moisture observation is taken by gravimetric method by collecting samples using an auger from the plots. The soil was collected from a depth of 5cm and 15cm and it is oven dried at 105^0C for 24-48 hrs after taking the fresh weight. The dry weight is recorded when the soil weight attains a constant value.

3.4.4. Physiological observations

3.4.4.1. Crop Growth Rate (CGR)

Crop growth rate (CGR) is one among the growth indices that is used to measure the dry matter accumulated per unit time per unit land area which was introduced by Watson in 1956. It is measured in g m $^{-2}$ day $^{-1}$.

$$\text{Crop Growth Rate } (CGR) = \frac{(W_2 - W_1)}{\rho(t_2 - t_1)}$$

Where W_1 and W_2 are the dry weight of the whole plant at times t_2 and t_1 and ρ is the ground area on which W_1 and W_2 are noted.

3.4.4.2. Relative growth rate (RGR)

It is a growth indice which used to calculate the increase in growth of a particular system with respect to the initial size per unit time. RGR grows exponentially which quantify the speed of plant growth. It is measured in mg g $^{-1}$ day $^{-1}$.

$$\text{Relative Growth Rate } (RGR) = \frac{(lnW_2 - lnW_1)}{(t_2 - t_1)}$$

Where W_1 and W_2 are the dry weight of the whole plant at times t_2 and t_1

3.4.5. Observations on weeds

3.4.5.1. Floristic composition of weed

Using a quadrant, a unit area of $1m^2$ were selected in the subplots. Weeds were collected entirely from the unit area at 30 and 60 days after sowing. Those collected weeds were cleaned and identified accordingly. The number of plants coming under each species per unit area were also noted down.

3.4.5.2. Weed density per unit area

The total number of weeds collected from the unit area selected using a quadrant were counted down and noted for the subplots at 30 and 60 days after sowing.

3***.4.5.3. Weed dry weight per unit area***

The collected weeds from the unit area were cleaned and weighted it to get the fresh weight. Then the samples are kept for oven drying at a temperature of 80^0C to a constant weight. The oven dried samples were weighed to get the dry weight of the weeds per unit area. The observation was taken at 30 and 60 days after sowing

3.4.6. Soil analysis

The soil samples were collected from the field before planting for soil analysis. Soils are collected from the experimental plot in a zigzag manner from 15 cm depth. Then the collected samples were dried and powdered separately after removing the debris. Nearly a 0.5 kg of soil sample is taken through halving method for the analysis for pH, electrical conductivity, organic carbon, available phosphorous and available potassium. Table 3.4 shows the results of chemical analysis.

3.4.7. Weather data

The various weather parameters on daily basis were collected from the Agromet observatory of College of Horticulture, Vellanikkara which includes maximum temperature, minimum temperature, relative humidity, rainfall, number of rainy days, bright sunshine hours, wind speed, and evaporation. These are converted into weekly data which was used for the study. The different weather parameters used in the study are presented in the Table 3.5.

Table 3.4. Chemical properties of the soil

Sl no.	Parameter	Sample	
		Quantity	Remarks
1	Soil pH	4.3	Extremely acid
2	Electrical conductivity (dSm^{-1})	0.07	Normal

3	Organic carbon (%)	1.34	Medium
4	Available phosphorous (kg ha^{-1})	9.29	Low
5	Available potassium (kg ha^{-1})	367.47	High

Table 3.5. Weather parameters used in the experiment

Sl. No.	Weather parameter	Unit
1	Maximum temperature (Tmax)	^{0}C
2	Minimum temperature (Tmin)	^{0}C
3	Rainfall (RF)	mm
4	Rainy days (RD)	Days
5	Relative humidity (RH) Forenoon relative humidity (RH I) Afternoon relative humidity (RH II)	%
6	Forenoon vapour pressure deficit (VPD I) Afternoon vapour pressure deficit (VPD II)	mm Hg
7	Bright sunshine hours (BSS)	hrs.
8	Wind speed (WS)	km hr^{-1}
9	Wind direction (WD)	Degree
10	Evaporation (EVP)	mm

3.5 HEAT UNITS

3.5.1. Growing Degree Days (GDD)

Growing Degree Days (GDD) is a measure of heat accumulation which influence growth, yield and yield attributes of finger millet which can be calculated by using Peterson equation (1965). Temperature is the major parameter that determine the accumulation level of GDD. Base or threshold temperature required for the calculation of GDD for finger millet is 10^0C (Rajegowda *et al*. 2015).

$$GDD = \sum_{i=1}^{n} \frac{Tmax+Tmin}{2} - Tb$$

Where,

n – Number of days from sowing date till the last date of harvesting

Tmax – Maximum temperature (^{0}C)

Tmin – Minimum temperature (^{0}C)

Tb – Base temperature (minimum threshold temperature)

3.5.2. Heliothermal Unit (HTU)

Heliothermal unit for finger millet was calculated during each phenophases of crop and correlated with duration and yield parameters. The Heliothermal Units were calculated using the formula given by Rajput (1980). The calculated Heliothermal Unit is expressed in ^{0}C day h.

$$HTU = \sum_{i=0}^{n} GDD\ X\ BSS$$

Where, GDD = Growing Degree Days

BSS = Actual bright sunshine hours

3.5.3. Photothermal Unit (PTU)

Effect of maximum possible sunshine hours on the crop were studied by calculating photothermal units in ^{0}C day h. The photothermal units were calculated using the equation given by Wilsie (1962).

$$PTU = \sum_{i=0}^{n} GDD\ X\ L$$

Where, L is the maximum possible sunshine hours

The maximum possible sunshine hours were calculated using Smithsonian table.

3.6. Cost of cultivation

Cost of cultivation helps to estimate the practicability of adopting a certain technique for the cultivation process in agricultural sector. The cost of cultivation of finger millet under different establishment methods like broadcasting, dibbling and transplanting was calculated by estimating the input cost based on the amount used. Simultaneously gross return was calculated from the grain and straw yield obtained from the field and ongoing price prevailing in the markets. Net return (₹ ha^{-1}) and benefit cost ratio for each treatment were calculated from these values by using the following formulae:

3.6.1 Gross income

Gross income indicates the economic produce (grain) and by-product (straw) obtained from the crops in the form of monetary value. It is calculated by multiplying the yields (of main and by-product) with the prevailing market prices and is expressed as Rs. ha^{-1}.

$$\text{Gross return (Rs. ha}^{-1}) = \text{Grain yield (kg ha}^{-1}) \times \text{Market price (Rs. kg}^{-1}) + \text{Straw yield (kg ha}^{-1}) \times \text{Market price (Rs. kg}^{-1})$$

3.6.2. Net return

Net profit actually implies the net profit obtained from the whole cultivation process. This is calculated from the gross return and cost of cultivation as:

$$\text{Net return (Rs. ha}^{-1}) = \text{Gross return (Rs. ha}^{-1}) - \text{cost of cultivation (Rs. ha}^{-1})$$

3.6.3. Benefit : Cost ratio

Benefit : cost ratio was computed as the ratio of net return and cost of cultivation which is indicated in the following formula:

$$\text{Benefit : cost ratio} = \frac{\text{Net return (Rs. ha}^{-1})}{\text{Total cost of cultivation (Rs. ha}^{-1})}$$

3.7. STATISTICAL ANALYSIS

The data obtained from the field experiment was used for the statistical analysis which was done using the standard procedure for split plot design introduced by Fisher (1947). ANOVA has been carried out for each observations to identify the existence of significant difference between main plot treatments (dates of planting) and sub plot treatments (planting methods) and their interaction. If the ANOVA result shows significant difference between the parameters, then the pair wise comparison was done using the computed critical differences.

Critical difference for comparing two main plot treatments (dates of planting) was calculated as

$$CD_1 = t_1 \times SE_1$$

Where t_1 = t value at degrees of freedom for main plot error

SE_1 = standard error of difference between two main plot treatment means

$$SE_1 = \sqrt{\frac{2E_1}{rb}}$$

Where, E_1 = error mean square value of main plot treatment in ANOVA

r = number of replications

b = number of sub plot treatments

Critical difference for the comparison of two subplot treatments (planting methods)

$$CD_2 = t_2 \times SE_2$$

Where, t_2 = t value at degrees of freedom for sub plot error

SE_2 = Standard error of difference between two sub plot treatments

$$SE_2 = \sqrt{\frac{2E_2}{ra}}$$

Where, E_2=Error mean square value of sub plot treatments in ANOVA

r = Number of replications

a = Number of main plot treatments

Critical difference value for the comparison of two sub plot treatment within a main plot treatment was found as

$$CD_3 = t_3 \times SE_3$$

Where, t_3 = t value at degrees of freedom for sub plot error

$$SE_3 = \sqrt{\frac{2E_2}{r}}$$

E_2 = Error mean square value of sub plot treatments in ANOVA

r = Number of replications

The effect of weather parameters on biometric and phenological characters of the crop, was estimated using the correlation analysis which was carried out by taking experimental data and the weather data. The weather data was taken from the daily data of the year 2018 and critical growth stage wise weather variables were worked out. This data along with the important crop growth and yield characters is used for the correlation analysis to obtain the relation between them with the weather.

The statistical analyses were carried out using different software packages like Microsoft – excel, SPSS for correlation analysis and WASP for ANOVA.

RESULTS

4. RESULTS

The study entitled "Crop weather relationship studies of finger millet in central zone of Kerala" was carried out at Instructional farm, Vellanikkara. The experimental data collected were statistically analysed and the results obtained are presented below:

4.1. Phenophases

The study of periodic plant cycle events as influenced by the plant environment and climatic conditions is described as the phenology. Phenology plays a major role in determining the performance of a crop growth and its productivity. Proper knowledge regarding the timing of the various phenological events will helps to improve the crop yield stability and quality of produce. This also promotes adoption of suitable crop management practices.

The phenophases of finger millet constitutes six different growth and development phases that initiates from sowing to physiological maturity (Rajegowda *et al*. 2015). These phenophases are:

i. Sowing to panicle initiation(**Ph_1**)
ii. Panicle initiation to flag leaf stage (**Ph_2**)
iii. Flag leaf to 50% flowering stage (**Ph_3**)
iv. 50% flowering to milk stage (**Ph_4**)
v. Milk stage to dough stage (**Ph_5**)
vi. Dough stage to physiological maturity (**Ph_6**)

These entire phenophases can be broadly classified into main three growth periods which are vegetative phase, reproductive phase and ripening phase. The phenophases from sowing to panicle initiation will comes under the vegetative period. Panicle initiation to flag leaf stage, flag leaf to 50% flowering will comes under reproductive period and the 50% flowering to milk stage, milk stage to dough stage and dough stage to physiological maturity will comes under ripening period.

4.2. Weather observations

Weather is the prime factor that determines the crop growth and productivity, through various weather variables like maximum temperature, minimum temperature, relative humidity, vapour pressure deficit, rainfall, number of rainy days, bright sunshine hours, wind speed and pan evaporation. The weather experienced during the study period of the year 2018 over the crop growing area were recorded in Fig. 4.1 - 4.6. The average weather prevailed during the entire crop period over standard meteorological weeks graphically were given for each weather parameters.

4.2.1. Air temperature

The air temperature experienced during the entire crop-growing period was plotted graphically on weekly basis in terms of maximum and minimum temperatures in Fig.4.1. Weekly mean temperature and temperature range were also plotted along with this. In case of maximum and minimum temperature, it showed a nonlinear progress from 20th to 46th week. The values seems as slightly decreasing towards the first week of June and then increased by the end of June. Thereafter it follows a variable trend and then increases towards the 46th week. Mean temperature also showed the same exact pattern as that while minimum temperature showed only slight variations in its trend for the whole period. The maximum temperature was observed during the month of November where it reached a value of 33.4^{o}C. The value of temperature range (TR) was from 5.4 ^{o}C to 10.8 ^{o}C during the crop growth period where the average value leads to 8.3 ^{o}C. The mean temperature during the crop period was continuously varying between 26.3^{o}C to 28^{o}C.

4.2.2. Relative Humidity (RH)

The observations on relative humidity has been done by recording the forenoon and afternoon relative humidity (RHI and RHII) for the entire experimental period. The mean relative humidity (RHmean) has been estimated from this and plotted graphically according to standard meteorological weeks in Fig.4.2. Even though the graph for the three

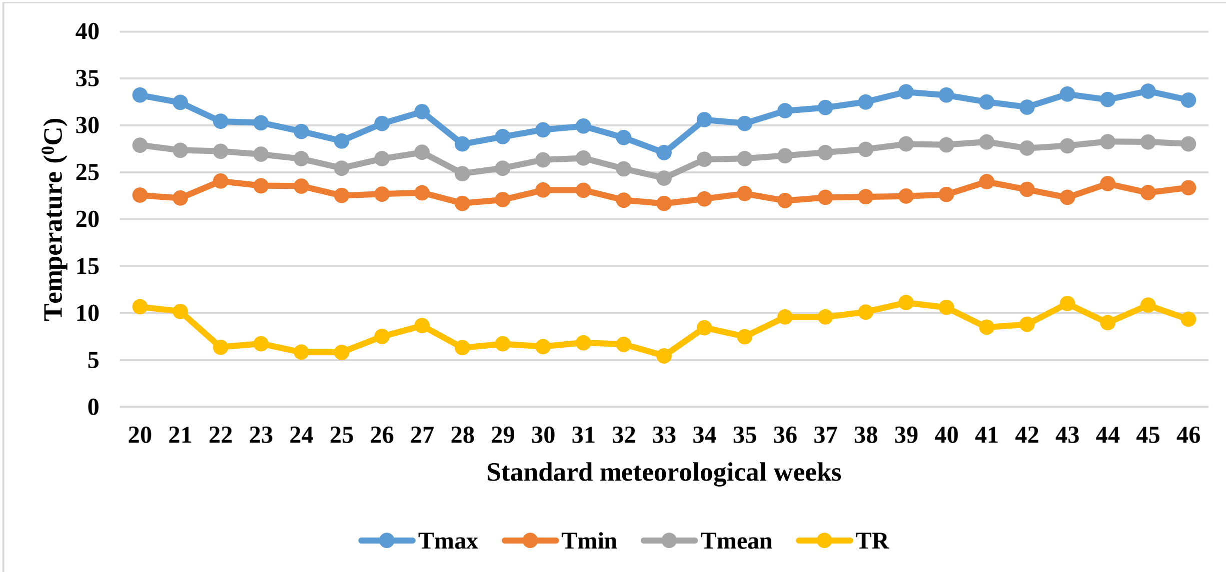


Fig. 4.1. Weekly air temperature during the crop period

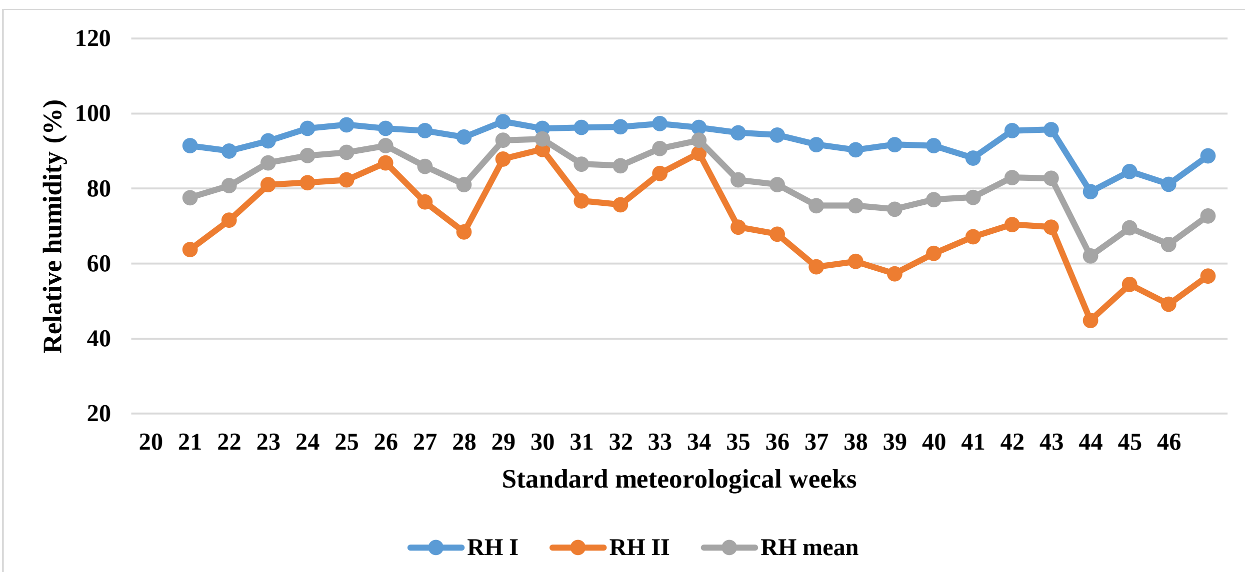


Fig. 4.2. Weekly relative humidity (RH) during crop period

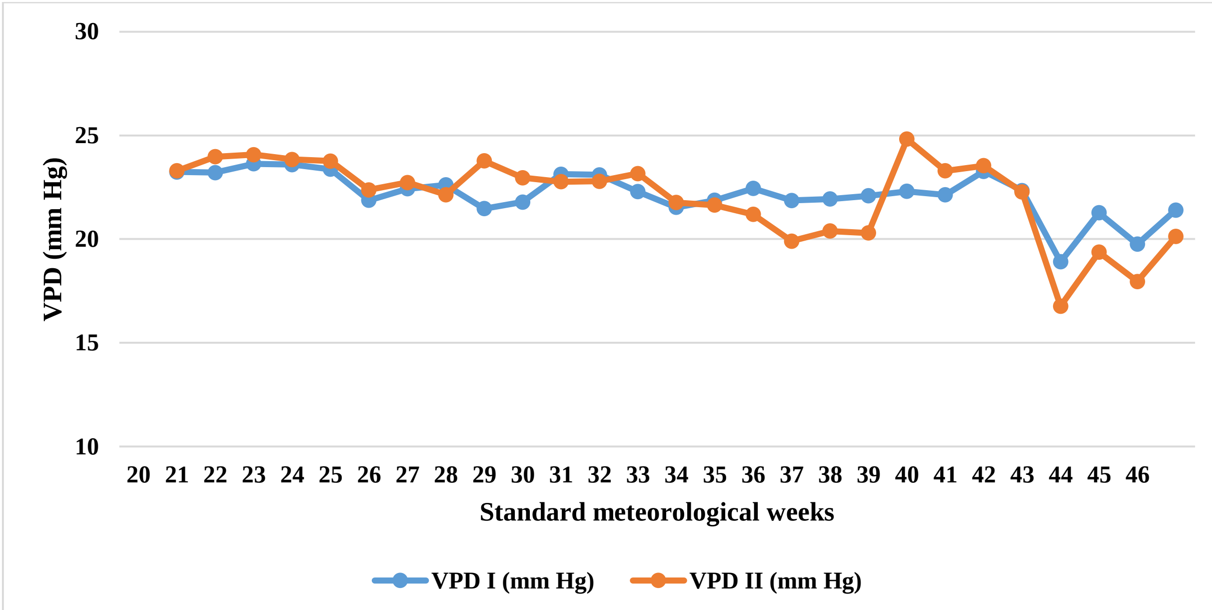


Fig. 4.3. Weekly vapour pressure deficit (VPD) during crop period

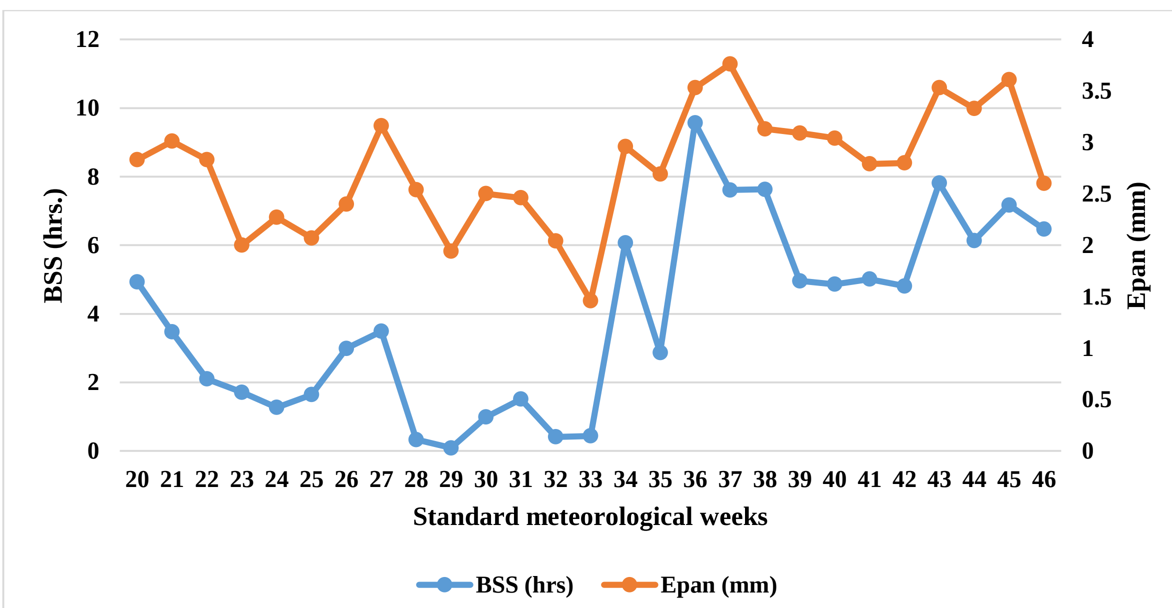


Fig. 4.4. Weekly bright sunshine hours (BSS) and evaporation (Epan) during crop period

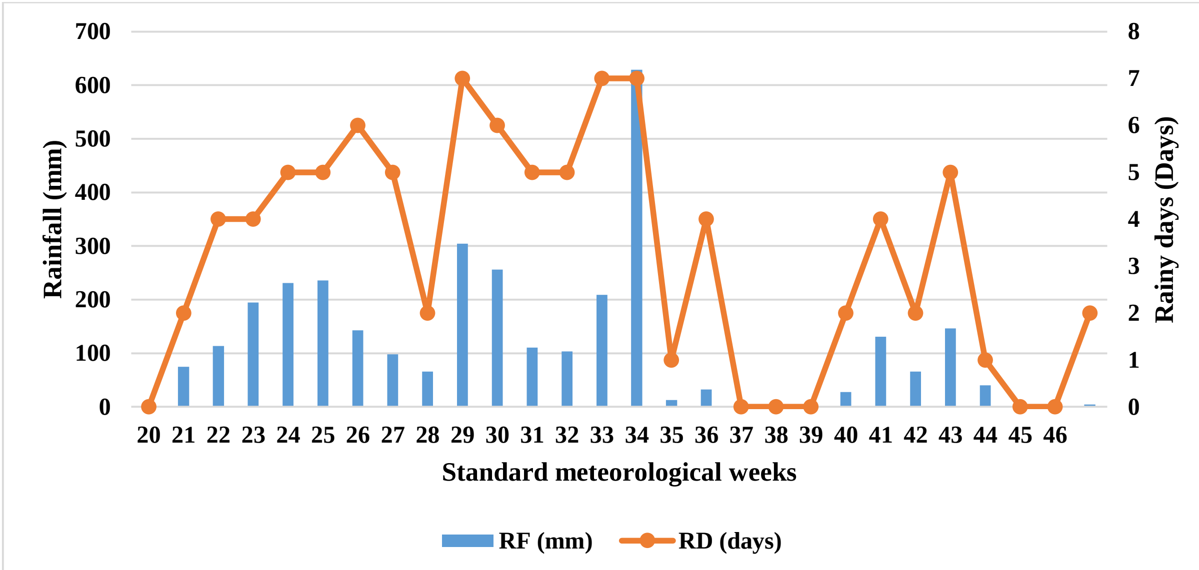


Fig. 4.5. Weekly rainfall (RF) and rainy days (RD) during crop period

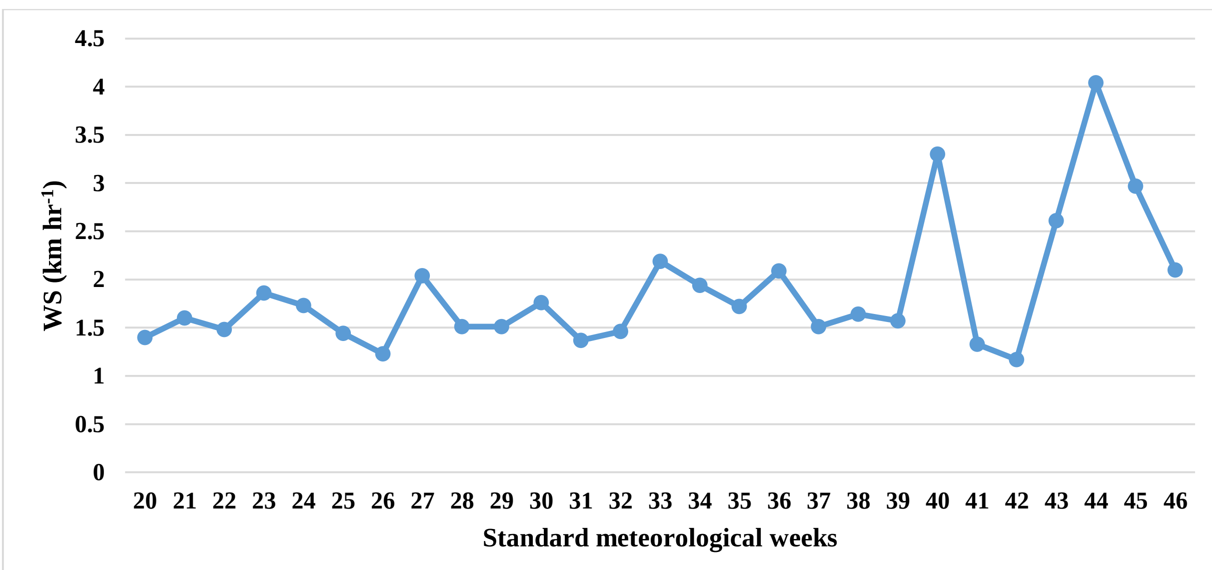


Fig. 4.6. Weekly wind speed during crop period

types of observations showed a steady state condition, slight difference can be observed in some points. The highest variations was observed in case of afternoon relative humidity. The forenoon relative humidity did not show any considerable change over different standard meteorological weeks except a high peak during the 28^{th} week and then a sudden decrease for the last three week. Afternoon relative humidity and mean relative humidity also showed same trend as forenoon relative humidity. Forenoon relative humidity ranged between 79– 98% and afternoon relative humidity ranged between 45 –98 %. All the experimental plots are exposed to the same RH conditions.

4.2.3. Vapour Pressure Deficit (VPD)

Vapour pressure deficit observations had been taken by measuring both the forenoon and afternoon vapour pressure deficit which were obtained using the dry and wet bulb temperatures recorded throughout the experimental period. The forenoon vapour pressure deficit and afternoon vapour pressure deficit experienced during the crop period averaged according to standard meteorological weeks is plotted graphically and presented in Fig. 4.3. The forenoon vapour pressure deficit (VPD I) for the period varied between 18.91 to 23.63 mm of Hg and afternoon vapour pressure deficit (VPD II) varied between 16.77 to 24.82 mm Hg.

4.2.4. Wind speed (WS)

The wind speed showed a considerable steady trend up to 39^{th} week and the suddenly it showed a high peak at 40^{th} and 44^{th} week. In between the values declined to the lowest peak. It showed values at a range of 1.17 to 4.04 $kmhr^{-1}$ during this period. The week towards the end of crop growth period showed the highest variations in the wind speed for all dates of planting. It is plotted graphically in Fig. 4.6.

4.2.5. Bright Sunshine Hours (BSS)

The bright sunshine hours prevailed during the crop period has been shown graphically in the Fig. 4.4. The bright sunshine duration followed a variable pattern with several peaks and troughs throughout the crop growth period. Even though it followed an irregular pattern, it showed an increasing trend towards the end. It ranged from 0.09-9.57 hrs day^{-1}. All the experimental plots are exposed to the same BSS conditions.

4.2.6. Rainfall and rainy days (RF and RD)

The rainfall experienced considerable variations in its trend for the crop growth period. It showed higher values up to mid-August as it progressed with the monsoon and there after follows a considerable decrease which is plotted graphically in Fig. 4.5. The cumulative rainfall during the crop growth stages indicates May 15th planting received the highest amount of accumulated rainfall which is 2813 mm followed by June 1st planting from sowing to maturity stage, where July 15th planting obtained less rainfall of 1801 mm. In addition, the number of rainy days were low for July 15th planting as 57 when compared with 81 for May 15th planting.

4.2.7. Pan evaporation (Epan)

Evaporation rate is measured by using pan evaporation which is recorded during the entire experimental period and was averaged according to standard meteorological weeks from 20 to 46. The value ranged from 1.46 to 3.76 mm. It is plotted graphically and presented in Fig. 4.4.

It follows the same pattern as that of bright sunshine hours in which the second half experienced comparatively higher values with respect to the first half of total crop period. It showed an increasing trend towards the end of the harvesting with the highest peak on the 37th week. Thereafter it decreased for a period of two to three weeks and again showed an increase from the 43rd week onwards.

Table 4.1. Weather data experienced during the crop growth period for each date of planting

Date of planting	Tmax (°C)	Tmin (°C)	RH I (%)	RH II (%)	VPD I (mm Hg)	VPD II (mm Hg)	WS (km hr^{-1})	BSS (hrs)	RF (mm)	RD (days)	Epan (mm)
May 15th	30.13	22.61	94.57	76.13	22.52	22.56	1.67	2.95	2813.00	81.00	2.57
June 1st	30.36	22.63	94.33	74.77	22.38	22.50	1.75	3.36	2643.60	79.00	2.62
June 15th	30.46	22.56	94.28	73.48	22.27	22.32	1.72	3.60	2233.60	72.00	2.66
July 1st	30.94	22.54	93.30	70.28	22.07	21.91	1.80	4.21	2135.20	64.00	2.80
July 15th	31.09	22.61	92.51	68.93	22.00	21.69	1.95	4.36	1801.20	57.00	2.82

4.3. Phenological observations of crop growth and development

Phenology deals with the study of the duration for different phenophases throughout the entire crop growth period. Number of days taken to attain different phenophases were noted for the finger millet with three different planting methods for all dates of planting. The phenophases considered under the study were sowing to panicle initiation, panicle initiation to flag leaf stage, flag leaf to 50% flowering stage, 50% flowering to milk stage, milk to dough stage and dough stage to physiological maturity. The observations are presented in Table 4.2.

4.3.1. Number of days from sowing to panicle initiation

Considered the number of days taken for the panicle initiation, it showed irregular trend from first date to last date of planting. The first date of planting took comparatively less days than second date of planting to attain the panicle initiation stage, while the values increased further up to fourth date and then again decreased to the lowest values of 77 for the last date of planting. In the case of most of the plantings, the crop sown with broadcasting and dibbling methods took equal durations while the transplanting took more days to attain panicle initiation.

4.3.2. Number of days from panicle initiation to flag leaf stage

The duration to attain the flag leaf stage from panicle initiation stage showed a slight decreasing trend for all the methods of planting while coming to the last date of planting. The highest duration has been taken for the June 15th planting which is 11 and then further it reduced to 8. Lowest days taken was 8 to attain the flag leaf stage which was for the July 1st planting. Except in June 15th planting, transplanting took more number of days compared to other methods to attain the flag leaf stage. In May 15th and June 15th planting, the duration taken was same for all the three methods of planting. Broadcasting and dibbling took same number of days to attain the flag leaf in all the planting method.

Table 4.2. Number of days taken for each phenophases of finger millet under different planting dates and methods

Crop Stages	**Dates of planting (Number of Days)**														
	May 15th			**June 1st**			**June 15th**			**July 1st**			**July 15th**		
	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
Panicle initiation	83	83	87	92	92	98	84	84	91	84	84	91	77	77	84
Flag leaf stage	10	10	10	11	11	10	9	9	9	8	8	9	9	9	10
50% flowering	11	11	10	9	9	11	9	9	8	8	8	9	8	8	9
Milk stage	11	11	9	8	8	7	8	8	8	7	7	6	7	7	9
Dough stage	7	7	7	7	7	5	6	6	7	7	7	10	6	6	6
Physiological maturity	5	5	7	7	7	7	10	10	6	9	9	6	7	7	5
Total	127	127	130	134	134	138	126	126	129	123	123	131	114	114	123

P1 – Broadcasting P2 – Dibbling P3 – Transplanting

4.3.3. Number of days from flag leaf to 50% flowering stage

Considering the number of days taken to attain the 50% flowering, the May 15th planting showed higher number of days compared to that of remaining planting dates. Broadcasting and dibbling took same number of days to attain the 50% flowering in all the planting methods. Transplanting took more number of days compared to dibbling and broadcasting methods in June 1st, July 1st and 15th planting. The duration followed a slight decreasing trend with delay in planting.

4.3.4. Number of days from 50% flowering to milk stage

The number of days taken to attain the milk stage also follows a slight declining trend in which the highest values was recorded in May 15th planting which is 11 and the lowest values are recorded during the July 1st and 15th date of planting in which lowest value obtained was 6. Most of all the dates except July 15th planting, transplanting took less number of days compared to other two methods to attain milk stage from 50% flowering stage. During June 15th planting all the planting methods showed same number of days to attain milk stage.

4.3.5. Number of days from milk stage to dough stage

Considering the number of days taken to attain the dough stage, most of all the plants took 7 days. In case of June 1st planting, the transplanting method showed the lowest value which is 5 compared to other two methods. May 15th and July 15th planting took same number of days to attain the dough stage from milk stage for all the planting methods. The number of days taken for milk stage to dough stage ranged from 6 to 7 in the case of broadcasting and dibbling and 5 to 10 for transplanting, where maximum was found for July 1st planting for transplanting. Then it decreased to 6 in July 15th planting.

4.3.6. Number of days for physiological maturity

The number of days taken to attain the physiological maturity from dough stage ranges from 5 to 10 in which the lowest values was observed in May 15th and July 15th

planting. The highest values were taken in June 15th planting. Both the broadcasting and dibbling method took same number of days to attain the physiological maturity while the transplanting took higher number of days for the physiological maturity from sowing. The duration from dough stage to physiological maturity followed a slight increasing trend with delay in planting. The total number of days required to attain the physiological maturity from sowing followed an irregular pattern with respect to dates of planting. The lowest duration was observed in July 15th date of planting which was 114 in broadcasting and dibbling and 123 in transplanting. The highest duration was observed in June 1st planting which is 134 in broadcasting and dibbling and 138 in transplanting.

4.4. WEATHER CONDITIONS PREVAILED DURING SPECIFIC GROWTH STAGES OF CROPS UNDER DIFFERENT PLANTING DATES AND METHODS

Table 4.3 to Table 4.8 showed the weather conditions experienced by the crop during different growth stages.

4.4.1. Weather conditions prevailed from sowing to panicle initiation stage under different planting dates and methods

4.4.1.1. Temperature (Maximum temperature, Minimum Temperature, Mean Temperature and Temperature Range)

The highest maximum temperature during the sowing to panicle initiation stage was 30.5^{o}C for transplanting and 30.3 for both broadcasting and dibbling during July 15th planting and lowest maximum temperature was 29.4^{o}C for broadcasting and dibbling and 29.6 for transplanting during June 1st planting. The highest minimum temperature was experienced by broadcasting and dibbling during May 15th planting (22.8^{o}C) and lowest minimum temperature was experienced by broadcasting and dibbling (22.3^{o}C). The highest minimum temperature experienced by transplanting was in May 15th planting (22.8^{o}C) and lowest minimum temperature was experienced by broadcasting and dibbling (22.3^{o}C) during July 15th planting. For all the planting dates and methods from sowing to panicle initiation stage, maximum temperature varied from 29.4 to 30.5^{o}C whereas minimum temperature varied between 22.3^{o}C to

22.8^{o}C. The mean temperature ranged from 26.0^{o}C to 26.5^{o}C, which was lowest during June 15th and highest during May 15th planting. The temperature range increased from May 15th to July 15th with a slight decrease in between during June 1st planting. The maximum temperature range of 8.2^{0}C has been seen in July 15th planting.

4.4.1.2. Relative Humidity (RH I, RH II and RH mean) and Vapour Pressure Deficit (VPD I and VPD II)

Forenoon relative humidity followed an irregular pattern in which it slightly increased from the initial to the mid stage and then again decreased towards the July 15th planting for all the planting methods. The maximum relative humidity was found to be 96% for June 1st planting in broadcasting and dibbling and minimum of 94% was observed during July 15th planting in transplanting. The afternoon relative humidity was showing a decreasing trend with delay in date of planting towards the July 15th planting. The maximum afternoon relative humidity was observed as 80% for June 1st date of planting in broadcasting and dibbling and minimum afternoon relative humidity was 72% for July 15th planting in transplanting. The mean relative humidity ranged from 83% to 88% with maximum observed for June 1st planting in both broadcasting and dibbling and minimum observed for July 15th planting in transplanting method.

The forenoon vapour pressure deficit ranged from 22.2 mm to 22.8 mm of Hg and 21.9 to 23.2 for afternoon vapour pressure deficit. The maximum forenoon vapour pressure deficit was observed for both broadcasting and dibbling during May 15th planting and the minimum was observed for both broadcasting and dibbling in July 15th planting. Both the forenoon and afternoon vapour pressure deficit was showing a general decreasing tendency towards delayed planting date.

4.4.1.3. Wind Speed (WS)

During transplanting to panicle initiation, the wind speed ranged from 1.6 to 1.8 kmhr^{-1}. The wind speed showed an increasing trend with delay in date of planting where maximum wind speed was observed for transplanting in July 15th and less wind speed was seen in May 15th planting for all the methods.

4.4.1.4. Bright Sunshine Hours (BSS)

Bright sunshine hours varied between 1.9 to 3.8 hrs. during the experimental period. Bright sunshine hours showed an increasing trend with delay in date of planting with a slight decline for June 1st planting. The duration was maximum for July 15th planting in all the planting methods and less in June 1st planting in both broadcasting and dibbling methods.

Table 4.3. Weather experienced by finger millet from sowing to panicle initiation under different planting dates and methods

Weather variable	Date of sowing														
	May 15th			June 1st			June 15th			July 1st			July 15th		
	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
Tmax (^{0}C)	30.2	30.2	30.1	29.4	29.4	29.6	29.4	29.4	29.6	30.0	30.0	30.3	30.3	30.3	30.5
Tmin (^{0}C)	22.8	22.8	22.8	22.4	22.4	22.7	22.5	22.5	22.4	22.4	22.4	22.4	22.3	22.3	22.3
Tmean (^{0}C)	26.5	26.5	26.4	26	26	26.1	26.0	26.0	26.1	26.2	26.2	26.3	26.3	26.3	26.4
TR (^{0}C)	7.3	7.3	7.3	6.8	6.8	6.9	7.0	7.0	7.2	7.6	7.6	7.9	8.0	8.0	8.2
VPD I (mm Hg)	22.8	22.8	22.8	22.5	22.5	22.5	22.3	22.3	22.2	22.2	22.2	22.2	22.2	22.2	22.2
VPD II (mm Hg)	23.2	23.2	23.2	22.8	22.8	22.7	22.5	22.5	22.2	21.9	21.9	22.1	21.9	21.9	22.0
RH I (%)	94.8	94.8	94.9	95.8	95.8	95.6	95.7	95.7	95.3	94.7	94.7	94.5	94.3	94.3	93.9
RH II (%)	78.5	78.5	78.7	80.4	80.4	79.3	78.5	78.5	76.9	73.9	73.9	73.1	72.6	72.6	71.8
RH mean (%)	86.7	86.7	86.82	88.1	88.1	87.4	87.1	87.1	86.1	84.3	84.3	83.8	83.4	83.4	82.9
RF (mm)	1929.1	1929.1	2103.4	2431.2	2431.2	2431.2	1974.8	1974.8	1975.3	1724.6	1724.6	1752.2	1417.2	1417.2	1548.2
RD	56	56	59	72	72	72	63	63	63	50	50	51	44	44	49
BSS (hrs.)	2.1	2.1	2.1	1.9	1.9	2.2	2.3	2.3	2.8	3.5	3.5	3.7	3.8	3.8	3.8
Epan (mm)	2.5	2.5	2.5	2.3	2.3	2.4	2.4	2.4	2.5	2.7	2.7	2.7	2.7	2.7	2.7
WS (km hr^{-1})	1.6	1.6	1.6	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.8

P1-Broadcasting P2- Dibbling P3- Transplanting

4.4.1.5. Rainfall (RF) and Rainy days (RD)

The rainfall received showed a slight increasing trend towards June 1st planting and then reduced steadily with delay in date of planting. The maximum amount was received for June 1st date of planting in all the three planting methods (2431.2 mm) and lowest rainfall of 1417.2 mm was observed for July 15th planting in broadcasting and dibbling.

Rainy days which ranged from 44 to 72 followed an increasing trend towards the June 1st date of planting and then reduced gradually to 44. Highest rainy days observed in June 1st and lowest in July 15th date of planting.

4.4.1.6. Pan evaporation (Epan)

The evaporation followed comparatively steady trend towards delayed date of planting with continuous evaporation rate of 2.7 mm for the last dates of planting. The value ranged from 2.3 mm to 2.7 mm in which maximum pan evaporation was observed for July 1st and July 15th planting whereas less evaporation was observed for June 1st planting.

4.4.2. Weather conditions prevailed from sowing to flag leaf stage under different planting dates and methods

4.4.2.1. Temperature (Maximum temperature, Minimum Temperature, Mean Temperature and Temperature Range)

The highest maximum temperature during the sowing to flag leaf stage was 30.7^{o}C for transplanting and lowest maximum temperature was 29.7^{o}C for broadcasting and dibbling in June 1st planting. The highest minimum temperature was experienced by broadcasting and dibbling during May 15th planting (22.8^{o}C) and lowest minimum temperature was experienced by broadcasting and dibbling (22.4^{0}C) in June 15th and July 1st planting. For all the planting methods and dates of planting from sowing to panicle initiation stage, maximum temperature varied from 29.4 to 30.5^{o}C whereas minimum temperature varied between 22.3^{o}C to 22.8^{o}C. The mean temperature ranged from 26.2^{o}C to 26.6^{o}C, which was lowest during June 15th and highest during July 15th planting for the transplanting method. The temperature range increased from May 15th to July 15th with a slight decrease in between during June 1st planting. The maximum temperature range of 8.2^{o}C has been seen in July 1st planting in transplanting and July 15th planting for all the planting methods.

4.4.2.2. Relative Humidity (RH I, RH II and RH mean) and Vapour Pressure Deficit (VPD I and VPD II)

Forenoon relative humidity followed a continuous decreasing trend with delay in date of planting for all the planting methods. The maximum relative humidity was found to be 95% for June 1st planting in broadcasting and dibbling and minimum of 94% was during July 15th planting in broadcasting and dibbling. The afternoon relative humidity followed a steady decreasing rate with delay in date of planting towards the July 15th planting. The maximum afternoon relative humidity was observed as 80% for June 1st date of planting in transplanting method and minimum afternoon relative humidity was 72% for July 15th planting in broadcasting and dibbling. The mean relative humidity ranged from 83% to 87% with maximum observed for May 15th planting in transplanting and minimum observed for July 15th planting in both broadcasting and dibbling

The forenoon vapour pressure followed a continuous decreasing trend with delay in date of planting for all the planting methods. Forenoon vapour pressure deficit ranged from 22.2 mm to 22.7 mm of Hg and 22.0 to 23.2 for afternoon vapour pressure deficit. The maximum forenoon vapour pressure deficit was observed for all the planting methods during May 15th planting and the minimum was observed for June 15th and July 1st for all the methods. Both forenoon and afternoon vapour pressure deficit was showing a general decreasing tendency towards delayed planting date.

4.4.2.3. Wind Speed (WS)

During transplanting to flag leaf, the wind speed ranged from 1.6 to 1.8 kmhr^{-1}. The wind speed showed an increasing trend with delay in date of planting whereas maximum wind speed was observed for transplanting in July 15th and less wind speed was seen in May 15th planting for all the methods.

Table 4.4. Weather experienced by finger millet from sowing to flag leaf stage under different planting dates and methods

Weather variable	**Date of sowing**														
	May 15th			June 1st			June 15th			July 1st			July 15th		
	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
Tmax (^{0}C)	30.0	30.0	29.9	29.7	29.7	29.8	29.7	29.7	29.9	30.3	30.3	30.6	30.6	30.6	30.7
Tmin (^{0}C)	22.8	22.8	22.7	22.6	22.6	22.6	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.5
Tmean (^{0}C)	26.4	26.4	26.3	26.2	26.2	26.2	26.1	26.1	26.2	26.4	26.4	26.5	26.5	26.5	26.6
TR (^{0}C)	7.2	7.2	7.2	7.1	7.1	7.2	7.3	7.3	7.5	7.9	7.9	8.2	8.2	8.2	8.2
VPD I (mm Hg)	22.7	22.7	22.7	22.4	22.4	22.4	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.3
VPD II (mm Hg)	23.2	23.2	23.1	22.5	22.5	22.4	22.2	22.2	22	22.1	22.1	22.2	22.1	22.1	22.2
RH I (%)	95	95	95.1	95.3	95.3	95.1	95.1	95.1	94.9	94.4	94.4	94	93.7	93.7	93.9
RH II (%)	79.3	79.3	79.7	78.3	78.3	77.4	76.4	76.4	75.1	73	73	72.5	71.9	71.9	72
RH mean (%)	87.2	87.2	87.4	86.8	86.8	86.3	85.8	85.8	85	83.7	83.7	83.25	82.8	82.8	82.95
RF (mm)	2313.1	2313.1	2766.7	2431.7	2431.7	2431.7	1975.3	1975.3	1976.2	1752.2	1752.2	1935.3	1548.2	1548.2	1615.2
RD	65	65	69	72	72	72	63	63	63	51	51	57	49	49	51
BSS (hrs.)	2	2	1.9	2.6	2.6	2.9	2.9	2.9	3.2	3.7	3.7	3.8	3.8	3.8	3.9
Epan (mm)	2.4	2.4	2.4	2.5	2.5	2.5	2.6	2.6	2.6	2.7	2.7	2.75	2.7	2.7	2.7
WS (km hr^{-1})	1.6	1.6	1.6	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.8

P1-Broadcasting P2- Dibbling P3- Transplanting

4.4.2.4. Bright Sunshine Hours (BSS)

Bright sunshine hours varied between 1.9 to 3.9 hrs. during the experimental period. Bright sunshine hours showed an increasing trend with delay in date of planting. The duration was maximum for July 15th planting and less in June 1st planting in in transplanting methods.

4.4.2.5. Rainfall (RF) and Rainy days (RD)

The rainfall received showed a slight increasing trend towards June 1st planting and then reduced steadily with delay in date of planting. The maximum amount was received for May 15th date of planting in transplanting method (2766.7 mm) and lowest rainfall of 1548.2 mm was observed for July 15th planting in broadcasting and dibbling.

Rainy days which ranged from 49 to 72 followed an increasing trend till the June 1st planting and then reduced gradually to 49. Highest rainy days observed in June 1st in all planting methods and lowest in July 15th date of planting for both broadcasting and dibbling.

4.4.2.6. Pan evaporation (Epan)

The evaporation followed a steady increasing trend with delay in date of planting. The value ranges from 2.4 mm to 2.8 mm in which maximum pan evaporation was observed for July 1st date in transplanting method and less evaporation was observed for May 15th date for all methods of planting.

4.4.3. Weather conditions prevailed from sowing to 50% flowering stage under different planting dates and methods

4.4.3.1. Temperature (Maximum temperature, Minimum Temperature, Mean Temperature and Temperature Range)

The highest maximum temperature during the sowing to 50% flowering stage was 30.9^{o}C for transplanting and 30.7^{o}C for both broadcasting and dibbling during July 15th planting and lowest maximum temperature was 29.8^{o}C in June 1st date for broadcasting and dibbling. The highest minimum temperature was experienced by the forenoon and afternoon vapour pressure deficit was showing a general decreasing tendency towards delayed planting date.

4.4.3.3. Wind Speed (WS)

During transplanting to 50% flowering, the wind speed ranged from 1.6 to 1.8 $kmhr^{-1}$. The wind speed showed an increasing trend with delay in date of planting where maximum wind speed was observed in July 1st and July 15th for all the methods and less wind speed was seen in May 15th planting for all the planting methods.

4.4.3.4. Bright Sunshine Hours (BSS)

Bright sunshine hours varied between 2.1 to 4.1 hrs during the experimental period. Bright sunshine hours showed an increasing trend with delay in date of planting. The duration was maximum for July 15th planting in all the planting methods and less in May 15th planting in all the methods.

4.4.3.5. Rainfall (RF) and Rainy days (RD)

The rainfall received showed a slight increasing trend towards June 1st planting and then reduced steadily with delay in date of planting. The maximum amount was received for May 15th date of planting in transplanting methods (2811.7 mm) and lowest rainfall of 1615.2 mm was observed for July 15th planting in broadcasting and dibbling.

Rainy days which ranged from 51 to 79 follows a steady decreasing trend with delay in date of planting. Highest rainy days was observed in May 15th and lowest in July 15th date of planting.

4.4.3.6. Pan evaporation (Epan)

The evaporation followed a steady increasing trend with delay in date of planting. The value ranged from 2.4 mm to 2.7 mm in which maximum pan evaporation was observed for July 15th planting in transplanting method whereas less evaporation was observed for May 15th planting for all the methods.

Table 4.5. Weather experienced by finger millet from sowing to 50% flowering stage under different planting dates and methods

Weather variable	**Date of sowing**														
	May 15th			June 1st			June 15th			July 1st			July 15th		
	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
Tmax (^{0}C)	29.9	29.9	29.9	29.8	29.8	30	29.9	29.9	30.1	30.5	30.5	30.7	30.7	30.7	30.9
Tmin (^{0}C)	22.7	22.7	22.6	22.6	22.6	22.6	22.4	22.4	22.4	22.4	22.4	22.5	22.5	22.5	22.5
Tmean (^{0}C)	26.3	26.3	26.3	26.2	26.2	26.3	26.2	26.2	26.3	26.5	26.5	26.6	26.6	26.6	26.7
TR (^{0}C)	7.2	7.2	7.3	7.2	7.2	7.4	7.5	7.5	7.7	8.1	8.1	8.2	8.2	8.2	8.4
VPD I (mm Hg)	22.6	22.6	22.6	22.4	22.4	22.4	22.2	22.2	22.2	22.2	22.2	22.3	22.3	22.3	22.2
VPD II (mm Hg)	23.0	23.0	23.0	22.3	22.3	22.3	22.0	22.0	22.2	22.2	22.2	22.3	22.2	22.2	22.1
RH I (%)	95.1	95.1	95.1	95.0	95.0	94.8	94.8	94.8	94.6	94.0	94.0	94.1	93.9	93.9	93.9
RH II (%)	79.0	79.0	78.9	76.7	76.7	75.6	75.0	75.0	74.2	72.5	72.5	72.3	72.0	72.0	70.9
RH mean (%)	87.1	87.1	87	85.9	85.9	85.2	84.9	84.9	84.4	83.3	83.3	83.2	82.95	83.0	82.4
RF (mm)	2779.6	2779.6	2811.7	2432.6	2432.6	2435.3	1977.7	1977.7	2035.9	1883.2	1883.2	1982	1615.2	1615.2	1800.2
RD	76	76	79	72	72	72	63	63	65	56	56	59	51	51	57
BSS (hrs.)	2.1	2.1	2.1	2.9	2.9	3.2	3.3	3.3	3.4	3.8	3.8	3.9	3.9	3.9	4.1
Epan (mm)	2.4	2.4	2.4	2.5	2.5	2.6	2.6	2.6	2.6	2.7	2.7	2.73	2.7	2.7	2.7
WS (km hr^{-1})	1.6	1.6	1.6	1.7	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.8	1.8	1.8

P1-Broadcasting P2- Dibbling P3- Transplanting

4.4.4. Weather conditions prevailed from sowing to milk stage under different planting dates and methods

4.4.4.1. Temperature (Maximum temperature, Minimum Temperature, Mean Temperature and Temperature Range)

The highest maximum temperature during the sowing to milk stage was 31.1^{0}C for transplanting and 30.8^{0}C for both broadcasting and dibbling during July 15th planting and lowest maximum temperature was 30^{0}C in May 15th date for all the methods. The highest minimum temperature was experienced by all the planting methods during May 15th planting (22.7^{o}C) and lowest minimum temperature was experienced in June 15th planting for all methods. The maximum temperature ranges from 30 to 31.1^{o}C for all the planting methods and dates of planting from sowing to milk stage whereas, minimum temperature varied between 22.4^{o}C to 22.7^{o}C. The mean temperature ranged from 26.3^{o}C to 26.9^{o}C, which was lowest during June 15th planting for all the planting methods and highest during July 15th planting for transplanting. The temperature range increased from May 15th to July 15th. The maximum temperature range of 8.5^{o}C has been seen in July 15th planting for transplanting.

4.4.4.2. Relative Humidity (RH I, RH II and RH mean) and Vapour Pressure Deficit (VPD I and VPD II)

Forenoon relative humidity followed a continuous decreasing trend for all the planting methods. The maximum relative humidity was found to be 95% for May 15th planting in both broadcasting and dibbling and minimum of 92% was during July 15th planting in transplanting methods. The afternoon relative humidity was also showing a steady decreasing trend with delay in date of planting towards the July 15th planting. The maximum afternoon relative humidity was observed as 77% for May 15th planting in broadcasting and dibbling and minimum afternoon relative humidity was 69% for July 15th planting in transplanting. The mean relative humidity ranged from 81% to 86% with maximum observed for May 15th planting in both broadcasting and dibbling and minimum observed for July 15th planting in transplanting.

The forenoon vapour pressure deficit ranged from 22 to 22.6 and 21.8 to 22.8 mm of Hg for afternoon vapour pressure deficit. The maximum forenoon vapour pressure deficit was observed for all the planting methods during May 15th planting and the minimum was observed for June 15th in transplanting methods. The maximum afternoon vapour pressure deficit was observed for all the planting methods during May 15th planting and the minimum was observed for July 15th for transplanting methods. Both the forenoon and afternoon vapour pressure deficit was showing a general decreasing tendency towards delayed planting date.

4.4.4.3. Wind Speed (WS)

During transplanting to milk stage, the wind speed ranged from 1.7 to 1.9 kmhr^{-1}. The wind speed showed an increasing trend with delay in date of planting where maximum wind speed was observed in July 15th for transplanting method and less wind speed was seen in May 15th and June 1st for all the planting methods and June 15th planting for both broadcasting and dibbling.

4.4.4.4. Bright Sunshine Hours (BSS)

Bright sunshine hours varied between 2.4 to 4.3 hrs during the experimental period. Bright sunshine hours showed an increasing trend with delay in date of planting. The duration was maximum for July 15th planting in transplanting methods and less in May 15th planting for both broadcasting and dibbling methods.

4.4.4.5. Rainfall (RF) and Rainy days (RD)

The rainfall received showed a continuous decreasing trend with delay in date of planting and it ranged from 1800.2 to 2812.2 mm. The maximum amount was received for May 15th date of planting in all the methods (2812.2 mm) and lowest rainfall of 1800.2 mm was observed for July 15th planting for all the methods.

Rainy days which ranged from 57 to 81 follows a steady decreasing trend with delay in date of planting. Highest rainy days observed in May 15th and lowest in July 15th planting for all the methods.

Table 4.6. Weather conditions experienced by the crop from sowing to milk stage under different planting dates and methods

Weather variable	**Date of sowing**														
	May 15th			June 1st			June 15th			July 1st			July 15th		
	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
Tmax (^{0}C)	30.0	30.0	30.0	30.1	30.1	30.2	30.2	30.2	30.3	30.7	30.7	30.8	30.8	30.8	31.1
Tmin (^{0}C)	22.7	22.7	22.7	22.6	22.6	22.5	22.4	22.4	22.4	22.5	22.5	22.5	22.5	22.5	22.6
Tmean (^{0}C)	26.4	26.4	26.4	26.4	26.4	26.4	26.3	26.3	26.35	26.6	26.6	26.7	26.7	26.7	26.9
TR (^{0}C)	7.3	7.3	7.3	7.5	7.5	7.7	7.8	7.8	7.9	8.2	8.2	8.3	8.3	8.3	8.5
VPD I (mm Hg)	22.6	22.6	22.6	22.4	22.4	22.4	22.2	22.2	22.2	22.3	22.3	22.3	22.3	22.3	22.0
VPD II (mm Hg)	22.8	22.8	22.8	22.3	22.3	22.4	22.2	22.2	22.3	22.3	22.3	22.2	22.1	22.1	21.8
RH I (%)	95.0	95.0	94.9	94.7	94.7	94.6	94.6	94.6	94.2	94.1	94.1	94.1	94.0	94.0	92.8
RH II (%)	77.9	77.9	77.7	75.5	75.5	75.1	74	74	73.8	72.3	72.3	71.7	71.4	71.4	69.3
RH mean (%)	86.45	86.45	86.3	85.1	85.1	84.85	84.3	84.3	84.3	83.2	83.2	82.9	82.7	82.7	81.05
RF (mm)	2812.2	2812.2	2812.2	2435.3	2435.3	2536.5	2035.9	2035.9	2186.9	1950.2	1950.2	2135.2	1800.2	1800.2	1800.2
RD	81	81	81	72	72	76	65	65	70	58	58	64	57	57	57
BSS (hrs.)	2.4	2.4	2.5	3.2	3.2	3.3	3.4	3.4	3.5	3.9	3.9	4.0	4.0	4.0	4.3
Epan (mm)	2.5	2.5	2.5	2.6	2.6	2.6	2.6	2.6	2.7	2.7	2.7	2.76	2.7	2.7	2.8
WS (km hr^{-1})	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.8	1.8	1.8	1.9

P1-Broadcasting P2- Dibbling P3- Transplanting

4.4.4.6. Pan evaporation (Epan)

The evaporation followed a steady increasing trend with delay in date of planting. The value ranged from 2.5 mm to 2.8 mm in which maximum pan evaporation was observed for July 15th planting in transplanting method whereas less evaporation was observed for May 15th planting for all the methods.

4.4.5. Weather conditions prevailed from sowing to dough stage under different planting dates and methods

4.4.5.1. Temperature (Maximum temperature, Minimum Temperature, Mean Temperature and Temperature Range)

The highest maximum temperature during the sowing to milk stage was 31.1^{o}C for transplanting and 30.8 for both broadcasting and dibbling during July 15th planting and lowest maximum temperature was 30^{o}C in May 15th planting for all the methods. The highest minimum temperature was experienced by all the planting methods during May 15th planting (22.7^{o}C) and lowest minimum temperature was experienced in June 15th planting for all methods. The maximum temperature ranges from 30 to 31.1^{o}C for all the planting methods and dates of planting from sowing to milk stage whereas, minimum temperature varied between 22.4^{o}C to 22.7^{o}C. The mean temperature ranged from 26.3^{o}C to 26.9^{o}C, which was lowest during June 15th planting for all the planting methods and highest during July 15th planting for transplanting. The temperature range increased from May 15th to July 15th. The maximum temperature range of 8.5^{o}C has been seen in July 15th for transplanting.

4.4.5.2. Relative Humidity (RH I, RH II and RH mean) and Vapour Pressure Deficit (VPD I and VPD II)

Forenoon relative humidity followed a continuous decreasing trend for all the planting methods. The maximum relative humidity was found to be 95% for May 15th planting in both broadcasting and dibbling and minimum of 92 % was during July 15th planting in transplanting methods. The afternoon relative humidity was also showing a steady decreasing trend with delay in date of planting towards the July 15th planting.

broadcasting and dibbling during May 15th planting (22.7^{o}C) and lowest minimum temperature was experienced in June 15th planting for all methods and in July 1st for broadcasting and dibbling (22.4^{0}C). For all the planting methods and dates of planting from sowing to 50% flowering, maximum temperature varied from 29.8 to 30.9^{o}C whereas minimum temperature varied between 22.4^{o}C to 22.7^{o}C. The mean temperature ranged from 26.2^{o}C to 26.7^{o}C, which was lowest during June 15th and highest during July 15th planting. The temperature range increased from May 15th to July 15th with a slight decrease during June 1st planting. The maximum temperature range of 8.4^{o}C has been seen in July 15th planting for transplanting.

4.4.3.2. Relative Humidity (RH I, RH II and RH mean) and Vapour Pressure Deficit (VPD I and VPD II)

Forenoon relative humidity followed a continuous decreasing trend for all the planting methods. The maximum relative humidity was found to be 95 % for May 15th planting and minimum of 94% was during July 15th planting in all methods. The afternoon relative humidity was showing a decreasing trend with delay in date of planting towards the July 15th planting. The maximum afternoon relative humidity was observed as 79% for May 15th date of planting in broadcasting and dibbling and minimum afternoon relative humidity was 71% for July 15th date in transplanting. The mean relative humidity ranged from 82% to 87% with maximum observed for May 15th planting in both broadcasting and dibbling and minimum observed for July 15th planting in transplanting.

The forenoon vapour pressure deficit ranged from 22.2 to 22.6 mm of Hg and 22 to 23 mm of Hg for afternoon vapour pressure deficit. The maximum forenoon vapour pressure deficit was observed for all the planting methods during May 15th planting and the minimum was observed for June 15th in all methods and July 1st in both broadcasting and dibbling methods. The maximum afternoon vapour pressure deficit was observed for all the planting methods during May 15th planting and the minimum was observed for June 15th both broadcasting and dibbling methods. Both

The maximum afternoon relative humidity was observed as 77% for May 15th date of planting in broadcasting and dibbling and minimum afternoon relative humidity was 69% for July 15th planting in transplanting. The mean relative humidity ranged from 81% to 86% with maximum observed for May 15th planting in both broadcasting and dibbling and minimum observed for July 15th planting in transplanting

The forenoon vapour pressure deficit ranged from 22 to 22.6 mm of Hg and 21.8 to 22.8 for afternoon vapour pressure deficit. The maximum value was observed for all the planting methods during May 15th planting and the minimum was observed for June 15th in transplanting methods. The maximum afternoon vapour pressure deficit was observed for all the planting methods during May 15th planting and the minimum was observed for July 15th for transplanting methods. Both the forenoon and afternoon vapour pressure deficit was showing a general decreasing tendency towards delayed planting date.

4.4.5.3. Wind Speed (WS)

During transplanting to milk stage, the wind speed ranged from 1.7 to 1.9 kmhr^{-1}. The wind speed showed an increasing trend with delay in date of planting where maximum wind speed was observed in July 15th for transplanting method and less wind speed was seen in May 15th and June 1st for all the planting methods and June 15th planting for the transplanting method.

4.4.5.4. Bright Sunshine Hours (BSS)

Bright sunshine hours varied between 2.4 to 4.3 hrs during the experimental period. Bright sunshine hours showed an increasing trend with delay in date of planting. The duration was maximum for July 15th planting in transplanting methods and less in May 15th planting for both broadcasting and dibbling methods.

4.4.5.5. Rainfall (RF) and Rainy days (RD)

The rainfall received showed a continuous decreasing trend with delay in date of planting and it ranges from 1800.2 to 2812.2 mm. The maximum amount was

Table 4.7. Weather experienced by finger millet from sowing to dough stage under different planting dates and methods

Weather variable	**Date of sowing**														
	May 15th			June 1st			June 5th			July 1st			July 15th		
	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
Tmax (^{0}C)	30.1	30.1	30.1	30.2	30.2	30.3	30.3	30.3	30.5	30.7	30.7	31	31	31	31.2
Tmin (^{0}C)	22.6	22.6	22.6	22.5	22.5	22.6	22.4	22.4	22.5	22.5	22.5	22.6	22.5	22.5	22.6
Tmean (^{0}C)	26.4	26.4	26.4	26.4	26.4	26.5	26.4	26.4	26.5	26.6	26.6	26.8	26.6	26.6	26.9
TR (^{0}C)	7.5	7.5	7.5	7.7	7.7	7.7	7.9	7.9	8.0	8.2	8.2	8.4	8.5	8.5	8.6
VPD I (mm Hg)	22.5	22.5	22.5	22.4	22.4	22.4	22.2	22.2	22.3	22.3	22.3	22.1	22.0	22.0	21.9
VPD II (mm Hg)	22.6	22.6	22.6	22.4	22.4	22.5	22.2	22.2	22.3	22.3	22.3	21.9	21.8	21.8	21.6
RH I (%)	94.7	94.7	94.7	94.5	94.5	94.3	94.2	94.2	94.3	94.2	94.2	93.1	93.0	93.0	92.1
RH II (%)	76.7	76.7	76.5	75.0	75.0	74.9	73.8	73.8	73.7	72.2	72.2	70.1	69.9	69.9	68.3
RH mean (%)	85.7	85.7	85.6	84.75	84.75	84.6	84.0	84.0	84.0	83.2	83.2	81.6	81.45	81.45	80.2
RF (mm)	2812.7	2812.7	2812.7	2539	2539	2643.3	2134.8	2134.8	2201.8	2098.2	2098.2	2135.2	1800.2	1800.2	1801.2
RD	81	81	81	77	77	79	69	69	71	63	63	64	57	57	57
BSS (hrs.)	2.8	2.8	2.9	3.3	3.3	3.3	3.5	3.5	3.6	3.9	3.9	4.2	4.2	4.2	4.4
Epan (mm)	2.6	2.6	2.6	2.6	2.6	2.6	2.7	2.7	2.7	2.7	2.7	2.8	2.8	2.8	2.8
WS (km hr^{-1})	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.7	1.8	1.8	1.9	1.8	1.8	2

P1-Broadcasting P2- Dibbling P3- Transplanting

received for May 15th date of planting in all the methods (2812.2 mm) and lowest rainfall of 1800.2 mm was observed for July 15th planting for all the methods.

Rainy days which ranged from 57 to 81 days followed a steady decreasing trend with delay in date of planting. Highest rainy days was observed in May 15th and lowest in July 15th date of planting for all the planting methods.

4.4.5.6. Pan evaporation (Epan)

The evaporation followed a steady increasing trend with delay in date of planting. The value ranged from 2.5 mm to 2.8 mm in which maximum pan evaporation was observed for July 15th planting in transplanting method whereas less evaporation was observed for May 15th planting for all the methods.

4.4.6. Weather conditions prevailed from sowing to physiological maturity under different planting dates and methods

4.4.6.1. Temperature (Maximum temperature, Minimum Temperature, Mean Temperature and Temperature Range)

The highest maximum temperature during the sowing to physiological maturity was 31.3^{o}C for transplanting and 31.1^{o}C for both broadcasting and dibbling methods during July 15th planting and lowest maximum temperature was 30.1^{o}C in May 15th date for both broadcasting and dibbling methods. The highest minimum temperature was experienced by transplanting method during June 1st planting (22.7^{o}C). The lowest minimum temperature was experienced in July 1st planting for both broadcasting and dibbling methods. The maximum temperature ranges from 30.1 to 31.3^{o}C for all the planting methods and dates of planting from sowing to physiological maturity whereas, minimum temperature varied between 22.5^{o}C to 22.7^{o}C. The mean temperature ranged from 26.4^{o}C to 27.0^{o}C, which was lowest during May 15th plating for both broadcasting and transplanting and highest during July 15th planting for transplanting. The temperature range increased from 7.5 in May 15th to 8.7 in July 15th. The maximum temperature range of 8.7^{o}C has been seen in July 15th planting for transplanting.

Table 4.8. Weather experienced by finger millet from sowing to physiological maturity under different planting dates and methods

Weather variable	**Date of sowing**														
	May 15th			June 1st			June 5th			July 1st			July 15th		
	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
Tmax (^{0}C)	30.1	30.1	30.2	30.4	30.4	30.4	30.5	30.5	30.5	30.9	30.9	31.1	31.1	31.1	31.3
Tmin (^{0}C)	22.6	22.6	22.6	22.6	22.6	22.7	22.6	22.6	22.6	22.5	22.5	22.6	22.6	22.6	22.6
Tmean (^{0}C)	26.4	26.4	26.4	26.5	26.5	26.6	26.6	26.6	26.6	26.7	26.7	26.9	26.9	26.9	27.0
TR (^{0}C)	7.5	7.5	7.6	7.8	7.8	7.7	7.9	7.9	7.9	8.4	8.4	8.5	8.5	8.5	8.7
VPD I (mm Hg)	22.5	22.5	22.5	22.4	22.4	22.4	22.3	22.3	22.3	22.1	22.1	22	22	22	21.9
VPD II (mm Hg)	22.6	22.6	22.5	22.5	22.5	22.5	22.3	22.3	22.3	21.9	21.9	21.7	21.7	21.7	21.4
RH I (%)	94.6	94.6	94.5	94.3	94.3	94.4	94.3	94.3	94.4	93.3	93.3	92.4	92.5	92.5	91.9
RH II (%)	76.1	76.1	75.6	74.8	74.8	74.8	73.5	73.5	73.4	70.3	70.3	69.1	68.9	68.9	67.6
RH mean (%)	85.4	85.4	85.1	84.6	84.6	84.6	83.9	83.9	83.9	81.8	81.8	80.8	80.7	80.7	79.8
RF (mm)	2813	2813	2813.6	2643.6	2643.6	2658.2	2233.6	2233.6	2349.8	2135.2	2135.2	2136.2	1801.2	1801.2	1801.2
RD	81	81	81	79	79	80	72	72	76	64	64	64	57	57	57
BSS (hrs.)	3.0	3.0	3.0	3.4	3.4	3.4	3.6	3.6	3.6	4.2	4.2	4.3	4.4	4.4	4.6
Epan (mm)	2.6	2.6	2.6	2.6	2.6	2.6	2.7	2.7	2.7	2.8	2.8	2.9	2.8	2.8	2.9
WS (km hr^{-1})	1.7	1.7	1.7	1.8	1.8	1.7	1.7	1.7	1.7	1.8	1.8	2.0	2.0	2.0	2.0

P1-Broadcasting P2- Dibbling P3- Transplanting

4.4.6.2. Relative Humidity (RH I, RH II and RH mean) and Vapour Pressure Deficit (VPD I and VPD II)

Forenoon relative humidity followed a continuous decreasing trend for all the planting methods. The maximum relative humidity was found to be 94% for May 15th planting in both broadcasting and transplanting methods and minimum of 91 % was during July 15th planting in transplanting method. The afternoon relative humidity was also showing a steady decreasing trend with delay in date of planting towards the July 15th planting. The maximum afternoon relative humidity was observed as 76% for May 15th planting in broadcasting and dibbling and minimum afternoon relative humidity was 67% for July 15th planting in transplanting. The mean relative humidity ranged from 79% to 85% with maximum observed for May 15th planting in both broadcasting and dibbling and minimum observed for July 15th planting in transplanting

The forenoon vapour pressure deficit ranged from 21.9 to 22.5 mm of Hg and 21.4 to 22.6 mm of Hg for afternoon vapour pressure deficit. The maximum forenoon vapour pressure deficit was observed for all the planting methods during May 15th planting and the minimum was observed for June 15th in transplanting methods. In case of afternoon vapour pressure deficits, maximum forenoon vapour pressure deficit was observed for both broadcasting and transplanting methods during May 15th planting and the minimum was observed in July 15th for transplanting. Both the forenoon and afternoon vapour pressure deficit was showing a general decreasing tendency towards delayed planting date.

4.4.6.3. Wind Speed (WS)

During sowing to physiological maturity, the wind speed ranged from 1.7 to 2 kmhr^{-1}. The wind speed showed an increasing trend with delay in date of planting where maximum wind speed was observed in July 15th for all the methods and also in July 1st planting for transplanting method and less wind speed was seen in May 15th and June 15th for all the methods and in June 1st for transplanting method.

4.4.6.4. Bright Sunshine Hours (BSS)

Bright sunshine hours varied between 3 to 4.6 hrs during the experimental period. Bright sunshine hours showed an increasing trend with delay in date of planting. The duration was maximum for July 15th planting in transplanting methods and less in May 15th planting for all the methods.

4.4.6.5. Rainfall (RF) and Rainy days (RD)

The rainfall received showed a continuous decreasing trend with delay in date of planting and it ranges from 1801.2 to 2813.6 mm. The maximum amount was received for May 15th planting in transplanting method (2813.6 mm) and lowest rainfall of 1801.2 mm was observed for July 15th planting for all the methods.

Rainy days which ranged from 57 to 81 days followed a steady decreasing trend with delay in date of planting. Highest rainy days observed in May 15th and lowest in July 15th date of planting for all the planting methods.

4.4.6.6. Pan evaporation (Epan)

The evaporation followed a steady increasing trend with delay in date of planting. The value ranged from 2.6 to 2.9 mm in which maximum pan evaporation was observed for July 15th planting in transplanting method, whereas less evaporation was observed for May 15th and June 1st planting for all the method.

Growing Degree Days

Growing Degree Days showed different trend at each phenophases in case of planting methods. During the phenophase from sowing to panicle initiation, transplanting showed the highest accumulation of GDD compared to other two methods for all dates of planting. In case of second phenophase, accumulation of GDD was higher for broadcasting and dibbling in May 15th and June 1st planting, while transplanting showed higher GDD for the remaining dates of planting. The remaining phenophases indicated a variable trend in the GDD accumulation. June 1st date of planting showed higher GDD compared to other dates of planting for the first two phenophases. In case of third and fourth phenophases, May 15th planting showed the higher GDD accumulation. Growing Degree Days experienced by each phenophases of finger millet under different planting dates and methods is given in the Table 4.9.

Helio Thermal Unit (HTU)

Accumulation of HTU was higher for transplanting compared to other two methods from sowing to panicle initiation and flag leaf to 50 % flowering stage in all dates of planting. Varied values of HTU accumulation were observed in the remaining phenophase for all the dates of planting. It showed an increasing trend with delay in date of planting for the first two phenophases. Helio Thermal Units (HTU) experienced by each phenophases of finger millet under different planting dates and methods are given in the Table 4.10.

Photo Thermal Unit (PTU)

PTU accumulation was found higher for transplanting method from sowing to panicle initiation in all the dates of planting, while coming to the second phenophase, broadcasting and dibbling showed higher PTU for the first and second date of planting. Varied trend were observed among the planting methods for the remaining phenophases. June 1st date of planting showed higher PTU compared to other dates of planting for the first two and fifth phenophases. In case of third and fourth phenophases, May 15th planting showed the higher PTU accumulation. Photo Thermal Units (PTU) experienced by each phenophases of finger millet under different planting dates and methods is given in the Table 4.11.

Table 4.9. Growing Degree Days experienced by each phenophases of finger millet under different planting dates and methods

	Ph1			Ph2			Ph3			Ph4			Ph5			Ph6		
	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
May 15th	1369.7	1369.7	1432.7	153.9	153.9	146.5	169.5	169.5	161.2	182.5	182.5	151.6	118.3	118.3	118.6	86.0	86.0	121.4
June 1st	1476.8	1476.8	1578.6	185.5	185.5	170.3	155.5	155.5	193.1	142.7	142.7	123.6	122.3	122.3	91.2	128.3	128.3	128.4
June 15th	1340.6	1340.6	1458.9	152.3	152.3	173.4	156.8	156.8	143.6	144.4	144.4	143.0	107.2	107.2	128.4	179.5	179.5	104.8
July 1st	1359.8	1359.8	1486.5	144.8	144.8	177.9	142.4	142.4	162.1	127.7	127.7	106.1	123.0	123.0	181.7	161.7	161.7	110.1
July 15th	1256.9	1256.9	1379.3	160.5	160.5	183.9	145.9	145.9	158.1	121.9	121.9	163.3	108.6	108.6	110.1	127.9	127.9	90.5

P1-Broadcasting P2- Dibbling P3- Transplanting

Ph1 – sowing to panicle initiation
Ph2- panicle initiation to flag leaf
Ph3- flag leaf to 50% flowering
Ph4 – 50% flowering to milk stage
Ph5 – Milk stage to dough stage
Ph6 – Dough stage to physiological maturity

Table 4.10.Helio Thermal Units (HTU) experienced by each phenophases of finger millet under different planting dates and methods

	Ph1			Ph2			Ph3			Ph4			Ph5			Ph6		
	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
May 15th	3146.9	3146.9	3205.2	69.0	69.0	10.7	653.9	653.9	750.3	922.8	922.8	951.0	1116.7	1116.7	1131.1	553.0	553.0	754.5
June 1st	3032.7	3032.7	3707.1	1486.3	1486.3	1552.5	1053.1	1053.1	1279.9	1065.0	1065.0	588.3	499.3	499.3	371.8	673.2	673.2	653.5
June 15th	3251.4	3251.4	4368.1	1383.8	1383.8	1225.5	1105.1	1105.1	778.1	766.9	766.9	672.2	479.2	479.2	653.5	886.0	886.0	543.6
July 1st	4971.9	4971.9	5837.0	901.3	901.3	759.0	665.2	665.2	828.4	656.6	656.6	562.8	598.1	598.1	1322.7	1260.3	1260.3	761.4
July 15th	4977.8	4977.8	5495.1	701.4	701.4	895.2	711.0	711.0	910.3	598.2	598.2	1150.2	931.0	931.0	761.4	790.3	790.3	664.4

P1-Broadcasting P2- Dibbling P3- Transplanting

Ph1 – sowing to panicle initiation
Ph2- panicle initiation to flag leaf
Ph3- flag leaf to 50% flowering
Ph4 – 50% flowering to milk stage
Ph5 – Milk stage to dough stage
Ph6 – Dough stage to physiological maturity

Table 4.11. Photo Thermal Units (PTU) experienced by each phenophases of finger millet under different planting dates and methods

	Ph1			Ph2			Ph3			Ph4			Ph5			Ph6		
	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
May 15th	16963.0	16963.0	17736.0	1887.7	1887.7	1796.9	2079.8	2079.8	1977.3	2223.4	2223.4	1842.4	1433.2	1433.2	1437.4	1041.7	1041.7	1470.8
June 1st	18253.4	18253.4	19487.8	2247.7	2247.7	2063.4	1884.1	1884.1	2340.4	1729.5	1729.5	1465.8	1441.4	1441.4	1062.5	1494.7	1494.7	1495.9
June 15th	16531.8	16531.8	17965.0	1845.9	1845.9	2101.6	1900.4	1900.4	1732.7	1733.6	1733.6	1665.4	1248.9	1248.9	1495.9	2091.2	2091.2	1220.9
July 1st	16688.2	16688.2	18223.8	1755.0	1755.0	2081.9	1658.4	1658.4	1887.9	1487.7	1487.7	1236.1	1432.4	1432.4	2103.0	1883.2	1883.2	1255.7
July 15th	15378.5	15378.5	16821.4	1877.8	1877.8	2141.9	1699.2	1699.2	1842.7	1419.6	1419.6	1889.3	1264.6	1264.6	1255.7	1490.0	1490.0	1032.6

P1-Broadcasting P2- Dibbling P3- Transplanting

Ph1 – sowing to panicle initiation
Ph2- panicle initiation to flag leaf
Ph3- flag leaf to 50% flowering
Ph4 – 50% flowering to milk stage
Ph5 – Milk stage to dough stage
Ph6 – Dough stage to physiological maturity

Soil moisture

The observation on soil moisture is done by taking the soil samples from both the 5cm and 15cm from the observation plot. The data were analyzed to obtain the effect of date of planting and planting method on the soil moisture values. The effect of dates of planting and planting method on soil moisture were analyzed and provided in the Table 4.12.

Soil moisture on different dates of planting

The result on soil moisture at different dates of planting implies the effect of dates and planting method on the soil moisture. The soil moisture followed different trends in case of different planting methods and dates. In case of broadcasting method, the soil moisture trend followed a zig zag pattern in which May 15th, June 15th and July 15th showed the highest value at 5cm depth, while at 15 cm depth May 15th showed the higher value and there after it gets reduced followed by a slight increase towards the last date of planting. But coming to the dibbling method, the soil moisture followed a decreasing trend in both the cases except a rise in June 15th planting for the 5cm depth. In case of transplanting method, it followed an increasing trend with delay in date of planting in 5cm depth, while in 15cm depth, it showed an increasing trend till June 15th and decreased in July 1st followed by a rise in July 15th planting. Effect of date of planting on soil moisture at 5 and 15 cm depth are given in the Fig. 4.7 to 4.16.

Effect of planting methods on soil moisture

Considering the planting method, it implies an effect on the soil moisture. By comparing the soil moisture observations, the highest value in case of broadcasting method for 15 cm depth, while for 5cm depth, the highest value can be seen for the dibbling method. The lowest value of soil moisture is seen for the broadcasting method in 5cm depth and for the 15 cm depth, it is the transplanting method. Effect of planting method on soil moisture at 5 and 15 cm depth are given in the Fig. 4.7 to 4.16.

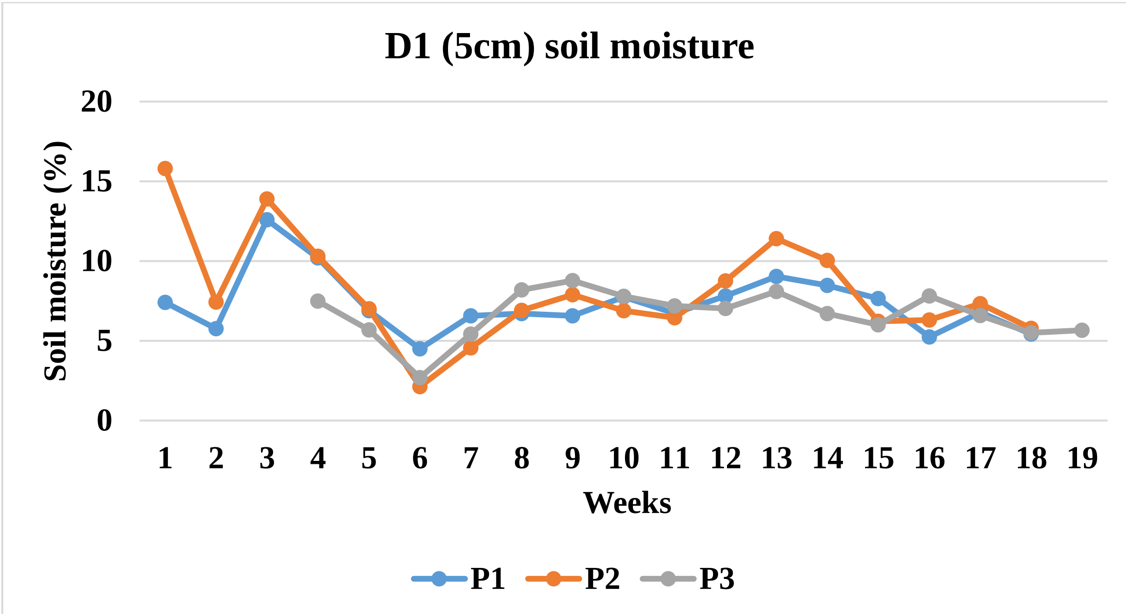


Fig. 4.7. Soil moisture at 5cm depth during first date of planting

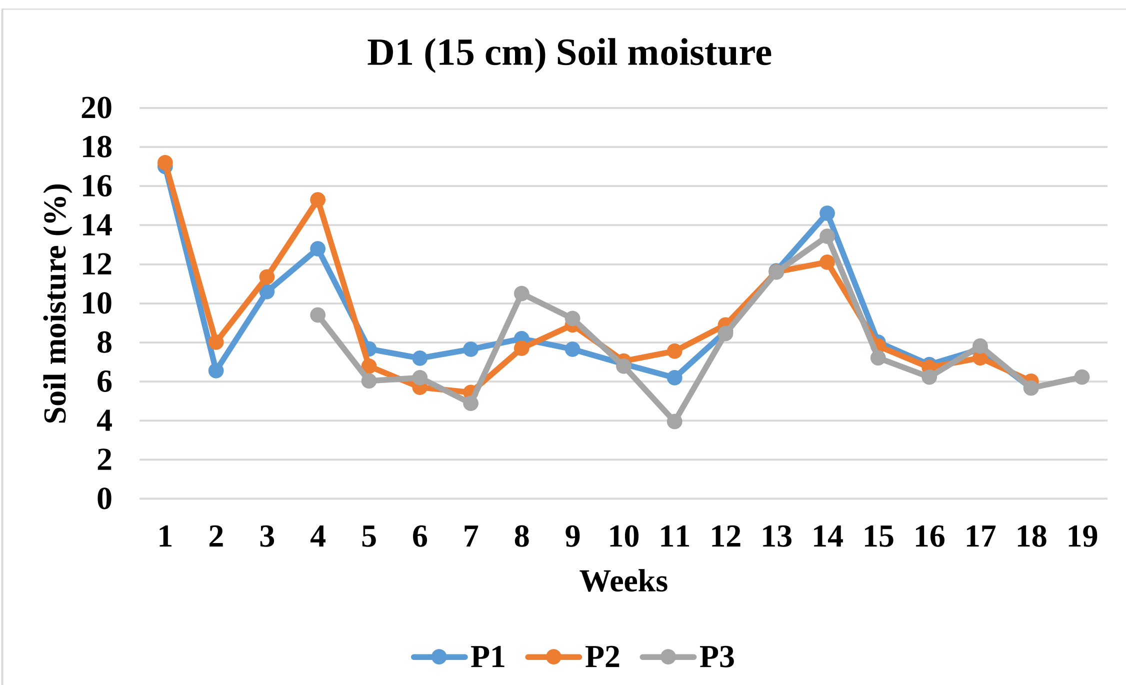


Fig. 4.8. Soil moisture at 15cm depth during first date of planting

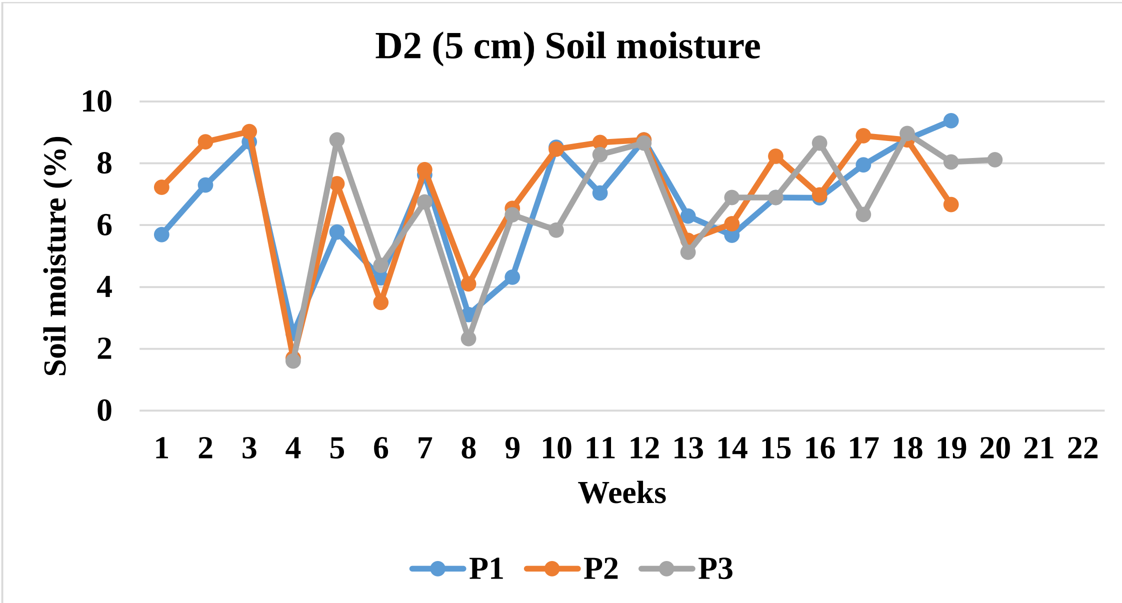


Fig. 4.9. Soil moisture at 5cm depth during second date of planting

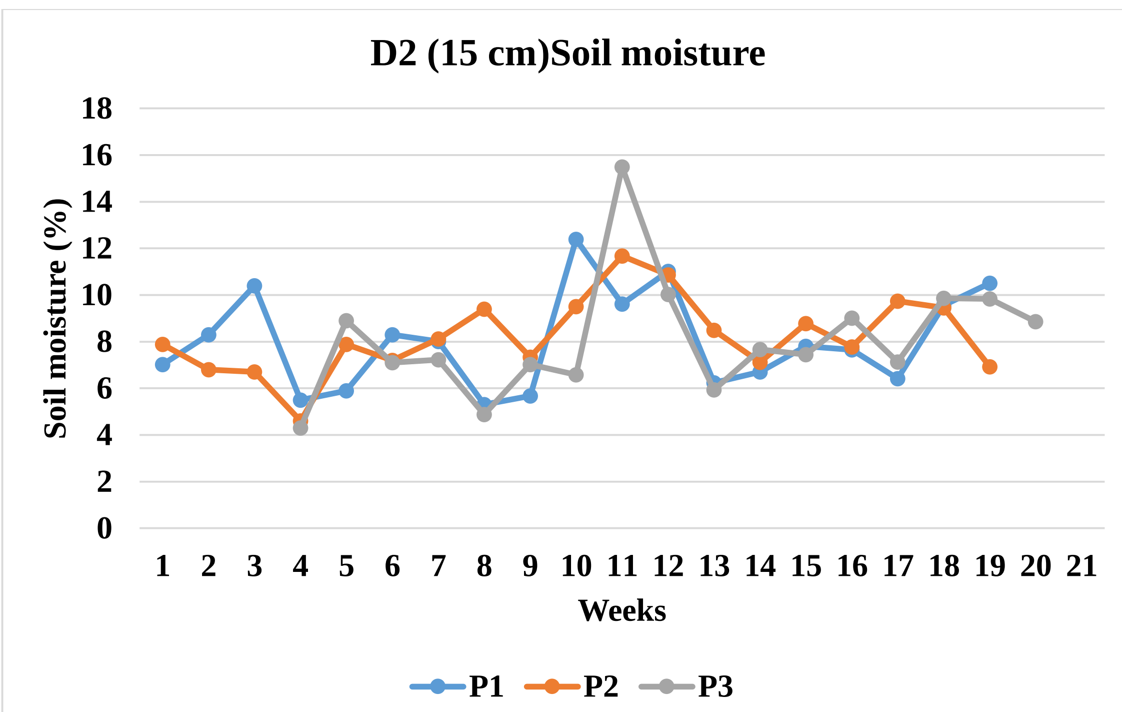


Fig. 4.10 Soil moisture at 15cm depth during second date of planting

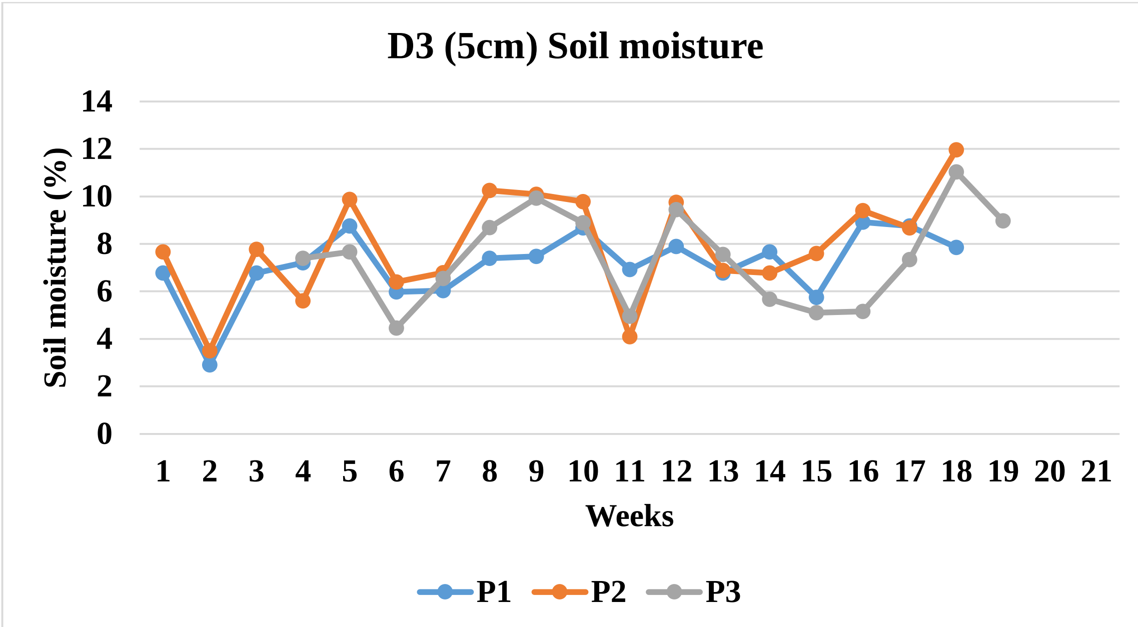


Fig. 4.11 Soil moisture at 5cm depth during third date of planting

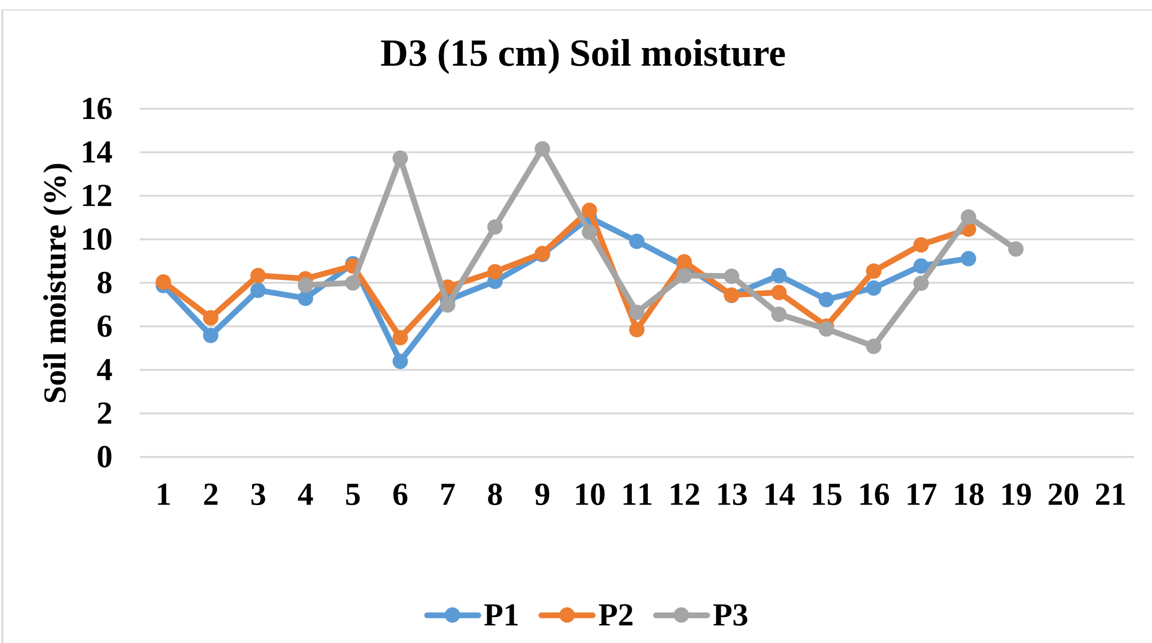


Fig. 4.12 Soil moisture at 15cm depth during third date of planting

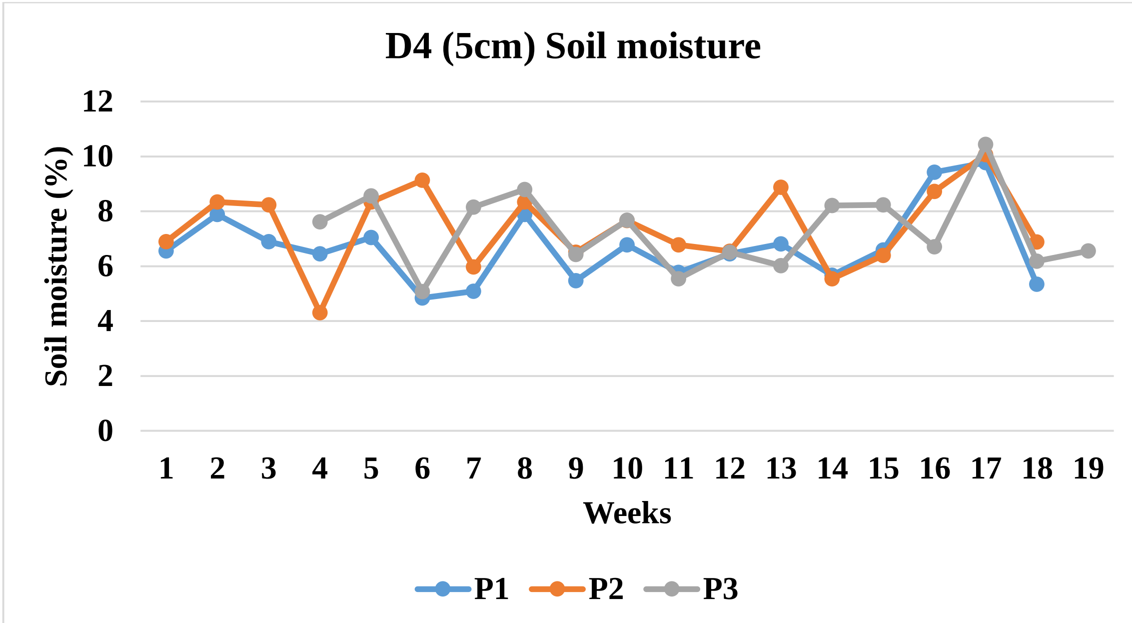


Fig. 4.13 Soil moisture at 5cm depth during fourth date of planting

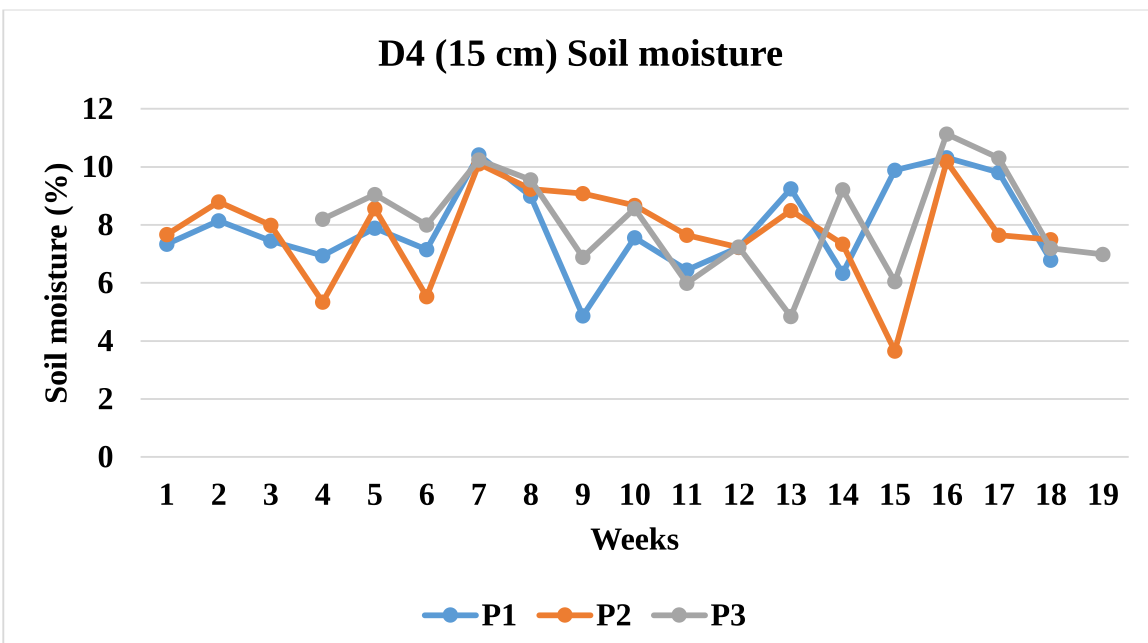


Fig. 4.14 Soil moisture at 15cm depth during fourth date of planting

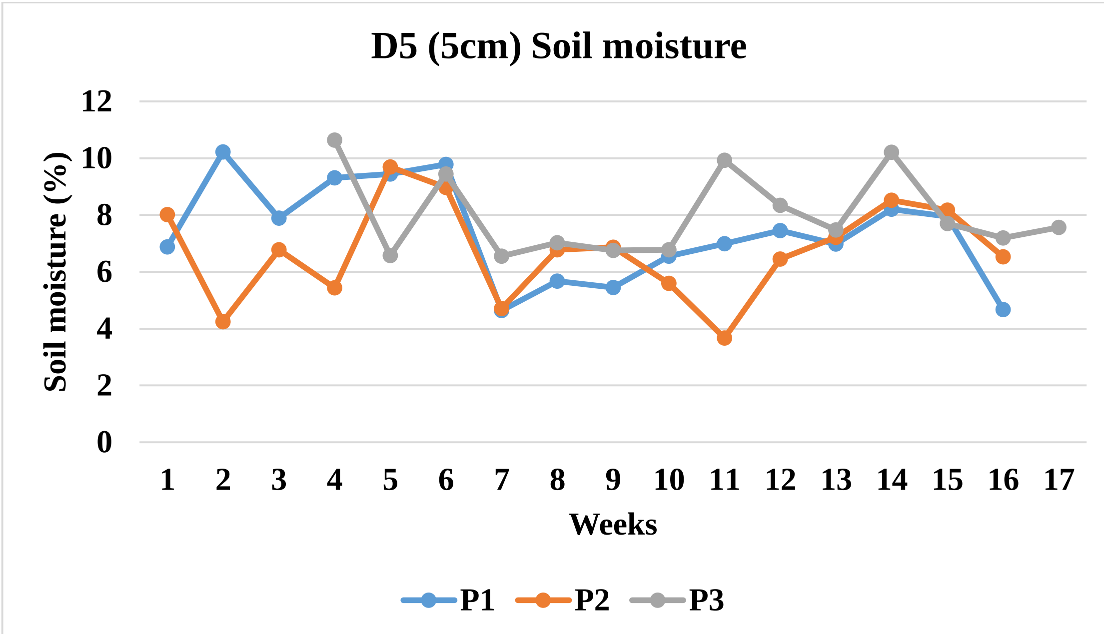


Fig. 4.15 Soil moisture at 5cm depth during fifth date of planting

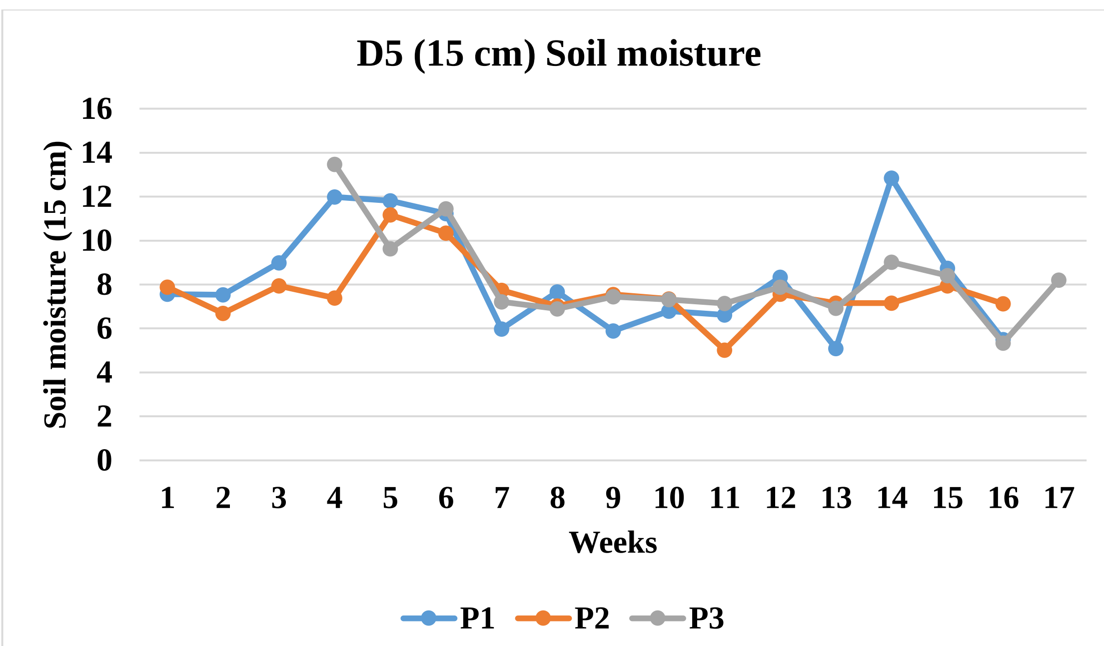


Fig. 4.16 Soil moisture at 15cm depth during fifth date of planting

Table 4.12. Effect of dates of planting and planting method of finger millet on soil moisture

Dates of planting	Soil moisture					
	Broadcasting		Dibbling		Transplanting	
	5 cm	15 cm	5 cm	15 cm	5cm	15 cm
D1	7.34	8.97	8.06	8.97	6.67	7.72
D2	6.60	8.02	7.00	8.22	6.60	8.08
D3	7.14	8.04	7.94	8.16	7.43	8.82
D4	6.71	7.93	7.42	7.82	7.29	7.58
D5	7.38	8.29	6.73	7.69	8.01	8.31

D1- 15th May D2- 1st June D3- 15th June D4- 1st July D5- 15th July

Soil temperature

The observation on soil temperature has been taken throughout the crop period at 5, 15 and 30 cm depths. The result of soil temperature analysis are given below:

Effect of dates of planting on soil temperature

Considering the effect of date of planting, it had noticeable influence on the soil temperature. During the May 15th planting, the soil temperature at 7.30 am for different planting methods ranged from 34.4 to 36.5^{0}C. But for June 1st planting it ranged from 35.2 to 37.3^{0}C. For June 15th planting it ranged from 33.5 to 35.4^{0}C and for July 1st planting it ranged from 33.9 to 34.8^{0}C. Coming to the last date of planting at July 15th, it ranged from 33.75 to 34.42^{0}C. Considering the temperature at 2.30 pm, it ranged from 36.3 to 38.4^{0}C for May 15th planting, 36.79 to 38.45^{0}C for June 1st planting, 36.0 to 37.6^{0}C for June 15th planting, 36.0 to 37.8^{0}C for July 1st planting and 36.27 to 37.51 in July 15th planting.

The observations showed that the soil temperature at 5, 15 and 30 cm depth indicates the highest value at June 1st date of planting and later on it will get decreased with delay in date of planting for the broadcasting method at 7.30 am, while there was a slight increase at July 1st planting for the 2.30 observations. In case of dibbling method of planting, the observation followed a continuous decreasing trend with delay in date of planting for both the 7.30 am and 2.30 pm observations. The same in case of transplanting method of planting, where the soil temperature followed a continuous decreasing trend in its values with delay in date of planting except for the slight increase in the July 1st date of planting at 2.30 pm observations. Effects of dates of planting on soil temperature is given in the Table 4.13.

Effects of planting method on soil temperature

The observation indicates that planting methods had considerable effect on the soil temperature. In case of soil temperature at 7.30 am, the values at 5cm depth showed highest value in case of dibbling method and the remaining broadcasting and transplanting showed similar values for both the 5cm and 15cm depths. But in case of 30 cm depth, the values of broadcasting and dibbling were almost similar and the lowest values were obtained for the transplanting method. Coming to the observations of 2.30 pm, all the depths showed variable trends for the temperature, In case of 5cm depth, the highest values were obtained for transplanting method, while the dibbling and transplanting showed similar values. While coming to the 15cm depth. It followed a continuous decreasing trend. In case of 30 cm depth, broadcasting showed the higher values followed by transplanting and the lowest values were obtained for the dibbling method. Effect of planting method on soil temperature is given in the Table 4.14.

Table 4.13. Effects of dates of planting of finger millet on soil temperature

Dates of planting	**Soil temperature**																	
	Broadcasting						**Dibbling**						**Transplanting**					
	Forenoon (7.30 am)			**Afternoon (2.30 pm)**			**Forenoon (7.30 am)**			**Afternoon (2.30 pm)**			**Forenoon (7.30 am)**			**Afternoon (2.30 pm)**		
	5 cm	15 cm	30 cm	5 cm	15 cm	30 cm	5 cm	15 cm	30 cm	5 cm	15cm	30 cm	5 cm	15 cm	30 cm	5 cm	15 cm	30 cm
D1	34.36	35.12	36.02	37.62	36.32	36.71	35.18	35.45	36.45	38.14	37.00	37.28	35.20	35.61	36.49	38.39	37.49	37.74
D2	35.93	36.41	37.25	38.45	37.71	37.44	35.22	35.81	36.66	38.05	37.01	36.79	35.44	35.77	36.77	38.07	36.94	36.98
D3	33.84	34.19	35.37	37.31	35.97	36.03	33.79	34.85	35.43	37.62	36.21	36.16	33.45	33.97	35.17	37.37	36.46	36.07
D4	33.87	34.16	34.44	37.80	37.11	36.68	34.74	34.35	34.59	37.45	37.18	36.43	33.96	34.50	34.40	37.72	36.94	35.99
D5	33.82	34.06	34.32	37.51	37.39	36.66	33.78	34.42	34.29	37.48	36.76	36.54	33.75	34.00	34.24	37.39	36.27	36.59

D1- 15th May D2- 1st June D3- 15th June D4- 1st July D5- 15th July

Table 4.14. Effects of planting method on soil temperature

Dates of planting	**Soil temperature**					
	Forenoon (7.30 am)			**Afternoon (2.30 pm)**		
	5 cm	15 cm	30 cm	5 cm	15cm	30 cm
Broadcasting	34.37	34.78	35.48	37.74	36.90	36.70
Dibbling	35.34	34.98	35.48	37.74	36.83	36.64
Transplanting	34.36	34.77	35.41	37.79	36.82	36.67

Observation on weeds

The observation on weeds had been taken at 30 and 60 days after sowing by counting the number of weeds per m^{-2} and by taking the dry weight of the weeds per m^{-2}. The floristic composition of the weeds also has been identified in the observation plot.

Floristic composition of weeds

Various kinds of weeds have been identified in the plot which mainly includes *Ludwigia Parviflora, Mitracarpus villosus, Alternanthera bettzickiana, Phyllanthus spp., Mollugo disticha, Cyperus rotundus, Cyperus haspan, Digitaria ciliaris, Cyanotis spp., Brachiaria mutica, mimosa pudica, Acalypha indica* etc. These weeds have been classified under various sections like broad leaved, sedges and grass types which is given in the following classification (Table 4.15):

Table 4.15. Classification of weeds

Broad leaved	**Sedges**	**Grass**
Ludwigia parviflora	*Cyperus rotundus*	*Digitaria ciliaris*
Mitracarpus villosus	*Cyperus haspan*	*Cyanotis spp.*
Alternanthera bettzickiana		*Brachiaria mutica*
Phyllanthus spp.		
Mollugo disticha		
Mimosa pudica		
Acalypha indica		

The other weeds which were identified occasionally were *Ludwigia adscendens, crotalaria sagittalis, Alysicarpus bupleurifolius, Cassia mimosoides, Iopomea pescaprae, Lindernia crustacea, Axonopus compressus, Corchorus olitorius* etc.

Weed density per m^2

Weed density per m^2 followed a various trends in all the dates of planting as well as in planting methods. The effect of date of planting on the weed density indicates that highest weed density per m^2 was observed for the May 15th and July 1st date of planting compare to other dates of planting at 30 days after sowing. But considering the weed density count at 60 days after sowing, it indicates the highest weed count was observed on June 1st date of planting and the lowest count was observed for July 1st date of planting compared to other dates. Effects of dates of planting and planting method of finger millet on weed density per m^2 are given in the Table 4.16.

Considering the planting methods, the highest weed density was recorded in broadcasting method (299m^{-2}) during the May 15th planting at 30 days after sowing. But considering the May 15th, June 1st, June 15th and July 15th planting at 60 days after sowing, dibbling showed considerably high weed density than that of broadcasting. Transplanting method showed considerably less weed density comparable with the other two methods in all the dates of planting.

Weed dry weight per m^2

The results from the observation on dry weight of the weeds per m^2 also implies same pattern as that of weed density count per m^{-2}. The highest weed dry weight is observed in July 1st date of planting in the dibbling method (98.9 g m^{-2}) at 60 days after sowing and the lowest dry weight was observed on June 1st date of planting in transplanting method (5.8 g m^{-2}) at 30 days after sowing. In case of May 15th planting, broadcasting showed the highest weed dry weight compared to other planting in both 30 and 60 days after sowing. The remaining observation showed the highest dry weight for the dibbling method at both the 30 and 60 days after sowing.

Considering the planting dates, it followed the same pattern as that of weed density. The highest weed dry weight was observed in case of May 15th and July 1st date of planting compared to other dates while the lowest dry weight was observed mostly in June 1st date of planting at 30 days after sowing. But considering the weed dry weight at 60 days after sowing, the highest dry weight was observed for June 1st date of planting and the lowest count was observed for July 1st date of planting. Effect of dates of planting and planting method of finger millet on weed dry weight per unit area is given in the Table 4.17.

Table 4.16. Effects of dates of planting and planting method of finger millet on weed density per m^2

Dates of planting	Number of weeds per m^2					
	Broadcasting		Dibbling		Transplanting	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
D1	299	244	284	272	235	180
D2	84	108	98	288	76	224
D3	106	164	88	196	108	21
D4	136	252	152	172	224	167
D5	88	168	50	195	45	94

D1- 15th May D2- 1st June D3- 15th June D4- 1st July D5- 15th July

Table 4.17. Effects of dates of planting and planting method of finger millet on weed dry weight per m^2 (g m^{-2})

Dates of planting	**Weed dry weight per m^2 (g m^{-2})**					
	Broadcasting		**Dibbling**		**Transplanting**	
	30 DAS	**60 DAS**	**30 DAS**	**60 DAS**	**30 DAS**	**60 DAS**
D1	86.96	47.45	61.72	35.32	49.04	23.44
D2	6.72	94.44	7.52	112.16	5.8	112.48
D3	23.84	55.12	8.92	62.13	9.24	9.48
D4	82.36	22.92	98.88	38.4	34.72	27.8
D5	6.76	53.24	15.32	73.24	14.24	27.64

D1- 15th May D2- 1st June D3- 15th June D4- 1st July D5- 15th July

4.6. CROP WEATHER RELATIONSHIPS

The influence of weather parameters on the performance of crop growth was estimated using the correlation analysis. The correlation analysis was carried out between weather variables of five different planting dates and phenophases duration, yield and yield attributes for three different planting methods which are broadcasting, dibbling and transplanting. The results are presented below.

4.6.1. Correlation analysis of weather and crop duration

The influence of various weather parameters like temperature, relative humidity, vapour pressure, wind speed, bright sunshine hours, rainfall, evaporation etc. on the duration of crop growth in three different planting methods were measured using correlation analysis. The influence of weather on the duration of each phenophases from sowing to harvesting was also calculated. The results are given below:

4.6.1.1. Effect of weather parameters on crop duration of finger millet in broadcasting method of planting

The output of correlation analysis done between weather variables and phenophases of finger millet cultivated under different planting method such as broadcasting, dibbling and transplanting are given in the Table 4.18, 4.19 and 4.20 respectively.

4.6.1.1.1. Sowing to panicle initiation

Maximum temperature, mean temperature, temperature range, rainy days and evaporation showed significant negative correlation with number of days taken from sowing to panicle initiation in broadcasting while forenoon relative humidity, afternoon relative humidity, mean relative humidity, bright sunshine hours and wind speed showed significant positive correlation.

4.6.1.1.2. Panicle initiation to flag leaf stage

Maximum temperature, minimum temperature, mean temperature, temperature range, afternoon vapour pressure deficit, rainfall, rainy days and evaporation showed negative correlation with number of days taken from panicle initiation to flag leaf stage in broadcasting while no any significant positive correlation was observed.

4.6.1.1.3. Flag leaf stage to 50 % flowering stage

Maximum temperature, minimum temperature, mean temperature, temperature range, forenoon and afternoon vapour pressure deficit showed significant negative correlation with number of days taken from flag leaf to 50 % flowering stage in broadcasting while bright sunshine hours and wind speed showed significant positive correlation

4.6.1.1.4. 50% flowering stage to milk stage

Maximum temperature and mean temperature showed significant negative correlation with number of days taken from the 50 % flowering to milk stage in broadcasting while rainfall showed significant positive correlation.

4.6.1.1.5. Milk stage to Dough stage

Maximum temperature, mean temperature and rainfall showed significant negative correlation with number of days taken from milk stage to dough stage in broadcasting while rainfall showed significant positive correlation while forenoon relative humidity, mean relative humidity and forenoon vapour pressure deficit showed significant positive correlation.

4.6.1.1.6. Dough stage to physiological maturity

Only the minimum temperature showed significant negative correlation with number of days taken from dough stage to physiological maturity in broadcasting while the mean temperature, bright sunshine hours and wind speed showed significant positive correlation.

4.6.1.2. Effect of weather parameters on crop duration of finger millet in dibbling method of planting

4.6.1.2.1. Sowing to panicle initiation

Maximum temperature, mean temperature, temperature range, rainy days and evaporation showed significant negative correlation with number of days taken from sowing to panicle initiation in dibbling while forenoon relative humidity, afternoon relative humidity, mean relative humidity, bright sunshine hours and wind speed showed significant positive correlation.

4.6.1.1.2. Panicle initiation to flag leaf stage

Maximum temperature, mean temperature and temperature range showed significant negative correlation with number of days taken from panicle initiation to flag leaf stage in broadcasting while no any significant positive correlation was observed.

4.6.1.1.3. Flag leaf stage to 50 % flowering stage

Maximum temperature, minimum temperature, mean temperature, temperature range, forenoon and afternoon vapour pressure deficit showed significant negative correlation with number of days taken from flag leaf to 50 % flowering stage in broadcasting while bright sunshine hours and wind speed showed significant positive correlation

4.6.1.1.4. 50% flowering stage to milk stage

Maximum temperature and mean temperature showed significant negative correlation with number of days taken from the 50 % flowering to milk stage in broadcasting while rainfall showed significant positive correlation.

4.6.1.1.5. Milk stage to Dough stage

Maximum temperature, mean temperature and rainfall showed significant negative correlation with number of days taken from milk stage to dough stage in broadcasting while forenoon relative humidity, mean relative humidity and forenoon vapour pressure deficit showed positive correlation.

4.6.1.1.6. Dough stage to physiological maturity

Only the minimum temperature showed significant negative correlation with number of days taken from dough stage to physiological maturity in broadcasting while the mean temperature, bright sunshine hours and wind speed showed significant positive correlation.

4.6.1.2. Effect of weather parameters on crop duration of finger millet in transplanting method of planting

4.6.1.2.1. Sowing to panicle initiation

Maximum temperature, mean temperature, temperature range and evaporation showed significant negative correlation with number of days taken from sowing to panicle initiation in transplanting while forenoon relative humidity, afternoon relative humidity, mean relative humidity, bright sunshine hours and wind speed showed significant positive correlation.

4.6.1.2.2. Panicle initiation to flag leaf stage

Temperature range showed a significant negative correlation while the forenoon relative humidity showed positive correlation with the duration taken for the transplanted crops to attain flag leaf stage with the weather variables.

4.6.1.2.3. Flag leaf stage to 50 % flowering stage

Afternoon vapour pressure deficit showed significant negative correlation with number of days taken from flag leaf to 50 % flowering stage in transplanting while no positive correlation has been observed.

4.6.1.2.4. 50% flowering stage to milk stage

Temperature range, forenoon relative humidity, mean relative humidity and bright sunshine hours showed significant negative correlation with number of days taken from the 50 % flowering to milk stage in transplanting while minimum temperature, rainfall, rainy days, wind speed and evaporation showed significant positive correlation.

4.6.1.2.5. Milk stage to Dough stage

Afternoon vapour pressure deficit, bright sunshine hours and wind speed showed significant negative correlation with number of days taken from milk stage to dough stage in transplanting while there was no positive correlation detected.

4.6.1.2.6. Dough stage to physiological maturity

Maximum temperature, temperature range and rainy days showed significant negative correlation with number of days taken from dough stage to physiological maturity in transplanting while after noon relative humidity, mean relative humidity, forenoon and after noon vapour pressure deficit showed significant positive correlation.

Table 4.18. Correlation between duration of phenophases for finger millet and weather variables in broadcasting

Stages	Tmax	Tmin	Tmean	Trange	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	-.772**	.407	-.525*	-.750**	.829**	.793**	.814**	.308	.485	.105	-.729**	.958**	.906**	-.785**
Ph_2	-.623*	-.390	-.604*	-.550*	.450	.193	.250	.195	-.499	-.042	-.064	.188	.111	-.131
Ph_3	-.965**	-.692**	-.987**	-.557*	.497	.336	.401	-.712**	-.536*	-.029	-.309	.775**	.663**	-.477
Ph_4	-.652**	-.388	-.815**	-.338	-.142	.139	.039	-.226	-.389	.811**	-.043	-.489	.248	.130
Ph_5	-.656**	-.285	-.816**	-.238	.790**	.388	.571*	.645**	.370	-.929**	-.087	.284	.282	-.454
Ph_6	.433	-.675**	.632*	.139	.050	-.037	-.005	-.092	.010	-.170	-.107	.566*	.728**	-.189

*Significant at 5% level ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

Table 4.19. Correlation between duration of phenophases for finger millet and weather variables in dibbling

Stages	Tmax	Tmin	Tmean	Trange	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	-.772**	.407	-.525*	-.750**	.829**	.793**	.814**	.308	.485	.105	-.729**	.958**	.906**	-.785**
Ph_2	-.623*	-.390	-.604*	-.550*	.450	.193	.250	.195	-.499	-.042	-.064	.188	.111	-.131
Ph_3	-.965**	-.692**	-.987**	-.557*	.497	.336	.401	-.712**	-.536*	-.029	-.309	.775**	.663**	-.477
Ph_4	-.652**	-.388	-.815**	-.338	-.142	.139	.039	-.226	-.389	.811**	-.043	-.489	.248	.130
Ph_5	-.656**	-.285	-.816**	-.238	.790**	.388	.571*	.645**	.370	-.929**	-.087	.284	.282	-.454
Ph_6	.433	-.675**	.632*	.139	.050	-.037	-.005	-.092	.010	-.170	-.107	.566*	.728**	-.189

*Significant at 5% level ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

Table 4.20. Correlation between duration of phenophases and weather variables in transplanting

Stages	Tmax	Tmin	Tmean	Trange	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph$_1$	-.817**	.314	-.756**	-.755**	.809**	.585*	.631*	.045	.145	-.202	-.468	.790**	.815**	-.659**
Ph$_2$	-.455	.098	-.330	-.580*	.556*	.464	.488	-.050	.037	-.352	-.152	.298	.126	-.323
Ph$_3$	-.443	-.248	-.451	-.275	.205	-.169	-.089	-.035	-.708**	.237	.427	-.458	.000	.236
Ph$_4$	-.463	.537*	-.067	-.570*	-.616*	-.375	-.523*	-.358	-.451	.672**	.677**	-.814**	-.778**	.542*
Ph$_5$	.210	-.214	-.114	.333	-.179	-.489	-.392	-.348	-.536*	-.289	.437	-.619*	-.615*	.057
Ph$_6$	-.707**	.443	-.248	-.831**	.388	.669**	.572*	.735**	.654**	-.317	-.634*	-.079	-.028	-.339

*Significant at 5% level ** Significant at 1% level

Ph$_1$ – Sowing to panicle initiation
Ph$_2$ – Panicle initiation to flag leaf stage
Ph$_3$ – Flag leaf stage to 50% flowering
Ph$_4$ – 50% flowering to milk stage
Ph$_5$ – Milk stage to dough stage
Ph$_6$ - Dough stage to physiological maturity

4.6.2. Correlation analysis between weather and yield

The influence of various weather parameters like temperature, relative humidity, vapour pressure, wind speed, bright sunshine hours, rainfall, evaporation etc. on the yield produced in three different planting methods were measured using correlation analysis. The influence of weather at each phenophases from sowing to harvesting to the yield produced was also calculated. The results are given below:

4.6.2.1. Effect of weather parameters on yield of finger millet in broadcasting method of planting

The output of correlation analysis done between weather variables and yield of finger millet cultivated under different planting method such as broadcasting, dibbling and transplanting are given in the Table 4.21, 4.22 and 4.23 respectively.

4.6.2.1.1. Sowing to panicle initiation

Rainy days and evaporation showed significant negative correlation with yield in broadcasting while minimum temperature, afternoon relative humidity, mean relative humidity, forenoon and afternoon vapour pressure deficit, bright sunshine hours and wind speed showed positive correlation.

4.6.2.1.2. Panicle initiation to flag leaf stage

Maximum temperature, mean temperature and temperature range showed significant negative correlation, while forenoon relative humidity showed significant positive correlation with the yield in broadcasting.

4.6.2.1.3. Flag leaf stage to 50 % flowering stage

Maximum temperature, minimum temperature, mean temperature, temperature range, forenoon and afternoon vapour pressure deficit showed negative correlation with the yield in broadcasting.

4.6.2.1.4. 50% flowering stage to milk stage

Bright sunshine hours showed significant negative correlation with yield in broadcasting while rainfall and evaporation showed significant positive correlation.

4.6.2.1.5. Milk stage to Dough stage

Minimum temperature and mean temperature showed significant negative correlation with yield in broadcasting.

4.6.2.1.6. Dough stage to physiological maturity

Only the mean temperature showed significant negative correlation with the yield in broadcasting while the minimum temperature showed significant positive correlation.

4.6.2.2. Effect of weather parameters on yield of finger millet in dibbling method of planting

4.6.2.2.1. Sowing to panicle initiation

Rainfall, rainy days and evaporation showed significant negative correlation with yield in dibbling while minimum temperature, afternoon relative humidity, mean relative humidity, forenoon and afternoon vapour pressure deficit and bright sunshine hours showed significant positive correlation.

4.6.2.2.2. Panicle initiation to flag leaf stage

Maximum temperature, mean temperature and temperature range showed significant negative correlation with the yield in dibbling while forenoon relative humidity showed significant positive correlation.

4.6.2.2.3. Flag leaf stage to 50 % flowering stage

Maximum temperature, mean temperature and afternoon vapour pressure deficit showed significant negative correlation with yield in dibbling.

4.6.2.2..4. 50% flowering stage to milk stage

Bright sunshine hours showed significant negative correlation with yield in dibbling while rainfall showed significant positive correlation.

4.6.2.2.5. Milk stage to Dough stage

Minimum temperature and mean temperature showed significant negative correlation with yield in dibbling while there was no any positive correlation is observed.

4.6.2.2.5. Dough stage to physiological maturity

Maximum temperature and mean temperature showed significant negative correlation with yield while minimum temperature and afternoon relative humidity showed significant positive correlation.

4.6.2.3. Effect of weather parameters on crop duration of finger millet in transplanting method of planting

4.6.2.3.1. Sowing to panicle initiation

Temperature range, rainfall, rainy days and evaporation showed significant negative correlation with yield in transplanting while minimum temperature, afternoon relative humidity, mean relative humidity, forenoon and afternoon vapour pressure deficit, bright sunshine hours and wind speed showed positive correlation.

4.6.2.3.2 Panicle initiation to flag leaf stage

Maximum temperature, minimum temperature, mean temperature, temperature range and forenoon vapour pressure deficit showed significant negative correlation with yield in transplanting while bright sunshine hours showed significant positive correlation.

4.6.2.3.3. Flag leaf stage to 50 % flowering stage

Maximum temperature, minimum temperature and mean temperature showed significant negative correlation with yield in transplanting while positive correlation was observed in rainfall.

4.6.2.3..4. 50% flowering stage to milk stage

Mean temperature range showed significant negative correlation with yield in transplanting while forenoon vapour pressure deficit showed significant positive correlation.

4.6.2.3.5. Milk stage to Dough stage

Maximum and mean temperature showed significant negative correlation with yield in transplanting while there was no positive correlation detected.

4.6.2.3.6. Dough stage to physiological maturity

Maximum temperature and temperature range showed significant negative correlation with yield while forenoon vapour pressure deficit showed significant positive correlation in transplanting.

Table 4.21. Correlation between grain yield of finger millet and weather variables in broadcasting

Stages	Tmax	Tmin	Tmean	TR	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph$_1$	-.158	.746**	.209	-.403	.334	.640*	.603*	.730**	.749**	-.499	-.659**	.617*	.522*	-.538*
Ph$_2$	-.665**	-.234	-.640*	-.655**	.660**	.410	.471	.296	-.190	-.341	-.275	.361	.252	-.362
Ph$_3$	-.615*	-.454	-.632*	-.331	.191	.020	.070	-.522*	-.561*	-.065	-.069	.380	.301	-.150
Ph$_4$	-.248	-.404	-.439	-.017	-.404	-.198	-.288	-.346	-.481	.555*	.513	-.606*	-.203	.519*
Ph$_5$	-.172	-.725**	-.688**	.353	.332	.076	.186	.381	.250	-.346	.100	-.158	-.040	-.139
Ph$_6$	-.467	.794**	-.784**	-.264	.325	.429	.399	.335	.421	-.175	-.176	.104	-.070	-.134

*Significant at 5% level   ** Significant at 1% level

Ph$_1$ – Sowing to panicle initiation
Ph$_2$ – Panicle initiation to flag leaf stage
Ph$_3$ – Flag leaf stage to 50% flowering
Ph$_4$ – 50% flowering to milk stage
Ph$_5$ – Milk stage to dough stage
Ph$_6$ - Dough stage to physiological maturity

Table 4.22. Correlation between grain yield of finger millet and weather variables in dibbling

Stages	Tmax	Tmin	Tmean	TR	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	-.158	.783**	.229	-.382	.345	.662**	.624*	.754**	.797**	-.573*	-.699**	.555*	.497	-.562*
Ph_2	-.750**	-.350	-.737**	-.714**	.671**	.456	.512	.253	-.255	-.301	-.303	.437	.325	-.397
Ph_3	-.698**	-.478	-.708**	-.426	.305	.065	.137	-.511	-.593*	-.163	-.053	.425	.323	-.222
Ph_4	-.262	-.512	-.489	.017	-.413	-.225	-.302	-.377	-.438	.663**	.385	-.555*	-.092	.466
Ph_5	-.160	-.696**	-.642**	.359	.234	.036	.119	.334	.181	-.145	.181	-.268	-.154	.012
Ph_6	-.619*	.746**	-.759**	-.390	.475	.515*	.510	.488	.474	-.298	-.289	.083	-.030	-.325

*Significant at 5% level   ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

Table 4.23. Correlation between grain yield of finger millet and weather variables in transplanting

Stages	Tmax	Tmin	Tmean	TR	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	-.291	.895**	.132	-.582*	.481	.748**	.713**	.880**	.890**	-.701**	-.802**	.683**	.505	-.633*
Ph_2	-.756**	-.651**	-.810**	-.576*	.403	.435	.435	-.732**	-.322	-.197	-.286	.599*	.421	-.383
Ph_3	-.629*	-.541*	-.751**	-.285	.249	.224	.243	-.246	-.308	.701**	-.051	-.508	.360	-.003
Ph_4	-.456	-.421	-.789**	-.150	.408	.313	.383	.575*	.282	-.393	-.012	-.371	-.092	-.498
Ph_5	-.714**	-.507	-.713**	.096	.368	.237	.306	.189	.214	-.153	.249	.344	.280	.308
Ph_6	-.586*	.159	-.347	-.548*	.383	.451	.438	.649**	.435	-.431	-.343	-.288	-.253	-.417

*Significant at 5% level   ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

4.6.3. Correlation between weather variables and yield attributes of finger millet under broadcasting method of sowing

The effect of weather parameters on the performance of various yield attributes like number of ear heads per m^2, finger number per ear head, finger length, thousand grain weight and straw yield were analyzed by using the correlation analysis. The analysis was carried out for the finger millet sown by three different methods which are broadcasting, dibbling and transplanting. The correlation results are given in the tables from Table 4.24 to Table 4.41.

4.6.5.1. Correlation between weather variables and number of ear heads per m^2 for broadcasted finger millet

Maximum temperature and mean temperature from sowing to panicle initiation stage showed significant positive influence on number of ear heads per m^2 of broadcasted finger millet while forenoon relative humidity, rainfall and wind speed during the same phenophases showed significant negative influence on it. Afternoon relative humidity, mean relative humidity, bright sunshine hours and wind speed showed significant positive correlation with this yield attribute during both the panicle initiation to flag leaf and flag leaf to 50% flowering stages. A positive correlation was also observed in case of afternoon vapour pressure deficit during panicle iniation to flag leaf stages. Temperature range, rainy days and evaporation showed a significant negative correlation with the number of ear heads for both the panicle initiation to flag leaf and flag leaf to 50% flowering stages. Forenoon relative humidity also showed significant positive correlation and maximum temperature showed a negative correlation with the number of ear heads per m^2 during flag leaf to 50% flowering stages. Forenoon relative humidity and wind speed showed a significant positive correlation with the number of ear heads per m^2 during 50% flowering to milk stage, while maximum temperature, mean temperature, temperature range and rainy days showed a significant negative correlation during the same phenophase. Rainy days and evaporation showed a significant positive correlation with the yield attribute during the milk stage to dough stage. Afternoon relative humidity, mean relative humidity, afternoon vapour pressure deficit, bright sunshine hours and wind speed showed a significant negative correlation with this yield attribute for the milk stage to dough stage and for bright sunshine hours and wind speed in case of dough stage to physiological maturity.

4.6.5.2. Correlation between weather variables and finger number per ear heads per square meter for broadcasted finger millet

Minimum temperature, forenoon, afternoon and mean relative humidity, afternoon vapour pressure deficit, bright sunshine hours and wind speed showed significant positive correlation with the finger number per ear heads per m^2 for broadcasted finger millet during sowing to panicle initiation stages while the maximum temperature, temperature range, rainy days and evaporation showed a significant negative correlation during the same phenophase. Maximum, minimum and mean temperature along with afternoon vapour pressure deficit and rainfall showed a negative correlation during panicle initiation to flag leaf stages. Minimum and mean temperature along with forenoon and afternoon vapour pressure deficit also showed a significant negative correlation with the finger number per ear heads during flag leaf to 50% flowering stages. While rainfall is the only weather parameter that showed a positive correlation, forenoon relative humidity and bright sunshine hours showed a negative correlation with this yield attribute during the 50% flowering to milk stage. Afternoon and mean relative humidity along with forenoon and after noon vapour pressure deficit showed a positive correlation with this yield attribute during the milk stage to dough stage. While forenoon, afternoon and mean relative humidity showed a significant positive correlation, maximum and mean temperature, rainfall and evaporation showed a significant negative correlation with the number of ear heads per m^2 during the dough stage to physiological maturity.

4.6.5.3. Correlation between weather variables and finger length for broadcasted finger millet

Minimum temperature, forenoon, afternoon and mean relative humidity, forenoon and afternoon vapour pressure deficit, bright sunshine hours and wind speed showed a positive correlation with finger length during sowing to panicle initiation stages. Maximum temperature, temperature range, rainy days and evaporation showed negative correlation during the same phenophase. Forenoon relative humidity is the only weather parameter that showed a positive correlation with the finger length during panicle initiation to flag leaf stage. Maximum, minimum and mean temperature and temperature range along with the afternoon vapour pressure deficit and showed negative correlation with the finger length during both the panicle initiation to flag leaf stage and flag leaf to 50% flowering stage. Temperature range and rainfall also showed a negative correlation with the finger length in case of panicle initiation to flag leaf stage. While rainfall is the only parameter that showed a positive correlation, forenoon relative humidity and bright sunshine hours showed negative correlation with the finger length during the 50% flowering to milk stage. Forenoon, afternoon and mean relative humidity along with forenoon and afternoon vapour pressure deficit showed a significant positive correlation with this yield attribute for both the milk stage to dough stage and dough stage to physiological maturity. Mean temperature showed a negative correlation with the finger length during the milk stage to dough stage. A positive correlation of minimum temperature and a negative correlation for maximum and mean temperature, rainfall, rainy days and evaporation pan with finger length was also observed during dough stage to physiological maturity.

4.6.5.4. Correlation between weather variables and thousand grain weight for broadcasted finger millet

No specific correlation was observed for the weather variables with the thousand grain weight during the sowing to panicle initiation stage. Minimum temperature showed a positive correlation with thousand grain weight during both the panicle initiation to flag leaf and 50% flowering to milk stages. Rainfall showed a significant positive correlation with the thousand grain weight during the flag leaf to 50% flowering stage. Forenoon vapour pressure deficit also showed a positive correlation with the thousand grain weight during the 50% flowering to milk stages. Rainfall showed a significant negative correlation with the thousand grain weight during milk stage to dough stage. Maximum temperature, temperature range, rainy days and evaporation showed a positive correlation with this yield attribute during dough stage to physiological maturity. Forenoon relative humidity and vapour pressure deficit showed a negative correlation with this yield attribute during dough stage to physiological maturity

4.6.5.5. Correlation between weather variables and straw yield for broadcasted finger millet

Minimum temperature, forenoon, afternoon and mean relative humidity, forenoon and afternoon vapour pressure deficit showed a positive correlation with the straw yield during sowing to panicle initiation, while rainfall, rainy days and evaporation showed a negative correlation. Forenoon, afternoon and mean relative humidity along with bright sunshine hours showed a positive correlation with the straw yield during panicle initiation to flag leaf. Minimum and mean temperature showed a negative correlation with straw yield for the stages like panicle initiation to flag leaf, flag leaf to fifty percent flowering, fifty percent flowering to milk stage and milk stage to dough stage. Maximum temperature and temperature range also showed a negative correlation with the straw yield during the panicle initiation to flag leaf. Bright sunshine hours showed a positive correlation, while maximum temperature and forenoon and after noon vapour pressure deficit showed a negative correlation with the straw yield during flag leaf to fifty percent flowering stage. Rainfall showed positive correlation and bright sunshine hours showed negative correlation during the 50% flowering to milk stage. Minimum temperature, forenoon, afternoon and mean relative humidity and forenoon vapour pressure deficit showed a positive correlation with the straw yield during dough stage to physiological maturity, while maximum and mean temperature, rainfall and evaporation showed negative correlation with the same.

4.6.5.6. Correlation between weather variables and harvest index for broadcasted finger millet

Rainfall was the only weather parameter that showed a positive correlation with the harvest index during sowing to panicle initiation stage. Coming to the second stage, minimum temperature showed a positive correlation with the harvest index.

No correlation has been observed in case of flag leaf to 50% flowering stage. During the 50% flowering to milk stage, rainfall showed negative correlation with the harvest index. Weather parameters didn't shown any correlation during milk stage to dough stage. Maximum temperature, rainfall and evaporation pan showed positive correlation with the harvest index during dough stage to physiological maturity, while forenoon, afternoon and mean relative humidity and forenoon vapour pressure deficit showed negative correlation with the same.

Table 4.24. Correlation between number of ear heads per m^2 of finger millet and weather variables in broadcasting

Stages	Tmax	Tmin	Tmean	TR	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	.729**	.289	.814**	.356	-.617*	-.279	-.338	.392	.185	-.656**	.181	-.491	-.538*	.401
Ph_2	-.423	.090	-.413	-.521*	.438	.758**	.711**	.504	.549*	.234	-.809**	.798**	.843**	-.776**
Ph_3	-.569*	.028	-.407	-.651**	.718**	.836**	.852**	-.003	.358	.016	-.723**	.697**	.669**	-.848**
Ph_4	-.803**	.000	-.760**	-.633*	.554*	.399	.481	-.050	-.461	.044	-.578*	.346	.799**	-.159
Ph_5	-.296	-.135	-.268	-.008	-.350	-.611*	-.523*	-.455	-.726**	.041	.848**	-.743**	-.815**	.790**
Ph_6	-.335	.011	-.145	.051	-.137	-.271	-.232	-.079	-.388	-.034	.264	-.780**	-.714**	.085

*Significant at 5% level   ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

Table 4.25. Correlation between finger number per ear head of finger millet and weather variables in broadcasting

Stages	Tmax	Tmin	Tmean	TR	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	-.529*	.594*	-.209	-.729**	.648**	.731**	.731**	.504	.637*	-.344	-.749**	.609*	.623*	-.644**
Ph_2	-.553*	-.695**	-.578*	-.447	.462	.106	.181	-.433	-.529*	-.627*	.115	.089	-.081	-.028
Ph_3	-.413	-.714**	-.590*	.068	-.125	-.316	-.281	-.673**	-.702**	.031	.262	.200	.129	.225
Ph_4	.106	-.338	-.072	.242	-.584*	-.141	-.319	-.084	.241	.794**	.261	-.710**	-.393	.058
Ph_5	-.272	-.256	-.493	-.057	.506	.549*	.551*	.660**	.559*	.042	-.253	.189	.252	-.256
Ph_6	-.578*	.375	-.553*	-.310	.683**	.577*	.622*	.510	.510	-.730**	-.356	.438	.473	-.622*

*Significant at 5% level ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

Table 4.26. Correlation between finger length of finger millet and weather variables in broadcasting

Stages	Tmax	Tmin	Tmean	TR	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	-.571*	.746**	-.175	-.822**	.725**	.867**	.860**	.651**	.790**	-.442	-.888**	.741**	.737**	-.758**
Ph_2	-.687**	-.748**	-.708**	-.578*	.595*	.183	.272	-.383	-.575*	-.706**	.068	.155	-.038	-.095
Ph_3	-.535*	-.815**	-.720**	.011	-.097	-.321	-.277	-.787**	-.822**	.023	.255	.274	.187	.205
Ph_4	.064	-.418	-.153	.243	-.672**	-.181	-.379	-.149	.154	.912**	.368	-.842**	-.445	.159
Ph_5	-.311	-.399	-.635*	.008	.584*	.578*	.601*	.749**	.622*	-.030	-.244	.168	.255	-.294
Ph_6	-.672**	.534*	-.714**	-.362	.754**	.668**	.707**	.579*	.599*	-.775**	-.393	.469	.470	-.654**

*Significant at 5% level   ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

Table 4.27. Correlation between thousand grain weight of finger millet and weather variables in broadcasting

Stages	Tmax	Tmin	Tmean	TR	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	.109	-.130	.023	-.232	-.141	-.195	-.189	-.070	-.221	.088	.219	.009	-.113	.280
Ph_2	.247	$.517^*$	.277	.150	.061	-.025	-.008	.248	.374	-.374	-.009	-.132	-.155	-.012
Ph_3	.235	-.203	.106	.475	-.491	-.020	-.154	-.246	.259	$.651^{**}$	-.244	.068	.185	.195
Ph_4	-.049	$.619^*$	.254	-.355	.248	.462	.406	$.586^*$	.153	-.279	.043	-.177	-.257	-.298
Ph_5	-.437	.288	-.200	-.468	.498	.312	.402	.312	.186	$-.671^{**}$	-.219	.449	.363	-.401
Ph_6	$.527^*$	-.160	-.098	$.665^{**}$	$-.522^*$	-.485	-.504	$-.622^*$	-.421	.046	$.608^*$	-.072	-.141	$.573^*$

*Significant at 5% level   ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

Table 4.28. Correlation between straw yield of finger millet and weather variables in broadcasting

Stages	Tmax	Tmin	Tmean	TR	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	-.181	.851**	.240	-.493	.384	.703**	.664**	.808**	.861**	-.707**	-.765**	.487	.465	-.571*
Ph_2	-.863**	-.651**	-.874**	-.803**	.742**	.530*	.587*	-.046	-.315	-.415	-.333	.535*	.394	-.456
Ph_3	-.798**	-.634*	-.843**	-.424	.357	.106	.183	-.635*	-.633*	-.126	-.068	.543*	.428	-.261
Ph_4	-.318	-.522*	-.564*	-.006	-.411	-.118	-.237	-.331	-.226	.853**	.160	-.576*	-.004	.245
Ph_5	-.287	-.577*	-.683**	.189	.258	.125	.185	.383	.182	.040	.226	-.300	-.219	.143
Ph_6	-.825**	.615*	-.737**	-.436	.662**	.571*	.609*	.585*	.463	-.607*	-.341	.069	.063	-.573*

*Significant at 5% level ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

Table 4.29. Correlation between harvest index of finger millet and weather variables in broadcasting

Stages	Tmax	Tmin	Tmean	TR	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	.310	-.409	.085	.302	-.399	-.478	-.474	-.330	-.470	.308	.516*	-.254	-.338	.455
Ph_2	.475	.728**	.513	.363	-.255	-.129	-.158	.439	.465	.186	-.022	-.186	-.097	.063
Ph_3	.396	.347	.438	.218	-.223	.103	.017	.285	.492	.284	-.222	-.151	-.051	.029
Ph_4	-.032	.482	.208	-.266	.398	.232	.309	.290	-.141	-.638*	.024	.273	.004	-.055
Ph_5	.002	.205	.174	-.111	-.014	-.154	-.101	-.199	-.169	-.448	-.028	.162	.108	-.159
Ph_6	.660**	-.198	.230	.505	-.695**	-.550*	-.607*	-.618*	-.449	.554*	.497	-.227	-.336	.722**

*Significant at 5% level ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

4.6.6. Correlation between weather variables and yield attributes of finger millet under dibbling method of sowing

4.6.5.1. Correlation between weather variables and number of ear heads per square meter for finger millet sown under dibbling method

Maximum and mean temperature showed positive correlation while forenoon relative humidity and rainfall showed negative correlation with the number of ear heads per m^2 during sowing to panicle initiation. Forenoon, afternoon and mean relative humidity, vapour pressure deficit, bright sunshine hours and wind speed showed positive correlation during panicle initiation to flag leaf, while maximum temperature, temperature range, rainy days and evaporation showed negative correlation during both the panicle initiation to flag leaf and flag leaf to fifty percent flowering stage. Forenoon, afternoon and mean relative humidity, bright sunshine hours and wind speed showed positive correlation during the flag leaf to fifty percent flowering stage. Wind speed was the only weather parameter that showed positive correlation during fifty percent flowering to milk stage, while maximum and mean temperature and temperature range showed negative correlation during the same stage. Rainy day and evaporation showed positive correlation with this yield attribute during milk stage to dough stage, while afternoon vapour pressure deficit, bright sunshine hours and wind speed showed negative correlation during the same stage. Only bright sunshine hours and wind speed showed negative correlation during dough stage to physiological maturity.

4.6.5.2. Correlation between weather variables and finger number per ear head for finger millet sown under dibbling method

Minimum temperature, forenoon, afternoon and mean relative humidity, forenoon and afternoon vapour pressure deficit, bright sunshine hours and wind speed showed positive correlation during sowing to panicle initiation. Maximum and mean temperature, temperature range, rainfall, rainy days and evaporation showed negative correlation with finger number per ear head during the same phenophase. Minimum temperature, afternoon vapour pressure deficit and rainfall showed negative correlation with this yield attribute during panicle initiation to flag leaf stage. Minimum temperature, forenoon and afternoon vapour pressure deficit showed negative correlation during flag leaf to 50% flowering. Rainfall and rainy days showed positive correlation, while forenoon relative humidity, bright sunshine hours and wind speed showed negative correlation for the yield attribute during 50% flowering to milk stage. Forenoon, afternoon and mean relative humidity and afternoon vapour pressure deficit showed positive correlation with this yield attributes during both the milk stage to dough stage and dough stage to physiological maturity, It also showed positive correlation with forenoon vapour pressure deficit during milk stage to dough stage. Mean temperature showed negative correlation with the same. Minimum temperature and bright sunshine hours also showed positive correlation with this yield attribute during dough stage to physiological maturity and mean temperature showed negative correlation with the same.

4.6.5.3. Correlation between weather variables and finger length for finger millet sown under dibbling method

Minimum temperature, forenoon, afternoon and mean relative humidity, forenoon and afternoon vapour pressure deficit, bright sunshine hours and wind speed showed positive correlation during sowing to panicle initiation. Maximum and temperature range, rainy days and evaporation showed negative correlation with finger length during the same phenophase. Forenoon relative humidity showed positive correlation with this yield attribute during panicle initiation to flag leaf stage. Maximum, minimum and mean temperature, temperature range, afternoon vapour pressure deficit and rainfall showed negative correlation with this yield attribute during panicle initiation to flag leaf stage. Maximum, minimum and mean temperature, forenoon and forenoon vapour pressure deficit showed negative correlation during flag leaf to 50% flowering. Rainfall and rainy days showed positive correlation, while forenoon relative humidity, bright sunshine hours and wind speed showed negative correlation for the yield attribute during 50% flowering to milk stage. Forenoon, afternoon and mean relative humidity and afternoon vapour pressure deficit showed positive correlation with this yield attributes during both the milk stage to dough stage and dough stage to physiological maturity, it also showed positive correlation with forenoon vapour pressure deficit during milk stage to dough stage. Mean temperature showed negative correlation with the same. Minimum temperature and bright sunshine hours also showed positive correlation with this yield attribute during dough stage to physiological maturity and maximum and mean temperature and rainfall showed negative correlation with the same.

4.6.5.4. Correlation between weather variables and thousand grain weight for finger millet sown under dibbling method

No significant correlation was observed between various weather variables with the thousand grain weight for all the phenophases from sowing to harvesting in finger millet sown under dibbling method.

4.6.5.5. Correlation between weather variables and straw yield for finger millet sown under dibbling method

Minimum temperature, afternoon and mean relative humidity, forenoon and afternoon vapour pressure deficit showed positive correlation during sowing to panicle initiation. Rainfall and rainy days showed negative correlation with straw yield during the same phenophase. Forenoon, afternoon and mean relative humidity and bright sunshine hours and wind speed showed positive correlation with this yield attribute during panicle initiation to flag leaf stage. Maximum, mean temperature, temperature range, rainy days and evaporation showed negative correlation with this yield attribute during panicle initiation to flag leaf stage. Only the bright sunshine hours and wind speed showed positive correlation during flag leaf to 50% flowering. While the maximum, minimum and mean temperature, temperature range and afternoon vapour pressure deficit showed negative correlation during flag leaf to 50% flowering. Rainfall showed positive correlation, while maximum and mean temperature showed negative correlation for the yield attribute during 50% flowering to milk stage. Minimum and mean temperature showed negative correlation during both milk stage to dough stage and dough stage to physiological maturity and also for maximum temperature in dough stage to physiological maturity.

4.6.5.6. Correlation between weather variables and harvest index for finger millet sown under dibbling method

Rainfall, rainy days and evaporation showed positive correlation during sowing to panicle initiation, while minimum temperature, afternoon and mean relative humidity, forenoon and afternoon vapour pressure deficit and bright sunshine hours showed negative correlation with harvest index during the same phenophase. Maximum, minimum and mean temperature along with temperature range showed positive correlation with this yield attribute during panicle initiation to flag leaf stage, but only the forenoon relative humidity showed negative correlation with harvest index during the same phenophase. Maximum, minimum and mean temperature and forenoon and afternoon vapour pressure deficit showed positive correlation with the harvest index during flag leaf to 50% flowering stages. Minimum temperature and bright sunshine hours showed positive correlation with this yield attribute during 50% flowering to milk stage, while rainfall was the only parameter that showed negative correlation. Only the mean temperature showed positive correlation during milk stage to dough stage. While the maximum and mean temperature, temperature range, rainfall and evaporation showed positive correlation during dough stage to physiological maturity. Minimum, forenoon, afternoon and mean relative humidity, forenoon and afternoon vapour pressure deficit showed negative correlation from dough stage to physiological maturity.

Table 4.30. Correlation between number of ear heads per m^2 of finger millet and weather variables in dibbling

Stages	Tmax	Tmin	Tmean	TR	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	.656**	.413	.804**	.211	-.518*	-.148	-.209	.510	.306	-.718**	.052	-.342	-.413	.295
Ph_2	-.515*	.061	-.500	-.611*	.555*	.795**	.765**	.526*	.505	.095	-.813**	.814**	.827**	-.803**
Ph_3	-.641*	-.108	-.513	-.621*	.660**	.785**	.797**	-.150	.244	.077	-.715**	.747**	.717**	-.803**
Ph_4	-.808**	-.017	-.775**	-.633*	.463	.395	.443	-.042	-.482	.147	-.461	.180	.688**	-.106
Ph_5	-.374	-.222	-.412	-.010	-.203	-.508	-.398	-.307	-.607*	-.079	.792**	-.679**	-.736**	.682**
Ph_6	-.374	.134	-.301	.060	-.094	-.211	-.177	-.059	-.323	-.103	.269	-.715**	-.681**	.081

*Significant at 5% level ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

Table 4.31. Correlation between finger number per ear head of finger millet and weather variables in dibbling

Stages	Tmax	Tmin	Tmean	TR	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	-.621*	.616*	-.283	-.726**	.740**	.832**	.832**	.524*	.678**	-.221	-.817**	.829**	.802**	-.774**
Ph_2	-.504	-.526*	-.508	-.408	.447	.011	.101	-.245	-.576*	-.595*	.196	-.038	-.202	.062
Ph_3	-.352	-.631*	-.511	.082	-.213	-.449	-.409	-.635*	-.801**	-.028	.356	.066	-.005	.334
Ph_4	.204	-.400	-.010	.342	-.723**	-.325	-.496	-.218	.026	.705**	.620*	-.824**	-.598*	.371
Ph_5	-.130	-.484	-.538*	.168	.567*	.543*	.573*	.713**	.685**	-.178	-.376	.273	.396	-.487
Ph_6	-.442	.626*	-.666**	-.328	.586*	.634*	.628*	.480	.636*	-.466	-.378	.562*	.462	-.432

*Significant at 5% level   ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

Table 4.32. Correlation between finger length of finger millet and weather variables in dibbling

Stages	Tmax	Tmin	Tmean	TR	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	-.603*	.797**	-.182	-.859**	.767**	.936**	.926**	.710**	.839**	-.402	-.938**	.904**	.851**	-.827**
Ph_2	-.678**	-.588*	-.679**	-.589*	.645**	.167	.269	-.198	-.554*	-.742**	.077	.104	-.093	-.084
Ph_3	-.521*	-.810**	-.705**	.037	-.177	-.381	-.347	-.821**	-.876**	.059	.259	.240	.161	.263
Ph_4	.081	-.408	-.133	.245	-.738**	-.243	-.447	-.187	-.009	.855**	.616*	-.960**	-.593*	.350
Ph_5	-.290	-.558*	-.735**	.118	.690**	.596*	.657**	.827**	.716**	-.269	-.316	.243	.362	-.473
Ph_6	-.559*	.723**	-.848**	-.308	.643**	.663**	.667**	.503	.642**	-.610*	-.337	.521*	.419	-.468

*Significant at 5% level ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

Table 4.33. Correlation between thousand grain weight of finger millet and weather variables in dibbling

Stages	Tmax	Tmin	Tmean	TR	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	-.140	-.168	-.214	-.120	.089	-.034	-.015	-.175	-.168	.234	.068	.085	.067	.018
Ph_2	.233	.155	.239	.227	-.144	-.232	-.220	-.085	-.014	-.134	.223	-.271	-.279	.222
Ph_3	.263	-.024	.185	.324	-.338	-.220	-.265	-.025	.028	.184	.118	-.190	-.144	.282
Ph_4	.208	.208	.298	.061	-.041	.039	.011	.206	.178	-.142	.133	-.092	-.265	-.070
Ph_5	-.022	.170	.058	-.147	.205	.232	.229	.167	.221	-.187	-.286	.328	.315	-.311
Ph_6	.279	-.098	.084	.198	-.148	-.104	-.120	-.194	-.054	.052	.122	.169	.140	.166

*Significant at 5% level   ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

Table 4.34. Correlation between straw yield of finger millet and weather variables in dibbling

Stages	Tmax	Tmin	Tmean	TR	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	.058	.903**	.484	-.405	.170	.583*	.527*	.906**	.867**	-.852**	-.662**	.374	.304	-.407
Ph_2	-.918**	-.461	-.913**	-.912**	.871**	.733**	.779**	.218	-.070	-.387	-.568*	.722**	.596*	-.674**
Ph_3	-.901**	-.621*	-.911**	-.534*	.467	.337	.393	-.653**	-.477	-.013	-.322	.731**	.632*	-.465
Ph_4	-.554*	-.410	-.733**	-.251	-.210	.051	-.046	-.267	-.401	.767**	.073	-.510	.154	.217
Ph_5	-.417	-.614*	-.801**	.156	.244	-.023	.089	.295	.007	-.132	.423	-.429	-.373	.261
Ph_6	-.776**	.641*	-.813**	-.288	.475	.392	.424	.420	.279	-.520*	-.139	-.168	-.201	-.371

*Significant at 5% level   ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

Table 4.35. Correlation between harvest index of finger millet and weather variables in dibbling

Stages	Tmax	Tmin	Tmean	TR	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	.323	-.756**	-.066	.504	-.496	-.730**	-.706**	-.684**	-.799**	.573*	.780**	-.505	-.527*	.639*
Ph_2	.779**	.769**	.802**	.681**	-.599*	-.365	-.422	.246	.468	.387	.159	-.388	-.248	.284
Ph_3	.687**	.592*	.747**	.345	-.289	.042	-.049	.567*	.693**	.218	-.109	-.386	-.263	.125
Ph_4	.144	.582*	.428	-.165	.513	.227	.350	.366	.081	-.868**	-.172	.558*	.078	-.232
Ph_5	.170	.503	.540*	-.199	-.217	-.199	-.214	-.393	-.264	-.204	-.100	.221	.131	-.095
Ph_6	.833**	-.538*	.617*	.532*	-.771**	-.665**	-.710**	-.684**	-.559*	.645**	.477	-.213	-.242	.709**

*Significant at 5% level ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

4.6.6. Correlation between weather variables and yield attributes of finger millet under transplanting method of sowing

4.6.6.1. Correlation between weather variables and number of ear heads per square meter for finger millet sown under transplanting method

Mean temperature and forenoon vapour pressure deficit showed positive correlation with the number of ear heads per m^2 during sowing to panicle initiation. Forenoon, afternoon and mean relative humidity, bright sunshine hours and wind speed showed positive correlation during panicle initiation to flag leaf, while maximum temperature, temperature range, rainy days and showed negative correlation during both the panicle initiation to flag leaf and flag leaf to 50% flowering stage. Evaporation also showed negative correlation during panicle initiation to flag leaf stage. Forenoon and mean relative humidity and wind speed showed positive correlation while the mean temperature also showed negative correlation with this yield attribute in flag leaf to 50% flowering stage. Only the rainy day showed positive correlation during the 50% flowering to milk stage and maximum temperature, temperature range and bright sunshine hours showed negative correlation with the same. Temperature range, rainy day and evaporation showed positive correlation during milk stage to dough stage, while minimum and mean temperature showed negative correlation during the same stage. Minimum temperature was the only parameter that showed negative correlation with this yield attribute during dough to physiological maturity stage.

4.6.6.2. Correlation between weather variables and finger number per ear head for finger millet sown under transplanting method

Minimum temperature, forenoon, afternoon and mean relative humidity, forenoon and afternoon vapour pressure deficit, bright sunshine hours and wind speed showed positive correlation during sowing to panicle initiation. Maximum and temperature range, rainfall, rainy days and evaporation showed negative correlation with finger number per ear head during the same phenophase. Minimum and mean temperature, forenoon afternoon vapour pressure deficit showed negative correlation with this yield attribute during panicle initiation to flag leaf stage. Rainfall was the only parameter that showed positive correlation while minimum temperature and bright sunshine hours showed negative correlation during flag leaf to 50% flowering. Afternoon and mean relative humidity and forenoon and afternoon vapour pressure deficit showed positive correlation, while mean temperature and evaporation showed negative correlation for the yield attribute during 50% flowering to milk stage. Forenoon, afternoon and mean relative humidity, forenoon and afternoon vapour pressure deficit showed positive correlation with this yield attributes during both the milk stage to dough stage and dough stage to physiological maturity, while maximum temperature showed negative correlation during milk stage to dough stage. Maximum temperature, temperature range and rainy days showed negative correlation with this yield attribute during dough stage to physiological maturity.

4.6.6.3. Correlation between weather variables and finger length for finger millet sown under transplanting method

Minimum temperature, forenoon, afternoon and mean relative humidity, forenoon and afternoon vapour pressure deficit, bright sunshine hours and wind speed showed positive correlation during sowing to panicle initiation. Maximum and temperature range, rainfall, rainy days and evaporation showed negative correlation with finger length during the same phenophase. Maximum, minimum and mean temperature, forenoon and afternoon vapour pressure deficit showed negative correlation with this yield attribute during panicle initiation to flag leaf stage. Rainfall showed positive correlation while the minimum temperature and bright sunshine hours showed negative correlation with this yield attribute during flag leaf stage to 50% flowering stage. Maximum, Minimum and mean temperature, temperature range, afternoon vapour pressure deficit and rainfall showed negative correlation with this yield attribute during panicle initiation to flag leaf stage. Minimum temperature and bright sunshine hours showed negative correlation during flag leaf to 50% flowering. Forenoon, afternoon and mean relative humidity and forenoon and afternoon vapour pressure deficit showed positive correlation with this yield attributes during 50% flowering to milk stage, milk stage to dough stage and dough stage to physiological maturity. Minimum and mean temperature, rainy days and evaporation showed negative correlation for the 50% flowering to milk stage. Wind speed also showed positive correlation during milk stage to dough stage with this yield attribute, while the maximum temperature and rainfall showed negative correlation. Maximum temperature and temperature range, rainy days and rainfall showed negative correlation with finger length during dough stage to physiological maturity.

4.6.6.4. Correlation between weather variables and thousand grain weight for finger millet sown under transplanting method

No significant correlation was observed between various weather variables with the thousand grain weight for all the phenophases from sowing to harvesting in finger millet sown under transplanting method.

4.6.6.5. Correlation between weather variables and straw yield for finger millet sown under transplanting method

Minimum temperature, afternoon and mean relative humidity, forenoon and afternoon vapour pressure deficit showed positive correlation during sowing to panicle initiation. Rainfall, rainy days and evaporation showed negative correlation with straw yield during the same phenophase. Forenoon relative humidity and bright sunshine hours showed positive correlation with this yield attribute during panicle initiation to flag leaf stage. Maximum, minimum, mean temperature, temperature range, forenoon vapour pressure deficit and evaporation showed negative correlation with this yield attribute during panicle initiation to flag leaf stage. Rainfall and wind speed showed positive correlation during flag leaf to 50% flowering, while the minimum and mean temperature showed negative correlation during flag leaf to 50% flowering. Forenoon vapour pressure deficit showed positive correlation, while maximum and mean temperature showed negative correlation for the yield attribute during 50% flowering to milk stage, milk stage to dough stage and dough stage to physiological maturity, while rainfall also showed negative correlation with the straw weight during dough stage to physiological maturity.

4.6.6.6. Correlation between weather variables and harvest index for transplanted finger millet

Weather parameters didn’t shown any specific correlation during sowing to panicle initiation stage. Rainfall was the only weather parameter that showed a positive correlation with the harvest index during panicle initiation stage to flag leaf stage. Coming to the third stage, minimum temperature showed a positive correlation with the harvest index and rainfall showed a negative correlation with the same. There is no any correlation has been observed in case of 50% flowering stage to milk stage. During the milk stage to dough stage, maximum temperature and rainfall showed positive correlation with the harvest index, while forenoon and mean relative humidity and forenoon vapour pressure deficit showed negative correlation. Maximum and mean temperature showed positive correlation with the harvest index during dough stage to physiological maturity, while bright sunshine hours and wind speed showed negative correlation with the same.

Table 4.36. Correlation between number of ear heads per m^2 of finger millet and weather variables in transplanting

Stages	Tmax	Tmin	Tmean	TR	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	.454	.336	.678**	.215	-.304	.009	-.043	.517*	.439	-.356	-.119	-.151	-.324	.148
Ph_2	-.626*	-.047	-.509	-.711**	.714**	.779**	.778**	-.103	.413	-.014	-.736**	.719**	.682**	-.767**
Ph_3	-.718**	-.188	-.676**	-.559*	.658**	.509	.575*	-.270	-.217	.485	-.541*	.178	.753**	-.255
Ph_4	-.719**	.397	-.458	-.696**	.002	-.277	-.158	-.053	-.495	-.095	.586*	-.607*	-.478	.312
Ph_5	-.196	-.760**	-.671**	.643**	-.037	-.452	-.309	-.212	-.482	-.092	.732**	-.426	-.501	.608*
Ph_6	-.085	-.514*	-.412	.282	-.150	-.332	-.265	-.121	-.361	-.013	.394	-.401	-.446	.169

*Significant at 5% level   ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

Table 4.37. Correlation between finger numbers per ear head of finger millet and weather variables in transplanting

Stages	Tmax	Tmin	Tmean	TR	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	-.634*	.652**	-.364	-.740**	.712**	.766**	.768**	.544*	.614*	-.596*	-.753**	.690**	.664**	-.735**
Ph_2	-.469	-.668**	-.583*	-.232	.067	-.020	-.004	-.660**	-.646**	-.373	.057	.222	.033	-.017
Ph_3	-.124	-.545*	-.350	.183	-.258	.068	-.007	-.178	.166	.568*	.039	-.590*	.000	.045
Ph_4	-.165	-.473	-.540*	.086	.413	.645**	.576*	.674**	.581*	-.135	-.418	.085	.298	-.566*
Ph_5	-.752**	-.029	-.352	-.401	.683**	.613*	.681**	.605*	.582*	-.471	-.126	.364	.417	-.286
Ph_6	-.748**	.199	-.429	-.698**	.581*	.673**	.658**	.664**	.646**	-.514	-.670**	.292	.327	-.372

*Significant at 5% level ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

Table 4.38. Correlation between finger length of finger millet and weather variables in transplanting

Stages	Tmax	Tmin	Tmean	TR	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	-.762**	.860**	-.402	-.922**	.885**	.965**	.964**	.724**	.803**	-.791**	-.948**	.891**	.822**	-.904**
Ph_2	-.603*	-.885**	-.761**	-.285	.065	.012	.022	-.887**	-.765**	-.356	.037	.329	.115	-.042
Ph_3	-.231	-.612*	-.461	.120	-.236	.139	.057	-.136	.164	.684**	.035	-.797**	-.002	-.014
Ph_4	-.233	-.639*	-.739**	.108	.599*	.801**	.759**	.882**	.724**	-.297	-.523*	.108	.392	-.760**
Ph_5	-.935**	-.097	-.492	-.438	.793**	.713**	.791**	.666**	.674**	-.539*	-.115	.479	.524*	-.277
Ph_6	-.894**	.304	-.472	-.879**	.647**	.810**	.769**	.818**	.781**	-.563*	-.800**	.257	.304	-.433

*Significant at 5% level   ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

Table 4.39. Correlation between thousand grain weight of finger millet and weather variables in transplanting

Stages	Tmax	Tmin	Tmean	TR	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	.107	-.183	.017	.150	-.128	-.198	-.189	-.204	-.217	.205	.221	-.086	-.095	.176
Ph_2	.274	.128	.253	.261	-.238	-.141	-.161	.113	.139	.287	.143	-.179	-.084	.188
Ph_3	.091	.305	.227	-.083	.043	-.105	-.075	.249	-.124	-.336	.157	.024	-.209	-.018
Ph_4	.216	-.081	.175	.192	.001	-.142	-.081	-.123	-.032	-.157	-.025	.110	.042	-.026
Ph_5	.284	.109	.197	.054	-.314	-.142	-.222	-.288	-.121	.294	-.105	.096	.056	.082
Ph_6	.316	.209	.371	.098	-.244	-.138	-.188	-.146	-.112	.261	.145	-.195	-.184	.064

*Significant at 5% level ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

Table 4.40 Correlation between straw yield of finger millet and weather variables in broadcasting

Stages	Tmax	Tmin	Tmean	TR	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	-.287	.743**	.073	-.508	.434	.670**	.639*	.774**	.791**	-.765**	-.729**	.450	.348	-.544*
Ph_2	-.836**	-.600*	-.848**	-.694**	.563*	.478	.501	-.604*	-.332	-.443	-.453	.658**	.450	-.541*
Ph_3	-.513	-.661**	-.731**	-.112	.129	.425	.378	-.399	.151	.872**	-.402	-.357	.525*	-.140
Ph_4	-.652**	-.057	-.745**	-.449	.325	.438	.414	.553*	.178	-.049	.001	-.287	-.022	-.217
Ph_5	-.833**	-.485	-.733**	.006	.699**	.294	.480	.528*	.238	-.627*	.374	-.066	-.032	.029
Ph_6	-.794**	-.289	-.787**	-.404	.474	.382	.436	.473	.328	-.515*	-.368	.163	.153	-.165

*Significant at 5% level   ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

Table 4.41. Correlation between harvest index of finger millet and weather variables in transplanting

Stages	Tmax	Tmin	Tmean	TR	RHI	RHII	RHm	VPDI	VPDII	RF	RD	BSS	WS	Epan
Ph_1	.328	-.239	.224	.335	-.324	-.365	-.363	-.239	-.285	.341	.379	-.160	-.232	.354
Ph_2	.382	.251	.372	.328	-.288	-.076	-.117	.188	.374	.566*	.128	-.182	-.011	.196
Ph_3	-.027	.535*	.248	-.318	.269	-.144	-.053	.401	-.421	-.549*	.259	.092	-.230	-.029
Ph_4	.281	-.119	.229	.255	-.022	-.397	-.239	-.275	-.179	-.362	.125	.005	-.094	-.010
Ph_5	.531*	.015	.221	.289	-.690**	-.399	-.545*	-.676**	-.357	.661**	-.049	.168	.050	.380
Ph_6	.633*	.357	.697**	.238	-.502	-.331	-.417	-.261	-.281	.486	.388	-.574*	-.554*	.081

*Significant at 5% level ** Significant at 1% level

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 – 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

4.6.7. Correlation analysis of heat units and crop duration

The influence of heat units like Accumulated Growing Degree Days (AGDD), Accumulated Helio Thermal Units (AHTU) and Accumulated Photo Thermal Units (APTU) on the duration of crop growth in three different planting methods were measured using correlation analysis. The influence of heat units on the duration of each phenophases from sowing to harvesting was also calculated. The results are given below:

4.6.7.1. Effect of heat units on crop duration of finger millet in different methods of planting

The output of correlation analysis done between the heat units and phenophases of finger millet cultivated under different planting method such as broadcasting, dibbling and transplanting are given in the Table 4.42, 4.43 and 4.44 respectively.

4.6.7.1.1. Correlation between heat units and duration of broadcasted finger millet

AHTU showed negative correlation with the duration of finger millet during sowing to panicle initiation stage. But at the same time, AHTU showed positive correlation with the same during 50% flowering to milk stage and dough stage to physiological maturity. The remaining two parameters, AGDD and APTU showed significant positive correlation during all the growth stages from sowing to physiological maturity.

4.6.7.1.2. Correlation between heat units and duration of finger millet under dibbling method

AHTU showed negative correlation with the duration of finger millet during sowing to panicle initiation stage. But at the same time, AHTU showed positive correlation with the same during 50% flowering to milk stage and dough stage to physiological maturity. The remaining two parameters, AGDD and APTU showed significant positive correlation during all the growth stages from sowing to physiological maturity.

4.6.7.1.3. Correlation between heat units and duration of finger millet under transplanting method

AGDD and APTU showed significant positive correlation during most of the growth stages from sowing to physiological maturity except the second phenophase which was from panicle initiation to flag leaf stage. AHTU also showed significant positive correlation with the duration of finger millet during flag leaf to 50% flowering, 50 % flowering to milk stage and milk stage to dough stage.

Table 4.42. Correlation between duration of finger millet and heat units in broadcasting

Stages	AGDD	AHTU	APTU
Ph_1	.980**	-.639*	.974**
Ph_2	.860**	.124	.908**
Ph_3	.975**	-.063	.962**
Ph_4	.991**	.563*	.986**
Ph_5	.969**	.063	.998**
Ph_6	.998**	.749**	.999**

Table 4.43. Correlation between duration of finger millet and heat units in dibbling

Stages	AGDD	AHTU	APTU
Ph_1	.980**	-.639*	.974**
Ph_2	.860**	.124	.908**
Ph_3	.975**	-.063	.962**
Ph_4	.991**	.563*	.986**
Ph_5	.969**	.063	.998**
Ph_6	.998**	.749**	.999**

Table 4.44. Correlation between duration of finger millet and heat units in transplanting

Stages	AGDD	AHTU	APTU
Ph_1	.987**	-.305	.982**
Ph_2	-.337	-.163	-.363
Ph_3	.928**	.725**	.957**
Ph_4	.982**	.879**	.998**
Ph_5	.993**	.866**	.998**
Ph_6	.977**	.229	.995**

*Significant at 5% level ** Significant at 1% level

Ph_1 – Sowing to panicle initiation

Ph_2 – Panicle initiation to flag leaf stage

Ph_3 – Flag leaf stage to 50% flowering

Ph_4 – 50% flowering to milk stage

Ph_5 – Milk stage to dough stage

Ph_6 – Dough stage to physiological maturity

4.6.8. Correlation analysis of heat units and crop yield

The influence of heat units like Accumulated Growing Degree Days (AGDD), Helio Thermal Units (AHTU) and Photo Thermal Units (APTU) on the yield of crop in three different planting methods were measured using correlation analysis. The influence of heat units at each phenophases from sowing to harvesting on the grain yield was calculated. The results are given below:

4.6.8.1. Effect of heat units on crop yield of finger millet in different methods of planting

The output of correlation analysis done between the heat units at each phenophases with the grain yield of finger millet cultivated under different planting method such as broadcasting, dibbling and transplanting are given in the Table 4.45, 4.46 and 4.47 respectively.

4.6.8.1. Correlation between heat units and grain yield of broadcasted finger millet

AGDD and APTU showed positive correlation with the grain yield during sowing to panicle initiation, flag leaf to 50 % flowering and 50 % flowering to milk stage. APTU showed positive correlation with the grain yield from panicle initiation to flag leaf stage and milk stage to dough stage also. AHTU showed positive correlation with the grain yield during 50% flowering to milk stage. Negative correlation with grain yield has been observed during dough stage to physiological maturity for all the heat units. AHTU showed negative correlation with the grain yield of finger millet during sowing to panicle initiation stage also.

4.6.8.2. Correlation between heat units and grain yield of finger millet under dibbling method

AGDD and APTU showed significant positive correlation during the growth stages from flag leaf to 50% flowering and 50% flowering to milk stage. APTU showed positive correlation during sowing to panicle initiation stage also. Negative correlation with grain yield has been observed during dough stage to physiological maturity for all the heat units. AHTU showed negative correlation with the grain yield of finger millet during sowing to panicle initiation stage in dibbling method.

4.6.8.3. Correlation between heat units and grain yield of transplanted finger millet

AGDD and APTU showed significant positive correlation with the grain yield during dough stage to physiological maturity. APTU showed positive correlation with the grain yield during 50% flowering to flag leaf stage also. AGDD and APTU showed significant negative correlation during panicle initiation to flag leaf stage. AHTU showed negative correlation with the grain yield during sowing to panicle initiation stage.

4.6.9. Regression equation

Regression equation for forecasting the grain yield using the weather during a particular phenophase of finger millet along with the adjusted R square are calculated and given here. Regression equation for the phenophase sowing to panicle initiation is:

Y=-116306.637+5223.313TMIN

(Adjusted R^2 = 0.785)

Regression equation for the phenophase panicle initiation to flag leaf stage is:

Y=14981.649-501.219TMIN-1558.271DTR+1743.266WS+2816.840EVP

(Adjusted R^2 = 0.752)

Regression equation for the phenophase flag leaf to fifty percent flowering stage is:

Y=68203.807-2393.629Tmean-282.539RD

(Adjusted R^2 = 0.786)

Regression equation for the phenophase milk stage to dough stage is:

Y=140899.142-3765.858TMAX-191.016RHI

(Adjusted R^2 = 0.753)

Regression equation for the phenophase dough stage to physiological maturity is:

Y=9976.494+1611.685VPI-1375.830VPII-1657.381DTR

(Adjusted R^2 = 0.764)

Table 4.45. Correlation between grain yield of finger millet and heat units in broadcasting

Stages	AGDD	AHTU	APTU
Ph_1	.637*	-.618*	.657**
Ph_2	.493	-.142	.583*
Ph_3	.611*	.086	.623*
Ph_4	.610*	.778**	.629*
Ph_5	.464	.179	.580*
Ph_6	-.589*	-.595*	-.587*

Table 4.46. Correlation between grain yield of finger millet and heat units in dibbling

Stages	AGDD	AHTU	APTU
Ph_1	.510	-.689**	.540*
Ph_2	.388	-.193	.478
Ph_3	.727**	.130	.734**
Ph_4	.699**	.726**	.716**
Ph_5	.261	.240	.407
Ph_6	-.567*	-.666**	-.561*

Table 4.47. Correlation between grain yield of finger millet and heat units in transplanting

Stages	AGDD	AHTU	APTU
Ph_1	.302	-.809**	.368
Ph_2	-.810**	-.331	-.773**
Ph_3	.462	.206	.583*
Ph_4	.067	.013	.178
Ph_5	-.424	-.060	-.366
Ph_6	.744**	.320	.802**

*Significant at 5% level ** Significant at 1% level

Ph_1 – Sowing to panicle initiation

Ph_2 – Panicle initiation to flag leaf stage

Ph_3 – Flag leaf stage to 50% flowering

Ph_4 – 50% flowering to milk stage

Ph_5 – Milk stage to dough stage

Ph_6 – Dough stage to physiological maturity

4.5. Biometric observations

4.5.1. Plant height at fortnightly interval

Effect of dates of planting on plant height with respect to the different planting methods has been studied by taking the plant height observations at fortnightly intervals. The results showed that the May 15th planting showed the highest plant height in most of the cases except observations taken at 75 and 90 days after sowing. Even though the July 15th planting showed similar plant height with June 1st planting at initial observations, it showed a huge decreasing trend in plant height towards the end of the growing period. Results of ANOVA performed for plant height at fortnightly intervals up to harvest stage are represented in Appendix II.

Table 4.51 and 4.52 showed the effect of different dates of planting and planting method on the plant height respectively. According to ANOVA, significant differences in plant height with respect to planting dates and irrespective to planting methods are observed in most of the observations. Plant height showed a clearly decreasing trend in observations made on 30 days after sowing with delay in planting in which the lowest height has been observed in 15th July and June 1st planting. The remaining observations follows an irregular trend for the plant height. No significant difference in plant height with respect to planting dates was observed at 60 and 90 days after sowing irrespective to the planting methods.

Considering the effect of planting method on plant height, significant difference was observed in 30, 45 and 60 days after sowing. The remaining period showed no significant difference in plant height with respect to planting method. Even though it showed an irregular trend in ranking the plant height with respect to the planting method, the highest plant height was observed in broadcasting which was on par with dibbling for the first two fortnightly intervals. Observation on third fortnightly interval showed highest plant height for dibbling method.

The interaction effect of dates of planting and planting method on the height at 30 days after sowing showed that for the May 15th planting, the broadcasting and dibbling methods which was on par with each other, have more height compared to the transplanting method. But coming to the last date of planting (July 15th), interaction effect in broadcasting method have comparatively less plant height than that of dibbling and transplanting method. Interaction effect of date of planting and planting method on the height at 75 days after sowing showed that except the July 1st planting, broadcasting showed the higher height which was on par with dibbling on May 15th planting compared to the transplanting method in all the remaining dates. Interaction effect of date of planting and planting method on the height at 90 days after sowing showed that, broadcasting showed more plant height than the remaining two in May 15th and June 15th planting, while it showed the lowest height on June 1st and July 1st planting. Dibbling have the highest height on June 1st and July 1st planting and transplanting showed the highest height on July 15th planting compared with the other two methods. Interaction effect of date of planting and planting method on the height at harvest, it showed that except June 1st planting, broadcasting have the highest height compared to other planting methods. June 1st planting showed the highest height with dibbling and transplanting method which was on par with each other. Table 4.53 showed the interaction effect of dates of planting and planting method with plant height.

Table 4.48. Effect of dates of planting on plant height of finger millet

Date of planting	Height 30 DAS	Height 45 DAS	Height 60 DAS	Height 75 DAS	Height 90 DAS	Height at harvest
15th May	57.10[a]	80[a]	99.94	110.77[a]	123.95	45.73[a]
1st June	25.85[d]	51.84[b]	79.47	96.69[b]	129.51	42.86[a]
15th June	41.92[b]	71.57[a]	83.86	127.05[a]	130.96	43.81[a]
1st July	32.76[c]	41.45[b]	71.31	86.55[b]	85.94	29.34[ab]
15th July	22.95[d]	25.36[c]	44.45	54.32[c]	54.18	20.33[b]
CD	6.69	11.29	NS	18.30	NS	21.10

Table 4.49. Effect of planting method on plant height of finger millet

Planting method	Height 30 DAS	Height 45 DAS	Height 60 DAS	Height 75 DAS	Height 90DAS	At harvest
Broadcasting	37.64[a]	54.91[a]	72.32[b]	96.86	104.55	105.80
Dibbling	37.86[a]	57.25[a]	79.53[a]	94.32	105.36	105.16
Transplanting	32.85[b]	49.98[b]	75.57[ab]	94.04	104.81	109.25
CD	3.46	3.46	4.85	NS	NS	NS

Table 4.50. Interaction effect of dates of planting and planting method on plant height of finger millet

Date of planting	Height 90 DAS			Height at harvest		
	P1	P2	P3	P1	P2	P3
15th May	131.16^{a}	124.49^{b}	116.20^{c}	129.43^{a}	133.07^{a}	137.19^{a}
1st June	114.91^{c}	141.45^{a}	132.17^{b}	118.28^{b}	137.26^{a}	128.59^{a}
15th June	142.63^{a}	119.87^{c}	130.37^{b}	142.93^{a}	120.87^{b}	131.43^{a}
1st July	81.21^{c}	91.19^{a}	85.43^{b}	85.40^{a}	85.43^{a}	88.03^{a}
15th July	52.83^{b}	49.80^{c}	59.90^{a}	52.93^{a}	49.17^{a}	61.00^{a}
CD	14.01			0.01		

Date of planting	Height 30 DAS			Height 75 DAS		
	P1	P2	P3	P1	P2	P3
15th May	68.39^{a}	61.47^{a}	41.45^{b}	121.03^{a}	109.37^{ab}	101.90^{b}
1st June	25.92^{a}	26.90^{a}	24.74^{a}	93.35^{a}	98.75^{a}	97.97^{a}
15th June	45.21^{a}	39.15^{a}	41.42^{a}	139.24^{a}	121.48^{b}	120.44^{b}
1st July	32.15^{a}	33.83^{a}	32.29^{a}	78.11^{b}	88.27^{ab}	93.28^{a}
15th July	16.53^{b}	27.97^{a}	24.34^{a}	52.59^{a}	53.76^{a}	56.60^{a}
CD	7.73			13.10		

P1-Broadcasting P2- Dibbling P3- Transplanting

4.5.2. Dry matter accumulation at fortnightly interval

Dry matter accumulation observation has been taken by taking the dry weight of the plants at fortnightly interval. The effects of dates of planting and planting methods on the dry matter observation has been studied. Table 4.54 and 4.55 showed the effect of five dates of planting and planting method on dry matter accumulation respectively. According to the ANOVA, significant differences in plant height with respect to planting dates are observed in most of all the observations. The observations followed an irregular trend for the dry matter accumulation at fortnightly intervals. Considering the effect of dates of planting on dry matter accumulation irrespective to the planting method, the results showed that the observation taken at 30, 75 and 90 days after sowing showed that May 15th planting had the highest dry matter accumulation. Dry matter accumulation at 45 and 60 days after sowing was highest for June 15th planting and the remaining observations are on par with each other. The observation at harvest revealed that the highest dry matter accumulation was observed in June 1st and June 15th planting. Results of ANOVA performed for dry matter accumulation at fortnightly intervals up to harvest stage are represented in Appendix II.

Considering the effect of planting method on dry matter accumulation, significant difference was observed in every observations. In all the observations, highest dry matter accumulation was observed on broadcasting method. The other two dibbling and transplanting methods were on par with each other for all the observation.

The interaction effect of dates of planting and planting method on the dry matter accumulation was observed on 45 and 60 days after sowing. Interaction effects at 45 days after sowing showed that for the June 15th planting, the broadcasting methods have the highest dry matter accumulation compared to the other two methods. Interaction effect of date of planting and planting method on the height at 60 days after sowing showed that in most of the planting dates broadcasting showed the highest values compared to the other two methods. In case of July 1st and July 15th planting, broadcasting which was on par with dibbling showed the highest dry matter accumulation. In case of 15th June planting, highest dry matter accumulation was observed on dibbling method and lowest on broadcasting method. Table 4.56 shows the interaction effect of dates of planting and planting method with dry matter accumulation.

Table 4.51. Effect of dates of planting on dry matter accumulation (kg ha^{-1}) of finger millet

Date of planting	**Dry matter accumulation 30 DAS**	**Dry matter accumulation 45 DAS**	**Dry matter accumulation 60 DAS**	**Dry matter accumulation 75 DAS**	**Dry matter accumulation 90DAS**	**At harvest**
15th May	474.14^{a}	1279.22^{b}	5682.24^{b}	24451.14^{a}	46749.54^{a}	13990.63b
1st June	151.26^{b}	770.97^{b}	2834.93^{b}	23307.09^{a}	9400.23^{b}	31932.81a
15th June	141.34^{b}	4496.66^{a}	16836.37^{a}	8978.19^{b}	20228.71^{b}	41631.28a
1st July	299.97^{b}	735.22^{b}	4282.64^{b}	13490.67b^{c}	15314.69^{b}	11327.28b
15th July	149.00^{b}	552.64^{b}	2348.89^{b}	5290.85^{c}	15383.55^{b}	9929.62b
CD	159.71	872.76	4092.19	6310.32	7446.66	10333.16

Table 4.52. Effect of planting method on dry matter accumulation of finger millet

Planting method	**Dry matter accumulation 30 DAS**	**Dry matter accumulation 45 DAS**	**Dry matter accumulation 60 DAS**	**Dry matter accumulation 75 DAS**	**Dry matter accumulation 90DAS**	**At harvest**
Broadcasting	404.16^{a}	2858.52^{a}	11573.08^{a}	23401.17^{a}	33163.99^{a}	32203..87^{a}
Dibbling	164.88^{b}	1073.88^{b}	3856.68^{b}	11223.54^{b}	16115.94^{b}	15503.94^{b}
Transplanting	160.38^{b}	768.42^{b}	3761.28^{b}	10686.06^{b}	14966.10^{b}	17579.16^{b}
CD	108.73	637.15	6328.91	5262.69	4654.86	5325.15

Table 4.53. Interaction effect of date of planting and planting method with dry matter accumulation of finger millet

Date of planting	Dry matter accumulation at 45 DAS			Dry matter accumulation at 60 DAS		
	P1	**P2**	**P3**	**P1**	**P2**	**P3**
15th May	1994.45[a]	1168.20[a]	675.00[a]	11573.08[a]	3939.30[b]	3572.10[b]
1st June	1401.20[a]	363.60[a]	548.10[a]	3856.68[a]	1356.30[a]	2841.30[a]
15th June	9088.97[a]	2705.40[b]	1695.60[b]	3761.28[c]	10226.70[a]	6655.50[b]
1st July	1235.47[a]	515.70[a]	454.50[a]	6437.23[a]	2747.70[b]	3663.00[ab]
15th July	572.53[a]	616.50[a]	468.90[a]	3958.77[a]	1013.40[b]	2074.50[ab]
CD	1424.70			2830.38		

P1-Broadcasting P2- Dibbling P3- Transplanting

4.5.3. Crop growth rate at fortnightly intervals

Crop growth rate indicates the intensity at which the plant growth takes place. This was measured by analyzing the accumulation of dry matter at each particular interval of time period. In order to analyze the effect of different dates of planting and planting method, analysis of variance was carried out for crop growth rate at fortnightly interval. The results are given in the Appendix II.

Considering the effect of different dates of planting, irrespective to the planting method, it showed significant relation in almost all observations. Table 4.57 showed the crop growth rate at fortnightly intervals for different dates of planting. In most of the cases, May 15th planting was considered superior to all other plantings. June 1st and July 15th planting was inferior to all other plantings in most of the cases except 60-75, 75-90 and 90-105 days after sowing. Considering the effect of planting method on the crop growth rate, there was no any significant relation was able to found in all the observations. Table 4.58 indicates the effect of planting method on the crop growth rate.

The interaction effect of dates of planting with respect to planting method was found non-significant in almost all the cases except 90-105 DAS. The interaction effect showed that in May 15th planting, broadcasting method was found superior to all other plantings, while in case of July 1st planting, it was found inferior to all other plantings. In July 1st planting, both dibbling and transplanting was found on par with each other. Interaction effect of date of planting and planting method with crop growth rate was given in the Table 4.59.

4.5.4. Relative growth rate at fortnightly intervals

Relative growth rate is also a growth indicating parameter which indicates the amount at which the plant growth takes place in comparison with initial growth. This was also measured by analyzing the accumulation of dry matter at each particular interval of time period with respect to the initial dry matter accumulation. In order to analyze the effect of different dates of planting and planting method, analysis of variance was carried out for crop growth rate at fortnightly interval. The results are given in the Appendix II.

Table 4.60 showed the relative growth rate at fortnightly intervals for different dates of planting. The result showed that significant effect of planting dates irrespective to the planting method are observed in almost all the cases except 30-45 and 45-60 days after sowing. May 15th planting was found superior to all other plantings in case of 15-30 and 60-75. Even though June 15th planting was found superior to all other plantings in case of 30-45 and 75-90 DAS, it was inferior to all other plantings in case of 15-30 and 60-75 DAS. July 1st and July 15th planting was found inferior to all other plantings in case of 30-45 and 60-75 days after sowing. July 15th planting was found inferior to all other plantings except 75-90 days after sowing. Considering the effect of planting method on the relative growth rate, there was no any significant relation was able to found in all the observations. Table 4.61 indicates the effect of planting method on the relative growth rate.

The interaction effects of dates of planting and planting method with the RGR was studied and the result showed significant effect in case of 15-30 and 90-105 DAS. The interaction effect showed that broadcasting and dibbling was found superior to transplanting in case of June 1st and June 15th date of planting at 15-30 DAS. In case of 90-105 DAS, the broadcasting method was found superior to all other methods in May 15th planting, but coming to July 1st planting the broadcasting method was found inferior to all other methods. Interaction effect of date of planting and planting method with relative growth rate was given in the Table 4.62.

Table 4.54. Effect of dates of planting on CGR (g m^{-2} day^{-1}) of finger millet

Date of planting	CGR 15-30 DAS	CGR 30-45 DAS	CGR 45-60 DAS	CGR 60-75 DAS	CGR 75- 90 DAS	CGR 90-105 DAS
15th May	1.99^{a}	4.50^{b}	21.14^{b}	89.29^{a}	114.91^{a}	-130.50^{e}
1st June	0.54^{bc}	2.83^{b}	10.26^{b}	101.48^{a}	70.47^{b}	23.62^{a}
15th June	0.37^{c}	18.54^{a}	53.13^{a}	54.84^{b}	53.81^{b}	10.85^{b}
1st July	1.26^{ab}	2.03^{b}	17.40^{b}	44.00^{b}	10.86^{c}	1.81^{b}
15th July	0.71^{bc}	2.19^{b}	7.95^{b}	12.27^{c}	48.78^{b}	-26.43^{d}
CD	0.80	3.96	18.11	26.97	32.79	11.12

Table 4.55. Effect of planting methods on CGR (g m^{-2} day^{-1}) of finger millet

Planting method	CGR 15-30 DAS	CGR 30-45 DAS	CGR 45-60 DAS	CGR 60-75 DAS	CGR 75- 90 DAS	CGR 90-105 DAS
Broadcasting	1.10	8.07	27.42	37.22	30.72	14.30
Dibbling	0.93	5.98	18.80	48.51	32.21	14.06
Transplanting	0.89	4.00	19.70	45.60	28.18	10.04
CD	NS	NS	NS	NS	NS	NS

Table 4.56. Interaction effect of date of planting and planting methods on CGR (g m^{-2} day^{-1}) of finger millet

Date of planting	**Crop Growth Rate 90-105 DAS**		
	P1	**P2**	**P3**
15th May	-64.68^{a}	-180.96^{b}	-145.87^{b}
1st June	16.03^{a}	24.42^{a}	30.43^{a}
15th June	8.57^{ab}	10.54^{a}	13.44^{b}
1st July	-31.38^{b}	21.67^{a}	11.52^{a}
15th July	-26.03^{a}	-29.40^{a}	-23.85^{a}
CD	61.06		

P1-Broadcasting   P2- Dibbling   P3- Transplanting

Table 4.57. Effect of dates of planting on RGR (mg g^{-1} day^{-1}) of finger millet

Date of planting	RGR 15-30 DAS	RGR 30-45 DAS	RGR 45-60 DAS	RGR 60-75 DAS	RGR 75- 90 DAS	RGR 90-105 DAS
15th May	0.16^{a}	0.07^{b}	0.09	0.10^{ab}	0.01^{b}	-0.05^{b}
1st June	0.12^{ab}	0.11^{b}	0.09	0.14^{a}	0.08^{a}	0.04^{a}
15th June	0.06^{b}	0.22^{a}	0.09	-0.01^{c}	0.05^{a}	0.05^{a}
1st July	0.16^{a}	0.06^{b}	0.12	0.08^{b}	0.05^{a}	-0.03^{b}
15th July	0.12^{ab}	0.08^{b}	0.10	0.05^{b}	0.01^{b}	-0.04^{b}
CD	0.061	0.066	NS	0.05	0.03	0.02

Table 4.58. Effect of planting methods on RGR (mg g^{-1} day^{-1}) of finger millet

Planting method	RGR 15-30 DAS	RGR 30-45 DAS	RGR 45-60 DAS	RGR 60-75 DAS	RGR 75- 90 DAS	RGR 90-105 DAS
Broadcasting	0.13	0.11	0.10	0.07	0.02	0.01
Dibbling	0.12	0.11	0.09	0.08	0.02	0.01
Transplanting	0.12	0.11	0.11	0.06	0.02	0.01
CD	NS	NS	NS	NS	NS	NS

Table 4.59. Interaction effect of date of planting and planting methods on RGR (mg g^{-1} day^{-1}) of finger millet

Date of planting	Relative Growth Rate 15-30 DAS			Relative Growth Rate 90-105 DAS		
	P1	**P2**	**P3**	**P1**	**P2**	**P3**
15th May	0.153^{a}	0.157^{a}	0.18^{a}	-0.023^{a}	-0.08^{b}	-0.07^{b}
1st June	0.16^{a}	0.123^{ab}	0.087^{b}	0.05^{a}	0.02^{a}	0.06^{a}
15th June	0.077^{a}	0.07^{a}	0.027^{b}	0.04^{a}	-0.01^{a}	0.02^{a}
1st July	0.167^{a}	0.163^{a}	0.147^{a}	-0.03^{b}	-0.03^{a}	-0.04^{a}
15th July	0.1^{a}	0.11^{a}	0.14^{a}	-0.03^{a}	-0.05^{a}	-0.03^{a}
CD	0.04			0.05		

P1-Broadcasting P2- Dibbling P3- Transplanting

4.5.5. Number of ear heads per unit area

The number of ear heads per unit area for the five dates of planting irrespective to the planting methods is given in the Table 4.63. As per the ANOVA, dates of planting had significant effect on the number of ear heads per unit area. The number of ear heads was highest for May 15^{th} planting ($91/m^2$), followed by July 15^{th} planting. June 1^{st}, June 15^{th} and July 1^{st} plantings had less number of ear heads per unit area and differed significantly from the other two plantings.

Effect of planting method on the number of ear heads per unit area is given in the Table 4.64. No significant difference was observed between the three different planting methods for the number of ear heads per unit area. Dates of planting and planting methods didn’t shown any interaction effect with the number of ear heads per unit area.

4.5.6. Number of fingers per ear head

The effect of different dates of planting on the number of fingers per ear head is given in the Table 4.63. Significant effect of date of planting on the number of fingers per ear head is observed. Early sown crops shown the highest number of fingers per ear head compared to the late sown crops. The highest number of fingers per ear head is recorded in June 1^{st} planting (six per ear head) which was on par with May 15^{th} and June 15^{th} planting. The lowest yield was recorded in July 15^{th} planting (Four per ear head) which was on par with July 1^{st} planting.

With respect to planting methods, transplanting method of planting showed the highest number of fingers per ear head (six per ear head) which was on par with dibbling method of planting. The lowest number was obtained in broadcasting method of planting (five per ear head). The effect of planting methods on the finger number per ear head was obtained from the Table 4.64. Dates of planting and planting methods didn’t shown any interaction effect with the number of fingers per ear head.

4.5.7. Finger length

The average finger length for the five date of planting irrespective to the planting method is given in the Table 4.63 in which it revealed that date of planting showed significant effect on the finger length. Comparison between dates of planting irrespective to the planting method showed that highest finger length was recorded in May 15th date of planting (8.56 cm) which was on par with June 1st planting. The lowest finger length was observed in July 15th planting (3.76 cm). Finger length was showing a continuous decreasing trend with delay in date of planting. No significant difference was observed between three planting methods for the finger length (Table 4.64). Dates of planting and planting methods didn't shown any interaction effect with the finger length.

4.5.8. Thousand grain weight

According to the ANOVA, no significant effect of planting dates irrespective to the different planting methods was observed. Comparison of thousand grain weight with respect to five date of planting is given in the Table 4.63.

The planting methods irrespective of date of planting is given in the Table 4.64. No significant influence of planting methods on thousand grain weight was also observed. Dates of planting and planting methods didn't shown any interaction effect with the thousand grain effect.

4.5.9. Harvest index

Harvest index obtained from the observations of grain yield and straw yield were used for the analysis. Considering the effect of planting dates irrespective to the planting method, the harvest index was getting higher towards the last date of planting. June 1st, July 1st and July 15th planting showed the highest values of harvest index compared to that of remaining dates. The lowest harvest index was observed for the May 15th and June 15th planting dates (Table 4.63).

Considering the influence of planting methods on the harvest index, there was no any significant effect has been observed. All the planting methods provide equal effect to the harvest index (Table 4.64). Dates of planting and planting methods didn’t shown any interaction effect on harvest index.

4.5.10. Straw yield

Straw yield showed a significant effect due to the planting dates irrespective of the varieties. It showed a gradual decrease in the yield with delay in the planting. The highest straw yield was obtained in May 15th planting (3095.56 kg ha^{-1}/ 3.1 t ha^{-1}) which was on par with June 1st and June 15th planting. The lowest yield was recorded in July 1st planting (123.33 kg ha^{-1}/ 0.12 t ha^{-1}). The mean values for the straw yield at different dates of planting are given in the Table 4.63.

The effect of planting methods on the straw yield was not showing any significant difference between each other. Comparison between the straw yields for the different planting methods are given in the Table 4.64. Dates of planting and planting methods didn’t shown any interaction effect with the straw yield.

4.5.11. Grain yield

The influence of date of planting and planting methods on grain yield has been given in the Table 4.63 and 4.64 respectively. Planting dates have significant influence on the grain yield irrespective of the varieties. The May 15th planting showed the highest yield (2057.8 kg ha^{-1}/ 2.06 t ha^{-1}) which was on par with June 1st planting. The lowest yield was recorded in July 15th planting which was on par with June 15th and July 1st date of planting. Grain yield was found to be decreasing with delay in dates of planting. Significant difference was observed between the planting methods in which the highest yield was recorded in transplanting method of planting (1308.3 kg ha^{-1}/ 1.31 t ha^{-1}). The dibbling method of planting was on par with broadcasting method in case of grain yield.

The interaction effects between dates of planting and planting methods on grain yield showed that in case of May 15th planting, the transplanting method gave more yield (2833.3 kg ha^{-1}/ 2.83 t ha^{-1}) compared to that of other two methods which was on par with each other. Yield obtained in the remaining treatments were on par with each other for all the planting methods. Interaction effect of planting dates and methods with grain yield is given in the Table 4.65.

Table.4.60. Effect of dates of planting on yield and yield attributes of finger millet

Date of planting	Number of ear heads per unit area	Finger number per ear head	Finger length (cm)	Thousand grain weight (g)	Harvest index	Straw yield (t ha^{-1})	Grain yield (t ha^{-1})
15th May	91.4^{a}	6.38^{a}	8.56^{a}	2.88	0.20^{b}	3.10^{a}	2.06^{a}
1st June	22.7^{c}	6.51^{a}	8.42^{a}	3.17	0.40^{a}	9.68^{ab}	1.74^{a}
15th June	29^{c}	6.27^{ab}	7.75^{b}	2.88	0.14^{b}	1.59^{ab}	5.39^{b}
1st July	39.8^{c}	4.78^{bc}	5.76^{c}	3.42	0.55^{a}	1.23^{b}	3.52^{b}
15th July	62.6^{b}	3.64^{c}	3.76^{d}	2.97	0.49^{a}	1.26^{b}	3.12^{b}
CD	19.7	1.50	0.62	NS	0.19	2.30	4.72

Table 4.61. Effect of planting methods on yield and yield attributes of finger millet

Planting method	**Number of ear heads per unit area**	**Number of fingers per ear head**	**Finger length (cm)**	**Thousand grain weight (g)**	**Harvest index**	**Straw yield (t ha^{-1})**	**Grain yield (t ha^{-1})**
Broadcasting	44.8	4.96[b]	6.86	3.14	0.34	2.87	8.23[b]
Dibbling	45.0	5.79[a]	6.77	2.91	0.34	3.08	8.66[b]
Transplanting	57.46	5.8[a]	6.91	3.13	0.39	3.54	1.31[a]
CD	NS	0.54	NS	NS	NS	NS	0.38

Table 4.62. Interaction effect of dates of planting and planting method with yield of finger millet

Date of planting	**Grain yield (t ha^{-1})**		
	P1	**P2**	**P3**
15th May	1.62[b]	1.72[b]	2.83[a]
1st June	1.65[a]	1.42[a]	2.13[a]
15th June	0.33[a]	0.68[a]	0.61[a]
1st July	0.31[a]	0.20[a]	0.54[a]
15th July	0.20[a]	0.32[a]	0.42[a]
CD	0.85		

P1-Broadcasting P2- Dibbling P3- Transplanting

4.6. Economics

4.6.1. Cost of cultivation

The major particulars where the cost has been incurred includes human labour, machine labour, seed, farm yard manure, fertilizers and plant protection chemicals. Estimation of cost of cultivation for the three planting methods is given in the Appendix II. Dibbling showed the highest cost of cultivation (Rs.44, 982.5 ha^{-1}) followed by transplanting. Lowest cost of cultivation was found in the broadcasting method due to the reduced labour charge, while transplanting and dibbling required more labour. Cost of cultivation for the three different planting methods are given in the Table 4.66.

4.6.2. Gross return

Gross return calculated for the three methods are given in the Table 4.66. The value seems to be nearly same for broadcasting and dibbling. But alteration to a significant extend was found in transplanting method. Transplanting showed the highest gross return (Rs. 83, 115/-) due to the higher yield obtained compared to other methods. The lowest gross return was found in broadcasting method due to the lesser yield production.

4.6.3. Net return

Net return also shows considerable variations as that of gross return. Net return calculated for the three methods are given in the Table 4.66. Net return obtained for broadcasting and dibbling were found to be similar, while transplanting method showed significantly higher value (Rs. 40,342.5/-) compared to rest of the methods. This is also due to the higher yield production in transplanting method which ultimately increased the gross return.

4.6.4. Benefit Cost ratio

Benefit Cost ratio for each planting method has also been calculated and given in the Table 4.66. The results showed that transplanting has highest B:C ratio (0.66) compared to others followed by broadcasting (0.41). Dibbling showed comparatively lowest B:C ratio due to the higher cost of cultivation as well as lesser yield production.

Table 4.63. Cost of cultivation, Gross return, Net return and Benefit Cost ratio for finger millet under three different planting methods

Planting methods	**Total cost of cultivation ($Rs.ha^{-1}$)**	**Gross return ($Rs.ha^{-1}$)**	**Net return ($Rs.ha^{-1}$)**	**B:C ratio**
Broadcasting	39,372.5	55, 508.5	16, 136	0.41
Dibbling	44,982.5	58, 700.5	13, 718	0.30
Transplanting	42,772.5	83, 115	40,342.5	0.66

Note: Selling price ($Rs.\ kg^{-1}$)

Finger millet grain: Rs. 50.00/-

Finger millet straw: Rs.5.0/-

DISCUSSION

5. DISCUSSION

The present study was done to estimate the crop weather relationship in finger millet in central zone of Kerala and to identify the ideal date of planting and best crop establishment method. The results obtained from the study was discussed in this following section.

5.1. WEATHER CONDITIONS PREVAILED DURING THE CROP PERIOD

Weather conditions prevailed during the entire crop period of 2018, which was given the prime importance in this study was analyzed through certain weather variables like maximum and minimum temperature, forenoon and afternoon relative humidity, forenoon and afternoon vapour pressure deficit, rainfall and number of rainy days, bright sunshine hours, wind speed and evaporation. Table 5.1- Table 5.11 represent the average values of different weather parameters experienced by the crop during various phenological stages under different planting methods.

The result showed that for all the planting methods, highest maximum temperature was obtained for 50 % flowering to milk stage in June 15th planting in broadcasting and dibbling and June 1st planting in transplanting. Lowest maximum temperature was obtained for May 15th planting for panicle initiation to flag leaf stage in all the methods. Highest minimum temperature was observed in June 1st planting during dough stage to physiological maturity for all the planting methods and also during milk stage to dough stage in June 15th planting for transplanting, while the lowest minimum temperature was obtained for June 1st planting in milk stage to dough stage in broadcasting and dibbling and in 50% flowering to milk stage in transplanting method. Highest forenoon relative humidity was observed for May 15th planting from panicle initiation to flag leaf stage for all the planting methods, while lowest fore noon relative humidity was observed in July 15th planting in milk stage to dough stage in all the planting methods and in July 1st planting for dough stage to physiological maturity in transplanting method. In case of after noon relative humidity, it was high for May 15th planting from panicle initiation to flag leaf stage for all the planting methods,

Table 5.1. Maximum temperature experienced by finger millet during the crop period under different planting methods

a) Broadcasting

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	30.2	28.6	29.0	30.6	31.9	31.7
D2	29.4	31.4	31.8	33.4	33.3	32.5
D3	29.4	31.9	32.2	33.7	33.1	32.1
D4	30.0	33.6	33.2	32.5	32.0	33.4
D5	30.3	33.1	32.4	32.0	33.5	32.8

b) Dibbling

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	30.2	28.6	29.0	30.6	31.9	31.7
D2	29.4	31.4	31.8	33.4	33.3	32.5
D3	29.4	31.9	32.2	33.7	33.1	32.1
D4	30.0	33.6	33.2	32.5	32.0	33.4
D5	30.3	33.1	32.4	32.0	33.5	32.8

c) Transplanting

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	30.1	27.49	30.1	31.0	32.0	31.9
D2	29.6	32.01	32.6	33.8	32.5	32.4
D3	29.6	32.11	33.5	33.1	32.4	32.0
D4	30.3	33.05	32.0	32.8	33.1	33.4
D5	30.5	32.62	32.4	33.0	33.4	33.5

S – Sowing PI – Panicle initiation FL- Flag leaf stage
F- 50% Flowering MS- Milk stage DS- Dough stage
P- Physiological maturity

Table 5.2. Minimum temperature experienced by finger millet during the crop period under different planting methods

a) Broadcasting

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	22.8	22.2	21.8	22.6	21.9	27.1
D2	22.6	22.3	22.6	22.3	21.7	28.4
D3	22.5	21.9	22.5	22.4	22.7	23.8
D4	22.4	22.6	22.4	24.0	23.2	22.4
D5	22.3	22.5	24.1	22.8	22.4	23.8

b) Dibbling

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	22.8	22.2	21.8	22.6	21.9	27.1
D2	22.6	22.3	22.6	22.3	21.7	28.4
D3	22.5	21.9	22.5	22.4	22.7	23.8
D4	22.4	22.6	22.4	24.0	23.2	22.4
D5	22.3	22.5	24.1	22.8	22.4	23.8

c) Transplanting

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	22.8	21.8	22.1	22.7	21.9	22.6
D2	22.7	22.04	22.5	21.5	24.0	24.3
D3	22.4	22.5	22.4	22.6	24.3	23.0
D4	22.4	22.53	24.0	22.6	23.3	23.3
D5	22.3	24.15	22.8	23.2	23.3	22.7

S – Sowing PI – Panicle initiation FL- Flag leaf stage
F- 50% Flowering MS- Milk stage DS- Dough stage
P- Physiological maturity

Table 5.3. Fore noon relative humidity experienced by finger millet during the crop period under different planting methods

a) Broadcsating

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	94.8	96.5	95.6	94.0	90.7	90.6
D2	95.8	91.9	91.4	90.0	91.9	90.6
D3	95.7	90.1	91.8	91.1	88.0	94.9
D4	94.7	91.0	89.1	95.4	95.7	82.1
D5	94.3	89.2	95.4	95.7	76.5	84.6

b) Dibbling

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	94.8	96.5	95.6	94.0	90.7	90.6
D2	95.8	91.9	91.4	90.0	91.9	90.6
D3	95.7	90.1	91.8	91.1	88.0	94.9
D4	94.7	91.0	89.1	95.4	95.7	82.1
D5	94.3	89.2	95.4	95.7	76.5	84.6

c) Transplanting

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	94.9	96.3	95.5	92.9	91.1	91.4
D2	95.6	89.9	92.4	91.6	86.8	95.3
D3	95.3	91.1	91.4	89.1	95.3	95.8
D4	94.5	89.9	94.8	94.8	81.0	78.7
D5	93.9	93.8	94.1	79.8	78.7	87.8

S – Sowing PI – Panicle initiation FL- Flag leaf stage
F- 50% Flowering MS- Milk stage DS- Dough stage
P- Physiological maturity

Table 5.4. After noon relative humidity experienced by finger millet during the crop period under different planting methods

a) Broadcasting

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	78.5	85.8	76.0	67.5	57.3	62.2
D2	80.4	60.0	58.9	59.1	65.6	71.0
D3	78.5	57.2	59.8	61.9	69.0	70.4
D4	73.9	63.0	66.4	70.4	69.7	46.4
D5	72.6	66.1	73.0	63.6	44.3	54.4

b) Dibbling

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	78.5	85.8	76.0	67.5	57.3	62.2
D2	80.4	60.0	58.9	59.1	65.6	71.0
D3	78.5	57.2	59.8	61.9	69.0	70.4
D4	73.9	63.0	66.4	70.4	69.7	46.4
D5	72.6	66.1	73.0	63.6	44.3	54.4

c) Transplanting

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	78.7	88.5	71.2	63.6	56.9	59.4
D2	79.3	59	57.9	65.9	71.0	71.9
D3	76.9	58.7	63.0	68.9	71.9	66.2
D4	73.1	67.6	69.2	62.2	50.6	49.5
D5	71.8	73.2	59.9	51.1	49.5	49.8

S – Sowing PI – Panicle initiation FL- Flag leaf stage

F- 50% Flowering MS- Milk stage DS- Dough stage

P- Physiological maturity

Table 5.5. Fore noon vapour pressure deficit experienced by finger millet during the crop period under different planting methods

a) Broadcasting

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	22.8	22.3	21.6	22.3	21.8	22.1
D2	22.5	22.1	22.2	21.9	22.5	22.5
D3	22.3	21.7	22.3	22.2	22.0	23.1
D4	22.2	22.1	22.1	23.3	22.3	19.5
D5	22.2	22.2	23.4	22.0	18.4	21.3

b) Dibbling

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	22.8	22.3	21.6	22.3	21.8	22.1
D2	22.5	22.1	22.2	21.9	22.5	22.5
D3	22.3	21.7	22.3	22.2	22.0	23.1
D4	22.2	22.1	22.1	23.3	22.3	19.5
D5	22.2	22.2	23.4	22.0	18.4	21.3

c) Transplanting

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	22.8	21.61	21.9	22.5	21.7	22.3
D2	22.5	21.74	22.3	22.4	21.6	23.6
D3	22.2	22.23	22.1	22.1	23.6	22.0
D4	22.2	22.17	23.2	21.8	19.8	20.1
D5	22.2	23.09	21.7	19.6	20.1	20.8

S – Sowing PI – Panicle initiation FL- Flag leaf stage
F- 50% Flowering MS- Milk stage DS- Dough stage
P- Physiological maturity

Table 5.6. After noon vapour pressure deficit experienced by finger millet during the crop period under different planting methods

a) Broadcasting

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	23.2	23.0	21.4	21.2	19.6	20.6
D2	22.8	20.2	20.0	21.5	24.7	24.2
D3	22.5	19.6	20.7	24.0	23.4	23.1
D4	21.9	23.8	23.4	23.5	22.3	17.5
D5	21.9	23.4	23.7	21.3	16.6	19.4

b) Dibbling

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	23.2	23.0	21.4	21.2	19.6	20.6
D2	22.8	20.2	20.0	21.5	24.7	24.2
D3	22.5	19.6	20.7	24.0	23.4	23.1
D4	21.9	23.8	23.4	23.5	22.3	17.5
D5	21.9	23.4	23.7	21.3	16.6	19.4

c) Transplanting

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	23.2	22.27	21.7	20.7	19.6	20.2
D2	22.7	19.89	20.7	25.1	23.7	23.5
D3	22.2	20.19	24.1	23.5	23.5	21.8
D4	22.1	23.56	22.9	20.9	18.2	18.2
D5	22.0	23.84	20.4	18.3	18.2	18.3

S – Sowing   PI – Panicle initiation   FL- Flag leaf stage
F- 50% Flowering   MS- Milk stage   DS- Dough stage
P- Physiological maturity

Table 5.7. Rainfall experienced by finger millet during the crop period under different planting methods

a) Broadcasting

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	1929.1	384.0	466.5	32.6	0.5	0.3
D2	2431.2	0.5	0.9	2.7	103.7	104.6
D3	1974.8	0.5	2.4	58.2	98.9	98.8
D4	1724.6	27.6	131	67	148	37.0
D5	1417.2	131	67	185	0	1.0

b) Dibbling

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	1929.1	384.0	466.5	32.6	0.5	0.3
D2	2431.2	0.5	0.9	2.7	103.7	104.6
D3	1974.8	0.5	2.4	58.2	98.9	98.8
D4	1724.6	27.6	131	67	148	37.0
D5	1417.2	131	67	185	0	1.0

c) Transplanting

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	2103.4	663.3	45.0	0.5	0.5	0.9
D2	2431.2	0.5	3.6	101.2	106.8	14.9
D3	1975.3	0.9	59.7	151.0	14.9	148.0
D4	1752.2	183.1	46.7	153.2	0.0	1.0
D5	1548.2	63.0	185.0	0.0	1.0	0.0

S – Sowing PI – Panicle initiation FL- Flag leaf stage
F- 50% Flowering MS- Milk stage DS- Dough stage
P- Physiological maturity

Table 5.8. Rainy days experienced by finger millet during the crop period under different planting methods

a) Broadcasting

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	56.0	9.0	11.0	5.0	0.0	0.0
D2	72.0	0.0	0.0	0.0	5.0	2.0
D3	63.0	0.0	0.0	2	4.0	3.0
D4	50.0	1	5	2	5.0	1.0
D5	44.0	5	2	6	0.0	0.0

b) Dibbling

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	56.0	9.0	11.0	5.0	0.0	0.0
D2	72.0	0.0	0.0	0.0	5.0	2.0
D3	63.0	0.0	0.0	2	4.0	3.0
D4	50.0	1	5	2	5.0	1.0
D5	44.0	5	2	6	0.0	0.0

c) Transplanting

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	59.0	10	10.0	2.0	0.0	0.0
D2	72.0	0	0.0	4.0	3.0	1.0
D3	63.0	0	2.0	5.0	1.0	5.0
D4	51.0	6	2.0	5.0	0.0	0.0
D5	49.0	2	6.0	0.0	0.0	0.0

S – Sowing PI – Panicle initiation FL- Flag leaf stage

F- 50% Flowering MS- Milk stage DS- Dough stage

P- Physiological maturity

Table 5.9. Bright sunshine hours experienced by finger millet during the crop period under different planting methods

a) Broadcasting

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	2.1	0.4	3.6	5.0	9.4	6.4
D2	1.9	8.0	6.7	7.5	4.1	5.2
D3	2.3	9.1	7.0	5.3	4.4	4.8
D4	3.5	6.2	4.6	5.0	4.8	7.8
D5	3.8	4.3	4.8	4.8	8.6	6.1

b) Dibbling

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	2.1	0.4	3.6	5.0	9.4	6.4
D2	1.9	8.0	6.7	7.5	4.1	5.2
D3	2.3	9.1	7.0	5.3	4.4	4.8
D4	3.5	6.2	4.6	5.0	4.8	7.8
D5	3.8	4.3	4.8	4.8	8.6	6.1

c) Transplanting

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	2.1	0.1	4.6	6.3	9.5	6.2
D2	2.2	9.1	6.6	4.7	4.0	5.0
D3	2.8	7	5.4	4.7	5.0	5.1
D4	3.7	4.2	5.0	5.3	7.3	6.9
D5	3.8	4.8	5.7	7.0	6.9	7.3

S – Sowing PI – Panicle initiation FL- Flag leaf stage
F- 50% Flowering MS- Milk stage DS- Dough stage
P- Physiological maturity

Table 5.10. Wind speed experienced by finger millet during the crop period under different planting methods

a) Broadcasting

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	1.6	1.7	2.1	1.8	1.9	1.4
D2	1.7	1.9	1.5	1.6	1.8	3.0
D3	1.7	1.9	1.5	1.7	3.5	1.3
D4	1.7	1.6	3.0	1.3	1.2	2.3
D5	1.7	2.9	1.3	1.2	2.9	4.0

b) Dibbling

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	1.6	1.7	2.1	1.8	1.9	1.4
D2	1.7	1.9	1.5	1.6	1.8	3.0
D3	1.7	1.9	1.5	1.7	3.5	1.3
D4	1.7	1.6	3.0	1.3	1.2	2.3
D5	1.7	2.9	1.3	1.2	2.9	4.0

c) Transplanting

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	1.6	1.8	2.0	1.9	1.9	1.4
D2	1.7	1.9	1.5	1.8	3.9	1.2
D3	1.7	1.5	1.6	3.1	1.2	1.2
D4	1.7	2.8	1.2	1.3	3.1	4.4
D5	1.8	1.8	1.4	3.2	4.4	2.0

S – Sowing PI – Panicle initiation FL- Flag leaf stage

F- 50% Flowering MS- Milk stage DS- Dough stage

P- Physiological maturity

Table 5.11. Evaporation experienced by finger millet during the crop period under different planting methods

a) Broadcasting

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	2.5	1.9	2.3	3.0	3.7	3.0
D2	2.3	3.5	3.2	3.5	2.7	3.1
D3	2.4	3.7	3.2	2.9	3.2	2.6
D4	2.7	3.2	3.1	2.6	2.9	3.5
D5	2.7	3.0	2.5	3.1	3.8	3.3

b) Dibbling

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	2.5	1.9	2.3	3.0	3.7	3.0
D2	2.3	3.5	3.2	3.5	2.7	3.1
D3	2.4	3.7	3.2	2.9	3.2	2.6
D4	2.7	3.2	3.1	2.6	2.9	3.5
D5	2.7	3.0	2.5	3.1	3.8	3.3

c) Transplanting

	S-PI	PI-FL	FL-F	F-MS	MS-DS	DS - PM
D1	2.5	1.6	2.8	3.2	3.8	3.1
D2	2.4	3.7	3.2	2.9	3.2	2.5
D3	2.5	3.3	3.0	3.2	2.5	3.1
D4	2.7	3.0	2.6	3.2	3.4	3.7
D5	2.7	2.7	3.2	3.5	3.7	3.0

S – Sowing PI – Panicle initiation FL- Flag leaf stage
F- 50% Flowering MS- Milk stage DS- Dough stage
P- Physiological maturity

while the lowest after noon relative humidity was observed in July 15th planting in milk stage to dough stage in all the planting methods and in July 1st planting for dough stage to physiological maturity in transplanting method. Coming to the forenoon vapour pressure deficit, it was higher for July 15th planting from flag leaf to 50% flowering stage for broadcasting and dibbling and in June 15th planting for milk stage to dough stage and in June 1st planting for dough stage to physiological maturity in transplanting. Lowest forenoon VPD was observed in July15th planting for milk stage to dough stage for broadcasting and dibbling, while it is during 50% flowering to milk stage in transplanting. Highest after noon vapour deficit was observed in June 1st planting from milk stage to dough stage in broadcasting and dibbling and in 50% flowering to milk stage in transplanting method, while the lowest was observed in July 15th date of planting in milk stage to dough stage in all the planting methods and in July 1st planting for dough stage to physiological maturity in transplanting method. Highest rainfall was observed in June 1st planting for sowing to panicle initiation in all methods, while less rainfall was received during July 15th planting towards the end of crop growth period. In case of rainy days the highest was observed in June 1st planting for sowing to panicle initiation in all methods, while less rainfall was received during July 15th planting towards the end of crop growth period and also in June 1st planting from the second phenophase onwards. Highest bright sunshine hours was observed in May 15th planting for milk stage to dough stage in all the planting methods, while lowest was also observed in May 15th planting for panicle initiation to flag leaf stage in all the methods. Highest wind speed was observed in July 15th planting for dough stage to physiological maturity in broadcasting and dibbling and in milk stage to dough stage for transplanting and also in July 1st planting for dough stage to physiological maturity for transplanting method, while the lowest wind speed was 1.2 km hr^{-1} which was observed randomly in several treatments. In case of evaporation the higher rate was observed for milk stage to dough stage in July 15th planting for broadcasting and dibbling and in May 15th planting for transplanting, while the lowest was observed in May 15th planting for panicle initiation to flag leaf stage in all the methods.

5.2. RELATIONSHIP BETWEEN WEATHER AND DURATION OF PHENOLOGICAL STAGES

Date of planting shows variable influence on the duration of each phenophases. Duration followed a decreasing trend with delay in date of planting on most cases. July 15th planting took less days to attain each stages as well it took less number of days for crop growth compared to other two methods. The weather conditions experienced by the crop planted on different dates were not the same. This shall be the reason for difference in duration of phenological stages. Considering the different types of planting methods, the highest number of days for attaining each stages was seen in case of transplanting compared to other two methods. Broadcasting and dibbling took equal number of days to attain every stages. Transplanting took more days to attain physiological maturity from sowing compared to other methods. But the difference between the durations for transplanting and the other two methods vary from only 3 to 9 days.

The results from the correlation analysis concluded that maximum and mean temperature and diurnal temperature range in all stages except from dough stage to physiological maturity, minimum temperature from dough stage to physiological maturity, rainfall during milk stage to dough stage and evaporation from sowing to panicle initiation, which have negative effect to the duration may lead to reduction of phenophase duration in broadcasting as well as in dibbling. While fore noon, after noon and mean relative humidity, bright sunshine hours and wind speed during sowing to panicle initiation stage and rainfall from 50 % flowering to milk stage led to increase in phenophases duration in broadcasting as well as in dibbling method of planting. While in case of transplanting method, maximum and mean temperature, diurnal temperature range and evaporation during sowing to panicle initiation, after noon vapor pressure deficit during flag leaf to 50% flowering stages, fore noon and mean relative humidity and bright sunshine hours during 50% flowering to milk stage, after noon vapour pressure deficit, bright sunshine hours and evaporation during milk stage to dough stage, maximum temperature, temperature range and rainy days from dough stage to physiological maturity resulted in reduction in phenophase duration in transplanting. Whereas fore noon, after noon and mean relative humidity, bright sunshine hours and wind speed during sowing to panicle initiation stage, minimum temperature, rainfall, rainy days and evaporation during 50% flowering to milk stage, after noon and mean relative humidity, forenoon and afternoon vapour pressure deficit during dough stage to physiological maturity may contributed to increase in phenophase duration in transplanting.

5.3. Effect of date of planting and planting method on micrometeorological parameters

5.3.1. Soil temperature

The study showed that soil temperature followed a decreasing trend with delay in the date of planting in the case of both fore noon and after noon soil temperature observations. In both the cases, soil temperature showed a slight increase during the second date of planting followed by a decreasing trend. Considering the planting methods, variable trends have been observed for both the fore noon and after noon soil temperature. Effect of date of planting and planting method on forenoon and after noon soil temperature is given in the Fig. 5.1 to 5.4 respectively. Since the major difference between these planting methods are the spacing and ground coverage. Since broadcasting method is having high plant density which indicates more shading effects than the other two methods. This may increase the amount of stored soil moisture that will reduce the soil temperature. This may be the reason for the reduced soil temperature in case of broadcasting method. While the variations and heat exchange with the open atmosphere through sensible heat flux is lesser in case of broadcasting due to shade effect, soil temperature in broadcasting was same or more than that of other methods. The result is in line with the research work of Ghanbari *et al.* (2010).

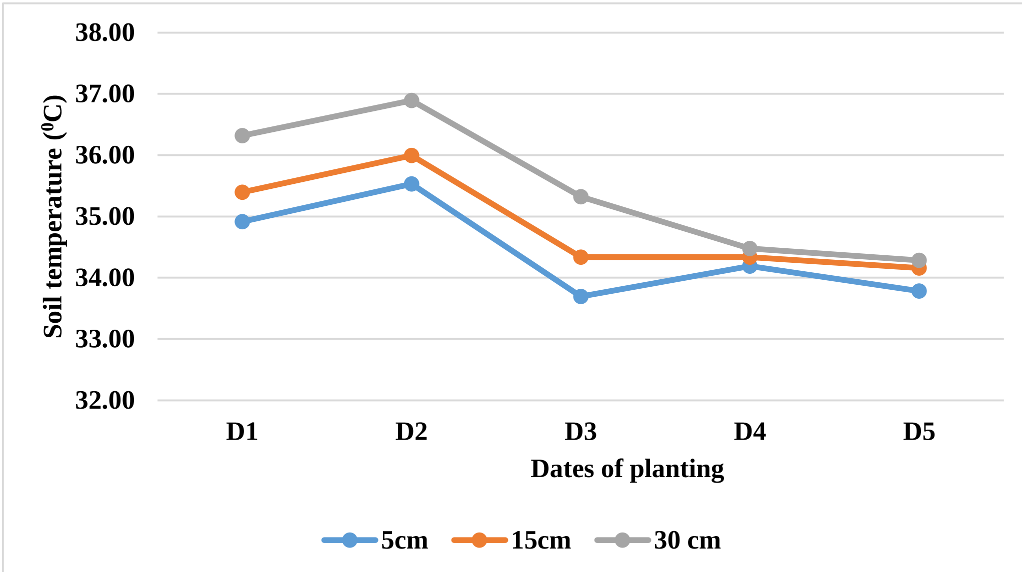


Fig. 5.1. Effects of dates of planting on fore noon soil temperature (^{0}C)

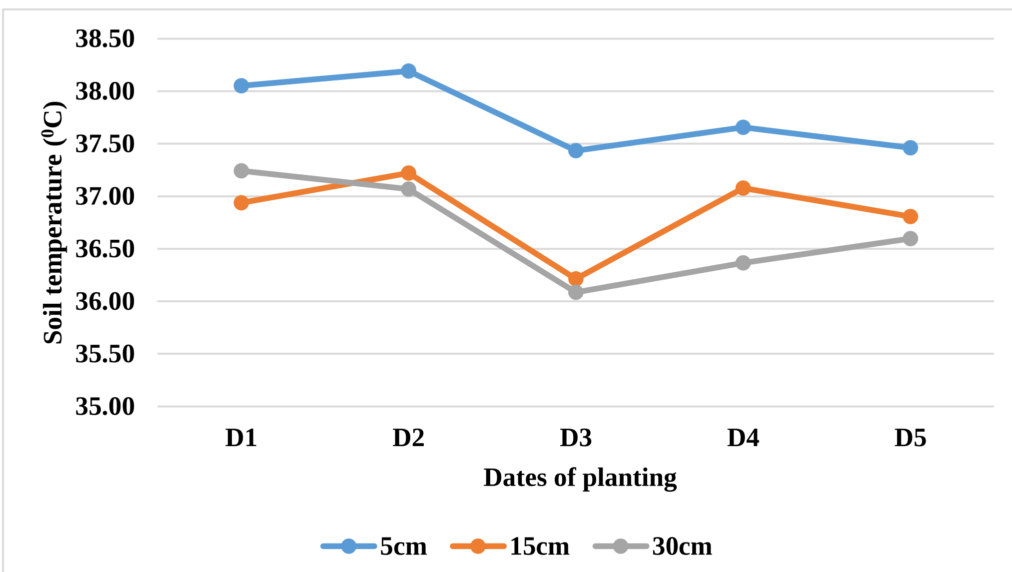


Fig. 5.2. Effects of dates of planting on after noon soil temperature (^{0}C)

D1 – May 15th	D2 - June 1st	D3 – June 15th	D4 – July 1st	D5 – July 15th

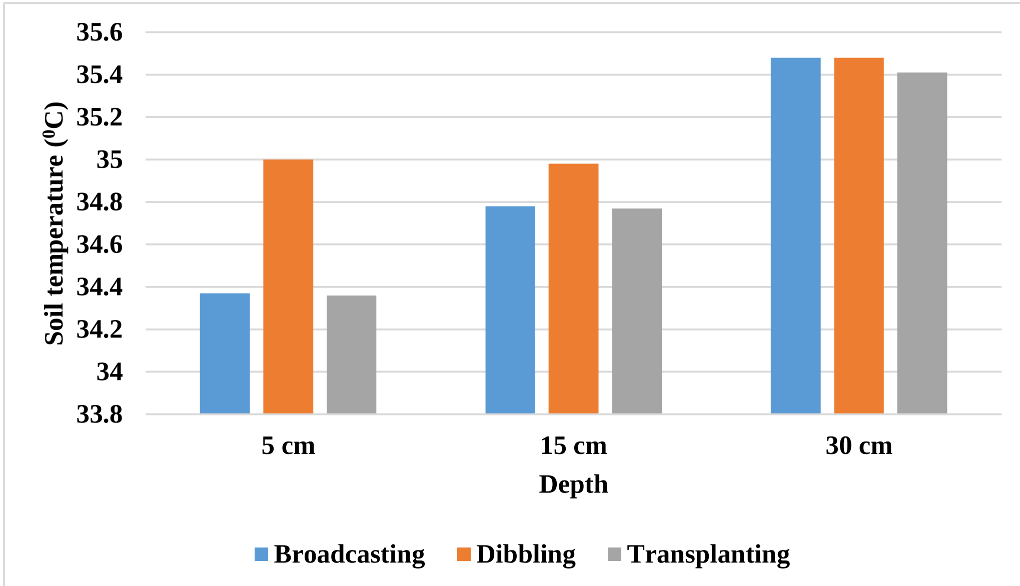


Fig. 5.3. Effects of planting method on fore noon soil temperature (^{0}C)

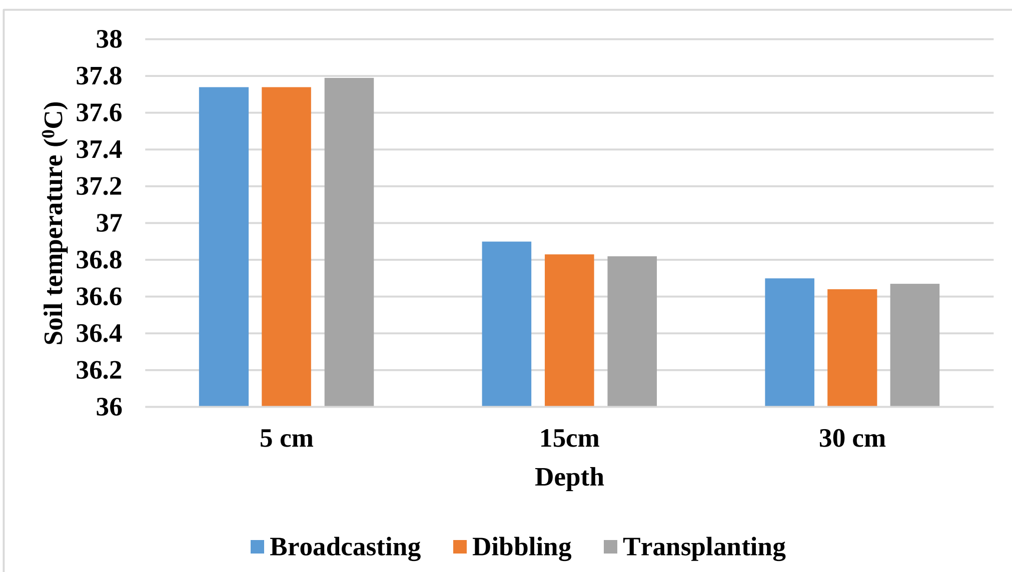


Fig. 5.4. Effects of planting method on after noon soil temperature (^{0}C)

5.3.2. Soil moisture

Date of planting did not showed any significant effect on the soil moisture, since all the observations have similar soil moisture values. The result on the effect of planting method on the soil moisture showed that broadcasting have comparatively higher amount of soil moisture than the other methods at 15cm soil depth. This may be due to the higher shading effect of plants under broadcasting method that will helps the soil to hold more amount of water through increased percolation into deeper layers. But at the same time soil moisture at 5cm was lesser for the broadcasting method. This can be due to the water loss through higher rate of evapotranspiration in broadcasting method because of the greater plant density. The result are similar to the findings of Ghanbari *et al.* (2010). Effect of date of planting and planting method on soil moisture is given in the Fig 5.5 and 5.6.

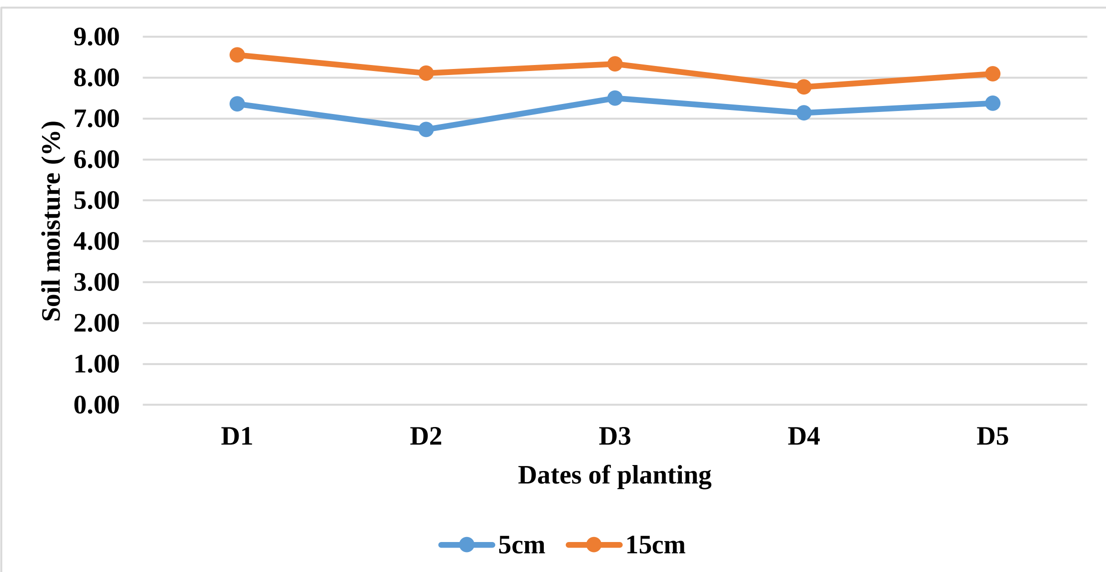


Fig. 5.5. Effect of date of planting on the soil moisture

D1 – May 15th	D2 - June 1st	D3 – June 15th	D4 – July 1st	D5 – July 15th

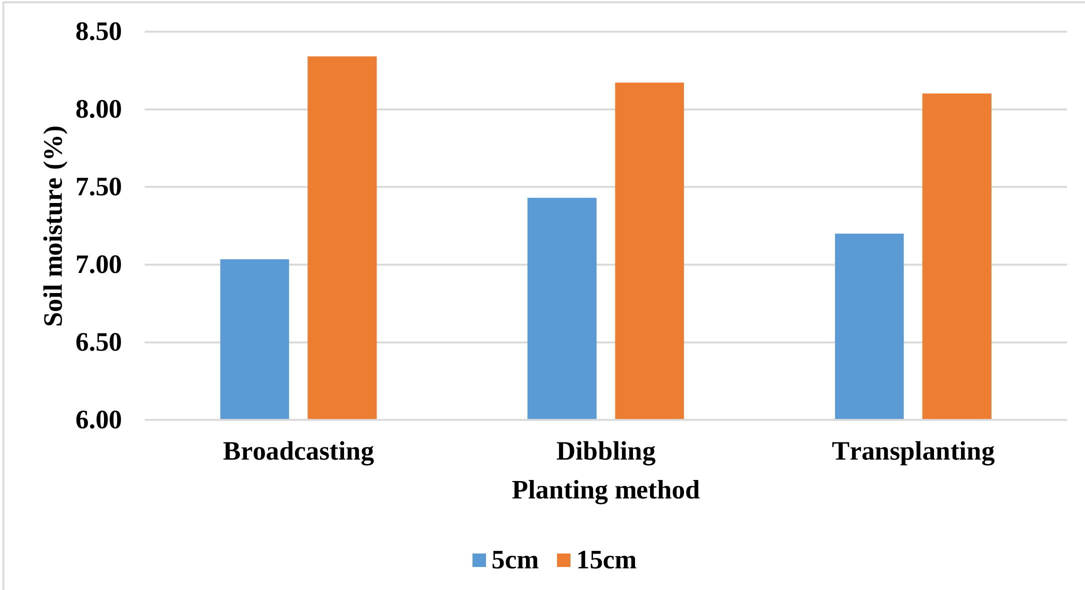


Fig. 5.6. Effect of planting method on the soil moisture

D1 – May 15th	D2 - June 1st	D3 – June 15th	D4 – July 1st	D5 – July 15th

5.4. Effect of date of planting and planting methods on weed density and dry weight per m^2

The floristic composition of weeds from the observation plot revealed that higher number of weeds observed were the broad leaved weeds like *Ludwigia parviflora, Mitracarpus villosus, Alternanathera bettzichiana* etc. followed by grasses which includes *Digitaria ciliaris, Brachiaria mutica* etc. Sedges like *Cyperus* spp. were also found from the plots.

Date of planting showed a variable effect to the weed density per m^2. The results showed that the planting at May 15th and July 1st were most favourable for the weeds which express highest count during that periods. The weed density per m^2 was higher in dibbling method of planting compared to the other two methods (Fig 5.7 and 5.8). Weeds density as well as weed dry weight per m^2 (Fig 5.9 and 5.10) showed that dibbling obtained higher values than broadcasting. This may be due to the less amount of light availablity for weeds growing below the canopy of the millet crop. The results were close to the research findings of Shinggu *et al.* (2009) and Murphy, 1996.

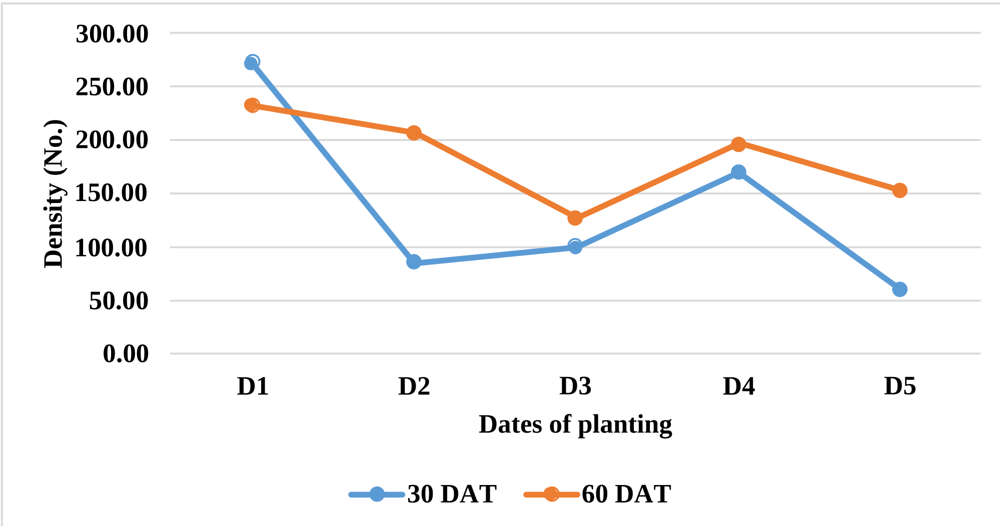


Fig. 5.7. Effect of date of planting on weed density per m^{-2}

D1 – May 15th	D2 - June 1st	D3 – June 15th	D4 – July 1st	D5 – July

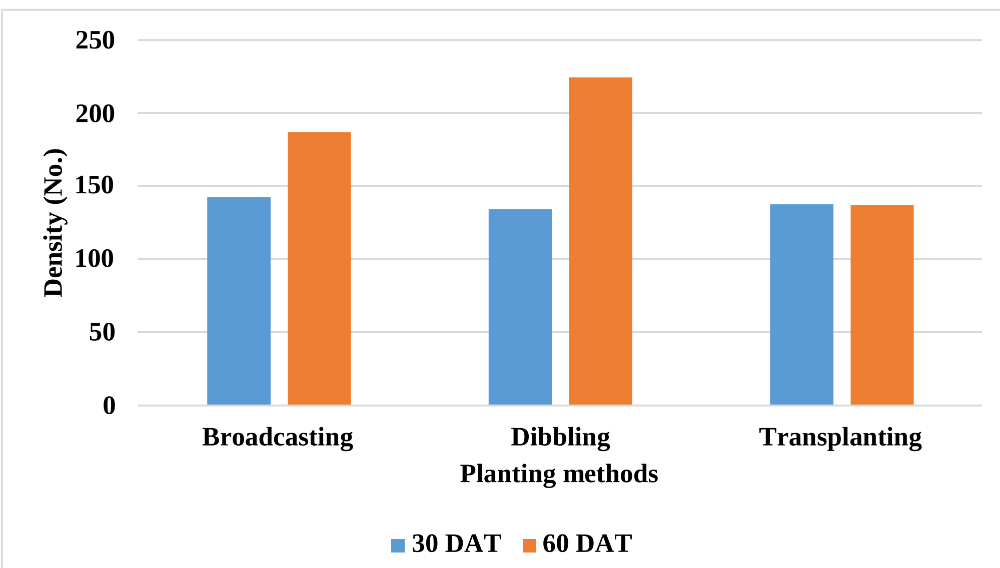


Fig. 5.8. Effect of planting method on weed density per m^{-2}

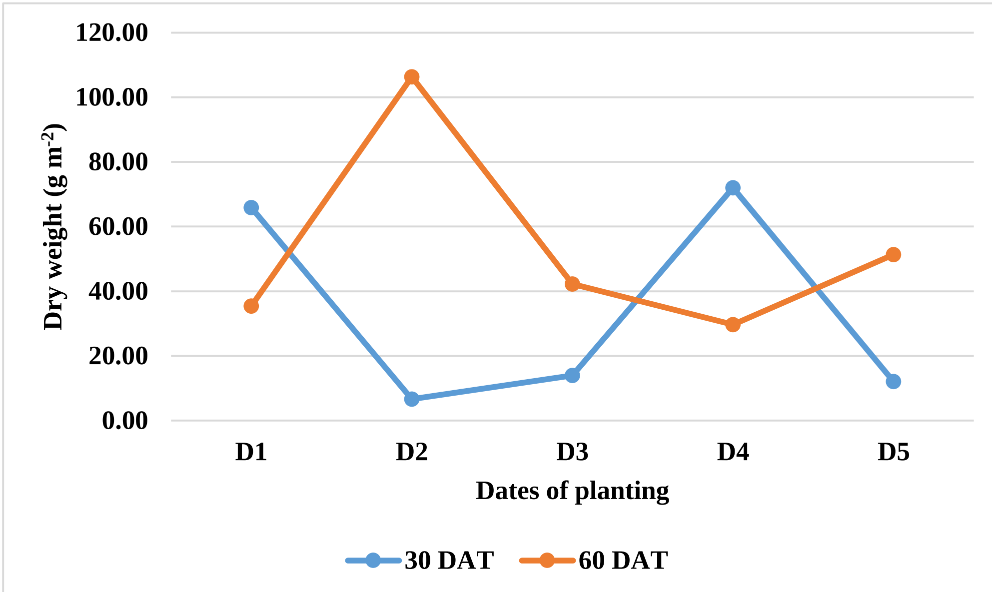


Fig. 5.9. Effect of date of planting on weed dry weight per m^{-2}

D1 – May 15th	D2 - June 1st	D3 – June 15th	D4 – July 1st	D5 – July

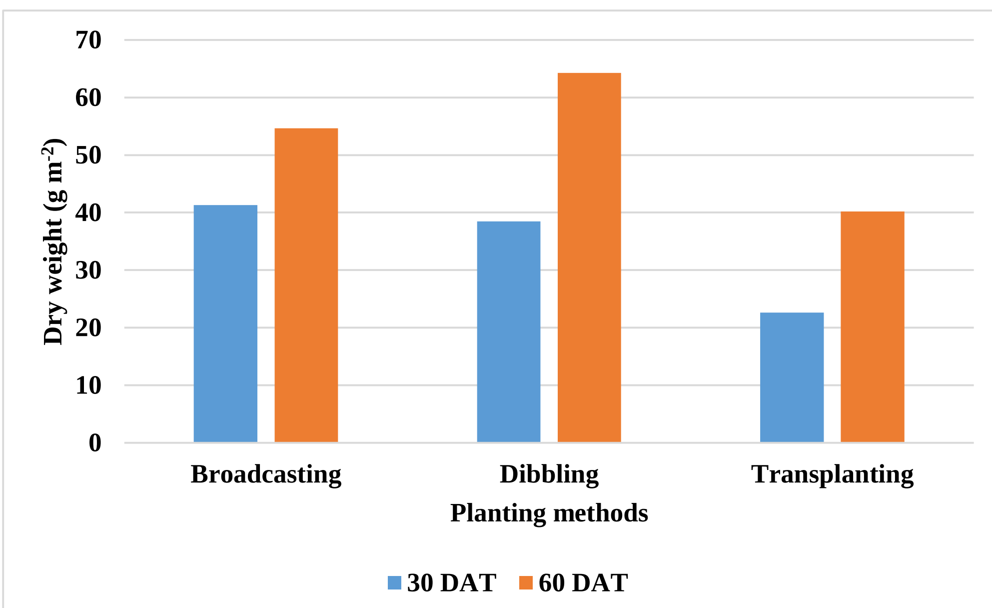


Fig. 5.10. Effect of planting method on weed dry weight per m^{-2}

5.5. Effect of date of planting and planting method on yield and yield parameters

5.5.1. Plant height

Considering the planting method, transplanting showed the highest plant height in case of May 15th, July 1st and July 15th planting. These results were in agreement with the findings of Dereje *et al*. (2016) and Kumar (2018). The plant height at weekly interval showed variable influence due to dates of planting. But plant height followed a decreasing trend with delay in date of planting. May 15th, June 1st and June 15th planting showed the considerably highest plant height compared to other two dates of planting. Influence of weather parameters on plant height with respect to planting dates and methods are given in the Fig 5.11 (a) and (b). Maximum and mean temperature, temperature range, wind speed, bright sunshine hours and evaporation was found to influence the plant height negatively in all the planting methods, while forenoon and afternoon relative humidity, mean relative humidity, forenoon and afternoon vapour pressure deficits, rainfall and number of rainy days were found to have positive influence on plant height (Table 5.12). The results in similar lines were obtained by Nagaraju and Kumar in 2009 and Maiti and Soto in 1990.

5.5.2. Dry matter production

Dry matter production showed significant relation with the planting date since it followed a continuous decreasing trend with delay in date of planting at 15 days prior to attaining physiological maturity. Dry matter accumulation at physiological maturity showed variable trend from all other trends due to the loss of biomass during that stage. May 15th planting showed the highest dry matter accumulation followed by June 1st planting. These results are in conformity with the works of Nagaraju and Kumar in 2009. Influence of weather parameters on dry matter accumulation with respect to planting date and methods is given in Fig 5.12. Correlation coefficients between dry matter production and various weather parameters are given in the Table 5.13.

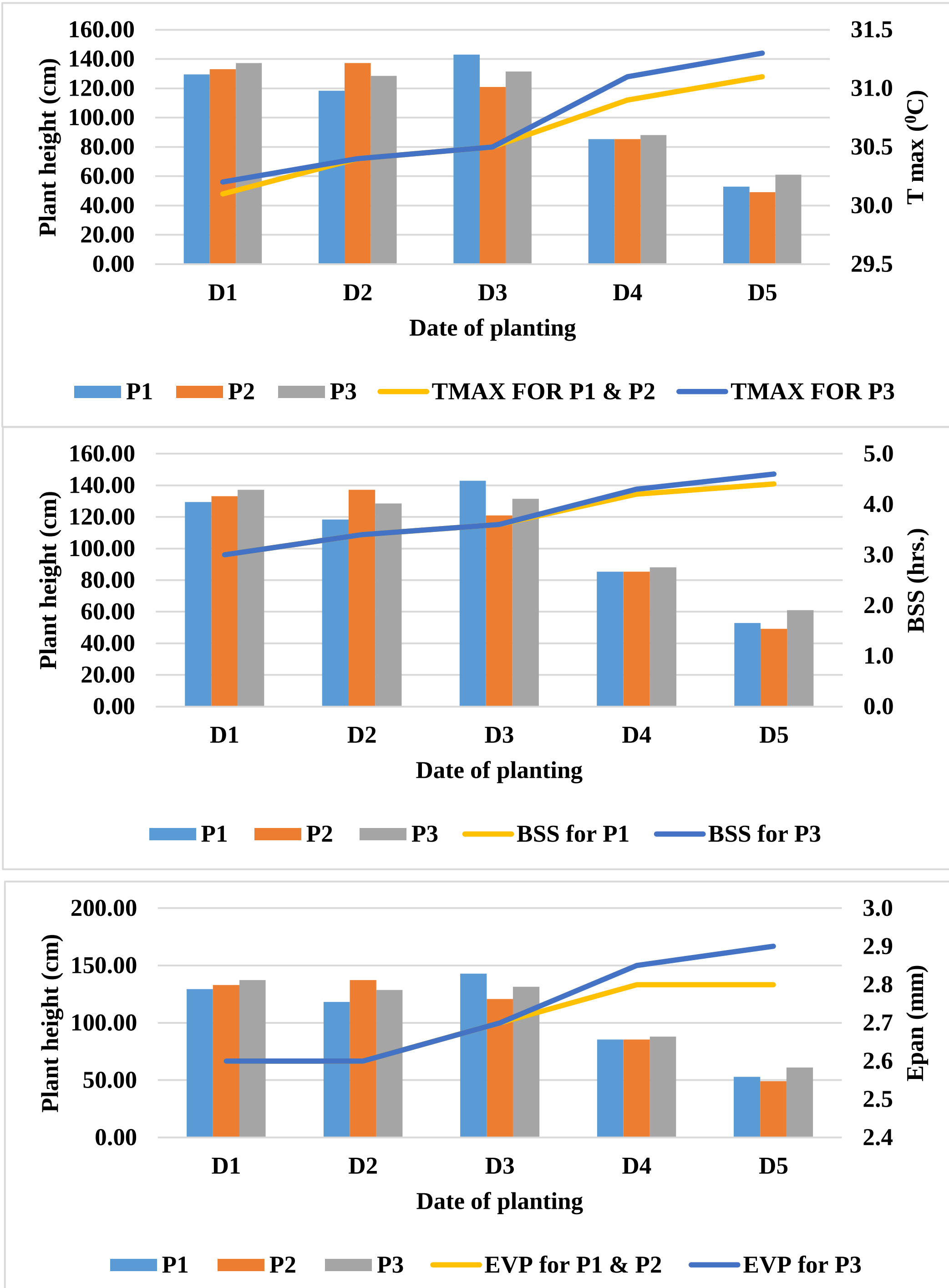
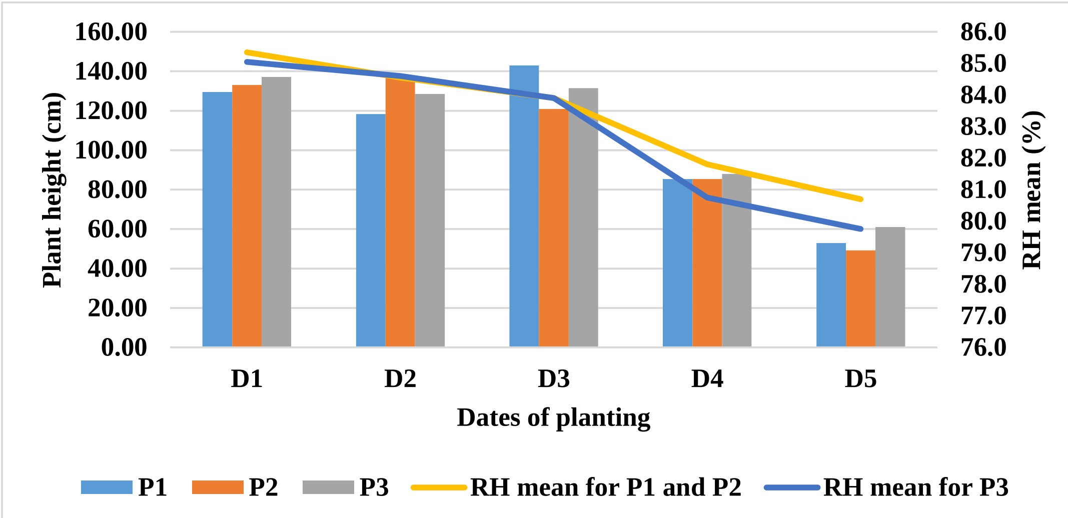


Fig. 5.11 (a) Influence of weather parameters on plant height with respect to planting date and method



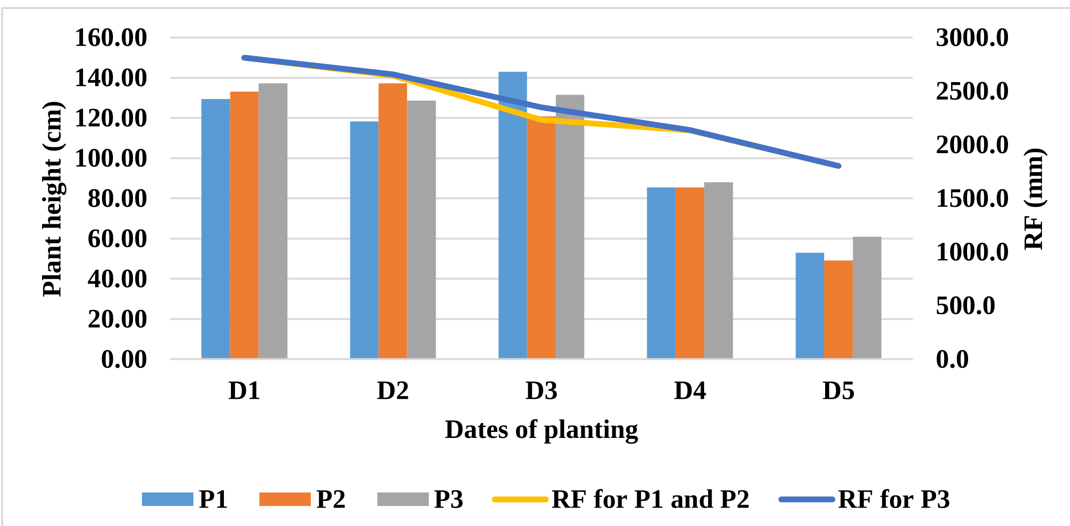


Fig. 5.11 (b) Influence of weather parameters on plant height with respect to planting date and method

D1 – May 15th	D2 - June 1st	D3 – June 15th	D4 – July 1st	D5 – July

P1 – Broadcasting	P2 – Dibbling	P3 - Transplanting

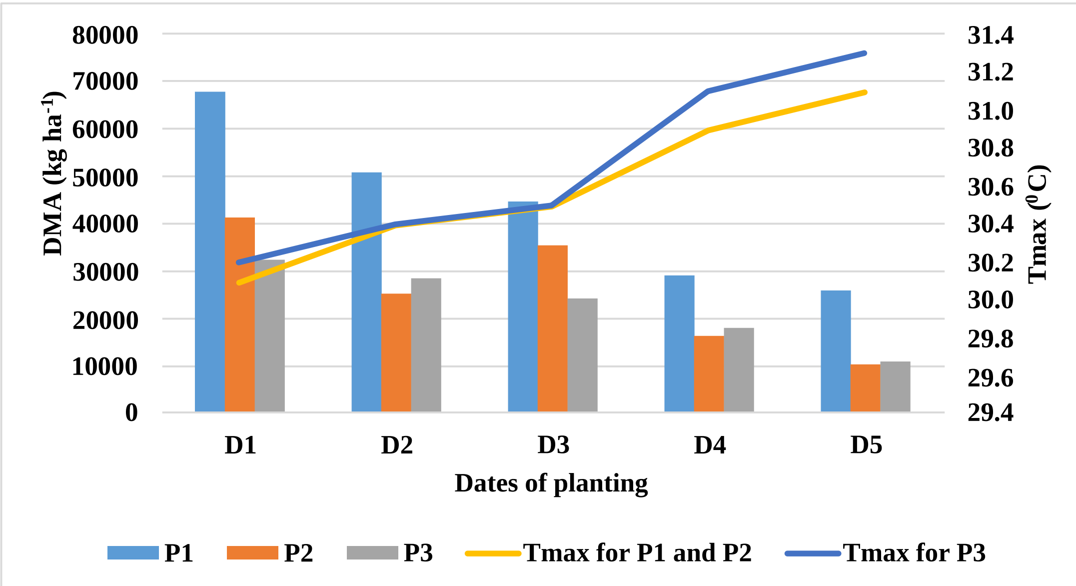
Table 5.12. Correlation coefficients between plant height and weather parameters

	Tmax	Tmean	DTR	RHI	RHII	RHMean	VPI	VPII	WS	BSS	RF	RD	Epan
P1	-.849**	-.850**	-.840**	.939**	.855**	.879**	.839**	.858**	-.913**	-.830**	.723**	.834**	-.735**
P2	-.864**	-.869**	-.850**	.909**	.887**	.897**	.881**	.899**	-.786**	-.857**	.846**	.901**	-.840**
P3	-.933**	-.931**	-.928**	.943**	.929**	.936**	.921**	.939**	-.911**	-.915**	.885**	.941**	-.903**

*Significant at 5% level ** Significant at 1% level

P1 – Broadcasting P2 - Dibbling P3 – Transplanting

Considering the planting methods also, it showed significant effect on the dry matter accumulation in all the stages. In all the stages, broadcasting showed the highest dry matter accumulation compared to that of dibbling and transplanting method. This may be due to high intensity of plant population per m^2 in case of broadcasting compared to other methods. This result is in line with the research findings of San-Oh *et al.* (2004).



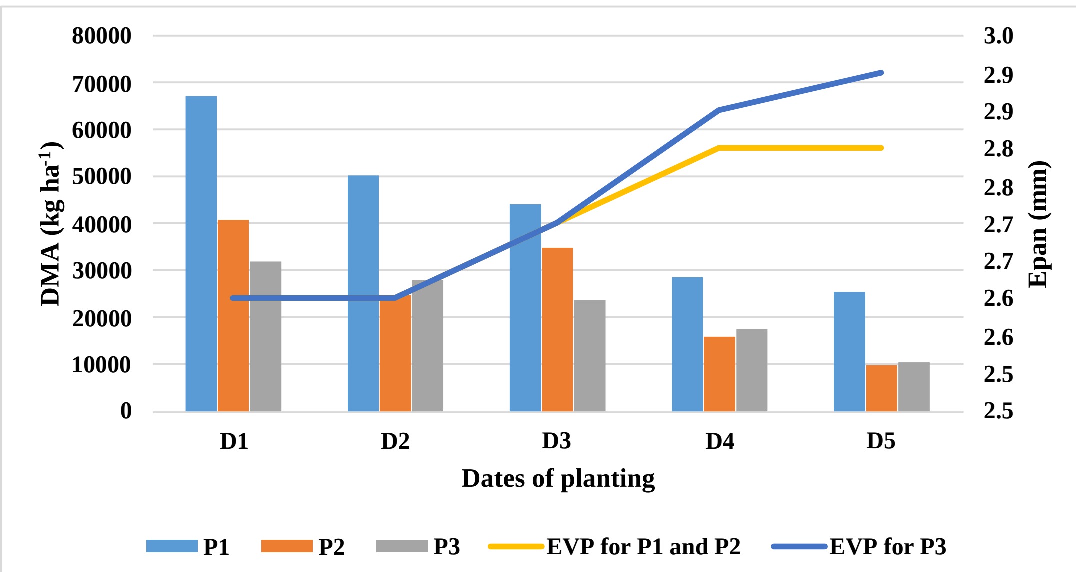


Fig.5.12 (a) Influence of weather parameters on dry matter accumulation with respect to planting date and methods

D1 – May 15th	D2 - June 1st	D3 – June 15th	D4 – July 1st	D5 – July

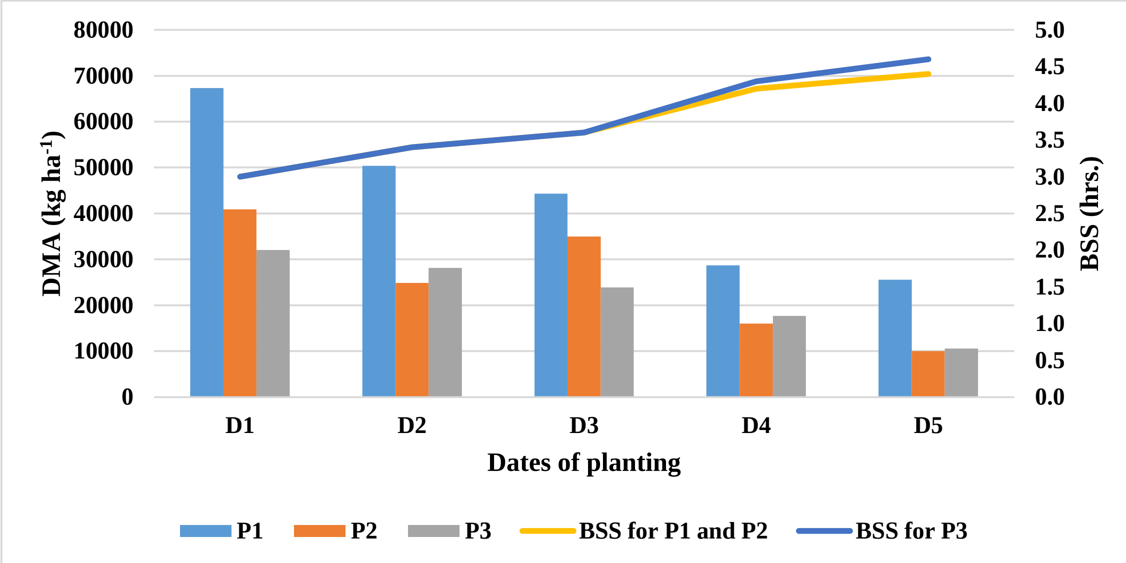


Fig. 5.12 (b) Influence of weather parameters on dry matter accumulation with respect to planting date and methods

D1 – May 15th	D2 - June 1st	D3 – June 15th	D4 – July 1st	D5 – July

5.5.3. Crop growth rate (CGR)

Crop growth rate showed almost similar trend in their activity for all the dates of planting. Broadcasting, dibbling and transplanting methods also showed similar trend in CGR. The rate was slow during the initial phases followed by a rise from 45-60 DAS to 75-90 DAS and then followed a decreasing trend. This may be due to under developed plant canopy and low absorption of light, which will cause reduction in the crop growth rates at early stages. As the canopy increases crop growth rate started increased from 45 – 60 days after planting. After attaining a fully developed growth the rate started decreasing due to reduction in the light penetration due to fully developed canopy and interplant competition also will increase that will ultimately reduce the activity of photosynthetic organs. The assimilate produced also will be taken for the grain production. Mani and Noori (2015) showed the similar findings. Trend of CGR in different dates of planting under broadcasting, dibbling and transplanting methods are given in the Fig 13 (a) to (c).

Table 5.13. Correlation coefficients between dry matter production and weather parameters

	Tmax	Tmean	DTR	RHI	RHII	RHMean	VPI	VPII	WS	BSS	RF	RD	Epan
P1	-.806**	-.796**	-.808**	.736**	.793**	.785**	.798**	.780**	-.595*	-.810**	.770**	.772**	-.764**
P2	-.822**	-.816**	-.820**	.816**	.796**	.805**	.791**	.778**	-.785**	-.809**	.694**	.751**	-.684**
P3	-.780**	-.774**	-.779**	.744**	.780**	.774**	.783**	.774**	-.711**	-.787**	.793**	.781**	-.774**

*Significant at 5% level ** Significant at 1% level

P1 – Broadcasting P2 - Dibbling P3 – Transplanting

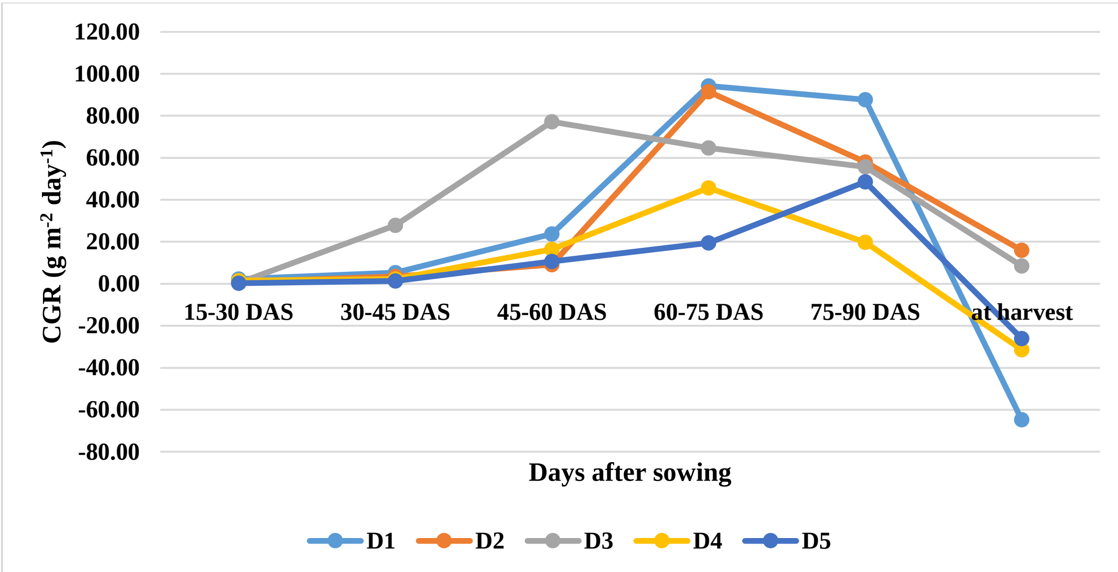


Fig. 5.13 (a) Trend of crop growth rate in different dates of planting in

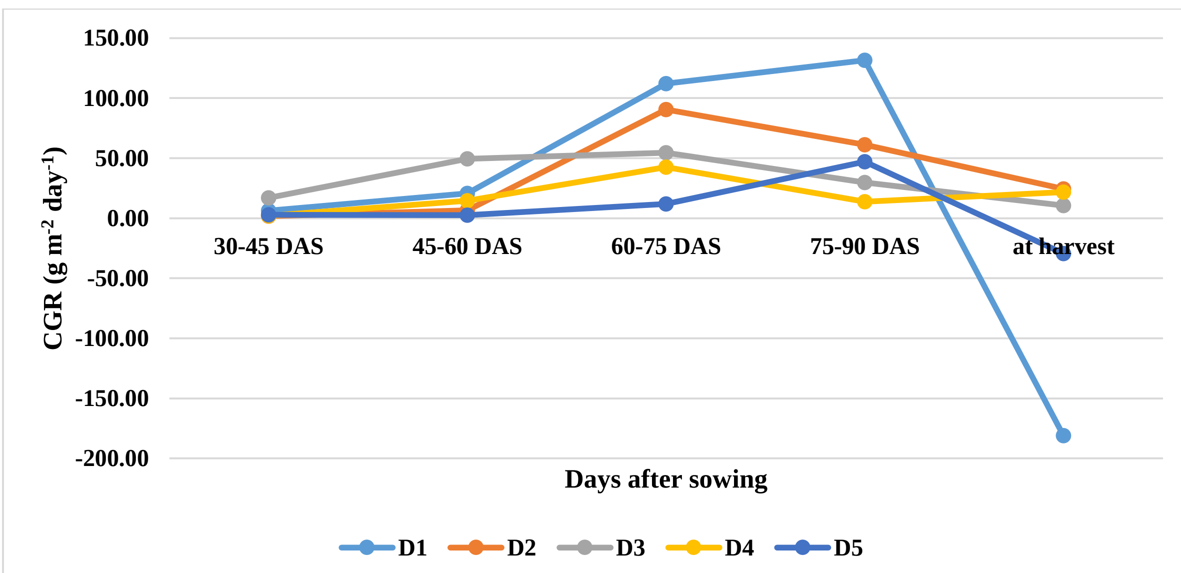


Fig. 5.13 (b) Trend of crop growth rate in different dates of planting in dibbling

D1 – May 15th	D2 - June 1st	D3 – June 15th	D4 – July 1st	D5 – July

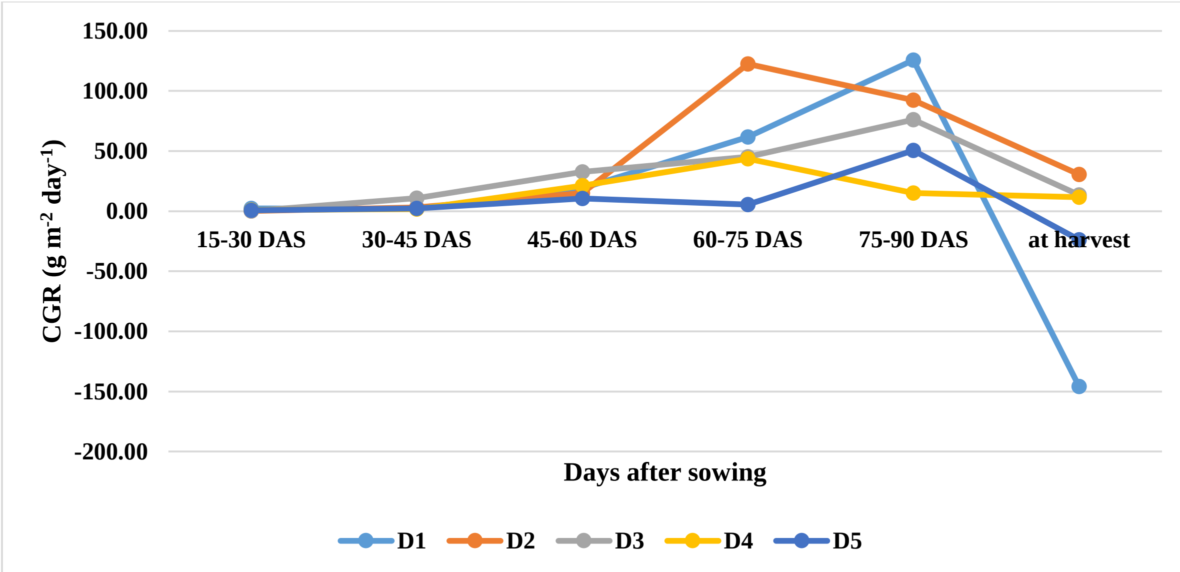


Fig. 5.13 (c) Trend of crop growth rate in different dates of planting in transplanting

D1 – May 15th	D2 - June 1st	D3 – June 15th	D4 – July 1st	D5 – July

5.5.4. Relative growth rate (RGR)

Relative growth rate also showed almost similar trend in their activity for all the dates of planting. Highest relative growth rate was observed for June 15th date of planting at 30-45 Days after sowing. Broadcasting, dibbling and transplanting methods also showed similar trend in CGR. In most of the dates, the rate was slow during the initial phases followed by a rise from 45-60 DAS and then followed a decreasing trend. This may be due to under developed plant canopy and low absorption of light, which will cause reduction in the crop growth rates at early stages. As the canopy increases crop growth rate started to increase from 45 – 60 days after planting. After attaining a fully developed growth the rate started decreasing due to reduction in the light penetration due to fully developed canopy and interplant competition also will increase that will ultimately reduce the activity of photosynthetic organs. The assimilate produced also will be taken for the grain production. This result is in line with the research findings of Mani and Noori (2015). Trend of RGR in different dates of planting under broadcasting, dibbling and transplanting methods are given in the Fig 5.14 (a) to (c).

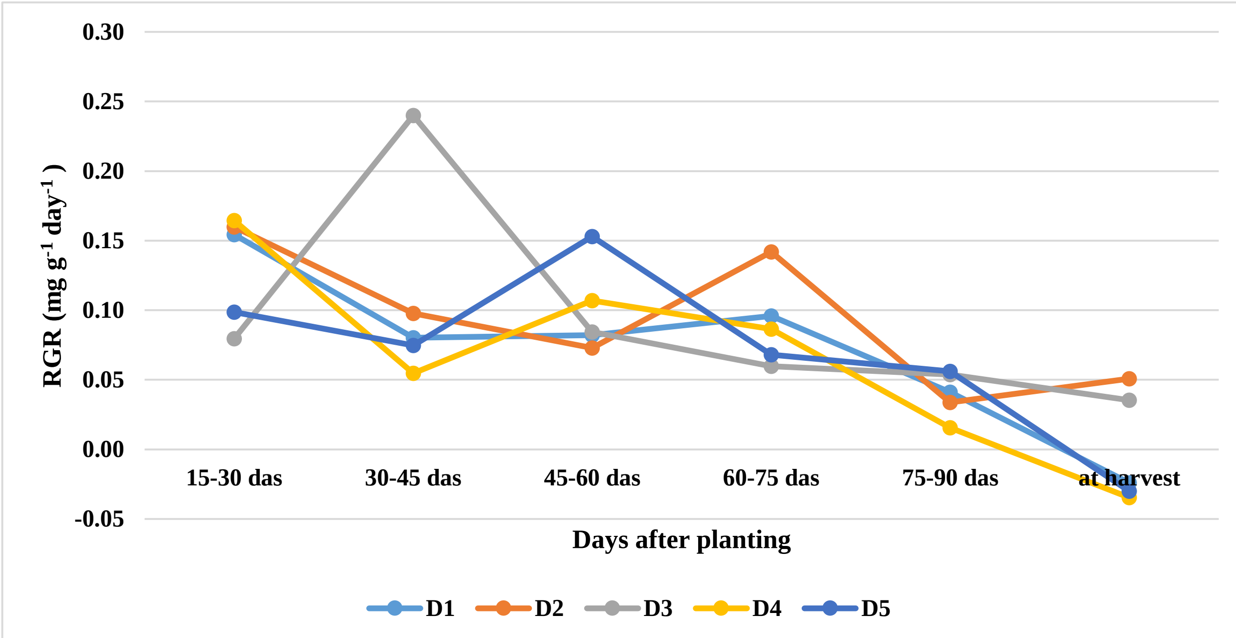


Fig. 5.14 (a) Trend of relative growth rate in different dates of planting in broadcasting

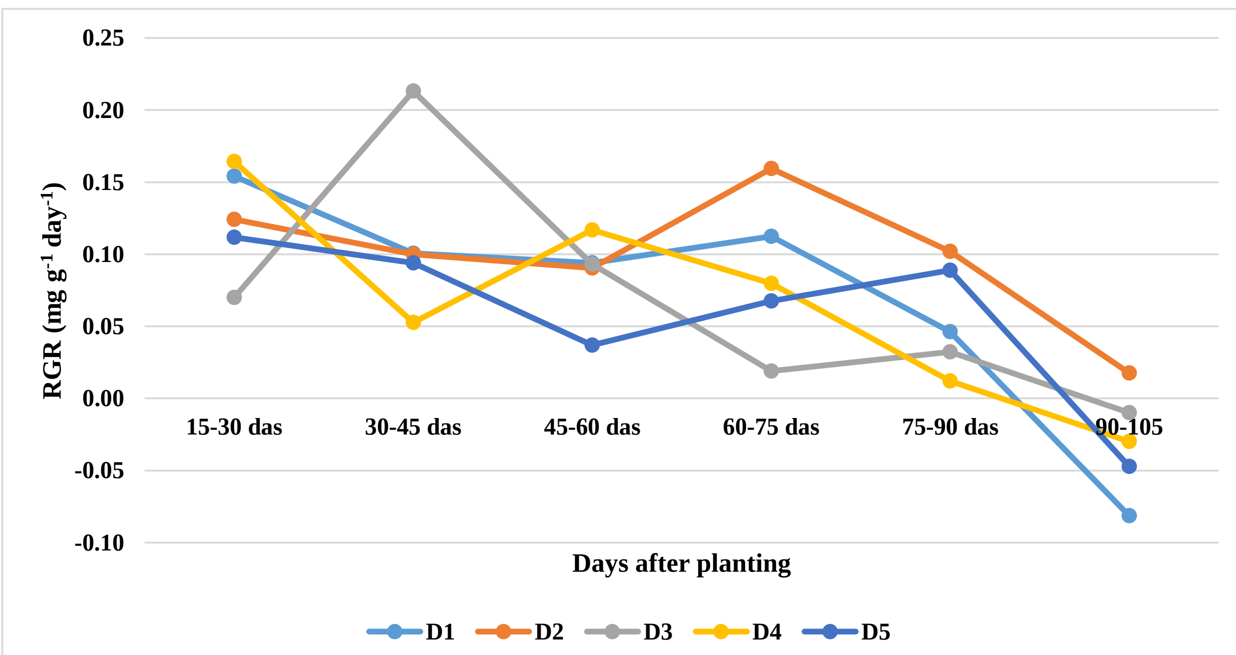


Fig. 5.14 (b) Trend of relative growth rate in different dates of planting in dibbling

D1 – May 15th D2 - June 1st D3 – June 15th D4 – July 1st D5 – July

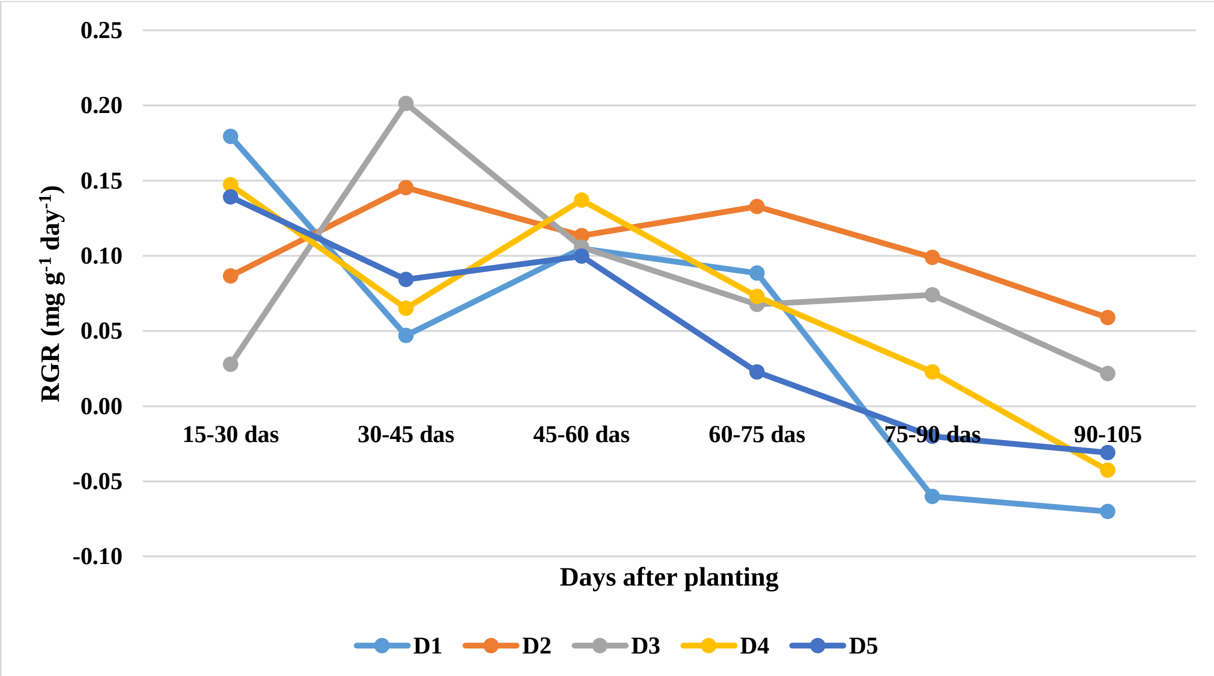


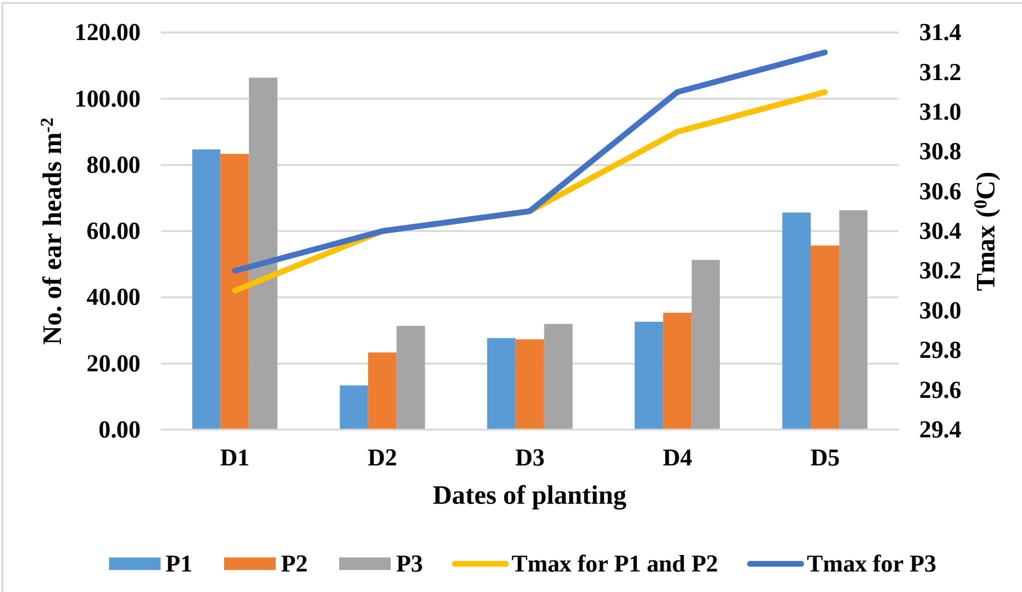
Fig. 5.14 (c) Trend of relative growth rate in different dates of planting in transplanting

D1 – May 15th	D2 - June 1st	D3 – June 15th	D4 – July 1st	D5 – July

5.5.5. Number of ear heads per m^2

Significant difference in number of ear heads per m^2 was observed with different dates of planting. Highest number of ear heads per m^2 was found for the May 15th planting. Later on it decreased to the lowest value and then followed an increasing trend till May 15th planting. Result from the studies made by Nagaraju and Kumar in 2009 showed that number of ear heads per m^2 followed a continuous decreasing trend with delay in date of planting. This statement supports only partially to the results obtained since it showed an increasing trend by the last date of sowing even though it showed an exact decreasing trend for the first and second date of sowing. This can be due to the effect of maximum temperature and rainfall on the yield parameter, since both of them have a negative correlation with the number of ear heads per m^2. Rainfall followed a decreasing trend with delay in date of planting. Since it was having a negative correlation with the number of ear heads per m^2, an increase in the number of ear heads per m^2 can be observed with decrease in the rainfall. Influence of maximum temperature and rainfall on number of ear heads per m^2 is given in the Fig 5.15 (a) and (b).

Considering the effect of planting method on the number of ear heads per m^2, significant influence is observed in all the cases. Transplanting method was found superior to other methods in all dates of planting in case of number of ear heads per m^2. The results in similar lines were obtained by Sarawale *et al.* (2016), Saha and Bharti in 2006 and Bhuva *et al.* (2006).



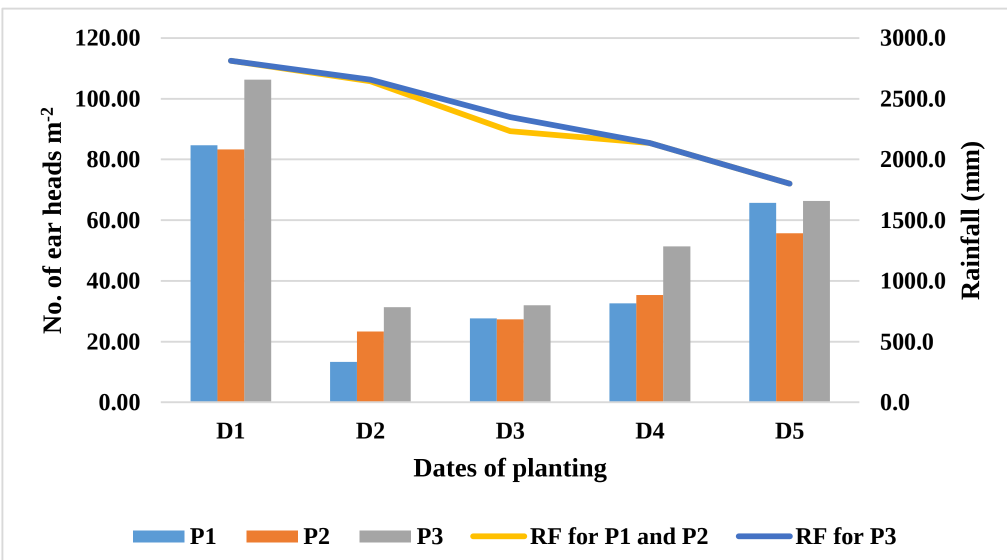


Fig. 5.15. Influence of maximum temperature and rainfall on number of ear heads per m^2 with respect to planting date and methods

D1 – May 15th	D2 - June 1st	D3 – June 15th	D4 – July 1st	D5 – July

P1 –Broadcasting	P2 – Dibbling	P3 - Transplanting

5.5.6. Finger number per ear head

Finger number per ear head showed a decreasing trend with delaying plantings. July 15th planting had the lowest number of fingers per ear head. These results have shown similarities with the results obtained by Nagaraju and Kumar in 2009 and Faghani *et al.* (2011). Considering the effect of planting methods on the finger number per ear head, significant influence has been observed. Transplanting and dibbling methods provide higher number of fingers per ear head than that of broadcasting method. The results obtained by Sarawale *et al.* (2016) and Nagaraju and Kumar in 2009 were in similar lines with the provided result.

5.5.7. Finger length

Finger length also followed a similar trend as that of finger number per ear head, since it showed a decreasing trend with delay in date of planting. The highest finger length was observed for May 15th planting which was on par with June 1st planting and there after it followed a decreasing trend till July 15th date of planting. These results were found to be in good agreement with the research findings of Nagaraju and Kumar in 2009. Planting methods did not show any significant influence on the finger length. They possess variable results in all the planting dates.

5.5.8. Thousand grain weight

Planting dates did not show any significant influence on the thousand grain weight. The readings followed a similar trend in all the dates of planting. Considering the planting method also, the result showed similar values for all the methods. No significant effect was observed for the interaction between the date of planting and planting method also.

5.5.9. Harvest index

The result of harvest index showed that date of planting had significant effect on the harvest index. Even though similar harvest index was observed for June 1st, July 1st and July 15th planting, the other two plantings show comparatively less harvest index. Ehdaie and Waines (2001) and Nagaraju and Kumar in 2009 reported no significant difference in the harvest index with respect to the planting dates. Planting method showed considerable effect on the harvest index in which transplanting method attained higher harvest index than the other methods in most of the treatments. The works of Nagaraju and Kumar in 2009 supported this result.

5.5.10. Straw yield

Planting possess significant effect on the straw yield in all the treatments. Straw yield showed a continuous decreasing trend with delay in date of planting except a slight increase in the third date of planting in transplanting. This result was in conformity with the research works of Nagaraju and Kumar in 2009. Considering the planting method, statistically it did not induce any significant effect on the straw yield.

5.5.11. Grain yield

Planting dates showed significant effect on the grain yield in all the treatments. Grain yield followed a continuous decreasing trend with delay in date of planting. Influence of weather parameters on the grain yield with respect to planting dates and methods are given in the Fig 5.16 (a) to (c). Correlation results showed that maximum temperature, mean temperature, diurnal temperature range, bright sunshine hours and evaporation showed significant negative correlation with the grain yield, while forenoon, afternoon and mean relative humidity, forenoon and afternoon vapour pressure deficit, rainfall and rainy days possess positive correlation with the same (Table 5.14). This results was in conformity with the research findings of Nagaraju and Kumar in 2009 and Maiti and Soto (1990). Considering the planting method, it possessed significant effect on the grain yield. Highest grain yield has been obtained from the transplanting method of planting followed by broadcasting and dibbling which was on par with each other in most of the planting dates. These results were found to be in good agreement with the research findings of Jain (2016), Kumar (2018) and Nagaraju and Kumar in 2009 and Sarawale *et al.* (2016).

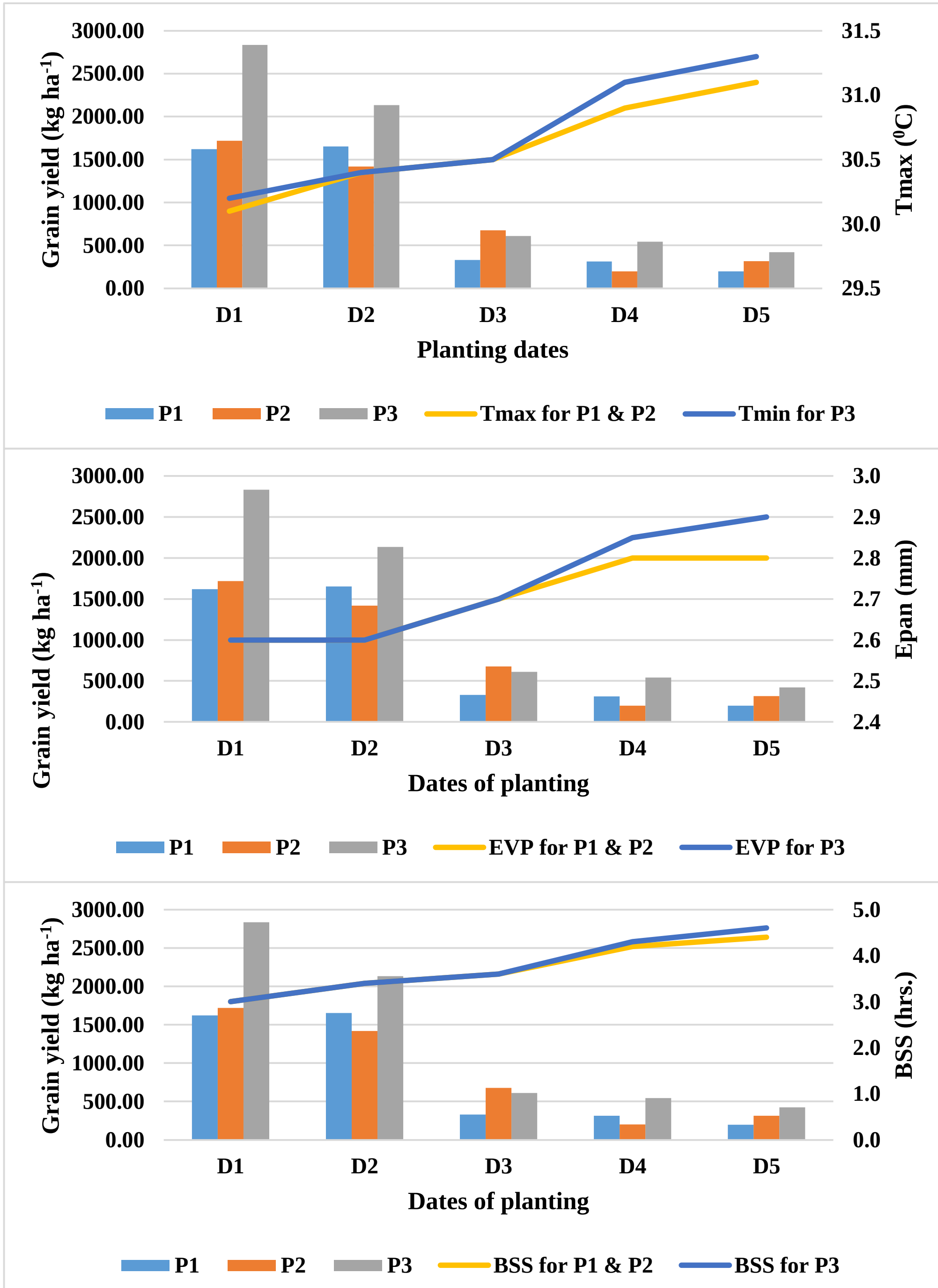


Fig. 5.16 (a) Influence of weather parameters on grain yield per m^2 with respect to planting date and methods

D1 – May 15th D2 - June 1st D3 – June 15th D4 – July 1st D5 – July

P1 – Broadcasting P2 – Dibbling P3 - Transplanting

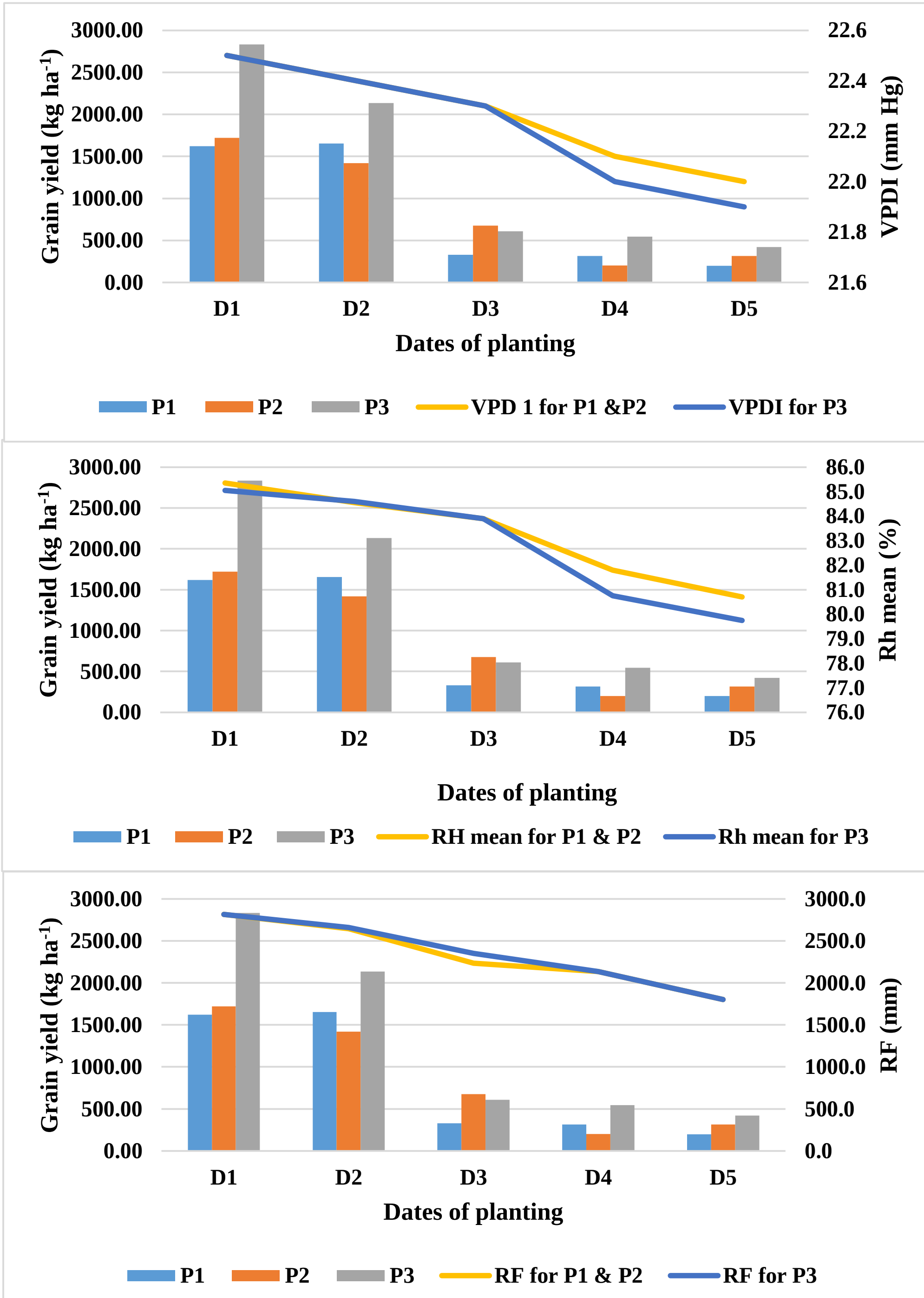


Fig.5.16 (b) Influence of weather parameters on grain yield per m^2 with respect to planting date and methods

D1 – May 15th D2 - June 1st D3 – June 15th D4 – July 1st D5 – July

P1 – Broadcasting   P2 – Dibbling   P3 - Transplanting

Table 5.14. Correlation coefficients between grain yield and weather parameters

	Tmax	Tmean	DTR	RHI	RHII	RHMean	VPI	VPII	BSS	RF	RD	Epan
P1	-.687**	-.679**	-.687**	.598*	.707**	.686**	.718**	.712**	-.705**	.775**	.732**	-.774**
P2	-.746**	-.726**	-.757**	.655**	.753**	.735**	.760**	.747**	-.762**	.759**	.747**	-.788**
P3	-.787**	-.780**	-.785**	.660**	.784**	.760**	.800**	.775**	-.802**	.852**	.791**	-.823**

*Significant at 5% level ** Significant at 1% level

P1- Broadcasting P2 – Dibbling P3- Transplanting

5.6. Effect of heat units on yield of finger millet

Considering the effect of accumulated Growing Degree Days, accumulated Heliothermal Units and accumulated Photothermal Units, the results showed that grain yield is significantly influenced by the AGDD, AHTU and APTU. AGDD and APTU was showing positive correlation with the grain yield during most of the phenophases which led to an increase in the yield with increase in the AGDD and APTU. Finger millet is considered as a tropical C4 cereal crop which required more heat units and this may be attributed to the positive relationship of grain yield with AGDD. This results are in agreement with the research findings of Rajegowda *et al*. 2015. The fluctuating temperature during the delayed sowing which coincides with the critical growth stages may be the reason for their yield reduction. The fluctuating temperature range during the crop growth period at different sowing dates are given in the Fig 5.17. The effect of heat units on grain yield were given in the Fig 5.18. (a).

5.7. Effect of heat units on duration of phenophases of finger millet

The relation of various heat units like AGDD, AHTU and APTU on the duration of each phenophases of finger millet were also studied. The result showed that with delay in date of planting as the GDD was getting reduced, the duration also gets decreased. This can be attributed to the less GDD requirements under delayed sowing compared to normally sown crops, which led to the reduced duration of phenophases in late sowing in all the planting methods. The fluctuating temperature conditions under delayed sowing may be the reason for the less GDD requirements during each phenophases. Increase in the duration with increase in heat units like AGDD helped the crop to attain the heat unit requirements of the crop at a particular phenophase. This results are in line with the experimental findings of Ram *et al*. 2012. The effect of heat units on the duration of phenophases are given in the Fig 5.17. (b).

5.8. Effect of planting methods on cost of cultivation of finger millet

The cost incurred for the cultivation of finger millet was estimated for the three different planting methods. The economics of finger millet cultivation under different methods showed that dibbling possessed the higher cost of cultivation and the lowest cost was under broadcasting method. This may be due to the less labour requirement in broadcasting method. Transplanting method has the highest gross return followed by dibbling method. In case of net return it was again highest for transplanting which was nearly two times more than that of dibbling and broadcasting method. This was due to the higher yield production in transplanting compared to the other methods. Benefit Cost ratio (B:C ratio) calculated from the net return and cost of cultivation was highest for the transplanting method and the lowest B:C ratio was found out in dibbling method, which again suggests that transplanting not only yields higher, but also economically feasible compared to other two methods of planting. This results are in agreement with the experimental findings of Kumar (2015) and Kumar (2018).

5.9. Optimum weather conditions required for better yield of finger millet

The optimum weather conditions required for the better growth and yield performance of finger millet estimated using the scatter plot technique is given in the Table 5.15. Since the May 15th planting with transplanting method attained the highest yield compared to all other plantings, the weather prevailed during that period was considered as the optimum weather required for the better growth and yield performance of finger millet in central zone of Kerala. Maximum temperature was found to be ranged from 29 to 32 ^{0}C during the vegetative phases and later on higher values are required at reproductive and ripening phase. Minimum temperature requirement also follows the same trend as that of maximum temperature in which it ranges from 21 to 22^{0}C during the first four phenophases and increased to 24^{0}C later on. Higher values of forenoon and after noon relative humidity are required during the initial stages compared to the later stages. Comparatively higher forenoon vapour pressure deficit is required during the sowing to panicle initiation, milk to dough stage and dough stage to physiological maturity which ranges from 22 to 23 mm Hg. Afternoon vapour pressure deficit also follows the same trend as that of forenoon vapour pressure deficit. It should be ranged from 19.5 to 23.5 mm Hg during the whole crop growing period which should require specific ranges at each phenophases. Rainfall and the rainy days required should be higher, nearly at the range of 2000 mm during the vegetative phase and later on it should be reduced. Rainfall less than 100 mm is required during the ripening phase and it should be less than 15 mm during the harvesting stage. Less bright sunshine hours are required during the vegetative phase and during panicle initiation to flag leaf stage. Thereafter it should be considerably increased up to a range of 4 to 9.5 hrs. during the ripening phase. Wind speed and evaporation should be in the range of 1.5 to 3.9 km hr^{-1} and 1.6 to 3.8 mm during the crop growth period. Requirement of Growing Degree Days (GDD), Helio Thermal Unit (HTU) and Photo Thermal Unit (PTU) are related with the duration of each phenophases of the finger millet crop.

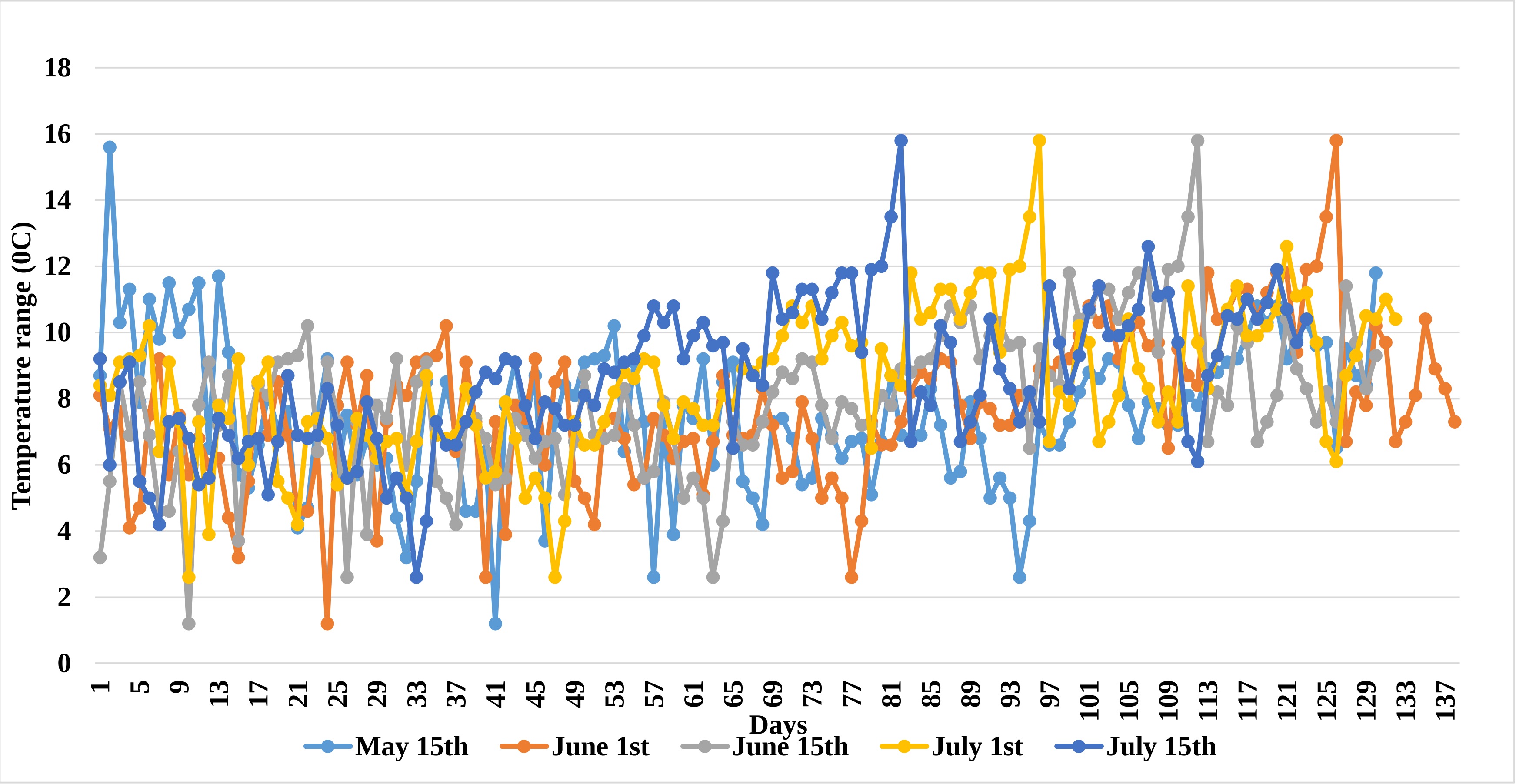


Fig. 5.17 Temperature range for five different planting dates during the crop growth period

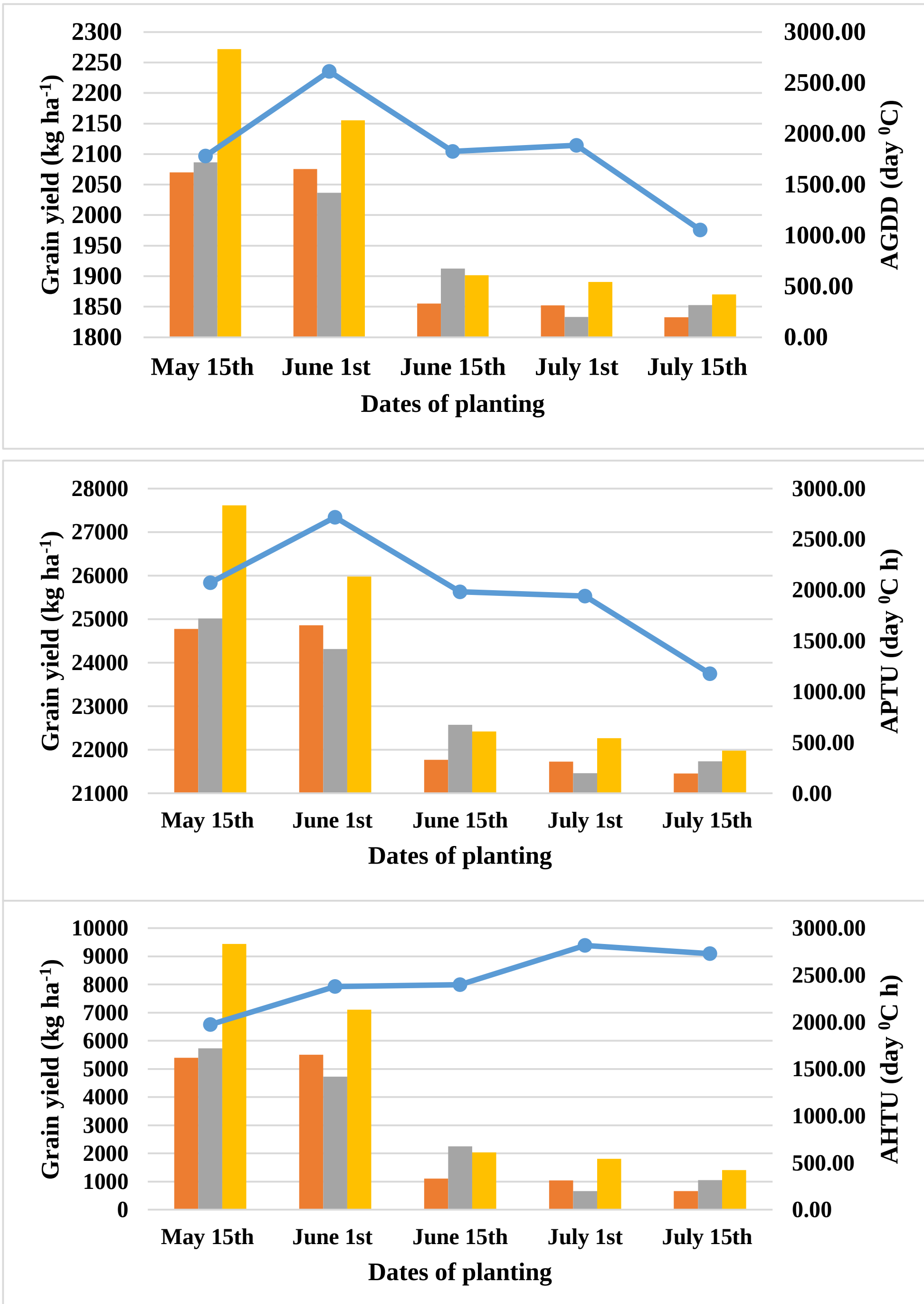


Fig. 5.18 (a) Effect of heat units on grain yield per m^2 with respect to planting date and methods

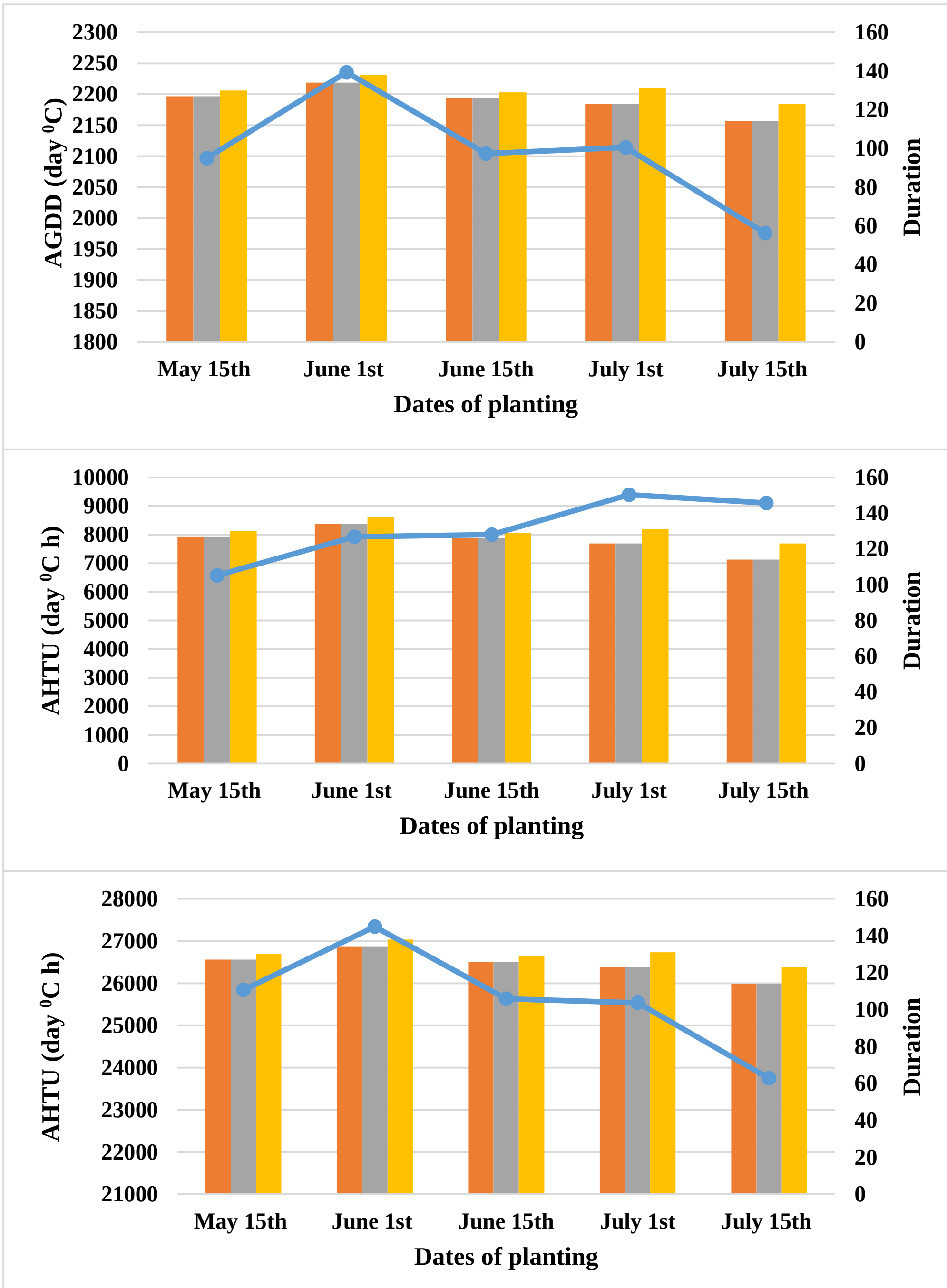


Fig. 5.18 (b) Effect of heat units on duration of each phenophases with respect to planting date and methods

Table. 5.15. Optimum weather conditions required for the better yield of finger millet

Weather parameters	Ph_1	Ph_2	Ph_3	Ph_4	Ph_5	Ph_6
Tmax (^{0}C)	29.5 - 30.1	27.5 – 32.5	30.2 – 32.5	31.0 – 33.8	32.0 – 32.5	31.9 – 32.4
Tmin (^{0}C)	22.7 - 22.8	21.7 – 22.2	22.2 – 22.5	21.5– 22.7	21.8 – 24.0	22.6 – 24.3
RHI (%)	95.0 - 95.5	90.0 – 96.3	92.4 – 95.5	91.8 – 93.0	87.0 – 91.1	91.4 – 95.3
RHII (%)	78.5 - 79.5	60.0 – 88.0	58.0 – 71.0	63.0 – 65.6	57.0 – 72.0	59.4 - 71.9
VPDI (mm Hg)	22.5 - 22.8	21.6 – 21.8	21.8 – 22.2	22.4 – 22.5	21.6 – 21.7	22.3 – 23.6
VPDII (mm Hg)	22.6 - 23.2	20.0 – 22.3	20.7 – 21.7	20.7 – 25.0	19.5 – 23.5	20.2 – 23.5
RF (mm)	2000 - 2500	< 670	<48	<100	<107	<14.9
RD (days)	60- 72	0 - 10	0- 10	2.0 – 4.0	0.0 -3.0	0.0-1.0
BSS (hrs.)	2.0 – 2.5	0.1-9.1	4.6-6.7	4.7- 6.3	4 – 9.5	5.0 - 6.2
WS (km hr^{-1})	1.6 – 1.7	1.7 – 1.8	1.7 – 1.9	1.5 – 2.2	1.9 – 3.9	1.2 – 1.4
Epan (mm)	2.4 – 2.5	1.6 – 3.7	2.6 – 3.4	2.9 – 3.2	3.2 – 3.8	2.5 – 3.1
GDD (day ^{0}C)	1433 - 1579	147-170	161-193	124-152	91.2-119	121.4-128.4
HTU (day ^{0}C h)	3205 - 3707	11-1553	750-1280	588-951	372-1131	653.5-754.5
PTU (day ^{0}C h)	17736 - 19500	1797-2063	1977-2340	1466-1842	1062-1437	1471-1496

Ph_1 – Sowing to panicle initiation
Ph_2 – Panicle initiation to flag leaf stage
Ph_3 – Flag leaf stage to 50% flowering
Ph_4 - 50% flowering to milk stage
Ph_5 – Milk stage to dough stage
Ph_6 - Dough stage to physiological maturity

SUMMARY

6. SUMMARY

The present investigation on "Crop weather relationship studies in finger millet (*Eleusine coracana* (L.) Gaertn) in central zone of Kerala" was conducted at Department of Agricultural Meteorology, College of Horticulture, Vellanikkara, Thrissur during 2018. The main objective of this study was to study the crop weather relationship and to determine the ideal time of planting and crop establishment method in finger millet.

Various weather, biometric, physiological and micrometeorological observations were made and noted during the study period. The biometric observations include plant height, numbers of ear heads m^{-2}, finger number per ear head, finger length, thousand grain weight, grain yield, straw yield, harvest index and dry matter production. Correlation and analysis of variance has been done to estimate the crop weather relationships in finger millet. The result are summarized below:

- Considering the micrometeorological parameters which include soil temperature and soil moisture, the highest soil temperature was observed for May 15th and June 1st planting in case of both the forenoon and afternoon soil temperature. While in case of planting method, significant variation was not observed for the afternoon soil temperature, but dibbling showed the highest value for forenoon soil temperature. Date of planting didn't shown any significant effect on the soil moisture, while in case of the planting method, broadcasting showed the highest value compared to the other methods.
- Weed observations made on the experimental plot suggests that broad leaved weeds like *Ludwigia parviflora*, *Mitracarpus villosus* were found in higher intensity rather than sedges and grasses. Sedges include *Cyperus spp*. Highest weed density was found in May 15th and and July 1st date of planting, while in case of planting method, it showed higher values in dibbling method followed

by broadcasting. Weed dry weight also showed higher values in dibbling followed by broadcasting method.

- Weather observations which includes various weather parameters like temperature, relative humidity, vapour pressure deficit, rainfall etc. influence the yield and the yield attributes. In most of the cases, temperature showed a negative correlation, while humidity factors showed a positive correlation with the yield and yield attributes.
- Heat units like GDD, HTU and PTU significantly influenced the duration of phenophases and yield of finger millet. GDD and PTU showed positive correlation with duration of phenophases as well as yield of finger millet, while HTU showed negative correlation with the same. This may be due to the more heat unit requirement of finger millet since it is a tropical C4 cereal crop.
- The observation on duration of each phenophases suggested that with delay in date of planting, the duration to attain each stages was showing a decreasing trend, So the highest duration was observed in June 1st planting and lowest duration was observed in case of July 15th planting. Comparing the various planting methods, transplanting showed the highest duration compared to other methods to attain each phenophases as well as in case of total duration also.
- Plant height was found higher in case of May 15th planting at 30 DAS, 45 DAS and 75 DAS which was on par with June 15th planting at 75 DAS. Broadcasting and dibbling method showed the higher values for plant height at 30 DAS and 45 DAS. Interaction effect was found for 35 DAS, 75 DAS, 90 DAS and at harvest observations May 15th planting at broadcasting showed the higher values during initial stages which shift towards the June 15th planting by the end of crop growth period.
- Dry matter accumulation was found higher for May 15th planting at 30, 75 and 90 DAS and June 15th showed the higher values in remaining observations. In

case of planting methods, transplanting was found superior compared to all other planting methods.

- Crop growth rate showed a variable trend throughout the crop growth period. The values were increasing gradually during the initial stages and there after followed a sudden increase and sudden decreasing trend. Both first and second date of planting showed a higher values at 75 DAS, while the third date of planting showed higher values at 60 DAS and fourth and fifth date showed higher values towards the end of crop growth period. Similar trend was followed for all the planting methods.
- Relative growth rate followed a variable trend during the initial growth stages and there after it showed a continuous decreasing trend till physiological maturity. Similar trend was followed for all the planting methods.
- Coming to the yield attributes, higher number of ear heads m^{-2}, finger length, straw yield etc. showed higher values for May 15th planting. Finger number per ear head was observed higher for June 1st date of planting which was on par with May 15th planting. Considering the planting method, significant difference was not observed with the yield attributes except finger number per ear head. In case of finger number per ear head, transplanting showed the highest values compared to other methods.
- Coming to the yield parameter which has been supported by all these yield attributes, we can see that highest yield was observed in May 15th and June 1st planting. In case of planting methods, transplanting was found superior compared to other methods. So the interaction effect showed that the treatment combination of May 15th planting with transplanting method showed the highest yield compared to all other treatments.
- Cost of cultivation incurred for the finger millet cultivation was observed highest for dibbling method and the lowest in broadcasting method, while coming to the B:C ratio, the highest value was obtained in transplanting and

the lowest was observed in dibbling method of planting. This reveals that the transplanting method of planting not only promotes higher yield production, but also economically feasible compared to broadcasting and dibbling.

So the present investigation concluded that the ideal date of planting can be considered as May 15^{th} and June 1^{st} planting and the best crop establishment method for finger millet cultivation can be suggested as transplanting in central zone of Kerala.

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APPENDICES

Appendix I

Abbreviations and units used

Weather parameters

Tmax : Maximum temperature

Tmin : Minimum temperature

TR : Temperature range

RH I : Forenoon relative humidity

RH II : Afternoon relative humidity

VPD I : Forenoon vapour pressure deficit

VPD II: Afternoon vapour pressure deficit

RF : Rainfall

RD : Rainydays

WS : Wind speed

Epan : Pan evaporation

BSS : Bright sunshine hours

Phenophases

S – PI : Sowing – panicle initiation

PI – FL : Panicle initiation- flag leaf

FL – F :Flag leaf – 50% flowering

F – MS : 50% Flowering- Milk stage

MS – DS : Milk stage-Dough stage

DS - PM: Dough stage – Physiological maturity

Planting methods

P1- Broadcasting

P2- Dibbling

P3- Transplanting

Units

g : gram

kg : kilogram

km hr^{-1}: kilometre per hour

^{0}C : degree Celsius

kg ha^{-1} : kilogram per hectare

% : per cent

g m^{-2} day^{-1} : Gram per meter square per day

mg g^{-1} day^{-1} : Milligram per gram per day

Growth indices

CGR – Crop growth rate

RGR – Relative growth rate

Appendix II

ANOVA of different plant growth characters of 2017 experiment

Plant height at different weeks after planting

Source of variation	DF	Mean sum of squares					
		30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At harvest
Date of planting	4	1719.673	4425.438	3743.839	6762.236	10303.86	11119.76
Error(a)	12	37.841	107.858	134.796	283.552	322.822	376.825
Planting method	1	120.404	206.565	195.251	36.25	2.542	72.632
DOP x Planting method	4	150.863	45.237	46.077	198.832	313.812	181.337
Error(b)	15	20.572	20.679	40.487	59.225	100.451	67.67

DF – degrees of freedom DOP – Date of planting

Appendix II (Contd.)

Dry matter accumulation at fortnightly intervals

Source of variation	**DF**	**Mean sum of squares**						
		15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	At harvest
Date of planting	4	2176.173	189582.6	24795318	321834234	654943520	1937684125	1816911486
Error(a)	8	455.726	21584.73	644590.4	14171176	33697455	46926319.2	90356606.2
Planting method	2	4566.258	291767.7	19116974	301440632	775643949	1557803941	1242690857
DOP x Planting method	8	542.061	45151.61	7983630	100058748	64380472	88773519.3	80068306.8
Error(b)	20	394.471	20375.52	699697.7	13807672	47736163	37346214.1	48876005.4

DF – degrees of freedom DOP – Date of planting

Appendix II (Contd.)

Grain yield, panicles per unit area, spikelets per panicle, filled grains, 1000 grain weight and straw yield at the time of harvesting

Source of variation	**DF**	**Mean sum of squares**					
		Grain yield	Number of ear heads per m^2	Finger number per ear head	Finger length	1000 grain weight	Straw yield
Date of planting	4	6224202	7118.411	14.274	38.16	0.49	99424942
Error(a)	8	188815.7	328.344	1.908	0.327	0.208	4475115
Planting method	2	1082400	789.756	3.473	0.074	0.25	1752178
DOP x Planting method	8	226424	96.894	0.533	0.511	0.067	2183533
Error(b)	20	247127.3	470.167	0.502	0.275	0.204	2367982

DF – degrees of freedom   DOP – Date of planting

Appendix II (Contd.)

Crop growth rate at fortnightly intervals

Source of variation	DF	Mean sum of squares					
		30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	105 DAT
Date of planting	4	3.912	449.822	2984.273	26034.41	42426.57	89049.1
Error(a)	8	0.544	13.246	277.399	615.627	909.741	104.577
Planting method	2	0.182	62.071	336.827	515.242	62.301	86.14
DOP x Planting method	8	0.41	45.246	338.276	1409.269	1415.573	4977.659
Error(b)	20	0.33	18.556	179.095	1143.194	1281.918	1285.075

DF – degrees of freedom DOP – Date of planting

Appendix II (Contd.)

Relative growth rate at fortnightly intervals

Source of variation	**DF**	**Mean sum of squares**					
		30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	105 DAT
Date of planting	4	0.016	0.037	0.001	0.037	0.027	0.033
Error(a)	8	0.003	0.004	0.003	0.002	0.001	0
Planting method	2	0.001	0	0.003	0.001	0	0
DOP x Planting method	8	0.002	0.002	0.003	0.001	0.001	0.002
Error(b)	20	0.001	0.001	0.001	0.001	0.001	0.001

DF – degrees of freedom DOP – Date of planting

Appendix II (Contd.)

Cost of cultivation under broadcasting method

Sl. No	Materials required	Quantity	Cost per unit	Amount (Rs. ha^{-1})
1.	Seed	25 kg ha^{-1}	Rs.30 / kg	750
2.	Fertilizer			
	1. Urea	45 kg ha^{-1}	Rs. 7 / kg	315
	2. SSP	22.5 kg ha^{-1}	Rs. 7.2 / kg	162
	3. MOP	22.5 kg ha^{-1}	Rs. 15 / kg	337.5
3.	Plant protection chemicals			
	Malathion	12.72 kg ha^{-1}	Rs. 40 / 500 gm	1018
	Folicur EC 250	100 ml ha^{-1}	Rs. 290/ 100 ml	290
4.	FYM	5 t ha^{-1}	Rs. 400 t^{-1}	2000
5.	Ploughing by tractor	15 hrs	Rs. 400 hr^{-1}	6000
6.	Labour charge	Number	500/head	Total
	1. Sowing	8	500/head	4000
	2. Fertilizer application	5	500/head	2500
	3. Manure application	5	500/head	2500
	4. Weeding	8	500/head	4000
	5. Spraying of pesticides	4	500/head	2000
	6. Harvesting	15	500/head	7500
	7. Threshing and cleaning	12	500/head	6000
	Total			39, 372.5

Appendix II (Contd.)

Cost of cultivation of finger millet under dibbling method

Sl. No	Materials required	Quantity	Cost per unit	Amount (Rs. ha^{-1})
1.	Seed	12 kg ha^{-1}	Rs.30 / kg	360
2.	Fertilizer			
	1. Urea	45 kg ha^{-1}	Rs. 7 / kg	315
	2. SSP	22.5 kg ha^{-1}	Rs. 7.2 / kg	162
	3. MOP	22.5 kg ha^{-1}	Rs. 15 / kg	337.5
3.	Plant protection chemicals			
	Malathion	12.72 kg ha^{-1}	Rs. 40 / 500 gm	1018
	Folicur EC 250	100 ml ha^{-1}	Rs. 290/ 100 ml	290
4.	FYM	5 t ha^{-1}	Rs. 400 t^{-1}	2000
5.	Ploughing by tractor	15 hrs	Rs. 400 hr^{-1}	6000
6.	Labour charge	Number	500/head	Total
	2. Sowing	16	500/head	8000
	3. Fertilizer application	5	500/head	2500
	4. Manure application	5	500/head	2500
	5. Weeding	12	500/head	6000
	6. Spraying of pesticides	4	500/head	2000
	7. Harvesting	15	500/head	7500
	8. Threshing and cleaning	12	500/head	6000
	Total			44, 982.5

Appendix II (Contd.)

Cost of cultivation of finger millet under transplanting method

Sl. No	Materials required	Quantity	Cost per unit	Amount (Rs. ha^{-1})
1.	Seed	5 kg ha^{-1}	Rs. 30 / kg	150
2.	Fertilizer			
	1. Urea	45 kg ha^{-1}	Rs. 7 / kg	315
	2. SSP	22.5 kg ha^{-1}	Rs. 7.2 / kg	162
	3. MOP	22.5 kg ha^{-1}	Rs. 15 / kg	337.5
3.	Plant protection chemicals			
	Malathion	12.72 kg ha^{-1}	Rs. 40 / 500 gm	1018
	Folicur EC 250	100 ml ha^{-1}	Rs. 290/ 100 ml	290
4.	FYM	5 t ha^{-1}	Rs. 400 t^{-1}	2000
6.	Ploughing by tractor	15 hrs	Rs. 400 hr^{-1}	6000
7.	Labour charge	Number	500/head	Total
	1. Sowing	16	500/head	8000
	2. Fertilizer application	5	500/head	2500
	3. Manure application	5	500/head	2500
	4. Weeding	8	500/head	4000
	5. Spraying of pesticides	4	500/head	2000
	6. Harvesting	15	500/head	7500
	7. Threshing and cleaning	12	500/head	6000
	Total			42, 772.5

Crop weather relationship studies in finger millet (*Eleusine coracana* (L.) Gaertn) in central zone of Kerala

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ABSTRACT OF THE THESIS

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ABSTRACT

Finger millet (*Eleusine coracana* (L.) Gaertn) is an important food crop next to rice, wheat and maize. The crop is native to Africa. Finger-millet is capable to withstand three stresses such as warming stress, water stress and nutrition stress, so it is called as Climate Change Compliant Crop (CCCC). These attributes combine to make finger millet a suitable crop for ensuring food security in drought prone areas of the countries.

The present study was done to estimate the crop weather relationship in finger millet (var : GPU-28) in central zone of Kerala and to identify the ideal date of planting and best crop establishment method during 2018. The field experiment was conducted at experimental field of Instructional Farm, College of Horticulture during the *kharif* season of 2018. Split plot design was adopted with five dates of planting *viz.,* May 15th, June 1st, June 15th, July 1st and July 15th as the main plot treatments and three planting methods *viz*., broadcasting, dibbling and transplanting as the sub plot treatments with number of replications as three.

Considering the weather observations, the daily observations of weather recorded during the crop period like maximum, minimum and mean temperature, rainfall and relative humidity showed considerable variations especially during the mid-growth period. Heat units like Growing Degree Days (GDD), Heliothermal Units HTU) and Photothermal Units (PTU) were also calculated for the crop growth period. Growth and yield attributes like plant height, dry matter accumulation, number of ear heads, finger number per ear head, finger length, thousand grain weight, grain yield, straw yield, harvest index and the duration of different phenophases were also noted. Growth indices such as crop growth rate and relative growth rate were worked out to analyze the growth and development of the crop. Micrometeorological and weeds observations were also made.

Correlation analysis was carried out using the weather parameters, yield and phenological data to estimate the crop weather relationship in finger millet. The results shows that maximum temperature was showing a negative correlation, while relative humidity, vapour pressure deficit and rainfall was showing positive correlation in most of the yield and yield contributing factors. Considering the micro meteorological observations, June 1st planting showed the highest values for both forenoon and afternoon soil temperature. Highest soil moisture was observed in broadcasting method of planting at 15cm depth and it did not show any considerable variations with respect to date of planting. Weed intensity and dry weight was shown higher during the dibbling method of planting.

Plant height was found to be higher for dibbling method of planting at 60 days after sowing and May 15th planting showed the higher values which was on par with June 15th planting. Dates of planting had significant effect on the dry matter accumulation which showed higher values for June 15th planting which was on par with June 1st planting at harvest in broadcasting method. Crop growth rate showed an increasing trend during the vegetative phases and there after followed a decreasing trend up to harvest, while relative growth rate showed a gradual decreasing trend from mid-growth period. Duration of phenophases was similar for both broadcasting and dibbling method, while transplanting took comparatively more days to attain each stages. Duration also showed a decreasing trend with delay in date of planting. Heat indices like GDD and PTU followed a decreasing trend with delay in date of planting which indicates their positive impact on the growth and yield performance of finger millet. Considering the yield attributes like number of ear heads m^{-2}, it showed higher values for transplanting method in May 15th planting. Finger number per ear head was higher for June 1st planting which was on par with both May 15th and June 15th planting. Highest finger number per ear head was attained for transplanting method which was on par with dibbling method of planting. Finger length showed the highest value in May 15th planting which was on par with June 1st planting. Date of planting showed significant effect on the straw yield as it was higher in May 15th planting and was lower in July 1st planting which was on par with July 15th planting. Harvest index attained higher values for July 1st planting which was on par with July 15th and June 1st planting. Interaction effect of the treatment combination of May 15th planting with transplanting method attained the highest grain yield (2833.3 kg ha^{-1}) compared to other methods. Assessment of cost of cultivation revealed dibbling method showed highest value while it was lowest in broadcasting method. But the B:C ratio was highest in transplanting and the lowest was observed in dibbling method of planting. This revealed that transplanting method not only encourages yield production, but also economically feasible compared to broadcasting and dibbling methods.

So the present investigation on the crop weather relationship in finger millet suggested that the positive contribution of various weather and micrometeorological parameters like relative humidity, vapour pressure deficit, rainfall, forenoon and afternoon soil temperature etc. and the reduced maximum temperature and temperature range which increased the production of number of ear heads, finger number per ear head, increased finger length, straw yield etc. This ultimately leads to increased grain yield in May 15th and June 1st date of planting. In case of the three planting methods, studies suggested that transplanting can be considered as best establishment method for finger millet cultivation in central zone of Kerala.