SPATIAL VARIABILITY OF CLIMATE CHANGE IMPACTS ON RICE (*Oryza sativa* L.) YIELD IN KERALA

By

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(2019-11-188)

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KERALA, INDIA

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2021

DECLARATION

I hereby declare that this thesis entitled **"SPATIAL VARIABILITY OF CLIMATE CHANGE IMPACTS ON RICE (*Oryza sativa* L.) YIELD IN 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

Date : 22-11-2021

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(2019-11-188)

CERTIFICATE

Certified that this thesis entitled **"SPATIAL VARIABILITY OF CLIMATE CHANGE IMPACTS ON RICE (*Oryza sativa* L.) YIELD IN KERALA"** is a bonafide record of research work done independently by **Ms. Riya K. R. (2019-11-188)** under my guidance and supervisionand 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. Riya K. R. (2019-11-188)**, a candidate for the degree of **Master of Science in Agriculture** with major field in Agricultural Meteorology, agree that this thesis entitled **"SPATIAL VARIABILITY OF CLIMATECHANGE IMPACTS ON RICE (*Oryza sativa* L.) YIELD IN KERALA"** may be submitted by **Ms. Riya K. R.** in partial fulfillment of the requirement for the degree.

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Riya K. R.

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Introduction

1. INTRODUCTION

Agriculture has been a part of mankind since time immemorial. India's rich soil and diverse climatic zones provided favorable conditions for agriculture. Hence agriculture in India has been regarded as the backbone of the Indian economy. According to the economic survey 2018 agriculture has given employment to more than 50% of the Indian labour pool. Hence agriculture contributed 17-18% to the nation's GDP. According to FAO, 2014 India leads in the production of pulses, jute and milk. India is the world's second largest producer of sugarcane, rice, wheat, groundnut, cotton, vegetables and fruit.

Rice is one of the essential food crops of the world. Almost 40% of the world's population consumes rice as their staple food. Rice is a heat and water-loving plant *i.e.* it requires hot and humid conditions. So from the dawn of civilization rice has been the life-giving cereal of the tropical region. Indian climate has proved to be highly suitable for rice production and it has been the world's second largest producer of rice. Rice can be grown in extensive agro-climatic regions. It is suitable for mountainous land like Jammu to below sea level areas like Kuttanad in Kerala. Near about 90% of rice production and consumption occurs in Asian countries. Daily millions of Indians find comfort with rice. Thus rice has been a staple food crop of India. Rice contains high carbohydrates, as a result, it provides instant energy so it is consumed by the majority of the nation's people. Rice is mainly cultivated in the rainfed condition in the regions receiving heavy rainfall. Hence the rice is mainly cultivated in the *kharif* season. Rice has been cultivated for nearly 60% of the total cropped area and nearly 77% of the entire nation's food production. Hence rice production in India can never be neglected.

As there is a steady increase in population, the demand for all the commodities increases. One of the basic commodities will be food. Increasing rice production is essential for assuring food security, alleviation of poverty and improving livelihood. Recent technologies like improved cultivars, optimum crop managing, modern types of machinery, *etc.* have paved the way to achieve the food demand and be self-sufficient. Despite all these technologies our weather and climate have been an all-time major concern for the farming society. Increases in temperature and carbon dioxide concentration along with the change in rainfall pattern which is all associated with climate change, have a direct or indirect effect on rice cultivation and production.

According to the Intergovernmental Panel on Climate Change there will be an increase of temperature by 1.4 -6.4°C in association with it there is an increase in the atmospheric CO_2 by 600-1550ppmv. Even though the increase in CO_2 enhances the photosynthesis rate this effect gets nullified by the increasing global temperature and thereby changes the water requirement and availability of crops. Increase in temperature changes the duration of crop phenophase, number of tillers and thereby affects yield of the crop. Studies have shown that an increase in temperature over the Indian region results in the yield decline of rice.

In Kerala rice is the main food. Nearly 12% of the total cultivated area in Kerala accounts for rice cultivation. Change in climatic conditions is having a significant effect on rice production. Hence it is high time to study the impact of climate change on rice cultivation. To study the impact of climate change on rice production in Kerala future climate of Kerala is needed to be estimated. The regional climate model helps to predict the future climate of an area. Thus, variation in future climate can be analyzed for all the districts of Kerala. Crop weather models have a vital role in climate change studies. Models help to simulate crop growth under future climate change scenarios. Crop models are the mathematical representation of real-world or simply growing plants in computers. Rice studies are mainly carried out in the CERES- Rice (Crop Environment Resource Synthesis- Rice) model. TheCERES- Rice has been calibrated and validated and found suitable for simulation of rice growth and development in the tropical humid climate. Since Kerala falls under this climate CERES-Rice crop simulation model has been used. This has been incorporated in Decision Support System for Agrotechnology Transfer (DSSAT). These help to stimulate the growth and development of rice with a minimum database. The weather parameters used in the models are solar radiation, rainfall, maximum and minimum temperature. A model is a tool for predicting the yield which will be useful in studying the spatial variability of rice production in Kerala in the future. Hence in this study, the impact of climate change on rice production has been carried out using the DSSAT model.

In this context under the Department of Agricultural Meteorology, College of Agriculture, Vellanikkara, has conducted the experiment entitled “Spatial variability of climate change impacts on rice (*Oryza sativa* L.) yield in Kerala”. The study has been carried out with the main objective to study the impact of climate change and expected changes in weather parameters like rain, solar radiation, minimum and maximum temperature on rice production in various districts of Kerala.

Review of literature

2. REVIEW OF LITERATURE

Rice plays an important role in the diet of more than half of the global population. Kerala is the southwest state of India. Rice is the staple food for the majority of Keralites. Weather and climate play a major role in the production of rice, like all other crops. Hence the main aim of this study is to analyse the spatial variability of rice production in Kerala. This chapter covers the review of literature based on the study that has been carried out.

1. Importance of rice cultivation
2. Impact of weather parameters on growth and yield of rice
3. Impact of dates of planting on growth and yield of rice
4. Influence of weather on the incidences of pests and diseases
5. Crop simulation models
6. Climate change
7. Spatial variability of climate change impact on rice in Kerala

2.1. IMPORTANCE OF RICE CULTIVATION

Cereals are one of the vital components of our balanced diet. Rice is one such cereal that is leading in the world and is considered to be stable food of more than 40% of the world's population. Rice is a good source of carbohydrates, iron, calcium, thiamine, vitamin E than any other cereal. Rice provides nearly 35% of energy and provides 28% of protein. Moreover, rice provides minerals and dietary fiber to the people who eat rice in their diet. China and India are the top rice producing countries and 90% of global rice production has been contributed by the Asian countries. In India, about 44.5 million Ha area is under rice cultivation which produces 172.6 million tonnes of rice. Rice cultivation employs nearly 70% of the rural population. At present India is cultivating more than 4000 cultivars of rice.

In India rice has been grown under different agro-climatic region which varies in altitude and climate. It has been found adapted to the high mountainous region also to the below sea level regions. The average temperature required for rice cultivation is 21 to37^{o}C and suitable in the region with an annual rainfall of 150-300cm. Hence, there are diverse growing seasons of rice in different parts of India, The temperature, soil types, rainfall, water availability, *etc.* determine the growing season. While in southern and eastern regions of the country, climatic conditions were found favorable hence rice cultivation can be carried out throughout the year. *Kharif* is the main growing season in the country.Rice is grown under rainfed conditions and irrigated conditions. The total area under irrigated rice is nearly 22.00 million ha *i.e.* 49.5 % of the total area under rice production in the country. The rainfed condition includes both upland rice production and low land rice production (Singh, 2009).

One of the attractive features of Kerala state is its luxurious green paddy field, even though the area under rice cultivation is reducing since the 1980s. Howevernow rice occupies the third position when compared with other crops regarding area under cultivation, first two positions are handled by coconut and rubber (Thomas, 2011). Major rice producing districts of Kerala are Palakkad and Alappuzha, the former is considered as the “Rice bowl of Kerala”. In Alappuzha, Kuttanad which is gifted with a large system of backwaters supports rice production.

In many regions of Kerala, rice cultivation has been carried out in such a manner that enriches the certain geographical and ecological features of those regions *e.g. kaipad* fields, *pokkali* fields, *kole* fields *etc.* In Kerala rice productivity is less *i.e.* nearly 2790 kg per ha but higher than the national average (2424 kg/ha). The highest productivity of rice is in Punjab *i.e.* 6021 kg per ha during 2019-20. Over the world, rice has been cultivated on 197 million ha which produces 996 million tonnes of rice (FAOSTAT, 2018).

2.2 IMPACT OF WEATHER PARAMETERS ON RICE GROWTH AND YIELD

Weather and climate are so powerful that their effect may let all the recent technological efforts go in vain. Even these parameters decide the flora and fauna of a region. Hence the impact of weather and climate on rice growth and yield can never be neglected. The potential production of rice is mainly depending upon the weather experienced during each phenophases. The weather has a certain effect on plant growth, height, leaf area, number of tillers and duration of each phenophase, yield and yield attributes.

Being a sub-tropical plant rice requires a high temperature ranging from 20º to 40 ºC. The crop gets affected when the temperature goes very high as well as very low. Yoshida (1981) reported that temperature is having a high influence on germination. Mackill *et al.* (1982) observed that a reduction in the yield as a result of reduced pollen shedding along with incomplete pollen growth when the temperature was above 34 ºC. Grain yield was found to be higher due to low-temperature grain filling stage. Ghosh *et al*. (1983) reported that the temperature and sterility were negatively correlated which indicates that lower temperature tempted high sterility. An increase in temperature of 35 ºC or greater than that inhibited the germination because high temperature leads to increased respiration rate (Sreenivasan, 1985). For tillering, the optimum temperature required was 25-31ºC. Sreenivasan (1985) found that tillering rate was inhibited by low temperature and a prolonged tillering period which resulted in more tillers and more panicles than at elevated temperature. Strong winds from grain filling to physiological maturity would lead to crop lodging and grain shattering (Sreenivasan, 1985). Strong wind results in sterility at flowering by dehydrating the pollen.

Higher temperatures above 28ºC during tillering to reproductive stage reduced the days to achieve heading stage and thereby shortening the life cycle of rice. The most sensitive stage to low temperature is the booting stage followed by the heading or flowering stage. Low temperature during this stage results in a higher rate of spikelet sterility. The number of grains per panicle and increased spikelet sterility was found to be reduced in short duration varieties under the low light stress during the reproductive stage (Murty and Sahu, 1987)

Tashiro and Wardlaw (1989) reported thattemperature below 28 ºC during grain filling enhanced its duration and along with increased seed size. This is because of a more favorable equilibrium between respiration and photosynthesis. At the same time, high temperature during the grain filling stage resulted in reduced of grain filling. Solar radiation captured by rice canopy plays a key role in defining crop biomass and yield of rice. According to Tsai and Lai, (1990) shading caused the delay in tillering and also reduced the tillering rate and total dry matter production. But it resulted in the increased height of plant, leaf area index and total chlorophyll content. According to Chan and Cheong (2001), the mean ET/Epan value of 1.56 mm was recorded during the season and 1.75mmduring off-season values. ET value varies with varieties and was found higher in the offseason. Rice needs a high degree of humidity for proper growth. Relative humidity of 80-85 % is best for shoot growth. Decrease in relative humidity resulted in low moisture content quick senescence of leaf and loss of chlorophyll.

Even then moisture stress observed 10 days after 50% flowering causes a significant reduction in single panicle weight, filled grains per panicle, test weight and also increased the number of sterile spikelets per panicle (Girish and Hittalmani, 2004). Hence this is considered to be the critical growth stage.

Chalky grain incidence was more common during high temperatures. Rice also exhibited photorespiration which enhanced during high temperature and light incidence. High temperature also resulted in a decline inamylase content and grain weight (Kim *et al.*, 2011). Since rice is water-loving crop rainfall has a major influence on rice production. According to Bhattacharya and Panda (2013) that there was an increase in production with per mm increase of rainfall over the Subtropical region. But continuous rain along with strong wind during the flowering season resulted in yield reduction. Abbas and Mayo (2021) reported rainfall during heading to flowering is having a negative impact on rice yield.

2.3 IMPACT OF DATES OF PLANTING ON RICE GROWTH AND YIELD

The date of planting of the rice crop is an essential factor for increased productivity. It guarantees that vegetative growth occurs throughout an optimum range of temperature and solar radiation and the cold sensitive stage occurs during the time when the minimum night temperatures are the warmest. The maximum yield of rice can be attained by planting the rice at an optimum time, which differs in different varieties (Reddy and Narayana, 1984).

Under rainfed conditions in Kerala according to Saseendran *et al.* (1998) the optimum date of transplanting was found from the 23rd to 26th meteorological week in case of multiple cropping while from the 26th to 32nd week for a rainfed crop. Planting of hybrid rice 'PA 6201' *i.e.* on July16th showed the maximum leaf area index, effective tillers and dry matter accumulation when compared to July 30th and August 16th planting. August 16th planting showed a 38% reduction in the total number of tillers, 13% of LAI and 18% of dry matter accumulation (Nayak *et al*. 2003). On time of sowing ensures that grain filling during optimum temperatures which enhances good grain quality (Dixit *et al*., 2004). Panicle initiation was delayed in early sown crop (5th and 10th June) and while 50% flowering was found earlier in late sown rice *i.e.* 25th June. Chopra and Chopra (2004) stated that growing degree days to reach each phenophases got reduced virtually linear manner by delaying in transplanting. Arumugam *et al*. (2007) reported that for long-duration varieties optimum sowing is prolonged up to July 1st fortnight while in case of medium-duration varieties it can be extended up to 2nd fortnight without causing a significant reduction in grain yield. Baloch *et al*. (2006) concluded that timely sowing could reduce the seed rate because the use of one seedling per hill was found appropriate under timely sowing conditions while to compensate the yield loss during delayed sowing conditions 4 seedlings per hill are recommended.

Rai and Kushwaha (2008) reported that the delayed planting in rice *i.e.* from June 15 to July 15 resulted in decreased leaf area index by 10%. Annie *et al.* (2009) observed that July 15th planting was found best during the rainy season with the highest number of effective tillers, higher leaf area index during the flowering stage, a higher number of filled grains per panicle, and an increase 1000 grain weight along with a significant reduction in the sterility percentage.

Early sowing is optimum for achieving maximum tillering, more panicles per m^2, leaf area index, chlorophyll content, panicle length and grain yield (Khalifa, 2009). Poonam (2009) and Nahar *et al.* (2009) experimented on dates of plantings *i.e.* September 1, September 10, September 20 and September 30. He concluded that there were significant in yield reduction and yield attributes were also negatively affected in delayed plantings. The number of sterile spikelets was increased in late transplanting due to the low temperature experienced during the panicle initiation stage.

Abayawickrama *et al*. (2017) reported that high daytime temperature at the time of grain filling stage results in low milling quality of rice. The temperature sensitive grain filling stage was used to determine the optimum sowing time. Wani *et al*. (2017) reported that Growing degree days required to achieve different phenophases like the flowering stage, milking stage, dough stage and harvest stages were found higher in the planting of 15th and 16th standard meteorological weeks while in late sowing *i.e.* 18 standard meteorological weeks showed a significant reduction in the GDD to reach above mention phenophases.

Satish *et al.* (2017) reported that heat units required to attain various phenological stages decreased with delaying planting. The first transplanted crop on 5th June took maximum days to reach each phenophase, maximum growing degree days and helio thermal units to each different phenophase. This reduced the duration of the crop towards late planting.

Patel *et al*. (2019) reported that a decline in the yield of rice during delayed sowing may be associated with a decrease in the number of filled grains, panicles and a lower 1000 grain weight. Incidence of favorable weather during each critical phonological stage may ensure a promising yield which can be achieved through timely sowing of the crop.

2.4 INFLUENCE OF WEATHERON THE INCIDENCES OF PESTS AND DISEASES

Pest and disease effect the rice production. Weather at a location also influences the pest and disease incidence of the crop. Yashoda *et al.* (2000) reported that weather conditions prevailing during 50% flowering have a major effect on the incidence of false smut disease in rice. Maximum temperature below 31°C, rainfall less than 5 mm, a high minimum temperature of 19°C and relative humidity greater than 90% during 50% flowering favors the incidence of false smut in rice.

Lenka *et al.* (2008) reported that the percentage disease incidence of sheath blight was found to be positively correlated with temperature (both maximum and minimum temperature) and rate of evaporation. Shamim *et al*. (2009) reported that the population of green leafhopper was found to be maximum during 43rd standard meteorological week and white-backed plant hopper was found to be maximum during 39th standard meteorological week and the incidence was found to reduce after that. Green leaf hopper and white backed plant hopper showed a positive correlation with bright sunshine hours. Planting after the optimum date of planting date resulted in reduced yield since delayed planting crops is more prone to pests and diseases (Reza, *et al*. 2011). The weather conditions favorable for the rice pest population were cloudy weather along with a well distributed uniformly distributed rainfall with more rainy days during the crop season (Singh *et al.* , 2012).According to a study conducted by Rana *et al*. (2017) indicated that the stem borer damage has a significant positive correlation with minimum and average temperature. Also,the maximum number of dead hearts was observed during the 35th standard meteorological week after that there is a decrease and later an increase was observed during the 40th standard meteorological week which coincides with the reproductive phase. An increase in rainfall enhanced the incidence of yellow stem borer.The probability of infestation of stem borer increases if the difference of morning and evening relative humidity is 10-20% (Mandal, 2018)

Dhaliwal *et al*. (2018) reported that the Brown spot disease incidence showed a positive correlation with forenoon relative humidity and a negative correlation with afternoon relative humidity. He concluded that the incidence of brown leaf spots has been influenced by temperature, relative humidity and amount of rainfall experienced during the crop season. An increase in maximum temperature, wind speed and evaporation increased the incidence of blast disease while the disease showed a negative correlation with relative humidity in rabi rice (Pradhan, 2018). Nessa, (2018) reported that high incidence of rice false smut occurred when the average temperature was found in the range of 22-27°C during the panicle initiation stage.

Even though the incidence of green leaf hopper was found throughout the crop period from the vegetative phase to reproductive phase, pest population was found to be decreased during initial dates of planting. Under delayed dates of planting the incidence of green leaf hopper was found to be increased (Yadav, 2018).The weather parameters like temperature, rainfall, relative humidity, *etc*., have a direct impact on insect pest incidence and their reproduction. Rainfall was found to be not only important for the survival of pests, but also the disposal of the pest populations. As a result of the incidence of yellow stem borer percent, dead hearts and percent of white ears were found to be highest in 41stand 47th standard meteorological week, respectively. The occurrence of dead hearts was found positively correlated with the mean relative humidity and afternoon relative humidity while the percent of white ears had a significant negative correlation with forenoon relative humidity, minimum temperature and rainfall.The results also showed that the rice leaf folder population correlated positively with relative humidity significantly (Sharma *et al.* 2018).

Sharma *et al.* (2019) found that the population of rice earhead bugs was first recorded on the 36th standard meteorological week and its peak population was observed during the 44th standard meteorological week.

Afternoon relative humidity and rainfall showed a positive correlation with the incidence of sheath blight (Prakasam, 2020). An increase in the incidence of grain discoloration (one of the novel diseases of rice), maybe animpact of climate change. Baite *et al*. (2020) reported that a temperature range of 25-37°C, high wind speed, moderate precipitation, and high relative humidity (70-76%) were favorable for the incidence of grain discoloration.

2.5. CROP SIMULATION MODELS

Scientists and engineers have been evolving more process-oriented simulation models for different crops for more than 40 years. Now in this century crop simulation models are available for most of the world’s major crops. The initial model was developed by De Wit, 1965 by relating the photosynthetic rate of the crop to yield and thereby predicting the yield.

International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) developed Decision Support System for Agrotechnology Transfer (DSSAT) with an international network of scientists to enable the use of crop models in a system. The development of DSSAT was initially motivated by the requirement to integrate information on soil, weather crop and management for taking better decisions in transferring production technology from one region to other regions with different soil and climatic condition (IBSNAT, 1993). Swain *et al.* (2007) calibrated and evaluated CERES–Rice modelfor cultivar IR 36 cultivated at Cuttack, Orissa. He predicted the phenological events accurately and also simulated yield at various levels of N and found in close agreement with actual yield. Basak, (2010) studied the impact of climate change on the yield of two varieties of *Boro* rice using the DSSAT model, yield of both the varieties for 2030, 2050, 2070 was simulated for 12 districts of Bangladesh by using the input of soil and weather data of each location.

Oteng-Darko (2012) simulated the yield of rice under various climate change scenarios in Ghana by using the CERES-rice model which was calibrated and evaluated. Weather data of eighteen years was used to run the model. He concluded that the model was sensitive to various weather parameters like temperature, rainfall, solar radiation and CO_2 concentration and these havean effect on rice yield. An increase or decrease of temperature by 4°C caused a reduction in yield by 34% when compared to the base scenario of 2006. The CERES-Rice model in the DSSAT was used to study the impact of climate change on rice and for further development of adaptation policies to maintain rice production over the western zone of Tamil Nadu. From the study, it was shown that rice yield was expected to decrease by 4 to 56% with an increase in temperature by 1 to 5°C from normal during various dates of planting *i.e.* June 1st to July 15th (Bhuvaneswari *et al*., 2014)

Dias, (2016) used a validated DSSAT model to forecast the rice yield for the *Yala* season in the mid-centuries and a decreasing trend of yield was observed along with a reduced growth period. Vyshak *et al*. (2016) simulated phenology and yield of rice using CERES –Rice model and calibrated genetic coefficients by 6000 iterations and validated the model using a field experiment. Ray, (2018) studied the effect of changing climate on the yield of *Swarna* rice variety through sensitivity analysis in the CERES rice model in the Keonjhar district of Odisha and it was found that an increase in both maximum temperature and minimum temperature has a negative impact on the yield of rice. Kant *et al.* (2018) experimented with three rice varieties CAU-R1, Shahsarang-1 and Lumpnah-1 at Umiam, Meghalaya and concluded that DSSAT- CERES rice model can be used for predicting the yield of the varieties considered under the study, even then calibration may be done for close prediction of yield and phenophases. It was found that the model successfully predicted yield at different levels of nitrogen. In a study conducted by Chaudari *et al*. (2019) in the south Gujarat region where he studied the impact of temperature and CO_2 on rice growth and yield using DSSAT. He observed that a rise in temperature by 1-2°C leads to a reduction in yield by 3.25% to -9.47%while a decrease in temperature by 1 to 2°C leads to increase in yield by 5.93%. Islam, (2021) conducted an experiment to study the DSSAT-CERES rice model simulation of upland rice yield under different temperatures *i.e.* 28°C, 30°C and 32°C. Results showed that a moderate temperature of 28°C has given the highest simulated yield while at maximum temperature 32°C gave the least simulated yield.

2.6. CLIMATE CHANGE

Climate is a key factor of an area in determining its flora and fauna. Change in climate affects every aspect of the environment. It may result in a change in temperature, precipitation, *etc*. which directly or indirectly affects biodiversity. According to Intergovernmental Panel on Climate Change (IPCC) report, 4th assessment global temperature is expected to rise by 1.4 to 6.4°C by 2100 along with an increase in atmospheric CO_2 from 600 to 1550ppmv (IPCC, 2007).

Various paths have been taken by the models to reach four different radiative forcings that correspond to different concentration paths of the greenhouse gases, which is called as Representative concentration pathway (RCPs). Representative specifies that each RCP gives only one out of many probable scenarios that leads to the specific radiative forcing characteristics and the word ‘pathway’ highlights that not only the long-term concentration levels but also the path that took overtime to reach that outcome is important. Hence, the RCP indicates the latest parallel process that initiates with the selection of four RCPs, each of which corresponds to a specific radiative forcing pathway (Moss *et al*., 2010). The four different scenarios are labeled as RCP 8.5, RCP 6.0, RCP 4.5 and RCP 2.6, which correspond to radiative forcings of 8.5 Wm^{-2}, 6.0 Wm^{-2}, 4.5 Wm^{-2} and 2.6 Wm^{-2}, respectively (Vuuren, 2011).

Xu and Xu, 2012 described the climate change in China using 11 climate models under RCP scenarios. They reported that warming is expected in all regions of China under the RCP scenarios, with the northern regions showing greater warming than the southern regions. The warming tendency from 2011 to 2100 is 0.06°C/10 a for RCP2.6, 0.24°C/10 a for RCP 4.5, and 0.63°C/10 a for RCP 8.5.

Chaturvedi *et al*. (2012) experimented on model climate change projections for India under different RCPs. He found out that the mean increase in temperature by 2030 was 1.7 to 2°C and 3.3 to 4.8°C by 2080 with respect to the pre-industrial period. The rainfall was projected to increase by 4 to 5% by 2030 and 6% to 14% by 2080. IPCC's fifth assessment report has developed a novel method for developing different climatic scenarios (IPCC, 2013). As per the fifth assessment under all the scenarios, the global ocean will warm in the future. The main reason for to rise in global mean sea-level temperature in the twentieth century is a thermal expansion which leads to ocean warming and glacier melt (Abraham *et al*., 2013).

Chou *et al.* (2014) assessed the climate change over South America under Representative concentration pathway (RCP) 4.5 and 8.5 and concluded that events of extreme rainfall are more frequent in southeastern part of South America and heavy rainfall rate was found reduced. An increase in temperature is expected in the future. A study conducted by Ramaraj and Geethalakshmi, (2014) reported that the maximum temperature of Coimbatore in Tamil Nadu is likely to rise by 0.2℃ to 2.2℃ under RCP 4.5 and by 0.6 to 2.7℃ under RCP 8.5 by the end of 21^{st} century. While in the case of rainfall it was found to increase in some areas and decrease in other areas. Deviation of rainfall ranged from -9.6 to 30%. Sanjay *et al*., 2020 reported a warming trend of

0.15°C, 0.15 °C and 0.13 °C per decade in the annual mean, maximum and minimum temperatures respectively since 1986 over India as a whole.

2.7. IMPACT OF CLIMATE CHANGE ON RICE

Wassmann *et al.* (2009) reported an increase in temperature over Asian countries from April to October. Hence these high-temperature days are likely to coincide with the critical growth stage of rice. Even though the production of rice in northwestern India is least affected. This is because the temperature is less than 33°C. But in southern and western Indian increase in temperature greater than 35°C is expected. So in the states like West Bengal, Jharkhand, Bihar, Orissa, Kerala, Karnataka and Tamil Nadu heat stress is expected which negatively affects rice cultivation.

Mishra (2013) studied the spatial variability of rice and wheat yield in the Indian Ganga Basin using DSSAT. The studies found that under projected climate (using regional climate models) showed a decrease in the yield of rice and wheat in the upper and middle Indian Ganga Basin during the 2011-40 periods.

Zhou (2021) studied the impact of climate change on rice and found that future temperature trends had a significant effecton other variables which include solar radiation and precipitation. He concluded that a higher temperature exerted a strong effect on the fertilization of rice and thereby reduced the yield. Increase temperature shortens the duration of each phenophase and grain filling which led to a reduction in the yield. Increased temperature limits the photosynthetic rate at the same time increased CO_2 leads to promoting the photosynthesis process. Hence the net result will be determined the dominant effect.

Materials and methods

3. MATERIALS AND METHODS

Under the Department of Agricultural Meteorology, College of Agriculture, Vellanikkara, an experiment has been conducted on "Spatial variability of climate change impacts on rice (*Oryza sativa* L.) yield in Kerala" during 2020-21.

3.1. DETAILS OF THE EXPERIMENT

3.1.1. Location of experiment

The field work was done during the months May 2020 to November 2020 at Agricultural Research Station, Kerala Agricultural University, Mannuthy, Thrissur. The station is at 22m above mean sea level placed at 10^0 32' N latitude and 76^0 20' E longitude.

3.1.2. Soil Characters

The soil type at the experimental site was sandy loam type. Mechanical composition of the soil at field has been defined in Table 3.1.

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 (%)	26.0

3.1.3. Climate

Climate of the experimental field has been categorized as a warm humid tropical region. Average maximum temperature experienced at experimental location during the crop period was 30.79^0C and average minimum temperature prevailed during the experimental period was 22.68^0C. Throughout the crop period total rainfall received was

2583.50mm. On an average experimental field received a bright sunshine hours of 3.49 hrs/day during experimental period. Average wind speed was found to be 1.6 km/hr^{-1} during the experimental period. Average forenoon relative humidity and afternoon relative humidity was found 94.38% and 74.21% respectively during the experimental period. Weather experienced during the experimental period is described in Table 3.2

3.1.4 Season of the experiment

Jaya and Jyothi, rice varieties were raised at Agricultural Research Station during the *kharif* season from May to November.

3.2. EXPERIMENTAL MATERIALS AND METHODS

3.2.1. Variety

Jaya and Jyothi were the two varieties used in the experiment. Former is a medium duration variety which has a growth period of 130 days and the latter is a short duration variety of 110-115 days growth period. Jaya has been developed from cross between Taichung (Native) 1 and T-141 at all local photosensitive variety of rice found in Orissa. Jaya has been grown all over India during *kharif* and *rabi* season under irrigated condition. Jyothi is a variety cultivated in Kerala during all the three seasons. It has wider adaptability. It is highly suited to wetland areas.It has beendevelopedfrom the cross between PTB-10 and IR 8.

3.2.2. Design and Layout

Split plot design has been used for the experiment, where the five dates of plantings (June 5th , June 20th , July 5th ,July 20th and August 5th) were considered as main plot treatments and the two varieties (Jaya and Jyothi) were considered as the sub plot treatments with four replications. Figure 3.1 depicts the layout of the field. The field has been divided into 40 plots each with a size of 4x4 m^2. Each variety has been spaced accordingly. Spacing used for Jaya was 20 cm x15 cm and the spacing for Jyothi was 15 cm x10 cm.

Table 3.2 Weekly weather parameters during experimental period 2020

SMW	Tmax ℃	Tmin ℃	RHI %	RHII %	WS Km hr^{-1}	BSS hrs	RF mm	RD	EVP mm	TR ℃	VPDI mmHg	VPDII mmHg
23	31.2	24.3	94.3	78.6	1.6	2.1	74.7	4.0	6.9	6.9	23.5	23.9
24	31.4	23.2	94.4	75.9	0.9	2.0	125.9	7.0	8.1	8.2	22.3	23.9
25	30.7	23.5	95.7	75.1	0.7	1.7	92.1	5.0	7.2	7.2	22.6	22.8
26	31.1	23.4	92.4	71.4	1.0	3.6	119.9	4.0	7.7	7.7	22.4	22.9
27	29.9	23.1	96.7	87.3	0.9	0.5	163.5	7.0	6.8	6.8	23.0	22.9
28	31.0	23.2	95.4	70.7	1.1	3.3	76.0	3.0	7.8	7.8	22.5	22.5
29	30.2	23.1	95.3	81.3	0.9	2.4	84.9	3.0	7.1	7.1	22.7	23.6
30	31.5	23.2	94.7	73.1	1.7	5.1	72.3	5.0	8.3	8.3	22.8	22.8
31	28.7	22.5	97.6	82.7	2.1	0.8	332.0	7.0	6.2	6.2	22.6	23.4
32	28.0	22.6	96.4	91.7	1.9	0.0	378.9	6.0	5.4	5.4	22.4	23.4
33	30.5	23.3	96.0	75.1	1.6	1.8	48.1	5.0	7.2	7.2	23.7	23.1
34	31.4	23.5	95.6	70.6	1.3	5.5	7.3	1.0	7.9	7.9	23.7	23.3
35	32.3	23.2	93.9	63.1	1.8	7.7	12.8	1.0	9.2	9.1	23.1	21.9
36	31.3	22.6	92.9	82.7	1.6	3.2	138.1	4.0	8.6	8.7	22.5	23.9

Table 3.2 Weekly weather parameters during experimental period 2020 (Contd.)

SMW	Tmax °C	Tmin °C	RHI %	RHII %	WS Km hr^{-1}	BSS hrs	RF mm	RD	EVP mm	TR °C	VPDI mmHg	VPDII mmHg
37	28.1	22.1	97.9	86.0	0.9	0.5	210.2	7.0	6.1	6.0	22.7	23.0
38	29.1	21.9	97.4	80.4	1.8	1.2	206.1	6.0	7.1	7.2	22.4	23.0
39	30.7	22.7	96.6	74.1	1.4	3.4	22.0	3.0	8.0	8.0	23.5	23.0
40	31.2	21.7	94.0	65.3	1.7	7.6	17.8	1.0	9.5	9.5	22.3	21.5
41	30.3	21.6	97.0	78.3	1.8	2.9	187.0	5.0	8.7	8.7	22.5	23.4
42	30.1	21.5	96.1	74.0	1.5	4.8	96.3	5.0	8.6	8.6	22.6	22.3
43	31.4	21.1	94.3	67.1	1.1	5.8	9.2	1.0	10.3	10.3	22.0	21.7
44	33.0	22.5	94.0	60.9	1.3	5.4	0.0	0.0	10.5	10.5	22.9	22.4
45	33.7	22.0	82.1	52.9	4.4	7.7	46.8	1.0	11.7	11.7	21.1	19.8
46	32.9	22.6	78.7	62.0	6.9	5.4	8.8	1.0	10.3	10.3	20.5	21.8

SMW – Standard meteorological week
Tmin – Minimum temperature
Tmax – Maximum temperature
RH I - Forenoon Relative humidity
RH II – After noon Relative humidity
EVP – Pan evaporation
BSS – Bright sunshine hours
VPD I – Forenoon vapour pressure deficit
VPD II – Afternoon vapour pressure deficit
TR- Temperature range
RF – Rain fall
RD – Rainy days

3.2.3. Treatments

As the design used was spilt plot. It contains main plot treatment and sub plot treatments. The main plot treatments included five dates of planting *i.e.* June 5^{th}, June 20^{th}, July 5^{th}, July 20^{th} and August 5^{th} and the sub plot treatments included two rice varieties Jaya and Jyothi. (Table 3.3.)

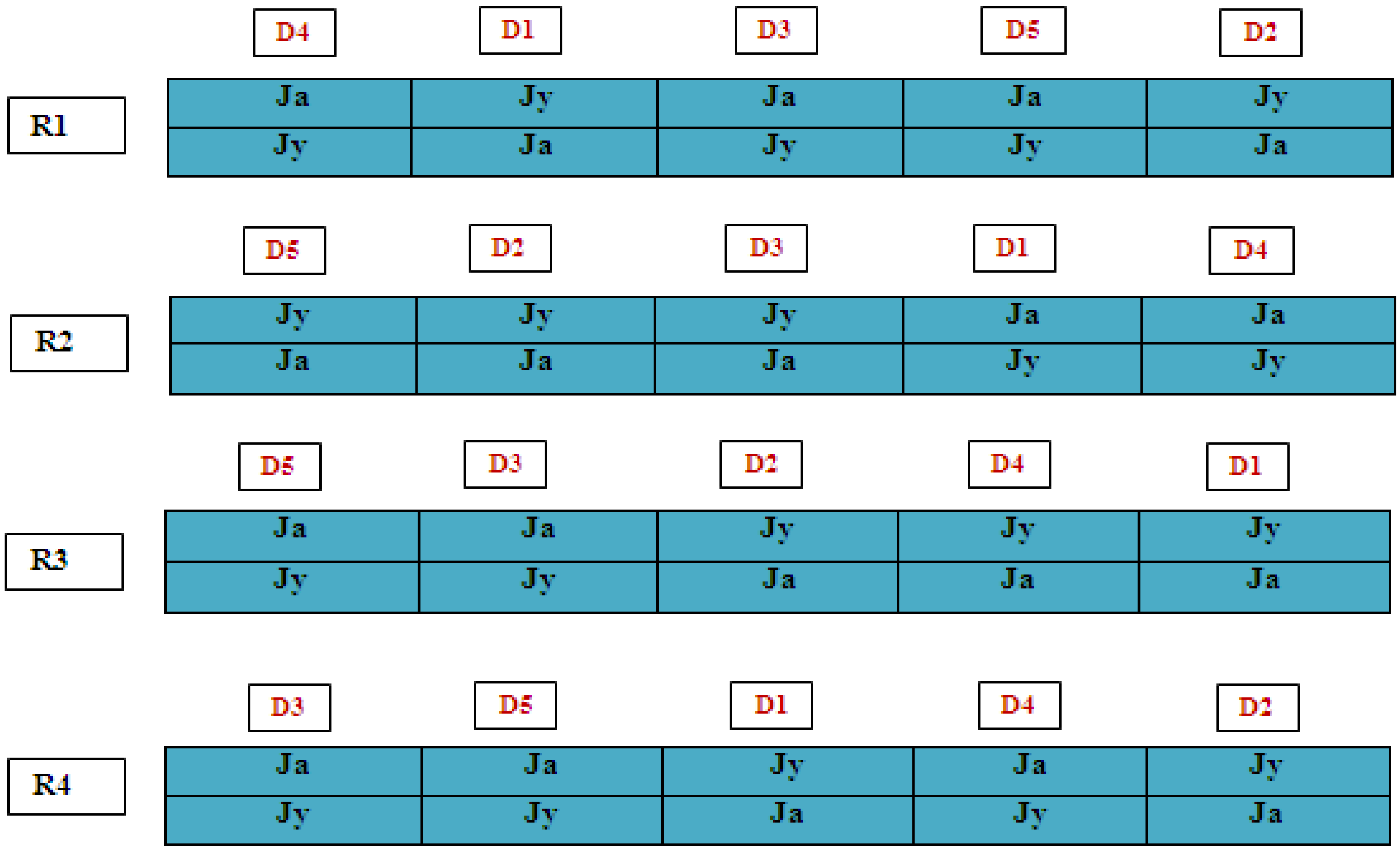
Table 3.3. Treatments used in the experiment

MAIN PLOT	**SUB PLOT**
Dates of planting	**Variety**
5^{th} June	Jaya
	Jyothi
20^{th} June	Jaya
	Jyothi
5^{th} July	Jaya
	Jyothi
20^{th} July	Jaya
	Jyothi
5^{th} August	Jaya
	Jyothi

3.3 CROP MANAGEMENT

3.3.1. Nursery Management

Nurseries were raised twenty one days before transplanting for Jaya where as for Jyothi nurseries were raised eighteen days before transplanting. Nursery has been well managed as per the recommendation of package of practices (KAU, 2016).



D1- June 5th, D2- June 20th, D3- July 5th, D4- July 20th, D5- August 5th

Fig.3.1. Layout of the experimental plot in split plot design

Plate I. Overall view of experimental field

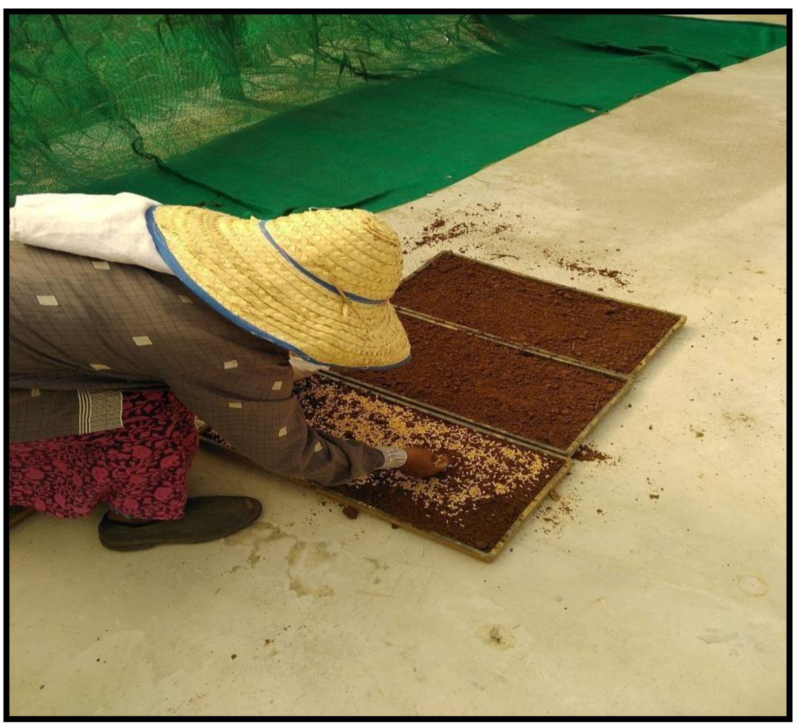


Plate II. Nursery preparation

Plate III. Transplanting

Plate IV. Harvesting and threshing

3.3.2. Land Preparation and planting

According to the Package of practices recommendation the field has been ploughed well in order to bring the fresh nutrients to the surface and to incorporate the stubbles. After that the land was puddled and then the experimental field was divided into plots as per the layout of the field. Planting was done on each date of plating as per the spacing recommended for each variety in the package of practices (KAU, 2016).

3.3.3. Application of Manures and Fertilizers

During the time of land preparation farm yard manure was applied to the field at a rate of 5000 kg ha $^{-1}$. Fertilizers was applied to the crop as per the recommendation in the package of practices (KAU, 2016). For medium duration (Jaya) 90N: 45 P_2O_5 : 45 K_2O kg ha^{-1} has been recommended while for short duration (Jyothi) 70N: 35 P_2O_5: 35 K_2O kg ha^{-1} has been recommended for medium duration). The recommended doses of fertilizers were applied using fertilizers like urea, Rajphos and potash. The entire dose of phosphorus , half dose of potassium and one third of nitrogen were given as basal dose and then next one third of nitrogen was applied during active tillering stage while remaining one third of nitrogen and half dose potassium were top dressed during panicle initiation stage.

3.3.4. After Cultivation

To control the weeds a pre-emergence herbicide Londax (Bensulfuron methyl 0.6% + Pretilachlor 6% GR) was broadcasted at the rate of 1 kg ha^{-1}. After 30 days and 45days after transplanting hand weeding was practiced. Proper control measures were undertaken to protect the crop from pest and diseases.

3.4. OBSERVATIONS

As per the demand of study different observations were taken from the field. In order to take the observations five plants has been selected randomly from each plot avoiding the border plants. Plant height, yield and yield attributes data of these plants were observed

3.4.1. Biometric characters

3.4.1.1. Plant height

Plant height at weekly intervals was noted using a meter scale for both the varieties in centimeter. The height of the plants from the base or culm to the tip of the longest leaf has been recorded for all the five observational plants in each plot.

3.4.1.2 Leaf area

Leaf area has been recorded at 15 days interval for both varieties in cm^2. Two plants from the same plot have been collected and then the leaf area is found out by direct method using the given formula.

$$A = b \times l \times w$$

A is the leaf area, b is the leaf shape coefficient that differs from species to species of the leaf (for rice it's taken as 0.7), w is the leaf width and l is the length of the leaf.

3.4.1.3. Dry matter production

Dry matter accumulation was recorded at 15 days interval for both the varieties in gram per plant. Randomly two plants were uprooted from the experimental field and then those samples were sun dried firstly and then oven dried at 80^0C until a constant weight is achieved.

3.4.1.4. Number of tillers / unit area

Number of tillers in a unit area was recorded during harvesting time.

3.4.1.5. Number of panicles / unit area

Number of panicles in a unit area was recorded during harvesting time.

3.4.1.6. Number of spikelets / panicle

Number of spikelets in a panicle was recorded during harvesting time. The panicles are collected randomly from the five observational plants.

3.4.1.7. Number of filled grains / panicle

Number of filled grains in a panicle was recorded during harvesting time from panicles that are collected randomly from the five observational plants.

3.4.1.8. Thousand grain weight

Cleaned, dry 1000 grains were counted and then the weight of 1000 grains was observed in grams.

3.4.1.9. Grain yield

At the harvest grain yield of each plot was recorded in kg ha $^{-1}$.

3.4.1.10. Straw yield

Straw obtained during the harvest time was dried and then the dry weight was recorded in kg ha $^{-1}$.

3.4.2. Phenological observations

3.4.2.1. Number of days for active tillering

Number of days required to achieve active tillering stage from transplanting was recorded in all dates of planting for both the varieties.

3.4.2.2. Number of days for panicle initiation

Number of days required to achieve panicle initiation stage from transplanting was recorded in all dates of planting for both the varieties.

3.4.2.3. Number of days for booting

Number of days required to achieve booting stage from transplanting was recorded in all dates of planting for both the varieties.

3.4.2.4. Number of days for heading

Number of days required to achieve heading stage from transplanting was recorded in all dates of planting for both the varieties.

3.4.2.5. Number of days for 50% flowering

Number of days required to achieve 50% flowering stage from transplanting was recorded in all dates of planting for both the varieties.

3.4.2.6. Number of days for physiological maturity

Number of days required to achieve physiological maturity stage from transplanting was recorded in all dates of planting for both the varieties.

3.4.3 Physiological observations

3.4.3.1. Leaf Area Index (LAI)

Leaf area index is a dimensionless quantity. It was calculated at an interval of 15 days obtained using leaf area calculated. The equation used was:

$$Leaf\ Area\ Index = \frac{Total\ leaf\ area\ of\ plant}{Leaf\ area\ occupied\ by\ plant}$$

3.4.3.2 Net Assimilation Rate (NAR)

Net assimilation rate measures the average photosynthetic efficiency of a crop. It is the ratio of rate of dry matter accumulation to leaf area index. It is given by the formula:

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{log_e L_2 - log_e L_1}{L_2 - L_1}$$

Where, NAR is the net assimilation rate. W_1 and W_2 are the dry weight of the plant at time t_1 and t_2 correspondingly. L_1 and L_2 are leaf area (m^{-2}) at the same time t_1 and t_2. It is expressed in g m^{-2} day $^{-1}$.

3.4.3.3. Leaf Area Duration (LAD)

Leaf Area Duration (LAD) was given by Power *et al*. (1967). It is used to correlate leaf area index and dry matter accumulation. It considers leaf area duration and magnitude of photosynthetic tissue of a crop canopy.

$$LAD = \frac{(L_2 + L_1)}{2} \times (t_2 - t_1)$$

$L_1$is the Leaf area index at time t_1, L_2 = Leaf area index at time t_2 and ($t_2 - t_1$) is the time interval in days.

3.4.3.4. Crop Growth Rate (CGR)

The dry matter accumulated per unit time per unit land area is determined by Crop Growth Rate (CGR) is the change in dry matter over a period. It is expressed in g m^{-2} day^{-1}. This method was given by Watson in 1956.

$$CGR = \frac{(W_2 - W_1)}{\rho(t_2 - t_1)}$$

W_1 and W_2 are the dry weight of the plant at time t_2 and $t_1$correspondingly. ρ is the area in $m^2$from where W_1 and W_2were noted.

3.4.4. Soil analysis

Analysis of soil of experimental field has been done by collecting the soil samples from the depth of 15cm and 30cm. Then the collected samples were parched and powdered separately. Then pH, available phosphorous, available potassium and organic carbon content were analysed and the results were shown in the Table 3.4.

3.4.5. Weather data

Weather data required for the experiment *i.e.* maximum and minimum temperature, rainfall, number of rainy days, relative humidity, bright sunshine hours, evaporation and wind speed were collected from the Principle Agromet observatory of College of Agriculture, Vellanikkara and these data were converted into weekly for the study. The various weather parameters used for the study are presented in the Table 3.5.

Table 3.4. Chemical properties of the soil

Sl. No.	Parameter	Sampling depth in cm	
		0 – 15	15 – 30
1	Organic carbon (%)	1.06	1.0
2	Soil pH	5.62	5.61
3	Available nitrogen (%)	0.06	0.06
4	Available phosphorous (kg ha^{-1})	14.62	13.98
5	Available potassium (kg ha^{-1})	506.91	406.00

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	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	Evaporation (Epan)	Mm
9	Wind speed (WS)	km hr^{-1}

3.5 STATISTICAL ANALYSIS

Split plot design was used in the experiment. The procedures given by Fisher (1947) were used for all the statistical analysis of the study. ANOVA has been performed to find out the significant difference between main plot treatments *i.e.* Dates of planting, sub plot treatments *i.e.* two varieties and their interaction. Critical difference values were calculated after finding out the significant difference between the treatments and interaction. Using critical differences pair wise comparison has been done.

For comparing the main plot treatments *i.e* .dates of planting critical difference has been calculated using the given formula,

$$CD_1 = t_1 \times SE_1$$

Where, t_1 is the t value at degrees of freedom for main plot error

$SE_1$is standard error of the difference between main plot treatment means

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

Where, $E_1$is the error mean square value of the main plot treatment, r is the number of replications and b is the number of sub plot treatments

For comparing two sub plot treatments (varieties) the given formula was used to calculate the CD value,

$$CD_2 = t_2 \times SE_2$$

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

SE_2 is the Standard error of difference between two sub plot treatments

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

Where, E_2 is Error mean square value of sub plot treatments in ANOVA, r is the number of replications and “a” is number of main plot treatments.

For the comparison of two main plot treatment means at the same or different levels of sub plot treatment CD value was calculated using the formula:

$$CD_3 = t \times SE_3$$

Where,

$$t = \frac{(b-1)\{E_2 t_2 + E_1 t\text{-}1\}}{(b-1)E_2 + E_1}$$

t_1 is the table value corresponding to the degrees of freedom of main plot error

t_2 is the table value corresponding to the degrees of freedom of sub plot error

SE_3 is the standard two main plot treatment means at the same or different levels of sub plot treatment

$$SE_3 = \sqrt{\frac{2[(b-1)E_2] + E_1}{rb}}$$

E_1 = Error mean square value of main plot treatment in ANOVA

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

r = Number of replications

b = Number of sub plot treatments

The influence of weather parameters on plant growth and development was analysed using correlation. Weather variables during each phenophases were correlated with various yield and yield attributes. Different software packages like Microsoft- Excel, SPSS and R studio were used for different statistical analysis.

3.6. CROP WEATHER MODELS

Crop growth was simulated using various models. It has become an extensively used tool for various agricultural research purposes. Crop models imitates the behavior of real crop since it predicts the growth of its components Models simulates the growth and development of the crop as function of weather, soil conditions and crop management. These models help in studying the impact of climate change, prediction of yield, optimum use of resources and also aids to in modification of the management practices for achieving optimum yield. A model helps in understanding the unknown through imagination. Decision support system for agro technology transfer (DSSAT) has been used for research work worldwide since last 15 years. This package includes models of 42 different crops with software that enables the evaluation and application of the crop models for various purposes

The main advantage of DSSAT is its ability to reduce considerably the time and cost of experiment which are necessary for proper evaluation of new variety and novel management techniques. DSSAT contains genetic information of each crop which is specific. Users provide experimental data to the model. This hence helps to evaluate the simulated output to the experimental data.

3.6.1. CERES-Rice model

Crop Estimation through Resource and Environment Synthesis model (CERES) rice model can be used in wide range of research problem like effect of irrigation, nitrogen, impact of environmental conditions, yield gap analysis, effect of climate change on rice production. Above all, the major objective of this model is to support farmers by recognizing their problems which limit yield and to study on thrust areas which improves the cropping system. The model simulates the impact of temperature and photoperiod on panicle initiation and duration of each phenophase. In this experiment we give the input data including weather data, soil data and crop management data. The weather file of 2020 *i.e.* during the crop period was given as input. This experiment mainly focuses on the impact of climate change on rice production of Kerala. Hence CERES–Rice model was used.

3.6.1.1. Input files and experiment data files

Input files and experiment data files required to run the CERES-Rice model are given in Table 3.6.

3.6.1.2. Output files

Output files given by the models which are useful for the users are given in Table 3.7

3.6.2. Running the Crop Model

After, all the anticipated files were created, the model was then run for all the treatments.

3.6.3. Model calibration and evaluation

Calibration is the process of making arbitrary changes to parameter / coefficient values in a model to match data from the real experiment. This is done by adjusting genetic coefficients. Calibration of genetic coefficient CERES-Rice model has been done with minimum data. Various datasets such as date of planting, spacing, plant density, irrigation details, leaf area, phenophases, method of harvesting and yield details. Common tools of statistics like Normalized Root Mean Square Error (RMSE) and D-stat index are used to evaluate the goodness of fit and performance of the model.

Table 3.6. Input files of CERES-Rice model

Internal file name		External description	Name
Experiment	FILEX	Experiment details file for a specific experiment (e.g., rice at AGVK): Contains data on treatments, field conditions, crop management and simulation controls	AGVK1701.RIX
Weather and soil	FILEW	Weather data, daily, for a specific (e.g., ATRA) station and time period (e.g., for one year)	ATRA1701.WTH
	FILES	Soil profile data for a group of experimental sites in general (e.g., SOIL.SOL) or for a specific institute (e.g., AGSANDLOAM. SOL)	SOIL.SOL
Crop and cultivar	FILEC	Cultivar/variety coefficients for a particular crop species and model; e.g., rice for the ‘CERES’ model, version 046	ICER046.CUL[1]
	FILEE	Ecotype specific coefficients for a particular crop species and model; e.g., rice for the ‘CERES’ model, version 046	RICER046.ECO[1]
	FILEG	Crop (species) specific coefficients for a particular model; e.g., rice for the ‘CERES’ model, version 046	RICERO46.SPE[1]
Experiment data files	FILEA	Average values of performance data for a rice experiment. (Used for comparison with summary model results.)	AGVK1701.RIA
	FILET	Time course data (averages) for a rice experiment. (Used for graphical comparison of measured and simulated time course results.)	AGVK1701.RIX
These names reflect a standard naming convention in which the first two spaces are for the crop code, the next three characters are for the model name, and the final three are for model version.			

Table 3.7. Output files of CERES-Rice model

Internal file name	External description	File name
OUTO	Overview of inputs and major crop and soil variables.	OVERVIEW.OUT
OUTS	Summary information: crop and soil input and output variables; one line for each crop cycle or model run.	SUMMARY.OUT
SEVAL	Evaluation output file (simulated vs. observed)	EVALUATE.OUT
OUTWTH	Daily weather	Weather. OUT
OUTM	Daily management operations output file	MgmtOps. OUT
ERRORO	Error messages	ERROR.OUT
OUTINFO	Information output file	INFO.OUT
OUTWARN	Warning messages	WARNING.OUT

3.6.4. Spatial variability of climate change impacts on rice

To evaluate the climate change over Kerala weather parameters like solar radiation, rainfall, maximum and minimum temperature from 1980 to 2020 has been collected for all the 14 districts of Kerala from the India Meteorological Department. Future climate has been estimated using climate model from MarkSim GCM-DSSAT weather file generator. The climate model used is GFDL-CM3developed at the Geophysical Fluid Dynamics Laboratory. The GFDL Climate Model version 3 (CM3) is a coupled general circulation model that has been developed for the atmosphere, ocean, land, and sea ice. The main aim of CM3 was to concentrate on the novel problem in climate change which includes interaction between aerosol and cloud, chemistry and climate, and coupling between stratosphere and troposphere (Donner, 2011). Venkat (2017) reported that GFDL-CM3 the model showed a good ability to simulate present climate over the central zone of Kerala. To assesses the future climate change over Kerala using Regional Integrated Model system by two types of future climate scenarios produced by the Hadley Center Global Environmental Model version 2 (HG2); the representative concentration pathways (RCP) 4.5 and 8.5 scenarios for the Intergovernmental Panel on Climate Change fifth assessment report (AR5) has been used. Analysis of the current climate (1980 – 2020) are compared with three different future 2010-2030 (near-century), 2021-2050 (mid-century), and 2051-2080 (end of century) simulations for the 14 districts of Kerala.

Rice yield simulated from the DSSAT- CERES – Rice model for different simulations has been carried out for 14 districts using corresponding district's weather and soil data. The spatial variability in rice production is thus analysed.

Results

4. RESULTS

The results acquired from the research work entitled "Spatial variability of climate change impacts on rice (*Oryza sativa* L.) yield in Kerala" were collected and elucidated.

4.1. PHENOPHASES

Phenology is one of the most important key features which influence the adaptability of a crop to its surroundings. Phenophases are the noticeable stage or a phase in the life cycle of a plant that can be defined by a start and an end point. Phenophases usually have a duration of a few days or weeks.

The whole growth period of rice has been subdivided into 6 phenophases in this study. Those are as following:

1. P1 - Transplanting to active tillering
2. P2 - Active tillering to panicle initiation
3. P3 - Panicle initiation to booting
4. P4 - Booting to heading
5. P5 - Heading to 50% flowering
6. P6 - 50% flowering to physiological maturity

All these growth stages are grouped into three phases like vegetative phase (P7) which includes from transplanting to panicle initiation, reproductive phase (P8) which include from panicle initiation to 50% flowering and the last stage *i.e.* ripening stage (P9) from 50% flowering to physiological maturity.

4.2. WEATHER OBSERVATIONS

Daily weather observations during the experimental period had been observed. The weather parameters include maximum temperature, minimum temperature, bright sunshine hours, rainfall, number of rainy days, relative humidity, vapour pressure deficit, wind speed and pan evaporation. Averages of these weather parameters over standard meteorological weeks were denoted graphically.

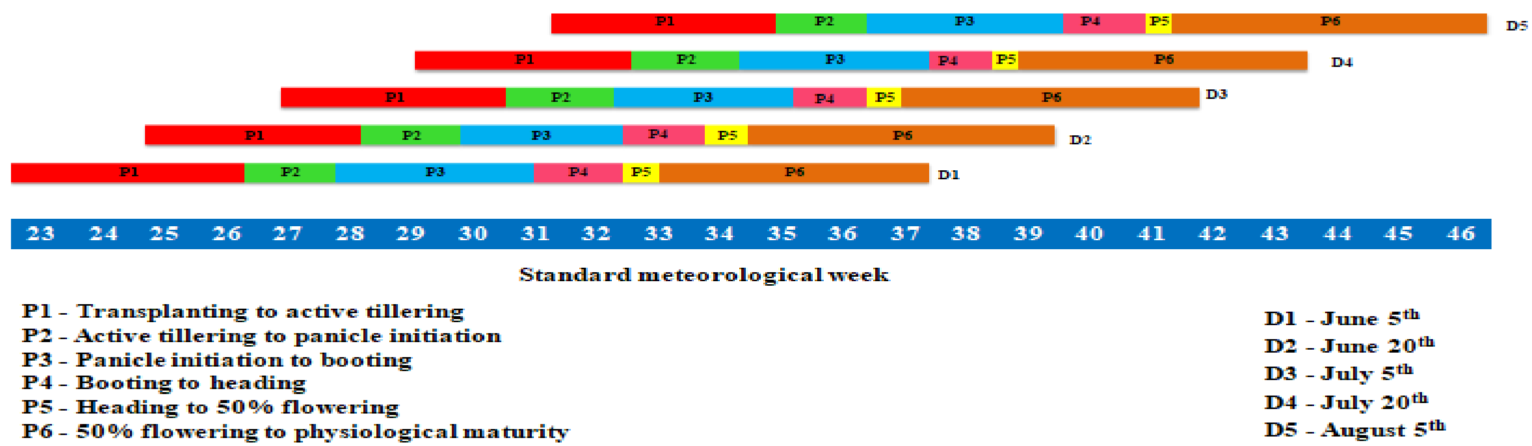


Fig 4.1. (a). Duration of phenophases in Jyothi

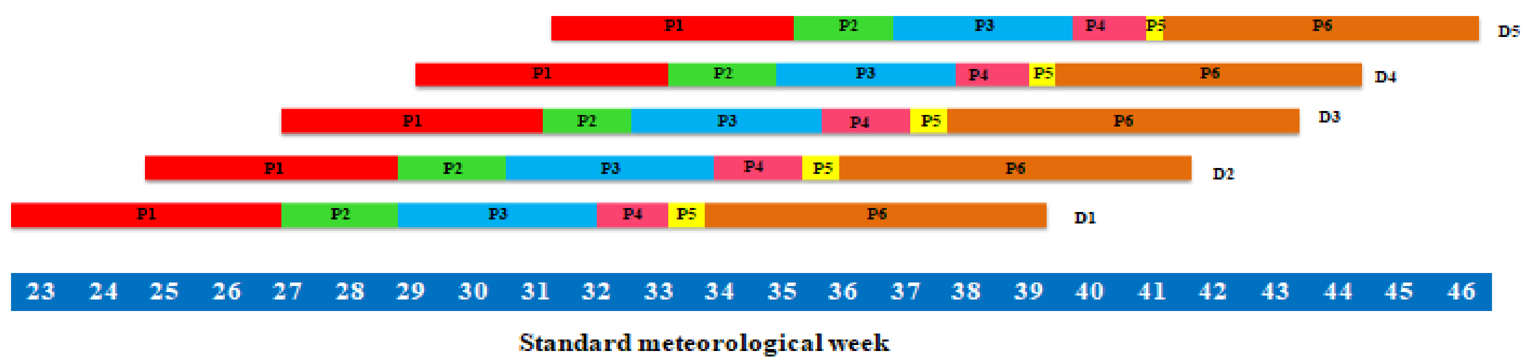


Fig 4.1. (b). Duration of phenophases in Jaya

4.2.1. Air temperature

Maximum temperature, minimum temperature, temperature range and mean temperature in every week had been plotted graphically against the standard meteorological weeks (Fig. 4.2). The maximum temperature ranged from 28 to 33.7°C. During the experimental period, the highest maximum temperature was recorded during the 45th standard meteorological week and the minimum value of maximum temperature was recorded during the 32nd standard meteorological week. The minimum temperature during the experimental period ranged from 21.1 to 24.3°C which was marked during 43rd and 23rd standard meteorological weeks respectively.

The temperature range was found less during the 32nd standard meteorological week and the highest value was recorded during the 45th standard meteorological week in the experimental period. The temperature range during the experimental period varied from 5.4 to 11.7°C. Mean temperature during the experimental period varied from 25.1 to 27.8°C which was observed during 45th and 37th standard meteorological weeks respectively. There was a decrease in the maximum temperature during the initial growth phase of August 5th planting and then the temperature increased in later meteorological weeks.

4.2.2. Relative humidity (RH)

Relative humidity varied non-linearly during the experimental period. The weekly average of forenoon and afternoon relative humidity was calculated from the daily weather data and plotted graphically (Fig 4.3). Forenoon relative humidity ranged from 97.9 to 78.7% during the crop period. The maximum value of forenoon relative humidity was marked during the 37th week and the minimum during the 46th week. It was observed that the forenoon relative humidity was decreasing towards the end of the experimental period. Afternoon relative humidity ranged from 52.9. to 91.7%. Maximum afternoon relative humidity was observed during the 32nd week and the minimum value was observed during the 45th week. Variation in afternoon relative humidity was higher when compared to the forenoon relative humidity. Soon after the August 5th planting, there was a reduction in afternoon relative humidity. Later, by the first week of September, there was an increase in the afternoon relative humidity. Mean relative humidity ranged from 94.05 to 67.5%. It showed the same trend as that of afternoon relative humidity.

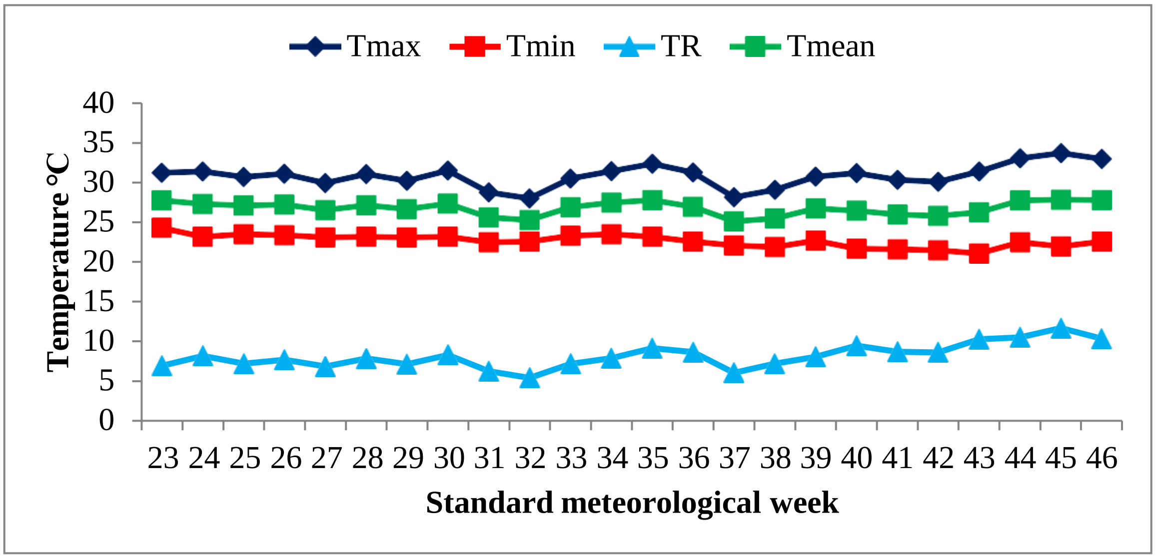


Fig.4.2. Weekly temperature observed during the experimental period

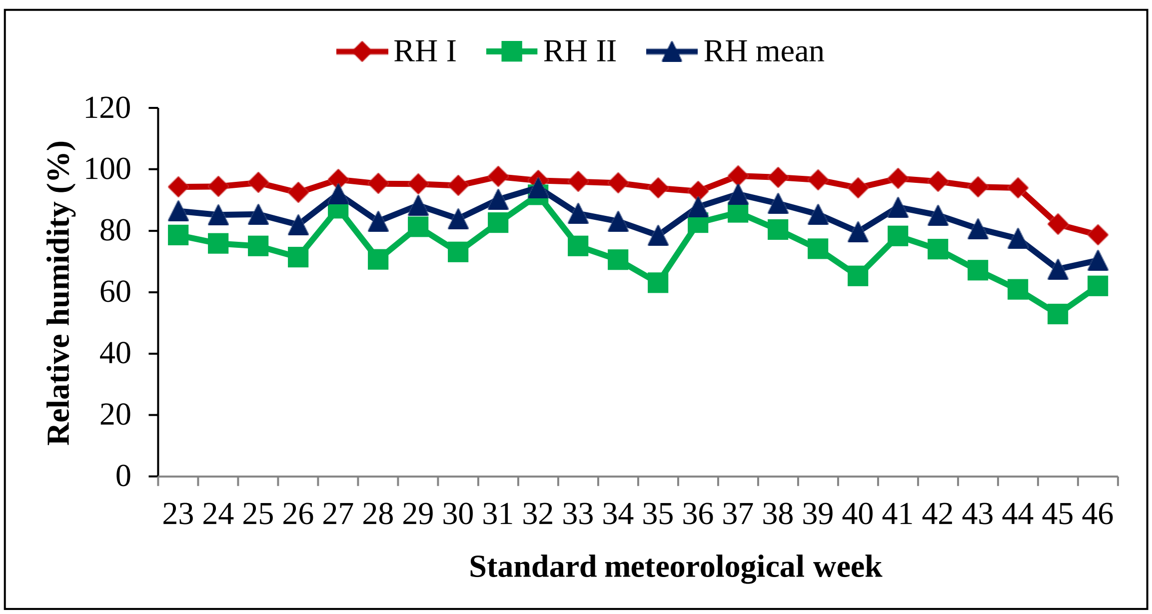


Fig. 4.3. Weekly relative humidity observed during the experimental period.

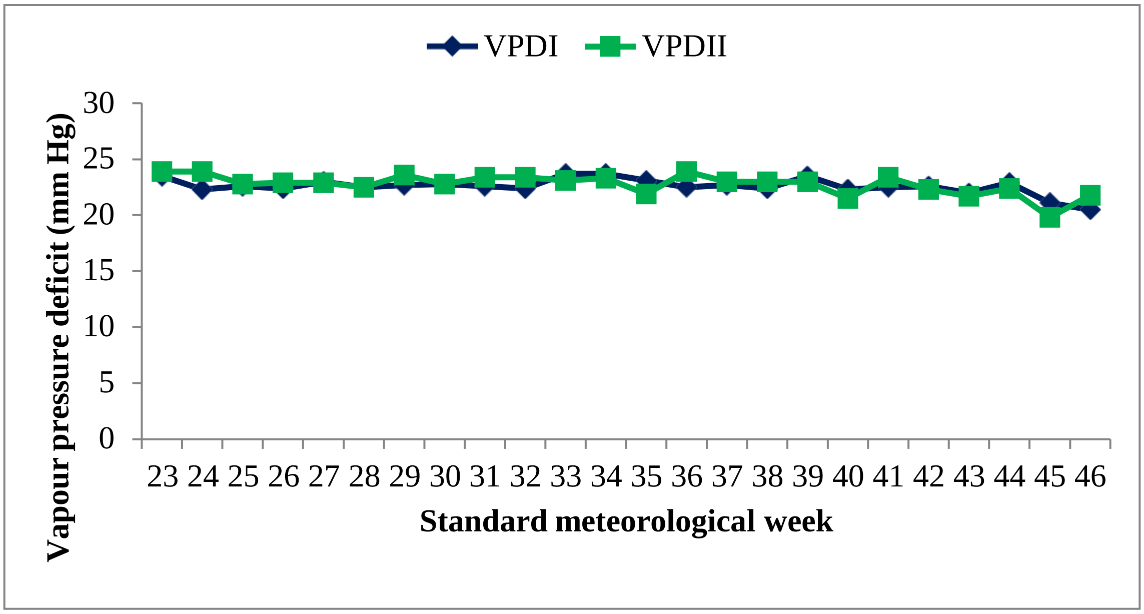


Fig.4.4. Weekly vapour pressure deficit observed during the experimental period

4.2.4. Pan evaporation (Epan)

Pan evaporation rate was recorded and the weekly average was found. The weekly evaporation rate has been plotted graphically (Fig 4.5). The evaporation rate ranged from 5.4 to 11.7mm. An increasing trend was observed in evaporation. The highest pan evaporation rate was recorded during the last stage of the experimental period *i.e.* 45^{th} week. The lowest value of pan evaporation was recorded in the 32^{nd} week.

4.2.5 Bright sunshine hours

Weekly bright sunshine hours during the crop period have been plotted (Fig. 4.5). Bright sunshine hours varied from 0 to 7.7 hrs during the experimental period. The highest bright sunshine hours was recorded during the 35^{th} week while 32^{nd} had zero sunshine hours. Sunshine hours showed an increasing trend bythe last weeks of the experimental period.

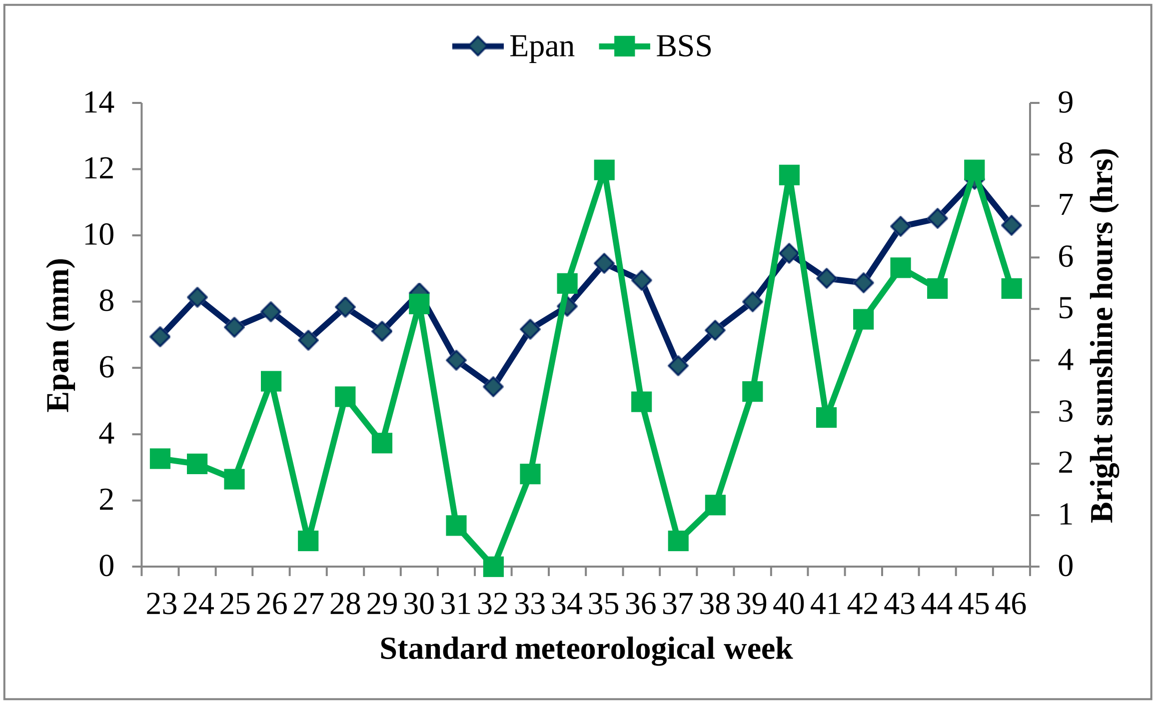


Fig 4.5.Weekly evaporation and bright sunshine hours observed during experimental period.

4.2.6. Wind speed

Wind speed experienced during the experimental period has been plotted on the graph. Weekly wind speed ranged from 0.7 to 6.9 km/hr. A sudden increase in the wind speed had been observed by the 45th week and the highest wind speed was observed during the 46th week. The lowest value of wind speed during the experimental period was observed in the 25th week.

4.2.7. Rainfall and rainy days

Rainfall received and the number of rainy days during each week have been plotted graphically (Fig. 4.6). Rainfall received during the experimental period ranged from 0 to 378.9mm. The maximum amount of rainfall was received during the 32nd standard meteorological week and during the 44th week, there was no rainfall. On 24th, 27th, 31st and 37th week all days were rainy days at the same time during the 44th week there was no rainy day.

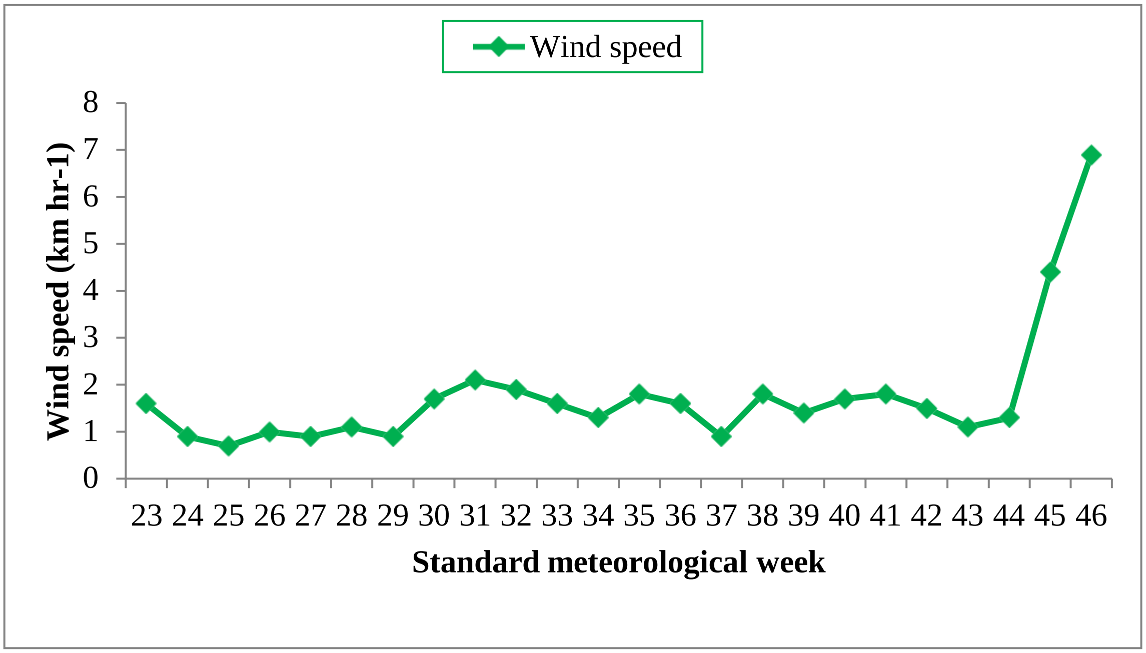


Fig.4.6 Weekly wind speed observed during the experimental period

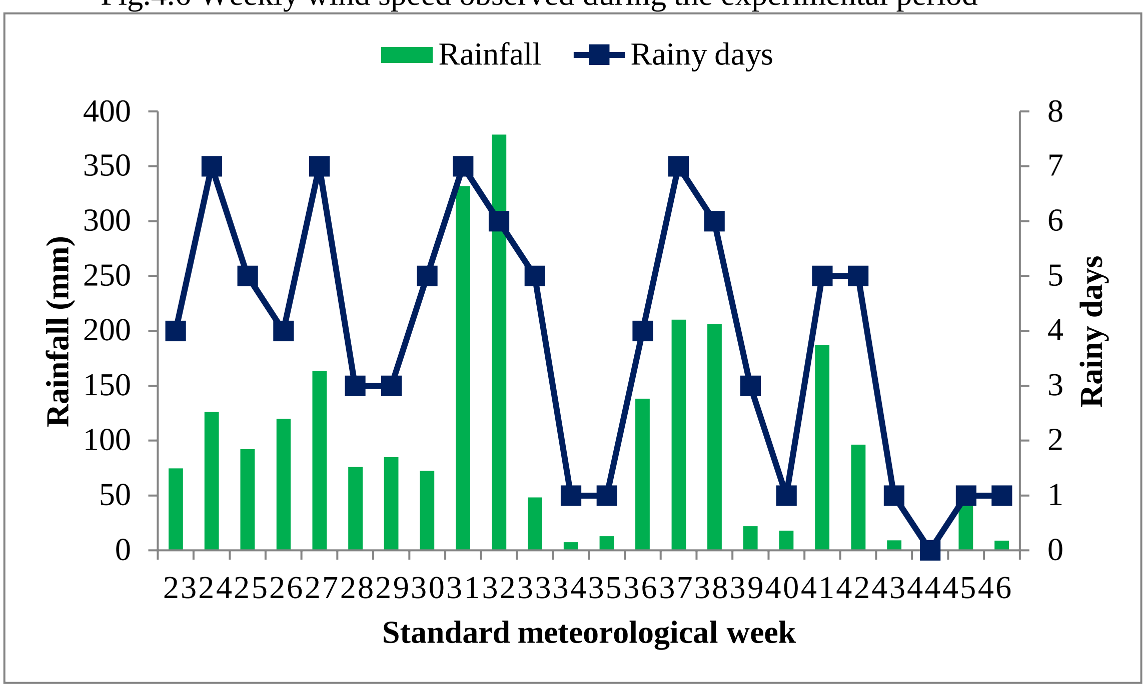


Fig.4.7 Weekly rainfall and rainy days observed during the experimental period

4.3. PHENOLOGICAL OBSERVATIONS

Phenophases are the noticeable stage or a phase in the life cycle of a plant that can be defined by a start and an endpoint. Phenophases usually have a duration of a few days or weeks. The length of each phenophase for five dates of plantings has been recorded for both varieties including Jaya and Jyothi. These observations included the number of days for active tillering, panicle initiation, booting, heading, 50% flowering and physiological maturity. The observations are shown in Table 4.1.

Table 4.1. Phenological observations of Jyothi and Jaya under different dates of planting

Phenophases	Dates of planting									
	June 5th		June 20th		July 5th		July 20th		August 5th	
	Jy	Ja	Jy	Ja	Jy	Ja	Jy	Ja	Jy	Ja
Active tillering	24	27	24	28	25	27	26	29	25	28
Panicle initiation	36	43	35	40	37	39	36	40	35	38
Booting	58	65	53	63	57	60	57	60	57	58
Heading	68	73	62	73	65	70	64	68	66	66
50% flowering	71	77	66	77	68	74	66	71	68	68
Physiological maturity	101	115	100	116	101	113	98	105	99	103
Total duration	116	134	115	135	116	132	113	124	114	122

Jy –Jyothi Ja – Jaya

4.3.1. Number of days for active tillering

The number of days taken for active tillering ranged from 24 to 30 days. Jaya took more days to reach active tillering than Jyothi. In Jyothi among the five dates of plantings, June5th and June 20th planting took fewer days *i.e.* 24 and in the case of Jaya, June 5th and July 20th planting took fewer days to reach the active tillering which was 27 days. July 20th planting took a maximum number of days to reach active tillering *i.e.* 29 and 26 days for Jaya and Jyothi respectively. In Jaya, June 5th and July 5th planting both took the same days to reach the active tillering stage *i.e.* 27 days while June 20th and August 5th planting took 28 days. In Jyothi, July 5th and August 5th plantings took 25 days to active tillering from transplanting.

4.3.2. Number of days for panicle initiation

Among the varieties, Jaya took more days from transplanting to panicle initiation on each date of planting. In Jyothi, July 5th planting took more days of 37 days while June 5th and July 20th plantings took 36 days. Fewer numbers of days (35 days) were taken by June 20th and August 5th planting to reach panicle initiation. In Jaya maximum number of days from transplanting to panicle initiation was observed in June 5th planting (43 days) followed by 5th July (39 days). June 20th planting and July 20th planting both took an equal number of days to reach panicle initiation, *i.e.* 40 days. August 5th planting took the least 38 days to panicle initiation from transplanting.

4.3.3. Number of days for booting

Jyothi variety of June 20th planting took less number of days from transplanting to booting 53 days while June 5th planting of Jyothi took more number of days of 58 days to reach the same. While other dates of plantings took an equal number of days (57 days) to reach booting in Jyothi. In Jaya, June 5th planting took a maximum number of days of 65 days to reach the booting stage followed by June 20th planting *i.e.* 63 days. July 5th and July 20th took the same number of days *i.e.* 60 days to attain the booting stage. The minimum number of days was taken by August 5th planting *i.e.*58 days.

4.3.4. Number of days for heading

In Jaya, the number of days for heading showed a decreasing trend towards the last planting. The maximum number of days was taken by June 5th and 20th planting *i.e.* 73 days followed by July 5th (70 days) and July 20th (68 days). A minimum number of days was recorded during August 5th planting *i.e.* 66 days. In Jyothi, among the 5 dates of planting June 5th planning of Jaya took more number days (68 days) to reach heading while June 20th planting of Jyothi took the least number of days (62 days). While July 5th, July 20th and August 5th planting took 65, 64 and 66 days respectively.

4.3.5. Number of days for 50% flowering

The number of days to reach 50% flowering was found to be less from heading for both the varieties. It ranged from 68 to 77 days in Jaya and 66 to 71 days in Jyothi. The maximum number of days was taken by Jaya of June 5th and 20th planting (77 days). The minimum number of days to reach 50% flowering was observed in August 5th planting (68 days) in Jaya. In Jyothi maximum number of days was taken by June 5th planting *i.e.* 71 days. June20th and July 20th took the same number of days *i.e.* 66 days similarly July 5th and August 5th plantings took the same number of days of 66 days from transplanting to 50% flowering.

4.3.6. Number of days for physiological maturity

On comparing both the varieties Jyothi took fewer days to achieve physiological maturity. In Jyothi, July 20th planting took a minimum number of days (98 days) to achieve physiological maturity. While June 20th planting took 100 days, June 5th and July 5th took the same number of days *i.e.* 101 days while the August 5th planting took 99 days to attain physiological maturity. In the case of Jaya, June 5th planting took the maximum number of days to attain physiological maturity *i.e.* 116 days followed by July 5th planting (113 days) and June 5th planting. The last 2 plantings took comparatively fewer days than other plantings *i.e.* 105 days for July 20th planting and 103 days for August 5th planting.

4.4 WEATHER CONDITIONS DURING DIFFERENT PHENOPHASES

Weather conditions experienced during different stages of phenophases were given from Table 4.2 to 4.7.

4.4.1. Weather conditions experienced during transplanting to the active tillering stage in different dates of planting

4.4.1.1. Temperature (Maximum temperature, Minimum temperature, and Temperature range)

During transplanting to active tillering the maximum temperature was found to be high in June 5th planting in Jaya and Jyothi *i.e.* 31.1°C and 31.0°C respectively. The maximum temperature was found lower during July 20th planting *i.e.* 29.8°C for Jaya and 29.9°C for Jyothi. The highest minimum temperature was experienced during June 5th planting *i.e.* 23.6°C in Jaya and Jyothi. The lowest minimum temperature was found in July 20th planting *i.e.* 23.0°C in Jaya and Jyothi. The temperature range was found to be higher in July 5th planting of Jyothi (7.6°C). In Jaya maximum temperature range was observed during June 5th and July 5th planting as 7.5°C. The lowest temperature range was found in July 20th planting for Jaya and Jyothi (6.9 °C).

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 during transplanting to active tillering ranges from 94.1 to 96.3%. Forenoon relative humidity was found higher during July 20th planting in both Jaya and Jyothi *i.e.* 96.2% and 96.3% respectively. The lowest forenoon relative humidity was experienced during the first date of planting in Jaya and Jyothi *i.e.* 94.1% and 94.5 % respectively. Afternoon relative humidity ranged from 74.4 to 81.2%. The highest value of afternoon relative humidity 81.2 % was found during the July 20th planting of Jyothi and 80.4% for Jaya during the same time. The lowest afternoon relative humidity was found during June 5th planting in Jyothi and Jaya *i.e.* 75.0% and 74.4% respectively.

Table 4.2. Weather conditions experienced by the crop from transplanting to active tillering

Dates of planting	Variety	Tmax	Tmin	RHI	RHII	RH Mean	Wind speed	BSS	Total RF	Rainy days	Evp.	TR	VPDI	VPDII
D1	Jy	31.0	23.6	94.5	75.0	84.8	0.9	2.2	318.1	18.0	2.3	7.5	22.7	23.4
	Ja	31.1	23.6	94.1	74.4	84.3	0.9	2.3	404.9	19.0	2.3	7.5	22.6	23.3
D2	Jy	30.6	23.3	95.2	76.8	86.0	0.9	2.3	420.8	18.0	2.2	7.3	22.7	22.8
	Ja	30.5	23.3	95.3	77.6	86.5	0.9	2.2	487.6	20.0	2.2	7.3	22.7	22.8
D3	Jy	30.8	23.1	95.4	76.4	85.9	1.2	3.1	301.7	15.0	2.5	7.6	22.7	23.0
	Ja	30.5	23.1	95.4	76.6	86.0	1.2	3.0	461.9	17.0	2.5	7.5	22.7	22.9
D4	Jy	29.8	23.0	96.3	81.2	88.7	1.8	2.4	801.1	20.0	2.4	6.9	22.8	23.4
	Ja	29.9	23.0	96.2	80.4	88.3	1.8	2.3	808.1	21.0	2.4	6.9	22.9	23.3
D5	Jy	30.2	23.1	95.8	77.1	86.4	1.8	3.0	470.3	13.0	2.5	7.1	23.2	23.1
	Ja	30.4	23.1	95.6	75.7	85.6	1.8	3.6	482.1	14.0	2.6	7.4	23.2	23.1

D1- June 5th, D2- June 20th, D3- July 5th, D4- July 20th, D5- August 5th
Jy- Jyothi Ja- Jaya

Table 4.3. Weather conditions experienced by the crop from transplanting to panicle initiation

Dates of planting	Variety	Tmax	Tmin	RHI	RHII	RH Mean	Wind speed	BSS	Total RF	Rainy days	Evp.	TR	VPDI	VPDII
D1	Jy	30.8	23.4	94.8	76.9	85.8	0.9	1.9	623.1	28.0	2.2	7.4	22.7	23.2
	Ja	30.8	23.4	94.9	76.8	85.9	1.0	2.0	709.8	31.0	2.2	7.4	22.7	23.1
D2	Jy	30.6	23.3	95.3	77.2	86.2	1.0	2.5	541.7	22.0	2.2	7.4	22.7	23.0
	Ja	30.7	23.3	95.1	76.7	85.9	1.1	2.9	579.4	26.0	2.4	7.5	22.7	23.0
D3	Jy	30.0	22.9	96.1	80.0	88.0	1.6	2.3	987.9	26.0	2.4	7.1	22.7	23.1
	Ja	29.9	22.9	95.9	80.3	88.1	1.5	2.1	1012.6	28.0	2.3	7.0	22.6	23.1
D4	Jy	30.1	23.0	96.2	79.4	87.8	1.7	2.6	847.1	24.0	2.5	7.0	23.0	23.4
	Ja	30.3	23.1	95.9	77.4	86.7	1.7	3.0	847.6	24.0	2.6	7.2	23.0	23.2
D5	Jy	30.7	23.0	94.9	76.6	85.8	1.8	3.6	607.0	17.0	2.5	7.7	23.0	23.1
	Ja	30.6	22.9	95.2	77.4	86.3	1.7	3.4	704.4	20.0	2.4	7.6	23.0	23.2

D1- June 5th, D2- June 20th, D3- July 5th, D4- July 20th, D5- August 5th
Jy- Jyothi Ja- Jaya

Table 4.4. Weather conditions experienced by the crop from transplanting to booting

Dates of planting	Variety	Tmax	Tmin	RHI	RHII	RH Mean	Wind speed	BSS	Total RF	Rainy days	Evp.	TR	VPDI	VPDII
D1	Jy	30.7	23.3	94.9	76.3	85.6	1.1	2.5	1001.8	40.0	2.4	7.4	22.7	23.1
	Ja	30.5	23.2	95.3	77.9	86.6	1.3	2.3	1385.4	46.0	2.3	7.3	22.7	23.2
D2	Jy	30.1	23.1	95.7	79.5	87.6	1.3	2.3	1277.3	38.0	2.3	7.1	22.7	23.1
	Ja	30.2	23.1	95.7	78.7	87.2	1.3	2.3	1343.3	45.0	2.3	7.1	22.8	23.1
D3	Jy	30.3	23.1	95.7	77.0	86.3	1.5	2.9	1068.4	34.0	2.5	7.3	22.9	23.0
	Ja	30.4	23.1	95.7	76.6	86.1	1.5	3.1	1080.8	35.0	2.5	7.4	22.9	23.0
D4	Jy	30.3	22.9	95.5	77.8	86.7	1.6	3.3	1184.2	34.0	2.5	7.4	22.9	23.1
	Ja	30.3	22.9	95.6	78.0	86.8	1.6	3.2	1229.4	37.0	2.5	7.4	22.9	23.2
D5	Jy	30.2	22.7	95.9	78.1	87.0	1.6	2.9	1059.5	34.0	2.3	7.4	23.0	23.1
	Ja	30.2	22.7	95.9	77.8	86.8	1.6	2.9	1076.7	35.0	2.3	7.5	23.0	23.1

D1- June 5th, D2- June 20th, D3- July 5th, D4- July 20th, D5- August 5th
Jy- Jyothi Ja- Jaya

Table 4.5. Weather conditions experienced by the crop from transplanting to heading

Dates of planting	Variety	Tmax	Tmin	RHI	RHII	RH Mean	Wind speed	BSS	Total RF	Rainy days	Evp.	TR	VPDI	VPDII
D1	Jy	30.4	23.2	95.4	78.6	87.0	1.3	2.2	1499.5	49.0	2.3	7.2	22.7	23.2
	Ja	30.4	23.2	95.3	78.4	86.8	1.3	2.1	1522.4	52.0	2.3	7.1	22.7	23.2
D2	Jy	30.2	23.1	95.7	78.8	87.2	1.4	2.2	1338.4	44.0	2.3	7.1	22.8	23.1
	Ja	30.4	23.2	95.5	76.8	86.1	1.4	2.9	1347.3	45.0	2.4	7.3	22.9	23.0
D3	Jy	30.5	23.0	95.3	76.9	86.1	1.5	3.2	1185.6	37.0	2.5	7.5	22.9	23.1
	Ja	30.4	23.0	95.4	77.7	86.6	1.5	3.0	1346.5	42.0	2.4	7.4	22.9	23.1
D4	Jy	30.2	22.8	95.8	78.5	87.2	1.6	3.0	1393.5	41.0	2.4	7.4	22.9	23.2
	Ja	30.2	22.8	95.8	78.1	87.0	1.6	3.0	1417.3	43.0	2.4	7.4	22.9	23.2
D5	Jy	30.3	22.6	95.7	76.6	86.2	1.6	3.4	1141.5	36.0	2.4	7.7	22.9	22.9
	Ja	30.3	22.6	95.7	76.6	86.2	1.6	3.4	1141.5	36.0	2.4	7.7	22.9	22.9

D1- June 5th, D2- June 20th, D3- July 5th, D4- July 20th, D5- August 5th
Jy- Jyothi Ja- Jaya

Table 4.6. Weather conditions experienced by the crop from transplanting to 50% flowering

Dates of planting	Variety	Tmax	Tmin	RHI	RHII	RH Mean	Wind speed	BSS	Total RF	Rainy days	Evp.	TR	VPDI	VPDII
D1	Ja	30.4	23.2	95.3	78.5	86.9	1.3	2.1	1521.4	52.0	2.3	7.1	22.7	23.2
	Jy	30.4	23.2	95.4	78.1	86.7	1.3	2.2	1560.6	55.0	2.3	7.2	22.8	23.2
D2	Ja	30.2	23.1	95.7	78.6	87.1	1.3	2.4	1345.2	45.0	2.3	7.1	22.8	23.2
	Jy	30.5	23.1	95.3	76.7	86.0	1.4	3.0	1380.9	47.0	2.5	7.4	22.9	23.0
D3	Ja	30.5	23.0	95.4	77.2	86.3	1.6	3.1	1272.7	40.0	2.5	7.5	22.9	23.1
	Jy	30.3	22.9	95.6	78.0	86.8	1.5	2.9	1429.1	46.0	2.4	7.4	22.9	23.1
D4	Ja	30.2	22.8	95.8	78.2	87.0	1.6	3.0	1414.8	42.0	2.4	7.4	22.9	23.1
	Jy	30.2	22.8	95.8	77.7	86.8	1.6	3.0	1418.6	43.0	2.4	7.4	22.9	23.1
D5	Ja	30.3	22.6	95.8	76.8	86.3	1.6	3.4	1149.2	37.0	2.4	7.7	22.9	23.0
	Jy	30.3	22.6	95.8	76.8	86.3	1.6	3.4	1149.2	37.0	2.4	7.7	22.9	23.0

D1- June 5th, D2- June 20th, D3- July 5th, D4- July 20th, D5- August 5th
Jy- Jyothi Ja- Jaya

Table 4.7. Weather conditions experienced by the crop from transplanting to physiological maturity

Dates of planting	Variety	Tmax	Tmin	RHI	RHII	RH Mean	Wind speed	BSS	Total RF	Rainy days	Evp.	TR	VPDI	VPDII
D1	Jy	30.5	23.1	95.2	77.5	86.3	1.3	2.7	1863.8	65.0	2.4	7.4	22.8	23.1
	Ja	30.4	23.0	95.4	77.5	86.5	1.4	2.6	2138.9	75.0	2.3	7.4	22.8	23.1
D2	Jy	30.3	22.9	95.6	77.9	86.7	1.4	2.7	1916.7	64.0	2.3	7.3	22.8	23.1
	Ja	30.3	22.8	95.6	77.1	86.3	1.4	3.0	2096.4	71.0	2.4	7.6	22.8	23.0
D3	Jy	30.3	22.7	95.8	77.1	86.4	1.5	3.1	1818.7	60.0	2.4	7.6	22.8	23.0
	Ja	30.3	22.5	95.8	76.5	86.1	1.5	3.3	1967.5	67.0	2.4	7.8	22.8	22.9
D4	Jy	30.3	22.5	95.8	76.2	86.0	1.6	3.5	1747.1	57.0	2.4	7.9	22.8	22.9
	Ja	30.5	22.4	95.7	75.3	85.5	1.6	3.8	1747.1	57.0	2.4	8.1	22.8	22.8
D5	Jy	30.9	22.3	94.0	72.6	83.3	1.9	4.1	1416.6	47.0	2.5	8.6	22.6	22.5
	Ja	30.9	22.3	94.0	72.6	83.3	1.9	4.1	1416.6	47.0	2.5	8.6	22.6	22.5

D1- June 5th, D2- June 20th, D3- July 5th, D4- July 20th, D5- August 5th
Jy- Jyothi Ja- Jaya

The highest value of mean relative humidity 88.7% was found during July 20th planting of Jyothi and 88.3% during July 20th planting of Jaya. The lowest mean relative humidity was found during June 5th planting in Jaya and Jyothi *i.e.*84.3% and 84.8% respectively.

Forenoon vapour pressure deficit during transplanting to active tillering ranged from 22.7 to 23.2 mm Hg. The highest forenoon vapour pressure deficit was observed during August 5th planting for Jaya and Jyothi as 23.2 mm Hg. The lowest forenoon vapour pressure deficit was found during June 5th planting in Jyothi (22.7 mm Hg) and Jaya (22.6 mm Hg). Afternoon vapour pressure deficit ranged from 22.8 to 23.4 mm Hg. The highest afternoon vapour pressure deficit was observed during July 20th planting for Jyothi (23.4 mm Hg). In the case of Jaya highest afternoon vapour pressure of 23.3 mm Hg was observed during June 5th and July 20th plantings. The lowest afternoon vapour pressure deficit was found during June 20th planting for Jaya and Jyothi as 22.8mm Hg.

4.4.1.3. Wind speed (WS)

Wind speed varied from 0.9 to 1.8 km hr^{-1}. Maximum wind speed was observed during July 20th and August 5th planting in both varieties and minimum during June 20th planting in Jyothi. In Jaya, the minimum wind speed of 0.9 km hr^{-1} was observed during June 5th and June 20th planting.

4.4.1.4. Bright sunshine hours (BSS)

Bright sunshine hours ranged from 2.1 to 3.4 hrs. In Jaya, the maximum bright sunshine hours (3.6hrs) was recorded during August 5th planting and minimum (2.3hrs) during June 5th planting. In Jyothi maximum bright sunshine hours (3.1hrs) was recorded during July 5th planting and minimum (2.2 hrs) during June 5th planting.

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

From transplanting to active tillering crop received a rainfall ranging from 301.7 to 808.1mm. July 5th planting of Jyothi received the minimum amount of rainfall (301.7mm) and in Jaya June 5th planting received a minimum amount of rainfall (404.9mm). July 20th planting of Jaya and Jyothi received a maximum amount of rainfall of 808.1 and 801.1mm respectively. The maximum number of rainy days in Jyothi was 20 days in July 20th planting. In Jaya maximum number of rainy days was observed in the June 20th planting (21 days). August 5th planting received less number of rainy days of 14 days and13 days for both Jaya and Jyothi respectively.

4.4.1.6. Pan Evaporation (Epan)

The evaporation rate ranged from 2.2 to 2.5 mm during the first phenophase. The evaporation rate was found less during the June 20th planting of Jaya and Jyothi, 2.2 mm. Towards the last dates of plantings, the evaporation of 2.5 mm was observed in both varieties.

4.4.2. Weather conditions experienced during transplanting to panicle initiation stage in different dates of planting

4.4.2.1. Temperature (Maximum temperature, Minimum temperature, and Temperature range)

During transplanting to panicle initiation stage the maximum temperature ranged from 29.9 to 30.8ºC. Maximum of maximum temperature was experienced during July 5th planting. The minimum value of maximum temperature experienced by Jaya and Jyothi was 29.9 ºC and 30.0ºC respectively. The lowest value of maximum temperature was observed during July 5th planting. The minimum temperature during the period ranged from 22.9 to 23.4ºC. The highest value of minimum temperature was observed during June 5th planting *i.e.* 23.4ºC for Jyothi and Jaya. The lowest value of minimum temperature experienced was the same for both varieties *i.e.* 22.9 ºC during July 5th planting. The temperature range was highest in August 5th planting *i.e.* 7.7 ºC for Jyothi and 7.6 ºC for Jaya. The minimum temperature range was experienced during July 5th planting for Jaya and July 20th planting for Jyothi *i.e.*7 ºC.

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

The highest forenoon relative humidity was experienced during active tillering to panicle initiation was recorded in July 20th planting for Jyothi *i.e.* 96.2% while for Jaya it was 95.9% which was recorded during July 5th and 20th planting. The lowest forenoon relative humidity was observed during June 5th planting *i.e.* 94.8% for Jyothi. In Jaya least forenoon relative humidity was observed June 5th and August 5th planting *i.e.* 77.4%. The afternoon relative humidity ranged from 76.6 to 80.3%. Highest afternoon relative humidity was recorded for both the varieties during July 5th planting which was 80.3% and 80.0% for Jaya and Jyothi respectively. Lowest afternoon relative humidity was observed during June 20th planting of Jaya (76.7%) and August 5th planting of Jyothi (76.6%). Mean Relative humidity ranged from 85.8 to 88.1%. Highest mean relative humidity was recorded during June 5th planting. Lowest mean relative humidity was observed during June 5th planting of Jaya (85.5%) and August 5th planting of Jyothi (85.8%).

The vapour pressure deficit was almost sTable throughout this stage. Forenoon vapour pressure deficit during transplanting to panicle initiation ranged from 22.7 to 23.0 mm Hg. Highest forenoon vapour pressure deficit in this stage was observed during last two plantings for both varieties *i.e.* 23.0 mm Hg. The lowest forenoon vapour pressure deficit was found during June 5th and June 20th planting for Jaya and Jyothi *i.e.* 22 mm Hg. Afternoon vapour pressure deficit ranged from 23.0 mm Hg to 23.4 mm Hg. Highest afternoon vapour pressure deficit was observed during July 20th planting for Jyothi (23.4 mm Hg) and July 20th and August 5th for Jaya (23.2 mm Hg) respectively. Lowest afternoon vapour pressure deficit was found during June 20th planting for Jaya and Jyothi as 23.0 mm Hg.

4.4.2.3. Wind speed (WS)

Wind speed during this period ranged from 0.9 to 1.8 km hr^{-1}. August 5th planting experienced the maximum wind speed during this period *i.e.* 1.8 km hr^{-1} Jyothi and Jaya. Minimum wind speed was experienced during June 5th of Jyothi.and Jaya *i.e.* 0.9 km hr^{-1} and 1 km hr^{-1} respectively.

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

During transplanting to panicle initiation rainfall ranged from 541.7 to 1012.6mm. Maximum amount of rainfall was received during July 5th planting for both varieties *i.e.* 1012.6 mm in Jaya and 987.9 mm in Jyothi. Minimum amount of rainfall was received during June 20th planting *i.e.*541.7 mm for Jyothi and 579.4 mm for Jaya. While maximum number of rainy days was recorded for June 5th planting *i.e.* 30 days for Jaya and in Jyothi maximum rainy days was observed during June 5th as well as in July 5th planting *i.e.* 28 days. Minimum number of rainy days was recorded for August 5th planting *i.e.* 20 days for Jaya and 17 days for Jyothi.

4.4.2.6. Pan Evaporation (Epan)

Highest evaporation rate was observed in July 20th planting in Jaya (2.6mm). In Jyothi, July 20th and August 5th planting recorded highest evaporation (2.5mm). Lowest evaporation rate was recorded during 5th and 20th June planting of Jyothi (2.2mm) and 5th June planting of Jaya (2.2mm).

4.4.4. Weather conditions experienced during transplanting to booting stage in different dates of planting

4.4.3.1. Temperature (Maximum temperature, Minimum temperature, and Temperature range)

Temperature was almost stable during the crop period transplanting to booting. Maximum temperature ranged from 30.2ºC to 30.7ºC . June 5th planting experienced highest value of maximum temperature for Jyothi and Jaya *i.e.* 30.7ºC . Lowest value of maximum temperature was recorded on June 20th planting which were 30.2 Jaya and Jyothi. In Jaya 30.2ºC was marked during 20th July and August 5th planting also. Minimum temperature ranged from 23.3ºC and 22.6ºC. There was a gradual reduction in minimum temperature from first date of planting. Highest value minimum temperature was observed during June 5th planting (23.3ºC) for both varieties and Minimum value of minimum temperature was observed during August 5th planting for Jyothi (22.7ºC) and Jaya (22.6ºC). Temperature range ramged from 7.1 to 7.7ºC. August 5th planting recorded highest value of temperature range for Jaya and Jyothi *i.e.* 7.7 ºC and 7.6 ºC respectively. June 20th planting recorded lowest value of temperature (7.1 ºC) for both varieties.

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

During transplanting to booting forenoon relative ranged from 95 to 95.8%. Maximum forenoon relative humidity was recorded during July 20th planting for Jaya it was 95.8% and for Jyothi 95.7% for all plantings except June 5th. Forenoon relative humidity was found minimum during June 5th planting for Jaya 95.1% and for Jyothi 95.0%. Afternoon relative humidity ranged from 76.5 to 79.1%. For Jyothi maximum afternoon relative humidity was observed during June 20th *i.e.* 79.1% and for Jaya it was 78.9%. Minimum value of afternoon relative humidity was observed during July 5th planting of Jaya (76.7%) and June 5th planting of Jyothi (76.5%). Mean relative humidity was found higher during June 20th planting for Jaya (87.4%) and for Jyothi (87.3%). Mean relative humidity was found lower during June 5th planting for Jaya (86.0%) and for Jyothi (85.8%).

Forenoon vapour pressure deficit during transplanting to panicle initiation ranged from 22.7 to 23.0 mm Hg. Highest forenoon vapour pressure deficit was observed during August 5th planting for Jyothi *i.e.* 23.0 mm Hg and the lowest forenoon vapour pressure deficit was found during June 5th planting for Jaya and Jyothi *i.e.* 22.7 mm Hg. June 20th planting of Jyothi also recorded the 22.7mm Hg vapour pressure deficit in this stage. Afternoon vapour pressure deficit ranged from 23.0 to 23.2 mm Hg. It was observed to be sTable in this phase. Highest afternoon vapour pressure deficit was observed during June 5th and July 20th planting for Jaya (23.2 mm Hg) and July 20th and August 5th for Jyothi (23.1 mm Hg). Lowest afternoon vapour pressure deficit was found during July 20th planting for Jaya and Jyothi as 23.0 mm Hg.

4.4.3.3. Wind speed (WS)

Wind speed during this period ranged from 1.1 to 1.6 km hr^{-1}. July 20th and August 5th planting experienced the maximum wind speed during this period *i.e.* 1.6 km hr^{-1} Jyothi and Jaya. Minimum wind speed was experienced during June 5th and 20th planting of Jaya *i.e.* 1.3 km hr^{-1} and in Jyothi minimum wind speed was experienced during 5th June *i.e.* 1.1 km hr^{-1}.

4.4.3.4. Bright sunshine hours (BSS)

Bright sunshine hours ranged from 3.3 to 2.3 hrs. The highest value of bright sunshine hours was recorded during 20th July *i.e.* 3.3 hrs and 3.2 hrs for Jyothi and Jaya respectively. Lowest value was recorded during first date of planting for Jaya *i.e.* 2.3 hrs and in Jyothi least bright sunshine hours was observed during June 5th and 20th plantings.

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

During transplanting to panicle initiation rainfall ranged from 1001.8 to 1385.4 mm. Maximum amount of rainfall was received during June 5th planting for Jaya *i.e.* 1385.4 mm and 1277.2 mm for Jyothi which was recorded during July 20th planting. Minimum amount of rainfall was received during June 5th planting *i.e.*1001.8 mm for Jyothi and 1080.8mm for Jaya. While maximum number of rainy days was recorded for June 5th planting *i.e.* 46 days for Jaya and 40 days for Jyothi. July 5th, July 20th and August 20th plantings of Jyothi observed same amount of rainy days *i.e.* 34 days. In Jaya July 5th and August 5th planting received same number of rainy days *i.e.* 46 days.

4.4.3.6. Pan Evaporation (Epan)

Evaporation rate was almost same in all dates of plantings. It ranged from 2.3 to 2.5 mm. Evaporation rate of 2.3 mm was recorded in most of the dates of planting.

4.4.4. Weather conditions prevailed during the crop period from transplanting to heading stage in different dates of planting

4.4.4.1. Temperature (Maximum temperature, Minimum temperature, and Temperature range)

During transplanting to heading stage maximum temperature was found to be high in July 5th planting of Jyothi *i.e.* 30.5°C. In Jaya maximum temperature was found to be same for first three dates of plantings. Maximum temperature was found least during June 20th and July 20th planting for Jyothi and July 20th planting of Jaya *i.e.* 30.2ºC. A gradual reduction in minimum temperature was observed towards the last plantings. The highest minimum temperature was experience during June 5th planting *i.e.* 23.2ºC in Jaya and Jyothi. Also in June 20th planting of Jaya the same temperature was observed.

Lowest minimum temperature was found in August 5th planting *i.e.* 22.6ºC in Jaya and Jyothi. The temperature range was found to be higher in August 5th planting of Jaya and Jyothi (7.7 ºC). Lowest temperature range *i.e.* 7.1 ºC was found in June 5th and June 20th planting of Jaya and Jyothi respectively.

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

Forenoon relative humidity during transplanting to heading ranges from 95.3 to 95.8%. Forenoon relative humidity was found higher during July 20th planting in both Jaya and Jyothi *i.e.* 95.8%. Lowest forenoon relative humidity was experienced during June 5th planting of Jaya (95.3%) and June 20th planting of Jyothi *i.e.* 95.3%. Afternoon relative humidity ranged from 76.6 to 78.8%. Highest value of afternoon relative humidity was recorded as 78.8 % for Jyothi during June 20th planting and 78.4% for Jaya during June 5th planting. Lowest afternoon relative humidity was found during July 20th planting in Jaya and Jyothi *i.e.* 76.6%. Mean relative humidity during this stage ranged from 86.1% to 87.2%. Maximum mean relative humidity was found to be during June 20th and July 20th planting of Jyothi (87.2%) and July 20th planting of Jaya (87.2%). Minimum mean relative humidity was found to during July 5th planting of Jyothi (86.1%) and June 20th planting of Jaya (86.1%).

Forenoon vapour pressure deficit during transplanting to heading ranged from 22.9 to 23.2 mm Hg. Highest vapour pressure deficit was observed same for Jaya and Jyothi *i.e.* 22.9 mm Hg. The lowest forenoon vapour pressure deficit was found during June 5th planting for Jaya and Jyothi *i.e.* 22.7 mm Hg. Afternoon vapour pressure deficit ranged from 22.9 to 23.2 mm Hg. Highest afternoon vapour pressure deficit was observed during June 5th and August 5th planting for Jaya and Jyothi as 23.2 mm Hg. Lowest afternoon vapour pressure deficit was found during August 5th planting for Jaya and Jyothi as 22.9 mm Hg.

4.4.4.3. Wind speed (WS)

Wind speed was increasing gradually towards last date of planting. Wind speed during July 20th and August 5th planting was same *i.e.* 1.6 km hr^{-1}. Lowest wind speed was recorded during June 5th, 1.3km hr^{-1} for Jaya and Jyothi.

4.4.4.4. Bright sunshine hours (BSS)

Highest bright sunshine hours were recorded during August 5th date of planting, 3.4hrs for both varieties. Lowest value of bright sunshine hours were recorded during June 5th planting for Jaya and Jyothi as 2.1 hrs and 2.2 hrs respectively.

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

From transplanting to heading crop received a rainfall ranging from 1141.5mm to 1522.4mm. June 5th planting of Jaya received the maximum amount *i.e.* 1522.4mm rainfall and for Jyothi, also June 5th planting received maximum amount *i.e.* 1499.5mm rainfall. July 20th planting of Jyothi received a minimum amount of rainfall of 1103.7 mm and in case of Jaya, August 5th planting received a minimum amount of rainfall of 1218.5mm. Number of rainy days was more for June 5th planting of Jaya and Jyothi which were 52 days and 49 days respectively. August 5th planting received less number of rainy days of 36 days for Jaya and Jyothi.

4.4.1.6. Pan Evaporation (Epan)

Evaporation rate ranged from 2.3 mm to 2.5mm during this phenophase. Maximum evaporation rate was recorded during July 5th planting of Jyothi as 2.5mm. Minimum evaporation rate of 2.3 mm was marked during 5th and 20th June planting for Jyothi and June 5th planting for Jaya.

4.4.5. Weather conditions prevailed during the crop period from transplanting to 50% flowering stage in different dates of planting

4.4.5.1. Temperature (Maximum temperature, Minimum temperature, and Temperature range)

During transplanting to 50% flowering the maximum emperature ranged from 30.2 to 30.5ºC. For Jyothi maximum temperature observed was 30.5ºC which was marked during July 5th planting while in Jaya highest value of maximum temperature was experienced on June 20th planting *i.e.* 30.5ºC. Lowest value of maximum temperature was observed during July 20th and June 5th planting for Jyothi *i.e.* 30.2ºC in Jaya it was marked on July 20th planting. Minimum temperature during the period ranged from 22.6ºC to 23.2ºC. Highest value of minimum temperature was observed during June 5th planting *i.e.* 23.2ºC for Jyothi and Jaya. Lowest value of minimum temperature experienced for both varieties were during August 5th planting *i.e.* 22.6ºC for Jaya and Jyothi. Temperature range was highest in August 5th planting *i.e.* 7.7 ºC for Jyothi and Jaya. Minimum temperature range was experienced during June 5th and 20th planting for Jyothi *i.e.* 7.2 ºC and June 5th for Jaya *i.e.* 7.1 ºC.

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

Forenoon relative humidity during transplanting to 50% flowering was more sTable. It ranges from 95.3 to 95.8%. Forenoon relative humidity was found higher during July 20th and August 5th planting in both Jaya and Jyothi *i.e.* 95.8%. Lowest forenoon relative humidity was experienced during first date of planting in Jaya and Jyothi *i.e.* 95.3%. Afternoon relative humidity ranged from 76.7 to 78.6%. Highest value of afternoon relative humidity was found to be 78.6% during June 20th planting of Jyothi. In Jaya during June 5th planting the highest afternoon relative humidity was recorded. Lowest afternoon relative humidity was found during August 5th planting in Jyothi *i.e.*76.8% and during June 20th planting of Jaya 76.7%. Mean relative humidity ranged from 86.0 to 87.1%. Maximum mean relative humidity was observed during July 20th planting of both varieties *i.e.* 86.9% for Jyothi and Jaya respectively. For Jaya lowest value of mean relative humidity was observed during 20^{th}June planting *i.e.* 86.0% and for Jyothi lowest value of mean relative humidity was observed during 5^{th} August planting *i.e.* 86.3%.

Forenoon vapour pressure deficit during transplanting to 50% flowering ranged from 22.7 to 22.9 mm Hg. Forenoon vapour pressure deficit was recorded same for all the plantings after June 20^{th} planting. The lowest forenoon vapour pressure deficit was found during June 5^{th} planting for Jaya and Jyothi *i.e.* 22.7 mm Hg and 22.8 mm Hg respectively. Afternoon vapour pressure deficit ranged from 22.9 to 23.2 mm Hg. The highest afternoon vapour pressure deficit was observed during June 5^{th} planting for Jaya and Jyothi as 23.2mm Hg. The lowest afternoon vapour pressure deficit was found during June 20^{th} and August 5^{th} planting for Jaya and during August 5^{th} planting of Jyothi as 23.0 mm Hg.

4.4.5.3. Wind speed (WS)

Wind speed varied from 1.3 to 1.6 km hr^{-1}. For Jyothi maximum wind speed of 1.6 km $hr^{-1}$was observed from July 5^{th} planting and a minimum wind speed of 1.3 km hr^{-1} during the first two plantings of Jyothi. For Jaya maximum wind speed of 1.6 km $hr^{-1}$was observed during July 20^{th} and August 5^{th} planting. A minimum wind speed of 1.3 km hr^{-1} was observed during the June 5^{th} planting of Jaya. Wind speed was comparatively less during the first two plantings.

4.4.5.4. Bright sunshine hours (BSS)

Bright sunshine hours ranged from 2.1 to 3.4 hrs. Bright sunshine hours showed an increasing trend. In Jaya, the maximum bright sunshine hours (3.4hrs) was recorded during August 5^{th} planting and minimum (2.1hrs) during June 5^{th} planting. In Jyothi maximum bright sunshine hours (3.4hrs) was recorded during August 5^{th} planting and minimum (2.2hrs) during June 5^{th} planting.

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

From transplanting to 50% flowering crop received a rainfall ranging from 1149.2 to 1560.6mm. August 5th planting of Jyothi and Jaya received the minimum amount of rainfall (1149.2mm). June 5th planting of Jaya and Jyothi received a maximum amount of rainfall of 1560.6mm and 1521.4mm respectively. The number of rainy days was more for the June 5th planting of Jaya and Jyothi which were 55 days and 52 days respectively. August 5th planting received fewer rainy days of 37days for Jaya and Jyothi.

4.4.5.6. Pan Evaporation (Epan)

The evaporation rate ranged from 2.3 to 2.5mm during transplanting to 50% flowering. In Jaya during June 5th planting recorded minimum evaporation of 2.3mm and maximum evaporation was observed during June 20th planting *i.e.* 2.5mm. In Jyothi during June 5th planting recorded minimum evaporation of 2.3 mm and maximum evaporation was observed during July 5th planting *i.e.* 2.5 mm.

4.4.6. Weather conditions experienced during transplanting to physiological maturity stage in different dates of planting

4.4.6.1. Temperature (Maximum temperature, minimum temperature and temperature range)

The temperature was almost sTable during the crop period transplanting to 50% flowering. The maximum temperature ranged from 30.3 to 30.9ºC. August 5th planting experienced the highest value of maximum temperature for Jyothi and Jaya *i.e.* 30.9ºC. The lowest value of maximum temperature was recorded on June 20th planting for Jyothi *i.e.* 30.3ºC and 30.3ºC was recorded for Jaya on July 5th and 20th planting. The minimum temperature ranged from 22.3ºC and 23.1ºC. There was a decreasing trend in minimum temperature from the first date of planting. The highest value minimum temperature was observed during June 5th planting for Jyothi (23.1ºC) and Jaya (23.0ºC). The minimum value of minimum temperature observed during August 5th planting (22.3ºC) for both varieties. The temperature range was between 7.3 ºC and

8.6 ºC. August 5th planting recorded the highest value of temperature range for Jaya and Jyothi *i.e.* 8.6 ºC. In Jyothi, June 20th planting recorded the lowest value of temperature range (7.3 ºC) while in Jaya, June 5th planting recorded the lowest value of temperature range (7.4 ºC).

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

During transplanting to physiological maturity forenoon relative humidity ranged from 94 to 95.8%. Maximum forenoon relative humidity was recorded during July 5th planting for Jaya it was 95.8% and during July 5th and 20th planting for Jyothi 95.8%. Forenoon relative humidity was found minimum during August 5th planting for Jaya and Jyothi *i.e.* 94.0%. Afternoon relative humidity ranged from 72.6 to 77.9%. For Jyothi maximum afternoon relative humidity was observed during June 20th (77.9%) and for Jaya, it was (77.5%). The minimum value of afternoon relative humidity was observed during August 5th planting for both varieties (72.6%). Mean relative humidity was found higher during June 5th planting for Jaya (86.5%) and for Jyothi during June 20thplanting (86.7%). Mean relative humidity was found lower during August 5th planting for Jaya and Jyothi (83.3%).

Forenoon vapour pressure deficit during transplanting to physiological remained constant during all dates of plantings except the last planting where the vapour pressure deficit decreased to 22.6 mm Hg. Afternoon vapour pressure deficit ranged from 22.5 to 23.1mm Hg. The highest afternoon vapour pressure deficit was observed during June 5th planting for Jaya and Jyothi as 23.1 mm Hg. The lowest afternoon vapour pressure deficit was recorded the same during August 5th planting for Jaya and Jyothi as 22.5mm Hg.

4.4.6.3. Wind speed (WS)

Wind speed was recorded maximum in August 5th planting *i.e.* 1.9 km hr^{-1} for Jaya and Jyothi. Minimum wind speed was recorded during June 5th plantings *i.e.* 1.4 km hr^{-1} for Jaya and 1.3 km hr^{-1} for Jyothi. A gradual increase in wind speed was observed towards the end of the experimental period.

4.4.6.4. Bright sunshine hours (BSS)

During this crop period, bright sunshine hours was recorded maximum in August 5th planting *i.e.* 4.1 hrs for Jaya and Jyothi. A minimum bright sunshine hour was recorded during June 5th plantings *i.e.* 2.6 hrs for Jaya and June 20thand July 5th planting of Jyothi *i.e.* 2.7 hrs.

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

From transplanting to physiological maturity crop received rainfall of 1485.9 mm to 2138.9 mm. The maximum amount of rainfall was received during July 20th planting for Jaya (2138.9mm) and Jyothi (2165.7mm). Minimum rainfall was recorded during the 5thAugust planting for both varieties (1485.9mm). The maximum number of rainy days was recorded for June 5th planting of Jaya and Jyothi *i.e.* 75 and 67 respectively. August 5th planting of both Jaya and Jyothi has the minimum number of rainy days (47 days).

4.4.3.6. Pan Evaporation (Epan)

The evaporation rate was recorded highest during the August 5th planting of both Jaya and Jyothi (2.5mm). The evaporation rate was recorded as 2.4 mm in Jyothi during all plantings except the last plantings. In Jaya evaporation ranged from 2.3 to 2.4 mm.

4.5.1. Influence of weather parameters on the duration of each phenophase in Jyothi

The impact of weather on each phenophase of Jyothi was analyzed by correlation. Table 4.8 represents the correlation duration of phenophase and weather variables in Jyothi

4.5.1.1. Transplanting to active tillering (P1)

Duration transplanting to active tillering showed a significant positive correlation withforenoon relative humidity, afternoon relative humidity, wind speed, evaporation and rainfall. Duration of this stage showed a significant negative correlation with maximum temperature, minimum temperature and temperature range.

Table 4.8. Correlation between duration of phenophase and weather variables in Jyothi

Stages	Tmax	Tmin	RHI	RHII	Wind	BSS	RF	RD	Evp	TR	VPDI	VPDII
P1	-0.834**	-0.866**	0.914**	0.868**	0.889**	0.331	0.776**	0.086	0.804**	-0.652**	0.298	0.404
P2	-0.802**	-0.327	0.698**	0.929**	-0.035	-0.915**	0.745**	0.926**	-0.994**	-0.798**	-0.586**	-0.541*
P3	0.331	-0.061	-0.077	-0.389	-0.957**	0.205	-0.42	-0.07	-0.242	0.535*	0.077	-0.275
P4	-0.227	0.238	0.041	0.106	0.869**	-0.046	0.427	0.213	0.038	-0.311	0.310	-0.153
P5	0.283	0.764**	-0.181	0.179	-0.585**	0.250	0.061	0.218	-0.156	-0.355	0.856**	0.831**
P6	-0.688**	-0.103	0.535*	0.472*	-0.397	-0.665**	0.848**	0.635**	-0.820**	-0.451*	0.081	0.266

Table 4.9. Correlation between duration of phenophase and weather variables in Jaya

Stages	Tmax	Tmin	RHI	RHII	Wind	BSS	RF	RD	Evp	TR	VPDI	VPDII
P1	-0.878**	-0.624**	0.773**	0.839**	0.667**	-0.135	0.881**	0.345	0.147	-0.949**	0.453*	0.244
P2	-0.242	0.248	0.550*	0.155	-0.541*	-0.392	0.268	0.736**	-0.169	-0.400	-0.175	-0.59**
P3	-0.308	0.495*	0.238	0.335	0.956**	-0.408	0.691**	0.490*	0.242	-0.689**	0.103	0.613**
P4	0.545*	0.491*	-0.69**	-0.097	-0.356	0.243	0.026	-0.141	0.189	0.263	0.496*	0.065
P5	-0.160	0.225	-0.329	-0.113	-0.130	-0.030	0.707**	0.707**	0.084	-0.24	-0.108	0.139
P6	-0.821**	0.524*	0.568**	0.790**	-0.421	-0.921**	0.903**	0.902**	-0.748**	-0.828**	0.623**	0.745**

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

P1 - Transplanting to active tillering
P2 - Active tillering to panicle initiation
P3 - Panicle initiation to booting
P4 - Booting to heading
P5 - Heading to 50% flowering
P6 - 50% flowering to physiological maturity

4.5.1.2. Active tillering to panicle initiation (P2)

Duration of this stage showed a significant positive correlation with forenoon relative humidity, afternoon relative humidity, rainfall and rainy days. At the same time, it showed a negative correlation with maximum temperature, bright sunshine hours, evaporation temperature range,forenoon and afternoon vapour pressure deficit.

4.5.1.3. Panicle initiation to booting (P3)

Duration of this stage showed a significant positive correlation with temperature range and a significant negative correlation with wind speed.

4.5.1.4. Booting to heading (P4)

Wind speed experienced in this stage showed a significant positive correlation with the duration of booting to heading.

4.5.1.5. Heading to 50% flowering (P5)

Minimum temperature, forenoon and afternoon vapour pressure deficit during this phenophase had a significant positive correlation with the duration of phenophase. Wind speed had a significant negative correlation with the duration of phenophase.

4.5.1.6. 50% flowering to physiological maturity (P6)

Weather parameters likeforenoon relative humidity, afternoon relative humidity, rainfall and rainy days showed a significant positive correlation with duration of phenophase while maximum temperature, bright sunshine hours, evaporation and temperature range during this phenophase had a negative correlation with the duration of phenophase

4.5.2. Influence of weather parameters on the duration of each phenophase in Jaya

The impact of weather on each phenophase of Jaya was analyzed by correlation. Table 4.9 represents the correlation duration of phenophase and weather variables in Jaya

4.5.2.1. Transplanting to active tillering (P1)

Forenoon relative humidity, afternoon relative humidity, wind speed, rainfall, and forenoon vapour pressure deficit showed a significant positive correlation with the duration of phenophase. At the same time maximum temperature, minimum temperature and temperature range had a significant negative correlation with the duration of phenophase.

4.5.2.2. Active tillering to panicle initiation (P2)

Forenoon relative humidity and rainy days showed a significant positive correlation with the duration of this phenophase. Wind speedand afternoon vapour pressure had a significant negative correlation with the duration of this phenophase.

4.5.2.3. Panicle initiation to booting (P3)

Minimum temperature, wind speed, rainfall, rainy days and afternoon vapour pressure deficit had a significant positive correlation with the duration of this phenophase. Duration panicle initiation to booting was found to be only negatively correlated to temperature range.

4.5.2.4. Booting to heading (P4)

Weather parameters like maximum temperature, minimum temperature and forenoon vapour pressure deficit showed a significant positive correlation with duration of booting to heading. While forenoon relative humidity showed a significant negative correlation with the duration of this phenophase.

4.5.2.5. Heading to 50% flowering (P5)

Duration of this phenophase has been significantly positively correlated with rainfall and the number of rainy days.

4.5.2.6. 50% flowering to physiological maturity (P6)

Duration of 50% flowering to physiological maturity showed a positive correlation with minimum temperature, forenoon and afternoon relative humidity, rainfall, number of rainy days, forenoon and afternoon vapour pressure deficit. It showed a negative correlation with maximum temperature, bright sunshine hours, evaporation and temperature range.

4.5.3. Influence of weather parameters on yield inJyothi

The impact of weather on the yield of Jyothi was analyzed by correlation and has been shown in Table 4.10.

4.5.3.1. Transplanting to active tillering (P1)

The minimum temperature during transplanting to active tillering showed a significant positive correlation with the yield while forenoon and afternoon relative humidity during this stage showed a significant negative correlation with yield.

4.5.3.2. Active tillering to panicle initiation (P2)

During this stage, wind speed and afternoon vapour pressure deficit had a significant negative correlation with yield.

4.5.3.3. Panicle initiation to booting (P3)

During panicle initiation to booting wind speed and forenoon relative humidvapour pressure deficit had a significant negative correlation with yield

4.5.3.4 .Booting to heading (P4)

Wind speed and rainfall during booting to heading had a significant positive correlation on yield.

4.5.3.5. Heading to 50% flowering (P5)

Weather parameters like forenoon relative humidity and wind speed had a significant negative correlation with yield.

4.5.3.6. 50% flowering to physiological maturity (P6)

During the last stage maximum temperature, minimum temperature and evaporation had a significant positive correlation on yield. Forenoon relative humidity, rainfall and the number of rainy days during this stage had a significant negative correlation with yield.

4.5.4. Influence of weather parameters on yield in Jaya

The impact of weather on the yield of Jaya was analyzed by correlation and has been shown in Table 4.11.

4.5.4.1. Transplanting to active tillering (P1)

Forenoon relative humidity, wind speed, rainfall, evaporation and forenoon vapour pressure deficit during transplanting to active tillering showed a significant positive correlation with grain yield. Maximum temperature and temperature range during this stage showed a significant negative correlation with grain yield.

4.5.4.2. Active tillering to panicle initiation (P2)

Maximum temperature, bright sunshine hours and temperature range had a positive significance on yield.Forenoon relative humidity and the number of rainy days had a significant negative correlation with yield.

4.5.4.3. *Panicle initiation to booting (P3)*

Minimum temperature, wind speed, evaporation rate and forenoon vapour pressure deficit during panicle initiation to booting had a significant negative correlation on yield.

4.5.4.4. *Booting to heading (P4)*

During this stage, forenoon relative humidity and wind speed showed a significant positive correlation with yield while minimum temperature showed a significant negative correlation with yield.

4.5.4.5. *Heading to 50% flowering (P5)*

During heading to 50% flowering rainfall and rainy days showed a positive correlation with yield. Other weather parameters didn't show any significant relationship with yield.

4.5.4.6.50% flowering to physiological maturity (P6)

During 50% flowering to physiological maturity maximum temperature and evaporation showed a positive correlation with yield. While, weather parameters like forenoon relative humidity, afternoon relative humidity, rainfall, rainy days, forenoon and afternoon vapour pressure had a significant negative correlation with yield.

Table 4.10 Correlation between yield and weather variables in Jyothi

Stages	Tmax	Tmin	RHI	RHII	Wind	BSS	RF	RD	Evp	TR	VPDI	VPDII
P1	0.414	0.638**	-0.610**	-0.581**	-0.21	-0.282	-0.257	-0.058	-0.27	0.157	0.243	0.247
P2	0.304	0.014	-0.327	0.033	-0.490*	0.069	-0.213	0.083	-0.173	0.337	-0.358	-0.748**
P3	-0.19	-0.127	0.35	0.16	-0.478*	-0.334	0.195	0.419	-0.229	-0.187	-.458*	0.430
P4	-0.401	-0.207	0.284	0.248	0.794**	-0.099	0.577**	0.265	-0.213	-0.307	-0.053	-0.157
P5	0.075	0.412	-0.452*	0.134	-0.447*	-0.091	-0.366	0.252	0.193	-0.243	0.138	0.113
P6	0.584**	0.489*	-0.471*	-0.251	0.308	0.372	-0.469*	-0.612**	0.614**	0.203	0.045	-0.010

Table 4.11 Correlation between yield and weather variables in Jaya

Stages	Tmax	Tmin	RHI	RHII	Wind	BSS	RF	RD	Evp	TR	VPDI	VPDII
P1	-0.583**	-0.358	0.451*	0.335	0.728**	0.262	0.472*	-0.404	0.454*	-0.652**	0.610**	0.355
P2	0.515*	0.054	-0.447*	-0.416	-0.175	0.501*	-0.422	-0.551*	0.342	0.571**	0.396	-0.123
P3	-0.203	-0.735**	0.068	0.264	-0.649**	-0.128	-0.093	0.111	-0.618**	0.178	-0.547*	-0.052
P4	-0.127	-0.600**	0.553*	-0.183	0.712**	0.107	-0.071	-0.089	0.141	0.199	-0.275	-0.313
P5	0.203	0.227	0.201	-0.296	0.136	-0.016	-0.719**	-0.744**	-0.072	0.128	0.401	-0.261
P6	0.697**	-0.419	-0.510*	-0.661**	0.398	0.349	-0.732**	-0.748**	0.629**	0.692**	-0.543*	-0.62**

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

P1 - Transplanting to active tillering

P2 - Active tillering to panicle initiation

P3 - Panicle initiation to booting

P4 - Booting to heading

P5 - Heading to 50% flowering

P6 - 50% flowering to physiological maturity

4.5.5. Influence of weather parameters on straw yield in Jyothi

The impact of weather on the straw yield of Jyothi was analyzed by correlation and has been shown in Table 4.12.

4.5.5.1. Transplanting to active tillering (P1)

Rainfall had shown a significant positive correlation with straw yield. Maximum temperature and temperature range significant negative correlation with straw yield.

4.5.5.2. Active tillering to panicle initiation (P2)

Straw yield showed a significant positive correlation with maximum temperature, minimum temperature, bright sunshine hours, and forenoon vapour pressure deficit during active tillering to panicle initiation. It had a significant negative correlation with afternoon relative humidity, rainfall and rainy days.

4.5.5.3. Panicle initiation to booting (P3)

The minimum temperature experienced during panicle initiation to booting showed a significant negative correlation with straw yield.

4.5.5.4. Booting to heading (P4)

The weather during booting to heading stage had was no significant correlation with the straw yield.

4.5.5.5. Heading to 50% flowering (P5)

During heading to 50% flowering evaporation had a significant positive correlation with straw yield. Rainfall and the number of rainy days during heading to 50% flowering had a significant negative correlation with straw yield.

4.5.5.6. 50% flowering to physiological maturity

Weather parameters observed during this phenophase didn't have any significant correlation with the straw yield of Jyothi.

4.5.6. Influence of weather parameters on straw yield in Jaya

The impact of different weather parameters on the straw yield of Jaya was analyzed by correlation and has been shown in Table 4.13.

4.5.6.1. Transplanting to active tillering (P1)

Weather parameters like forenoon relative humidity, wind speed and evaporation experienced during transplanting to active tillering had a significant positive impact on the straw yield of Jaya. A significant negative correlation was shown by maximum and minimum temperature with straw yield during this initial stage in Jaya.

Table 4.12 Correlation between straw yield and weather variables in Jyothi

Stages	Tmax	Tmin	RHI	RHII	Wind	BSS	RF	RD	Evp	TR	VPDI	VPDII
P1	-0.499*	-0.303	0.351	0.426	0.301	-0.259	0.508*	0.131	-0.062	-0.587**	0.110	0.114
P2	0.542*	0.489*	-0.385	-0.631**	-0.239	0.501*	-0.595**	-0.565**	0.537*	0.442	0.453*	0.361
P3	-0.308	-0.536*	0.157	0.412	0.18	-0.236	0.419	0.348	-0.418	-0.057	-0.395	0.064
P4	-0.229	-0.171	0.38	-0.106	-0.31	-0.123	-0.16	0.09	-0.121	-0.154	0.209	-0.272
P5	0.24	-0.174	-0.243	-0.457*	0.056	0.441	-.532*	-0.600**	0.588**	0.284	0.084	-0.210
P6	0.269	-0.224	-0.22	-0.32	0.19	0.354	-0.26	-0.249	0.227	0.323	-0.27	-0.313

Table 4.13 Correlation between straw yield and weather variables in Jaya

Stages	Tmax	Tmin	RHI	RHII	Wind	BSS	RF	RD	Evp	TR	VPDI	VPDII
P1	-0.493*	-0.507*	0.497*	0.228	0.640**	0.389	0.383	-0.35	0.626**	-0.36	0.38	0.212
P2	-0.037	-0.226	0.013	0.051	0.296	0.012	0.089	-0.212	-0.061	0.04	0.238	0.169
P3	0.271	-0.284	-0.235	-0.273	-0.646**	0.334	-0.510*	-0.379	-0.116	0.515*	-0.018	-0.439
P4	-0.191	-0.668**	0.309	0.177	0.522*	-0.091	0.354	0.235	-0.182	0.174	-0.510*	0.070
P5	-0.315	0.027	0.506*	0.043	-0.358	-0.447*	-0.214	-0.314	-0.484*	-0.33	0.333	-0.402
P6	0.492*	-0.533*	-0.327	-0.571**	0.282	0.633**	-0.625**	-0.554*	0.524*	0.584**	-0.479*	-0.578**

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

P1 - Transplanting to active tillering

P2 - Active tillering to panicle initiation

P3 - Panicle initiation to booting

P4 - Booting to heading

P5 - Heading to 50% flowering

P6 - 50% flowering to physiological maturity

4.5.6.2. Active tillering to panicle initiation (P2)

There was no significant correlation observed between weather prevailed during active tillering to panicle initiation and straw yield in Jaya.

4.5.6.3. Panicle initiation to booting (P3)

Temperature range had a positive correlation with the weather experienced during panicle initiation to booting. A significant negative correlation was observed between straw yield and weather parameters like wind speed and rainfall.

4.5.6.4. Booting to heading (P4)

There was a significant positive correlation found between wind speed experienced during booting to heading and straw yield. Minimum temperature and vapour pressure deficit had a significant negative correlation with straw yield during this stage.

4.5.6.5. Heading to 50% flowering (P5)

Forenoon relative humidity experienced during heading to 50% flowering had a significant positive correlation with straw yield. Bright sunshine hours and evaporation had a significant negative correlation with straw yield.

4.5.6.6. 50% flowering to physiological maturity

Maximum temperature, bright sunshine hours, evaporation and temperature range during 50% flowering to physiological maturity showed a significant positive correlation with straw yield. At the same time weather parameters like minimum temperature, afternoon relative humidity, mean relative humidity, rainfall, rainy days, forenoon and afternoon vapour pressure deficit had a significant negative correlation with straw yield.

4.5.7. Influence of weather variables and yield attributes of Jyothi

A correlation analysis has been performed between the yield attributes like number of tillers per unit area, number of panicles per unit area, number of spikelets per panicles, number of filled grains per panicle, number of chaff per panicle and thousand grain weight with meteorological variables for variety Jyothi. Table 4.14 to 4.19 depicts the results of the correlation performed.

4.5.7.1. Correlation between weather variables and number of tillers per unit area

As a result of a correlation analysis, it was found that the forenoon relative humidity and afternoon vapour pressure deficit during panicle initiation to booting had a significant negative correlation with the number of tillers per unit area. Afternoon vapour pressure deficit that prevailed during heading to 50% flowering had a significant positive correlation with the number of tillers per unit area. Wind speed during heading to 50% flowering had a significant negative correlation with the number of tillers per unit area. A significant correlation was not observed during the last phenophase between weather parameters and the number of tillers per unit area.

4.5.7.2. Correlation between weather variables and number of panicles per unit area

From the analysis, it was observed that rainfall and afternoon vapour pressure showed a significant negative relationship with the number of panicles per unit area during transplanting to active tillering. There was no significant relationship between weather experienced during active tillering to panicle initiation and the number of panicles per unit area. During panicle initiation to booting temperature range experienced had a significant negative correlation with the number of panicles per unit area while afternoon vapour pressure deficit had a significant positive correlation in this stage. The evaporation rate experienced during booting to heading had a significant positive correlation with the number of panicles per unit area. Wind speed during heading to 50% flowering showed a significant negative correlation with the number of panicles per unit areawhile afternoon vapour pressure deficit had a significant positive correlation in this stage. Weather experienced during 50 % flowering to physiological maturity showed no significant correlation with the number of panicles per unit area.

4.5.7.3. Correlation between weather variables and number of spikelets per panicles

From the correlation analysis, it was observed that minimum temperature during active tillering to panicle initiation, wind speed during panicle initiation to booting and afternoon vapour pressure deficit during booting to 50% flowering had a significant negative correlation with the number of spikelets per panicle in Jyothi.

Table 4.14 Correlation between number of tillers and weather variables in Jyothi

Stages	Tmax	Tmin	RHI	RHII	Wind	BSS	RF	RD	Evp	TR	VPDI	VPDII
P1	0.291	0.292	-0.254	-0.4	-0.28	0.042	-0.386	-0.182	-0.271	0.243	0.232	-0.358
P2	0.141	-0.096	-0.258	0.04	-0.087	0.132	0.003	-0.151	-0.03	0.191	-0.418	-0.172
P3	-0.422	-0.173	0.466*	0.346	0.161	-0.464*	0.291	0.402	-0.212	-0.497*	-0.128	0.512*
P4	0.162	0.212	-0.212	-0.262	0.232	0.215	-0.116	-0.159	0.322	0.074	0.236	-0.283
P5	0.430	0.204	0.024	0.326	-0.535*	0.284	-0.155	-0.011	0.132	0.142	0.214	0.456*
P6	0.196	0.242	-0.262	-0.06	0.212	-0.018	0.114	-0.057	0.159	0.028	-0.061	-0.003

Table 4.15. Correlation between number of panicles and weather variables in Jyothi

Stages	Tmax	Tmin	RHI	RHII	Wind	BSS	RF	RD	Evp	TR	VPDI	VPDII
P1	0.286	0.174	-0.148	-0.336	-0.315	0.184	-0.448*	-0.200	-0.219	0.336	0.139	-0.545*
P2	-0.047	-0.195	-0.104	0.151	0.107	0.031	0.185	-0.100	-0.078	0.014	-0.433	0.021
P3	-0.374	-0.059	0.397	0.28	0.312	-0.388	0.207	0.271	-0.09	-0.510*	0.044	0.462*
P4	0.364	0.362	-0.409	-0.364	0.044	0.294	-0.306	-0.283	0.464*	0.211	0.293	-0.212
P5	0.425	0.134	0.223	0.406	-0.472*	0.282	0.045	0.008	-0.022	0.189	0.22	0.548*
P6	-0.039	0.157	-0.086	0.09	0.089	-0.228	0.354	0.205	-0.084	-0.111	-0.016	0.081

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

P1 - Transplanting to active tillering
P2 - Active tillering to panicle initiation
P3 - Panicle initiation to booting
P4 - Booting to heading
P5 - Heading to 50% flowering
P6 - 50% flowering to physiological maturity

Table 4.16. Correlation between number of spikelets per panicles and weather variables in Jyothi

Stages	Tmax	Tmin	RHI	RHII	Wind	BSS	RF	RD	Evp	TR	VPDI	VPDII
P1	0.017	-0.065	0.038	-0.098	0.271	0.398	-0.124	-0.435	0.441	0.084	0.347	0.195
P2	-0.078	-0.457*	-0.084	0.163	0.331	0.009	0.264	0.238	-0.007	0.069	-0.237	-0.346
P3	0.199	0.093	0.016	-0.326	-0.495*	0.117	-0.417	-0.137	-0.077	0.225	0.376	-0.124
P4	0.203	-0.398	-0.213	-0.093	0.163	0.342	0.07	-0.29	0.127	0.35	-0.518*	-0.152
P5	-0.144	-0.287	0.294	0.321	0.108	-0.311	0.248	0.236	-0.229	0.108	-0.486*	-0.178
P6	0.225	-0.221	-0.254	-0.281	0.311	0.253	-0.284	-0.263	0.27	0.288	-0.274	-0.282

Table 4.17. Correlation between filled grains per panicle and weather variables in Jyothi

Stages	Tmax	Tmin	RHI	RHII	Wind	BSS	RF	RD	Evp	TR	VPDI	VPDII
P1	0.324	0.492*	-0.496*	-0.414	-0.083	-0.212	-0.136	-0.011	-0.066	0.129	0.112	0.424
P2	0.105	-0.056	-0.104	0.136	-0.346	-0.096	-0.075	0.277	-0.244	0.138	-0.211	-0.71**
P3	0.139	0.092	0.011	-0.151	-.545*	0.025	-0.1	0.057	-0.004	0.138	-0.203	0.052
P4	-0.406	-0.303	0.295	0.385	0.687**	-0.162	0.636**	0.297	-0.341	-0.275	-0.262	0.044
P5	-0.213	0.288	-0.372	0.056	-0.135	-0.338	-0.146	0.367	-0.012	-0.347	-0.045	-0.121
P6	0.409	0.354	-0.278	-0.164	0.161	0.311	-0.472*	-0.515*	0.467*	0.136	0.101	0.025

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

P1 - Transplanting to active tillering
P2 - Active tillering to panicle initiation
P3 - Panicle initiation to booting
P4 - Booting to heading
P5 - Heading to 50% flowering
P6 - 50% flowering to physiological maturity

Table 4.18. Correlation between number of chaff per panicle and weather variables in Jyothi

Stages	Tmax	Tmin	RHI	RHII	Wind	BSS	RF	RD	Evp	TR	VPDI	VPDII
P1	-0.394	-0.675**	0.658**	0.436	0.345	0.613**	0.065	-0.366	0.473*	-0.091	0.163	-0.356
P2	-0.202	-0.33	0.059	-0.027	0.724**	0.128	0.325	-0.137	0.300	-0.114	0.061	0.581**
P3	0.004	-0.032	-0.004	-0.098	0.239	0.074	-0.236	-0.189	-0.059	0.03	0.569**	-0.174
P4	0.684**	0.027	-0.554*	-0.561*	-0.719**	0.501*	-.733**	-0.65**	0.535*	.650**	-0.13	-0.186
P5	0.136	-0.614**	0.723**	0.208	0.269	0.148	0.401	-0.252	-0.187	0.528*	-0.374	-0.010
P6	-0.316	-0.640**	0.128	-0.042	0.069	-0.166	0.339	0.414	-0.348	0.083	-0.367	-0.279

Table 4.19. Correlation between thousand grain weight and weather variables in Jyothi

Stages	Tmax	Tmin	RHI	RHII	Wind	BSS	RF	RD	Evp	TR	VPDI	VPDII
P1	0.689**	0.693**	-0.689**	-0.668**	-0.654**	-0.223	-0.561*	0.165	-0.507*	.575**	-0.201	-0.243
P2	-0.219	-0.067	0.175	0.435	-0.320	-0.368	0.196	0.289	-0.545*	-0.224	-.478*	-0.424
P3	-0.092	0.285	0.124	0.073	0.095	-0.157	0.140	0.096	0.268	-0.347	-0.195	0.367
P4	-0.114	0.432	-0.077	0.212	0.571**	-0.161	0.321	0.241	-0.013	-0.277	0.289	0.207
P5	0.064	0.632**	-0.238	0.283	-0.492*	-0.091	0.039	0.438	-0.19	-0.408	0.453*	0.506*
P6	-0.085	0.669**	0.102	0.369	-0.213	-0.34	0.265	0.124	-0.082	-0.408	0.461*	0.495*

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

P1 - Transplanting to active tillering
P2 - Active tillering to panicle initiation
P3 - Panicle initiation to booting
P4 - Booting to heading
P5 - Heading to 50% flowering
P6 - 50% flowering to physiological maturity

4.5.7.4. Correlation between weather variables and number of filled grains per panicle

Minimum temperature observed during transplanting to active tillering showed a significant positive correlation and forenoon relative humidity at the same stage showed significant negative with the number of filled grains per panicle. Afternoon vapour pressure deficit during active tillering to panicle initiation showed a significant negative correlation with the number of filled grains per panicle. In the next stage, wind speed showed a negative correlation with the number of filled grains per panicle. During booting to heading rainfall showed a significant positive correlation with the number of filled grains per panicle. At the time of heading to 50% flowering, there was no significant correlation with weather experienced during that period. Evaporation rate during 50% flowering to physiological maturity showed a significant positive correlation while rainfall and the number of rainy days during this stage showed a significant negative correlation with the number of filled grains per panicle.

4.5.7.5. Correlation between weather variables and number of chaff per panicle

The number of chaff per panicle showed a significant positive correlation with forenoon relative humidity, bright sunshine hours and evaporation experienced during transplanting to active tillering. It showed a significant negative correlation with the minimum temperature that prevailed during the same time. Wind speed, evaporation, and afternoon vapour pressure deficit had significant positive correlation with the number of chaff per panicle during active tillering to panicle initiation stage. From panicle initiation to booting forenoon vapour pressure had significant positive correlation with the number of chaff per panicle. Maximum temperature, bright sunshine hours, evaporation and temperature range experienced during booting to heading had significant positive correlation with number of chaff per panicle also relative humidity (forenoon and afternoon), wind speed, rainfall and number of rainy days. Forenoon relative humidity during heading to 50% flowering had significant positive correlation with the number of chaff, at the same time the minimum temperature had a significant negative correlation. Minimum temperature during 50% flowering to maturity showed significant negative correlation with the number of chaff per panicle.

4.5.7.6. Correlation between weather variables and thousand grain weight

Maximum temperature, minimum temperature and temperature range prevailed during transplanting to active tillering showed a positive correlation with thousand grain weight. Forenoon relative humidity, wind speed, evaporation and rainfall during this showed a significant negative correlation with thousand grain weight. Evaporation and forenoon vapour pressure deficit experienced during active tillering to panicle initiation showed a significant negation correlation with thousand grain weights. During panicle initiation to booting, there was no significant correlation between weather parameters and thousand grain weight. Wind speed during booting to heading showed a significant positive correlation with thousand grain weight. Minimum temperature and vapour pressure deficit during heading to 50% flowering had a significant positive effect on thousand grain weight while wind speed during this stage showed a negative correlation. Minimum temperature and vapour pressure deficit during last the phenophase had a significant positive correlation with thousand grain weight.

4.5.8. Influence of weather variables and yield attributes of Jaya

A correlation analysis has been performed between the yield attributes like number of tillers per unit area, number of panicles per unit area, number of spikelets per panicles, number of filled grains per panicle, number of chaff per panicle and thousand grain weight with meteorological variables for variety Jaya. Table 4.20 to 4.28 depicts the results of the correlation performed.

4.5.8.1. Correlation between weather variables and number of tillers per unit area

Evaporation observed during transplanting to the active tillering stage had a significant negative correlation with the number of tillers per unit area. During active tillering to panicle initiation maximum temperature, minimum temperature, bright sunshine hours evaporation and temperature range had a significant negative correlation with the number of tillers per unit area. While during the same phase relative humidity (forenoon and afternoon), wind speed, rainfall, number of rainy days and afternoon vapour pressure deficit had a significant negative correlation with the number of tillers per unit area. Afternoon relative humidity, rainfall, number of rainy days and afternoon vapore pressure deficit experienced during panicle initiation to booting had a significant positive correlation on the number of tillers per unit area.

Maximum temperature, bright sunshine hours, evaporation, forenoon vapour pressure deficit and temperature range showed a significant negative correlation with the number of tillers per unit area during the same phenophase. During booting to heading the recorded forenoon vapour pressure deficit had a significant positive correlation with the number of tillers per unit area. At the time weather parameter rainfall showed a significant negative correlation with the number of tillers per unit area. During heading to 50% flowering weather parameters like maximum temperature, wind speed, bright sunshine hours, evaporation and temperature range had a significant positive correlation with the number of tillers per unit area. During the same phase relative humidity (forenoon and afternoon), rainfall and the number of rainy days showed a significant negative correlation with the number of tillers per unit area. There was no significant correlation observed between weather parameters and the number of tillers per unit area during the last phenophase.

Table 4.20 Correlation between number of tillers and weather variables in Jaya

Stages	Tmax	Tmin	RHI	RHII	Wind	BSS	RF	RD	Evp	TR	VPDI	VPDII
P1	-0.059	0.279	-0.132	0.256	-0.089	-0.426	0.172	0.202	-0.451*	-0.363	0.016	0.237
P2	0.670**	0.571**	-0.454*	-0.680**	-0.673**	0.628**	-0.708**	-.446*	0.616**	0.560*	0.31	-0.533*
P3	-0.543*	-0.393	0.248	0.721**	0.223	-0.556*	0.645**	.654**	-0.507*	-0.459*	-0.647**	0.661**
P4	0.024	0.307	0.337	-0.389	0.063	0.129	-0.514*	-0.338	0.353	-0.142	0.448*	-0.368
P5	0.688**	0.409	-0.547*	-0.568**	0.632**	0.579**	-.534*	-0.453*	0.569**	0.558*	0.099	0.24
P6	-0.013	0.259	0.052	0.156	-0.132	-0.072	0.098	0.007	-0.15	-0.114	0.186	0.188

Table 4.21 Correlation between number of panicles and weather variables in Jaya

Stages	Tmax	Tmin	RHI	RHII	Wind	BSS	RF	RD	Evp	TR	VPDI	VPDII
P1	-0.560*	-0.238	0.400	0.671**	0.236	-0.351	0.540*	0.116	-0.228	-0.727**	0.039	0.216
P2	0.676**	0.672**	-0.453*	-0.780**	-0.396	0.802**	-0.767**	-0.819**	0.847**	0.530*	0.670**	-0.408
P3	-0.357	-0.460*	-0.018	0.571**	-0.082	-0.354	0.362	0.470*	-0.555*	-0.183	-0.550*	0.445*
P4	0.119	0.064	0.475*	-0.423	0.435	0.191	-0.347	-0.299	0.423	0.081	0.446*	-0.400
P5	0.556*	0.464*	-0.517*	-0.584**	0.322	0.361	-0.600**	-0.689**	0.194	0.405	0.122	0.293
P6	0.038	-0.242	0.128	-0.001	-0.167	0.186	-0.075	-0.09	-0.093	0.125	-0.006	-0.088

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

P1 - Transplanting to active tillering
P2 - Active tillering to panicle initiation
P3 - Panicle initiation to booting
P4 - Booting to heading
P5 - Heading to 50% flowering
P6 - 50% flowering to physiological maturity

Table 4.22. Correlation between spikelets per panicle and weather variables in Jaya

Stages	Tmax	Tmin	RHI	RHII	Wind	BSS	RF	RD	Evp	TR	VPDI	VPDII
P1	0.032	-0.114	0.029	-0.074	0.12	0.169	0.077	0.024	0.357	0.162	-0.077	0.183
P2	-0.490*	-0.312	0.492*	0.402	0.356	-0.496*	0.468*	0.334	-0.458*	-0.448*	-0.066	0.131
P3	0.542*	0.285	-0.385	-0.524*	-0.183	0.557*	-0.489*	-0.576**	0.431	0.524*	0.327	-0.394
P4	-0.382	-0.316	0.046	0.551*	-0.093	-0.417	0.571**	0.529*	-0.546*	-0.200	-0.552*	0.506*
P5	-0.576**	-0.015	0.568**	0.179	-0.478*	-0.573**	0.322	0.29	-0.453*	-0.580**	0.286	-0.503*
P6	0.038	-0.102	0.022	-0.117	-0.046	0.13	-0.183	-0.092	0.129	0.069	-0.018	-0.083

Table 4.23.Correlation between filled grains per panicle and weather variables in Jaya

Stages	Tmax	Tmin	RHI	RHII	Wind	BSS	RF	RD	Evp	TR	VPDI	VPDII
P1	-0.565**	-0.407	0.464*	0.328	0.742**	0.293	0.515*	-0.346	0.571**	-0.55**	0.517*	0.427
P2	0.281	-0.048	-0.2	-0.244	-0.012	0.278	-0.215	-0.408	0.158	0.340	0.386	-0.079
P3	0.056	-0.564**	-0.134	0.026	-.688**	0.131	-0.299	-0.147	-0.394	0.407	-0.378	-0.208
P4	-0.291	-0.696**	0.564**	0.070	0.639**	-0.092	0.190	0.155	-0.105	0.092	-0.483*	-0.068
P5	-0.056	0.237	0.419	-0.228	-0.09	-0.27	-0.542*	-0.59**	-0.277	-0.138	0.513*	-0.458*
P6	0.653**	-0.457*	-0.439	-0.68**	0.323	0.761**	-0.76**	-0.73**	0.626**	0.674**	-0.504*	-0.618**

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

P1 - Transplanting to active tillering
P2 - Active tillering to panicle initiation
P3 - Panicle initiation to booting
P4 - Booting to heading
P5 - Heading to 50% flowering
P6 - 50% flowering to physiological maturity

Table 4.24. Correlation between number of chaff per panicle and weather variables in Jaya

Stages	Tmax	Tmin	RHI	RHII	Wind	BSS	RF	RD	Evp	TR	VPDI	VPDII
P1	0.525*	0.218	-0.351	-0.384	-0.574**	-0.066	-0.453*	0.275	-0.204	0.687**	-0.517*	-0.348
P2	-.689**	-0.263	0.563**	0.605**	0.383	-0.672**	0.624**	0.648**	-0.536*	-0.694**	-0.449*	0.280
P3	0.388	0.764**	-0.162	-0.494*	0.459*	0.331	-0.166	-0.35	0.718**	0.041	0.686**	-0.198
P4	0.054	0.376	-0.565**	0.333	-0.633**	-0.175	0.273	0.234	-0.288	-0.15	0.028	0.428
P5	-0.439	-0.322	0.065	0.444*	-0.348	-0.22	0.799**	0.798**	-0.151	-0.335	-0.334	0.085
P6	-0.569**	0.275	0.403	0.491*	-0.289	-0.59**	0.562**	0.609**	-0.460*	-0.538*	0.395	0.459*

Table 4.25. Correlation between thousand grain weight and weather variables in Jaya

Stages	Tmax	Tmin	RHI	RHII	Wind	BSS	RF	RD	Evp	TR	VPDI	VPDII
P1	-0.146	0.103	0.001	0.074	0.248	0.01	0.116	-0.197	-0.014	-0.347	0.407	0.200
P2	0.597**	0.178	-0.527*	-0.457*	-0.469*	0.502*	-0.509*	-0.354	0.358	0.620**	0.143	-0.26
P3	-0.494*	-0.594**	0.348	0.532*	-0.166	-0.461*	0.347	0.462*	-0.59**	-0.277	-0.603**	0.308
P4	0.018	-0.105	0.313	-0.356	0.315	0.21	-0.407	-0.317	0.306	0.073	0.091	-0.42
P5	0.499*	0.178	-0.171	-0.323	0.499*	0.386	-0.616**	-0.527*	0.381	0.446*	0.151	0.028
P6	0.402	0.05	-0.362	-0.279	0.269	0.293	-0.3	-0.393	0.303	0.283	-0.22	-0.207

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

P1 - Transplanting to active tillering

P2 - Active tillering to panicle initiation

P3 - Panicle initiation to booting

P4 - Booting to heading

P5 - Heading to 50% flowering

P6 - 50% flowering to physiological maturity

4.5.8.2. Correlation between weather variables and number of panicles per unit area

Afternoon relative humidity and rainfall observed during transplanting to active tillering had a significant positive correlation with the number of panicles per unit area. While during the same maximum temperature and temperature range had a significant negative correlation withthe number of panicles per unit area. During active tillering to panicle initiation maximum temperature, minimum temperature, bright sunshine hours, evaporation, temperature range and forenoon vapour pressure deficit had a significant positive correlation with the number of panicles per unit area. Relative humidity (afternoon and mean), rainfall and number of rainy days experienced during this stage had a significant negative correlation withthe number of panicles per unit area. Afternoon relative humidity, afternoon vapor pressure deficit and the number of rainy days experienced during panicle initiation to booting had a significant positive correlation on the number of panicles per unit area. Minimum temperature, evaporation and forenoon vapour pressure deficit showed a significant negative correlation with number of panicles per unit area during the same phenophase. During booting to heading forenoon relative humidity and forenoon vapour pressure deficit showed a significant negative correlation. During heading to 50% flowering weather parameters like maximum temperature and minimum temperature had a significant positive correlation with the number of panicles per unit area. During the same phase relative humidity (forenoon and afternoon), rainfall and the number of rainy days showed a significant negative correlation with the number of panicles per unit area. There was no significant correlation observed between weather parameters and the number of panicles per unit area during the last phenophase.

4.5.8.3. *Correlation between weather variables and number of spikelets per panicles*

There was no significant correlation between the number of spikelets per panicle and weather parameters during the transplanting to active tillering. Forenoon relative humidity and rainfall showed a significant positive correlation with the number of spikelets per panicle during active tillering to panicle initiation. While maximum temperature, temperature range, evaporation, and bright sunshine hours during this stage had a significant negative correlation with the number of spikelets per panicle. Maximum temperature, temperature range and bright sunshine hours during panicle initiation to booting showed a significant positive correlation with the number of spikelets per panicle. Afternoon relative humidity, rainfall and number of rainy days during panicle initiation to booting showed a significant negative correlation with the number of spikelets per panicle. While, afternoon relative humidity, rainfall and number of rainy days during booting to heading showed a significant negative correlation with the number of spikelets per panicles Evaporation and temperature range observed during booting to heading had a significant negative correlation with the number of spikelets per panicle. During heading to 50% flowering forenoon relative humidity had a significant positive correlation and maximum temperature, wind speed, bright sunshine hours, evaporation, temperature range and forenoon vapour pressure deficit had a significant negative correlation with the number of spikelets per panicles. There was no significant correlation between weather variables and spikelets per panicle in the last stage.

4.5.8.4. Correlation between weather variables and number of filled grains per panicle

Forenoon relative humidity, wind speed, rainfall, evaporation and forenoon vapour pressure deficit during transplanting to active tillering had a significant positive correlation with the number of filled grains per panicles, and maximum temperature and temperature range during the same stage had a significant negative impact on the number of filled grains per panicles. A significant correlation between weather that prevailed during active tillering to panicle initiation was found to be absent. Minimum temperature and wind speed experienced during panicle initiation to booting showed a significant negative correlation with the number of filled grains per panicle. Forenoon relative humidity and wind speed during booting to heading showed a significant positive correlation with the number of filled grains while minimum temperature and forenoon relative humidity had a significant negative correlation with the number of filled grains per panicle. Forenoonvapour pressure deficit during heading to 50% flowering had a significant positive correlation with filled grains per panicle Rainfall, number of rainy days and afternoon vapour pressure deficit during heading to 50% flowering had a significant negative correlation with filled grains per panicle. Weather parameters like maximum temperature, bright sunshine hours, evaporation and temperature range showed a significant positive correlation with filled grains during the last phenophase. At the same time minimum temperature, afternoon relative humidity, rainfall, rainy days, forenoon vapour pressure deficit and afternoon vapour pressure deficit had a significant negative correlation with filled grains per panicle.

4.5.8.5. Correlation between weather variables and number of chaff per panicle

Maximum temperature and temperature range during transplanting to active tillering significant positive correlation between the number of chaff per panicle. Wind speed, rainfall and forenoon vapour pressure deficit at the same time showed a significant negative correlation with number of chaff per panicle. Number of chaff per panicle showed a significant positive correlation with relative humidity (forenoon and afternoon), rainfall and rainy days experienced during active tillering to panicle initiation. Maximum temperature, bright sunshine hours, evaporation, forenoon vapour pressure deficit and temperature range during this phenophase had a significant negative correlation with number of chaff per panicle. During panicle initiation to booting minimum temperature, wind speed, evaporation and forenoon vapour pressure deficit had a significant positive correlation with number of chaff and afternoon relative humidity had a significant negative correlation in this stage. Forenoon relative humidity and wind speed experienced during booting to heading had a significant negative correlation with number of chaff per panicle. Afternoon relative humidity, rainfall and rainy days had a significant positive correlation with number of chaff per panicle during heading to 50% flowering. The number of chaff per panicle showed a positive correlation with afternoon relative humidity, rainfall, number of rainy days and afternoon vapour pressure deficit during 50% flowering to physiological maturity had a significant positive correlation with number of chaff per panicle. It showed a significant negative correlation with maximum temperature, bright sunshine hours, evaporation and temperature range.

4.5.8.6. Correlation between weather variables and thousand grain weight

There was no significant correlation between thousand grain weight and weather parameters during the transplanting to active tillering. Maximum temperature, bright sunshine hours and temperature range during active tillering to panicle initiation had a significant positive correlation with thousand grain weight. Relative humidity (forenoon and afternoon), wind speed and rainfall during active tillering to panicle initiation showed a significant negative correlation with thousand grain weight. Afternoon relative humidity and rainy days had a significant positive correlation with thousand grain weight during panicle initiation to booting. While maximum temperature, minimum temperature, evaporation and forenoon vapor pressure deficit had a significant negative correlation with thousand grain weight. During booting to heading there was no significant correlation with thousand grain weight. Rainfall and number of rainy days during heading to 50% flowering had a significant negative correlation with thousand grain weight. In this stage maximum temperature, wind speed and temperature range showed a significant positive correlation with thousand grains. No significant correlation was found between weather variables and thousand grains in the last stage.

4.6. PLANT CHARACTERS

4.6.1 Weekly plant height

The results of ANOVA which wasdone for weekly plant height till the harvesting stage of the crop are represented in Appendix II. The effect of date of planting, variety and their interaction with plant height has been depicted in Table 4.26 (a and b). Dates of planting had a significant influence on weekly plant height during 1st, 3rd, 4th, 5th, 6th, 7th and 8th week irrespective of varieties. From the 9th week onwards dates of planting did not show any significant influence on plant height. Plant height was found higher during the 1st week (24.69cm) and 3rd week (38.89cm) for July 20th planting. Plant height for June 5th planting was observed to be higher during the 4th week (40.19cm) and 5th week (74.80cm). From 6th to 8th week, June 5th, June 20th and July 5th planting were found to be on par. From 8th week onwards dates of planting did not show any significant influence on weeklyplant height. Varieties differ significantly concerning weekly plant height. Among both the varieties, plant height was observed to be significantly higher for Jyothi in all weeks.

The interaction was found significant during 3rd, 4th, 5th, 9th, 10th, 11th, 12th and 13th week. In Jyothi, the highest plant height was recorded for 5th June planting during the 3rd week (47.16cm), 4th week (66.00cm), 5th week (84.03cm). From 8th to 13th week onwards June 20th planting showed maximum height. In the case of Jaya, July 20th planting observed maximum height during the 3rd week andJuly 5th planting showed maximum height in the 4th and 5th week. From the 8th week onwards plant height was found to be on par during all dates of planting in Jaya.

Table 4.26 (a) Effect of date of planting on plant height at weekly intervals

Date of planting	**Plant height (cm)**														
	Week 1			Week 2			Week 3			Week 4			Week 5		
	Ja	Jy	Mean	Ja	Jy	Mean	Ja	Jy	Mean	Ja	Jy	Mean	Ja	Jy	Mean
5th June	20.46	23.65	22.06^{c}	27.25	32.48	29.86	33.23^{c}	47.16^{a}	40.19^{a}	48.44^{b}	66.005^{a}	40.1925^{a}	65.56^{ab}	84.03^{a}	74.80^{a}
20th June	19.00	21.86	20.43^{c}	27.57	33.13	30.35	35.50^{bc}	40.08^{b}	37.79^{ab}	49.06^{b}	56.960^{b}	37.7875^{ab}	63.21^{b}	73.92^{b}	68.57^{bc}
5th July	22.07	22.68	22.37^{bc}	31.92	32.58	32.25	37.68^{ab}	39.04^{bc}	38.36^{ab}	55.78^{a}	58.435^{b}	38.3575^{ab}	68.74^{a}	71.32^{bc}	70.03^{b}
20th July	23.62	25.76	24.69^{a}	30.93	32.94	31.93	39.72^{a}	38.06^{bc}	38.89^{a}	49.23^{b}	49.54^{c}	38.8900^{ab}	62.36^{b}	67.69^{c}	65.02^{c}
5th August	23.23	25.30	24.27^{ab}	30.23	30.26	30.25	36.18^{abc}	35.11^{c}	35.64^{b}	44.68^{b}	46.36^{c}	35.6425^{b}	53.76^{c}	54.86^{d}	54.31^{d}
CD	NS		1.9841	NS		NS	4.114		2.778	5.417		3.713	5.431		4.523

Date of planting	**Plant height (cm)**											
	Week 6			Week 7			Week 8			Week 9		
	Ja	Jy	Mean	Ja	Jy	Mean	Ja	Jy	Mean	Ja	Jy	Mean
5th June	81.09	96.12	88.60^{a}	93.93	100.76	97.34^{a}	100.23	109.88	105.05^{a}	105.99^{a}	118.71^{ab}	112.35
20th June	79.81	95.43	87.62^{a}	93.63	107.91	100.77^{a}	100.06	116.47	108.26^{a}	102.49^{a}	123.54^{a}	113.01
5th July	90.23	96.72	93.47^{a}	96.83	101.38	99.11^{a}	102.06	105.62	103.84^{a}	109.11^{a}	110.28^{bc}	109.70
20th July	71.20	82.17	76.68^{b}	87.49	91.13	89.31^{b}	96.06	101.34	98.70^{b}	105.69^{a}	109.24^{c}	107.46
5th August	66.73	71.37	69.05^{c}	85.58	88.92	87.25^{b}	95.11	99.36	97.23^{b}	105.26^{a}	109.23^{c}	107.25
CD	NS		6.445	NS		6.199	NS		5.033	8.576		NS

Table 4.26 (a) Effect of date of planting on plant height at weekly intervals (Contd.)

Date of planting	**Plant height (cm)**											
	Week 10			Week 11			Week 12			Week 13		
	Ja	Jy	Mean	Ja	Jy	Mean	Ja	Jy	Mean	Ja	Jy	Mean
5th June	111.62[a]	125.96[ab]	117.66	110.41[a]	128.57[ab]	119.49	112.55[a]	131.00[ab]	121.77	112.55[a]	130.99[ab]	121.77
20th June	109.37[a]	135.17[a]	123.39	115.99[a]	137.40[a]	126.69	118.40[a]	139.34[a]	128.87	118.40[a]	139.34[a]	128.87
5th July	113.15[a]	116.55[b]	114.85	118.15[a]	121.94[b]	120.04	121.60[a]	128.68[b]	125.14	121.60[a]	128.68[ab]	125.14
20th July	113.90[a]	117.33[b]	115.61	116.61[a]	120.75[b]	118.68	120.61[a]	124.93[b]	122.77	120.61[a]	124.93[b]	122.76
5th August	113.67[a]	116.86[b]	115.27	115.49[a]	119.65[b]	117.57	120.04[a]	124.98[b]	122.50	120.04[a]	124.98[b]	122.51
CD	10.493		NS	10.416		NS	9.945		NS	10.785		NS

Table 4.26 (b) Comparison between varieties with respect to plant height at weekly intervals

	Plant height (cm)												
Variety	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13
Jyothi	23.85[a]	32.27[a]	39.89[a]	55.46[a]	70.36[a]	88.36[a]	98.02[a]	106.53[a]	114.20[a]	122.37[a]	125.66[a]	129.78[a]	129.78[a]
Jaya	21.68[b]	29.59[b]	36.46[b]	49.44[b]	62.73[b]	77.81[b]	91.49[b]	98.70[b]	105.71[b]	112.33[b]	115.33[b]	118.64[b]	118.64[b]
CD	1.36	1.76	1.91	2.534	1.91	3.047	5.043	4.157	4.1275	3.270	3.565	3.50	4.02

4.6.2 Dry matter accumulation at fortnightly intervals

The results of ANOVA which was done for dry matter accumulation which was recorded at fortnightly intervals till the harvesting stage of the crop are represented in Appendix II. The effect of date of planting, variety and their interaction with dry matter accumulation has been depicted in Table 4.27 (a and b).

Irrespective of variety a significant difference in dry matter accumulation as a result of dates of planting was observed during 60, 75 and 90 days after planting. There was no significant difference during 15, 30 and 45 days after planting.

At 60 days after planting June 20th planting was found to be on par with July 20th and August 5th planting. June 5th, July 5th, July 20th and August 5th plantings were found to be on par with each other. At 75 days after planting June 20th planting and August 5th planting were found to be on par. August 5th planting was found to be on par with July 5th and July 20th planting. June 5th, July 5th and July 20th planting were found to be on par with each other. At 90 days after planting June 20th planting and August 5th planting were found to be on par.August 5th planting was found to be on par with June 5th and July 20th planting. At the same time June 5th, July 5th and July 20th plantings were found to be on par.

Among the two varieties, a significant difference was observed during all intervals. Dry matter accumulation of Jyothi variety was found to be higher *i.e.*553.94 kg/ha, 1909.81 kg/ha, 4444.8 kg/ha, 8978.77 kg/ha, 12187.11kg/ha and 9311.07 kg/ha at 15, 30, 45, 60, 75 and 90 days after planting respectively.A significant difference was not observed in the interaction between different dates of plantings and varieties

Table 4.27 (a) Effect of date of planting on dry matter accumulation

Date of planting	Dry matter accumulation (kg ha^{-1})								
	15 DAP			30 DAP			45 DAP		
	Ja	Jy	Mean	Ja	Jy	Mean	Ja	Jy	Mean
5th June	299.97	499.95	399.96	666.66	2299.77	1483.22	1791.49	4466.22	3128.85
20th June	426.24	733.26	579.75	1039.90	1994.80	1517.35	2758.06	5307.80	4032.93
5th July	324.97	606.61	465.79	1208.21	1956.47	1582.34	2718.06	4687.86	3702.96
20th July	337.47	416.63	377.05	927.41	1249.88	1088.64	2037.30	3507.98	2772.64
5th August	437.46	513.28	475.37	1047.40	2013.13	1530.26	2838.88	4254.58	3546.73
CD	NS		NS	NS		NS	NS		NS

Date of planting	Dry matter accumulation (kg ha^{-1})								
	60 DAP			75 DAP			90 DAP		
	Ja	Jy	Mean	Ja	Jy	Mean	Ja	Jy	Mean
5th June	4099.96	7832.55	5966.26[b]	5766.61	10465.62	8116.11[c]	5480.78	9215.745	7348.26[bc]
20th June	5257.81	10607.27	7932.54[a]	7445.92	14440.22	10943.07[a]	6837.65	12072.13	9454.89[a]
5th July	3501.32	8130.85	5816.09[b]	6291.04	11587.17	8939.11[bc]	5728.59	6486.018	6107.31[c]
20th July	4487.05	8924.11	6705.58[ab]	6366.03	11748.83	9057.43[bc]	6107.72	8705.796	7406.76[bc]
5th August	4672.03	9399.06	7035.55[ab]	6984.30	12693.73	9839.02[ab]	6740.99	10075.66	8408.33[ab]
CD	NS		1266.12	NS		1370.04	NS		1344.64

Table 4.27 (b) Comparison between varieties with respect to dry matter accumulations

Variety	15 DAP	30DAP	45DAP	60DAP	75DAP	90DAP
Jyothi	553.94[a]	1902.81[a]	4444.89[a]	8978.77[a]	12187.11[a]	9311.07[a]
Jaya	365.22[b]	977.91[b]	2428.76[b]	4403.63[b]	6570.78[b]	6179.15[b]
CD	147.04	435.01	NS	726.00	726.00	1132.3

4.6.3. Yield and yield attributes

The results of ANOVA which was done on yield and yield attributes were shown in Appendix II. The effect of date of planting, variety and their interaction with various yield and yield attributes has been presented in Table 4.28 (a) and (b). CD values were calculated and then comparisons were made.

4.6.3.1 Number of tillers per m^2

Significant differences in the number of tillers per unit area were observed as an effect of dates of planting. Among five dates of planting, on June 20^{th}, June 5^{th} and August 5^{th}plantings were found to be on par. Among the varieties, Jaya (307) was found to be superior to Jyothi (259). A significant difference in the interaction of dates of planting and varieties was found to be absent.

4.6.3.2. Number of panicles per unit area

The number of panicles per unit area was found to have no significant difference due to the effect of dates of planting. Among the two varieties number of panicles per unit area was found to be higher in Jaya (251) when compared with Jyothi (208). A significant difference has been observed in the interaction of different dates of planting with rice varieties. In Jaya, among the five dates of plantings number of panicles were found to be on par with June 20^{th} planting, June 5^{th}, June 20^{th} and August 5^{th} plantings. In Jyothi, 20^{th} June and 5^{th} July planting, 5^{th} August planting were found to be on par. 5^{th} June, 5^{th} July planting and 5^{th} August planting were found on par with each other. July 20^{th} planting (133) was found to be inferior to all other plantings.

4.6.3.3. Number of spikelets per panicle

There was a significant difference in the number of spikelets per panicle as an effect of dates of plantings and varieties. Among different dates of plantings, spikelet number was found to be on par in July 5^{th} planting (116), June 5^{th}, July 20^{th} and August 5^{th} plantings. Spikelets number was found in June 20^{th} planting was found to be on par with July 20^{th}

planting. A Significant difference was not observed as an effect of varieties and as an interaction between different dates of plantings and varieties.

4.6.3.4. Number of filled grains per panicle

A significant difference was found in the number of filled grains as an effect of dates of planting. Number of filled grains was found in June 5thplanting, August 5th planting and July 20th planting was found to be on par with. June 20th planting and July 5th planting were found to be on par and was inferior to other plantings. There was no significant difference among varieties and interaction between varieties and dates of plantings.

4.6.3.5. 1000 grain weight (g)

There was no significant difference in 1000 grain weight as an effect of dates of plantings and varieties. A significant difference was observed in the interaction between different dates of plantings and varieties. In Jaya June 5th, July 20th, August 5th and June 20th plantings were found to be on par with each other. In Jyothi June 5th, June 20th and July 5th plantings were found to be on par with each other. Also, July 5th planting was found to be on par with all other dates of planting.

4.6.3.6. Straw yield (kgha$^{-1)}$

There was no significant difference in straw yield and among different dates of plantings and varieties. A significant difference was not observed in straw yield as a result of interaction between different dates of plantings and varieties.

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

A significant difference was observed in grain yield as an effect of dates of planting. June 5th planting was found to be on par with August 5th planting. August 5th planting was found to be on par with remaining all dates of plantings. There was no significant difference among varieties. The interaction between varieties and dates of plantings showed a significant difference. In Jaya, July 20th and August 5th planting were found to be on par while other dates of plantings were found to be on par. In the case of Jyothi June 5th planting and August 5th plantings were found to be on par.

Table 4.28 (a) Effect of date of planting on yield and yield attributes

Date of planting	Number of tillers per unit area			Number of panicles per unit area			Number of spikelets per panicle			Number of filled grains per panicle		
	Ja	Jy	Mean	Ja	Jy	Mean	Ja	Jy	Mean	Ja	Jy	Mean
5th June	320	268	294^{a}	234^{ab}	185^{bc}	210	103	110	109^{a}	47^{bc}	92^{a}	69^{a}
20th June	337	300	318^{a}	264^{ab}	265^{a}	265	90	92	91^{b}	36^{c}	43^{c}	40^{c}
5th July	249	249	249^{b}	221^{b}	232^{ab}	226	116	116	116^{a}	45^{bc}	51^{bc}	48^{bc}
20th July	327	186	256^{b}	292^{a}	133^{c}	212	104	105	105^{ab}	72^{a}	52^{bc}	62^{ab}
5th August	300	294	297^{a}	245^{ab}	225^{ab}	235	102	118	110^{a}	63^{ab}	68^{b}	65^{ab}
CD	NS		31.78	68.72		NS	NS		15.57	21.79		17.47

Date of planting	1000 grain weight (g)			Straw yield (kg ha^{-1})			Grain yield (kg ha^{-1})		
	Ja	Jy	Mean	Ja	Jy	Mean	Ja	Jy	Mean
5th June	26.75^{a}	27.60^{a}	27.18	5572.50	4642.50	5107.50	2000^{b}	5275^{a}	3637.5^{ab}
20th June	26.50^{ab}	26.50^{ab}	26.50	4990.00	4702.50	4846.25	1600^{b}	2350^{b}	1975.0^{c}
5th July	24.00^{b}	25.78^{abc}	24.89	4717.50	4562.50	4640.00	1245^{b}	1675^{b}	1460.0^{c}
20th July	27.25^{a}	24.75^{bc}	25.25	5795.00	3547.50	4671.25	4575^{a}	1625^{b}	3100.0^{b}
5th August	27.75^{a}	23.25^{c}	26.25	5566.67	6136.67	5851.67	4225^{a}	3950^{a}	4087.5^{a}
CD	2.74		NS	NS		NS	1539.64		980.00

Table 4.28 (b) Comparison between varieties and yield attributes

Variety	Tillers per m^{2}	Panicles per m^{2}	Spikelets per panicle	Filled grains per panicle	1000 grain weight	Straw yield (kg ha^{-1})	Grain yield (kg ha^{-1})
Jaya	307^{a}	251^{a}	104	62.34	26.45	2975	2729
Jyothi	259^{b}	208^{b}	108	63.07	25.58	2729	2975
CD	41.89	35.86	NS	NS	NS	NS	NS

4.7. GROWTH INDICES

4.7.1. Leaf area index (LAI) at fortnightly intervals

The results of ANOVA which was done for leaf area index recorded at fortnightly intervals till the harvesting stage of the crop are represented in Appendix II. The effect of date of planting, variety and their interaction with leaf area index has been depicted in Table 4.29 (a and b).

As an effect of date of planting on leaf area index showed a significant difference at 15 days after planting and 30 days after planting. At 15 days after planting 5thJuly, 20th July and 5thAugust planting were found to be on par, and 5th June and 20th June plantings were found to be on par. During 30 days after planting July 20th planting was found to be on par with 5th July and 5th August planting. There was a significant difference in leaf area index in both varieties during all intervals. Jyothi was found to be superior when compared to Jaya.

Interaction between dates of planting and varieties showed a significant difference at 15 days after planting and 75 days after planting. At 15 days after planting in Jyothi 5th August planting was found to be superior. July 5th and 20th planting were on par and June 5th and 20th planting was on par. In Jaya, July 20th planting was found to be on par with 5th August, 5th July and 5th June. Also, June 20th planting was found to be on par with 5th June, 5th July and 5th August.

Table 4. 29 (a) Effect of date of planting on leaf area index (LAI) at fortnightly intervals

Date of planting	Leaf area index								
	15 DAP			30 DAP			45 DAP		
	Ja	Jy	Mean	Ja	Jy	Mean	Ja	Jy	Mean
5th June	0.16^{ab}	0.16^{c}	0.16^{b}	0.20	1.10	0.65^{c}	1.09	2.63	1.86
20th June	0.10^{b}	$0.23b^{c}$	0.17^{b}	0.17	1.23	0.70^{bc}	1.11	2.87	1.99
5th July	0.19^{ab}	0.31^{b}	0.25^{a}	0.62	1.34	0.98^{abc}	2.92	2.88	2.90
20th July	0.25^{a}	0.32^{b}	0.28^{a}	0.93	1.42	1.17^{a}	1.25	2.32	1.79
5th August	0.17^{ab}	0.46^{a}	0.31^{a}	0.72	1.48	1.10^{ab}	1.18	2.77	1.97
CD	0.109		0.0754	NS		0.415	NS		NS

Date of planting	Leaf area index								
	60 DAP			75 DAP			90 DAP		
	Ja	Jy	Mean	Ja	Jy	Mean	Ja	Jy	Mean
5th June	2.72	3.25	2.98	3.91^{a}	3.45^{c}	3.68	3.45	3.21	3.33
20th June	2.41	3.80	3.10	3.58^{a}	4.98^{b}	4.28	3.00	4.40	3.70
5th July	3.02	4.42	3.72	3.47^{a}	6.56^{a}	5.01	3.04	5.56	4.30
20th July	3.12	4.80	3.96	3.89^{a}	6.03^{ab}	4.96	3.25	5.31	4.27
5th August	2.91	5.81	4.36	3.27^{a}	6.13^{ab}	4.70	3.05	4.96	4.01
CD	NS		NS	1.526		NS	NS		NS

Table 4.29 (b) Comparison of leaf area index (LAI) of varieties at fortnightly intervals

Varieties	Leaf area index					
	15 DAP	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
Jaya	0.17^{b}	0.53^{b}	1.51^{b}	2.84^{b}	3.63^{b}	3.16^{b}
Jyothi	0.29^{a}	1.31^{a}	2.69^{a}	4.42^{a}	5.43^{a}	4.69^{a}
CD	0.050	0.246	0.482	0.672	0.608	0.658

DAP – Days after planting   Jy- Jyothi Ja - Jaya

4.7.2. Leaf area duration (LAD) at fortnightly intervals

The results of ANOVA which wasdone for leaf area duration at fortnightly intervals till the harvesting stage of the crop are represented in Appendix II. The effect of date of planting, variety and their interaction with leaf area duration has been depicted in Table 4.30 (a and b).

Dates of planting had a significant influence on leaf area duration at 15 days after planting irrespective of varieties. Leaf area duration observed at 15 days after planting in August 5th planting, 20th July planting and 5th July planting was found to be on par and leaf area duration observed in 20th June was found to be on par with 5th June and 5th July. Among both the varieties, leaf area duration was observed to be significantly higher for Jyothi in all intervals.

Interaction between dates of planting and varieties was found to be significant at 15 and 75 days after planting. During 15 days after planting in Jyothi, the highest leaf area duration was found to be in August 5th planting (3.42). Minimum leaf area duration was observed in 5th June planting *i.e.* 1.20 and was found to be on par with 20th June planting. In Jaya maximum leaf area duration was found to be in 20th July planting and was found to be on par with all other dates of planting except in 20th June which recorded the minimum leaf area duration (0.75). During 75-90 days after planting leaf area duration was found to be par with all dates plantings in Jaya. While in Jyothi, July 5th, July 20th and 5th August planting recorded the higher leaf area duration and was found to be on par. Minimum leaf area was recorded during June 5th planting (25.86).

Table 4.30 (a) Effect of date of planting on leaf area duration (LAD) at fortnightly intervals

Date of planting	Leaf area duration								
	0-15			15 - 30 DAP			30 - 45 DAP		
	Ja	Jy	Mean	Ja	Jy	Mean	Ja	Jy	Mean
5th June	1.20^{ab}	1.20^{c}	1.20^{c}	1.52	8.25	4.88	8.15	19.74	13.94
20th June	0.75^{b}	1.74^{bc}	1.25^{bc}	1.27	9.21	5.24	8.34	21.51	14.93
5th July	1.40^{ab}	2.30^{b}	1.85^{ab}	4.67	10.05	7.36	21.94	21.61	21.77
20th July	1.87^{a}	2.37^{b}	2.12^{a}	6.97	10.63	8.80	9.40	17.40	13.40
5th August	1.25^{ab}	3.42^{a}	2.34^{a}	5.40	11.09	8.25	8.83	20.77	14.80
CD	0.817		0.609	NS		NS	NS		NS

Date of planting	Leaf area duration								
	45-60 DAP			60-75 DAP			75-90 DAP		
	Ja	Jy	Mean	Ja	Jy	Mean	Ja	Jy	Mean
5th June	20.37	24.35	22.36	29.32^{a}	25.86^{c}	27.59	25.90	24.06	24.98
20th June	18.08	28.48	23.28	26.89^{a}	37.32^{b}	32.11	22.47	33.02	27.74
5th July	22.67	33.12	27.90	26.02^{a}	49.19^{a}	37.61	22.83	41.66	32.25
20th July	23.43	36.04	29.73	29.22^{a}	45.25^{ab}	37.24	24.35	39.79	32.07
5th August	21.84	43.61	32.73	24.55^{a}	45.96^{ab}	35.26	22.89	37.22	30.06
CD	NS		NS	11.44		NS	NS		NS

Table 4.30 (b) Comparison of leaf area duration (LAD) of varieties at fortnightly intervals

Varieties	Leaf area duration					
	15 DAP	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
Jaya	1.30^{b}	3.97^{b}	11.33^{b}	21.28^{b}	27.20^{b}	23.69^{b}
Jyothi	2.21^{a}	9.84^{a}	20.21^{a}	33.12^{a}	40.72^{a}	35.15^{a}
CD	0.38	3.11	3.62	5.04	4.56	4.94

DAP – Days after planting Jy- Jyothi Ja - Jaya

4.7.3. Crop growth rate (CGR) at fortnightly intervals

The results of ANOVA which wasdone for crop growth rate at fortnightly intervals till the harvesting stage of the crop are represented in Appendix II. The effect of date of planting, variety and their interaction with crop growth rate has been shown in Table 4.31 (a and b).

A significant difference as an effect of dates of plantings was found at an interval except during 15 to 30 days intervals. The crop growth rate during 30- 45 days after planting was found in June 20th, 5th July and 5th August planting were found to be on par. August 5th planting was found to be on par with July 20th and June 5th planting. During 45 to 60 days after planting August 5th planting showed a higher crop growth rate *i.e.* 37.70g m^{-2} day^{-1}. June 20th and July 5th planting were found to be on par. The crop growth rate of June 5th and July 5th planting was found to be on par. During 60 to 75 days to planting crop growth rate was found to be higher in June 20th planting and August 5th planting was found to be on par with each other. August 5th planting was found to be on par with July 5th and July 20th planting. June 5th planting showed the highest crop growth rate (-5.60g m^{-2} day^{-1}) and the least crop growth rate was found in July 5th planting (-21.36g m^{-2} day^{-1}) during 75 to 90 days after planting.

Among the varieties, Jyothi was found to be superior during all time intervals except at an interval of 30 to 45 days after planting and 60 to 75 days after planting during this period varieties showed no significance.

An interaction was observed during 75 to 90 days intervals. In Jyothi, 5th June planting showed maximum crop growth rate (-8.33g m^{-2} day^{-1}) and minimum crop growth rate was observed in July 5thplanting (-34.01g m^{-2} day^{-1}). In Jaya, all dates of plantings were found to be on par.

Table.4.31 (a). Effect of date of planting on crop growth rate (CGR) at fortnightly intervals

Date of planting	Crop growth rate (g m^{-2} day^{-1})					
	60 – 75 DAP			75 - 90 DAP		
	Jy	Ja	Mean	Jy	Ja	Mean
5th June	17.56	16.67	17.11^{c}	-8.33^{a}	-2.86^{a}	-5.60^{a}
20th June	25.56	21.88	23.72^{a}	-15.79^{b}	-6.08^{a}	-10.94^{b}
5th July	23.04	13.80	18.42^{bc}	-34.01^{c}	-8.72^{a}	-21.36^{c}
20th July	18.83	18.79	18.81^{bc}	-20.29^{b}	-2.58^{a}	-11.44^{b}
5th August	21.97	23.13	22.55^{ab}	-17.46^{b}	-2.43^{a}	-9.94^{b}
CD	NS		4.76	7.71		4.08

Date of planting	Crop growth rate (g m^{-2} day^{-1})								
	15 - 30 DAP			30 - 45 DAP			45 - 60 DAP		
	Jy	Ja	Mean	Jy	Ja	Mean	Jy	Ja	Mean
5th June	12.00	3.67	7.83	14.44	11.25	12.85^{b}	22.44	23.08	22.76^{c}
20th June	8.41	6.13	7.27	22.09	17.18	19.64^{a}	35.33	25.00	30.17^{b}
5th July	9.00	4.89	6.95	18.21	19.04	18.63^{a}	22.96	19.63	21.29^{c}
20th July	5.56	5.90	5.73	15.06	11.10	13.08^{b}	36.11	24.50	30.31^{b}
5th August	10.00	6.10	8.05	14.94	17.92	16.43^{ab}	39.50	35.90	37.70^{a}
CD	NS		NS	NS		4.64	NS		5.17

Table.4.31(b) Comparison of crop growth rate (CGR) of varieties at fortnightly intervals

Varieties	Crop growth rate (g m^{-2} day $^{-1}$)				
	15 - 30 DAP	30 - 45 DAP	45 - 60 DAP	60 - 75 DAP	75 - 90 DAP
Jyothi	8.99^{a}	16.95	31.27^{a}	21.39	-19.18^{b}
Jaya	5.34^{b}	15.30	25.62^{b}	18.85	-4.54^{a}
CD	2.62	NS	4.5	NS	3.60

DAP – Days after planting   Jy- Jyothi Ja - Jaya

4.7.4. Net assimilation rate (NAR) at fortnightly intervals

The results of ANOVA which was done for net assimilation rate at fortnightly intervals till the harvesting stage of the crop are represented in Appendix II. The effect of date of planting, variety and their interaction with crop growth rate has been shown in Table 4.32(a and b).

The date of planting was found to have a significant influence on the net assimilation rate. During the time interval of 15 to 30 days after planting June 5th and 20th plantings were found to be superior and on par while July 5th, July 20th and August 5th plantings were found to be on par with each other. During the interval of 30 to 45 days after planting June 20th (7.41 gm^{-2} day^{-1}) was found to be superior to other plantings. June 5th, July 5th and August 5th plantings were found to be on par with each other. During the interval of 60 to 75 days net assimilation rate was found to be higher in June 20th planting and July 20th (1.63gm^{-2} day^{-1}) planting and August 5th (1.91 gm^{-2} day^{-1}) planting were found to be inferior and on par. June 5th planting was found to be on par with July 20th and August 5th planting during the interval of 75 to 90 days after plantings. July 20th planting (1.59 gm^{-2} day^{-1}) was found to be inferior to all other dates of plantings.

Among the varieties, a significant difference was observed during 15 to 30 days interval, 60 to 75 days after planting and 75 to 90 days after planting. Net assimilation was found to be higher in Jaya.

Significant interaction of dates of planting and varieties was observed 30 to 45 days after planting and 60 to 75 days after planting. In Jyothi, net assimilation was found to be higher on June 20th planting *i.e.*9.37gm^{-2} day^{-1}. July 5th, 20th and August 5th plantings of Jaya were found to be on par. In Jaya, July 5th planting was found to be on par with June 5th and June 20th plantings. During 60 to 75 days interval in Jyothi, June 20th planting was found to be on par with July 5th and August 5th planting. In Jaya June 5th, June 20th and July 20th planting were found to be on par with each other and 20th July and 5th August was found to be on par.

Table.4.32(a). Effect of date of planting on net assimilation rate (NAR) at fortnightly intervals

Date of planting	Net assimilation rate (NAR) g m^{-2} day^{-1}								
	15 - 30 DAP			30 - 45 DAP			45 - 60 DAP		
	Jy	Ja	Mean	Jy	Ja	Mean	Jy	Ja	Mean
5th June	15.89	4.86	10.38^{a}	6.16^{b}	3.89^{ab}	5.02^{b}	3.05	4.63	4.89
20th June	16.91	6.04	11.47^{a}	9.37^{a}	5.46^{ab}	7.41^{a}	5.23	4.56	4.13
5th July	5.59	4.56	5.08^{b}	2.75^{c}	5.83^{a}	4.29^{bc}	1.99	3.29	3.84
20th July	2.47	5.02	3.74^{b}	3.01^{c}	3.53^{b}	3.27^{c}	3.85	4.41	3.26
5th August	6.01	4.50	5.26^{b}	3.56^{c}	5.41^{ab}	4.49^{bc}	3.94	2.58	2.64
CD	NS		4.15	2.16		1.57	NS		NS

Date of planting	Net assimilation rate (g m^{-2} day^{-1})					
	60 – 75 DAP			75 - 90 DAP		
	Jy	Ja	Mean	Jy	Ja	Mean
5th June	1.23^{b}	3.08^{a}	2.15^{bc}	-0.51	-0.48	-0.49^{a}
20th June	1.95^{a}	3.47^{a}	2.71^{a}	-1.06	-0.81	-0.94^{b}
5th July	1.55^{ab}	3.02^{a}	2.29^{b}	-2.33	-0.84	-1.59^{c}
20th July	1.16^{b}	2.10^{b}	1.63^{d}	-1.22	-0.27	-0.74^{ab}
5th August	1.56^{ab}	2.27^{b}	1.91^{cd}	-1.20	-0.20	-0.70^{ab}
CD	0.63		0.35	NS		0.316

Table.4.32 (b) Comparison of net assimilation rate (NAR) of varieties at fortnightly interval

Varieties	Net assimilation rate (NAR)				
	15 - 30 DAP	30 - 45 DAP	45 - 60 DAP	60 - 75 DAP	75 - 90 DAP
Jaya	9.37^{a}	3.89	4.82	2.79^{a}	-0.52
Jyothi	5.00^{b}	3.61	4.97	1.49^{b}	-1.26
CD	3.84	NS	NS	0.59	0.35

4.8. RESULTS OF DSSAT-CERES SIMULATION

Calibration of DSSAT- CERES rice the model has been done using the experimental data that has been collected from a field experiment conducted in the year 2020. The genetic coefficient that has been generated for previous experiments in the Department of Agricultural Meteorology has been used to simulated crop yield. The genetic coefficient that has been used is shown in Table 4.33

Table 4.33 Genetic coefficients of Jyothi and Jaya used in CERES-Rice model

Variety	P1	P2R	P5	P2O	G1	G2	G3	G4	PHINT
Jaya	557.0	60.3	465.4	10.4	57.0	0.0286	1.10	1.10	81.0
Jyothi	551.0	22.3	444.0	11.4	50.4	0.0256	1.10	1.10	82.0

4.8.1. Comparison of simulated and observed yield

The simulated and observed yield of both varieties during different dates of planting has been shown in Table 4.34. In Jyothi during the first date of planting observed yield was found to be greater than the simulated. While in all other plantings the simulated yield was found to be higher. In Jaya, the model yield was found to be higher during the first three dates of plantings and during the last two dates of plantings observed yield was found to be higher.

Table 4.34. Observed and simulated yield of varieties under different planting days

Variety		D1	D2	D3	D4	D5
Jyothi	Observed	5275	2350	1675	1625	3950
	Simulated	4393	4449	4208	3658	4238
Jaya	Observed	2000	1600	1245	4575	4225
	Simulated	3306	3702	3666	3701	3723

The overall performance DSSAT model has been shown in Table 4.35 The d-stat value of Jyothi has been found to be 0.505.

Table 4.35 Observed and simulated yield from CERES model of two varieties

Variety name	Observed (Mean)	Simulated (Mean)	RMSE	d-Stat
Jaya	2729	3620	1612.524	0.502
Jyothi	2975	4170	1807.474	0.505

The duration of each observed phase is in accordance with the simulated value. Table 4.36 describes the duration of the simulated and observed phenological periods with the corresponding RMSE and d-stat values.

Table 4.36 Observed and simulated phenophase duration of varieties

Variety	**Phenophases**	**Observed** (Mean)	**Simulated**(Mean)	**RMSE**	**d-Stat**
Jaya	Anthesis	71	75	4.539	0.390
	Panicle initiation	38	41	3.286	0.480
	Physiological maturity	110	109	5.329	0.416
Jyothi	Anthesis	66	66	0.775	0.59
	Panicle initiation	34	33	2.049	0.425
	Physiological maturity	100	100	2.236	0.152

4.7. CLIMATE CHANGE STUDIES

To assess the change in the future climate of Kerala, the current climate (1980 – 2020) was evaluated against the simulated weather data obtained from the MarkSim GCM-DSSAT weather file generator using the climate model GFDL CM3. The current climate (1980 – 2020) has been compared with three different future 2010-2030(near-century), 2021-2050(mid-century), and 2051-2080 (late-century) simulations for the 14 districts of Kerala which has been divided into five agro-climatic zones i.e. Northern zone, central zone, high range zone, problematic zone, and southern zone under RCP 4.5

and 8.5. The Annual and seasonal changes in weather parameters (solar radiation, maximum temperature, minimum temperature and rainfall) have been discussed.

4.7.1. Annual

Annual variation of weather parameters (solar radiation, maximum temperature, minimum temperature and rainfall) for the 14 districts of Kerala under RCP 4.5 and 8.5 has been shown in Table 4.37 and 4.38 respectively. Variation of each weather parameter has been discussed below

4.7.1.1. Solar radiation

There was a mean change in the amountof annual solar radiation projected by the GFDL CM3 regional climate model for all the time series near, mid and late centuries under RCPs 4.5 and 8.5.

Under RCP 4.5, in the northern zone of Kerala, an increased amount of solar radiation received was observed in the Malappuram district during all simulations. The maximum deviation of solar deviation was observed in Malappuram by end of century (1.57MJ/m^2) in the northern zone of Kerala. Kasargod and Kozhikode showed a similar trend in the amount of solar radiation *i.e.* it showed a decrease till mid-century later an increase was observed during the end of century. In Kannur, there was an increase in solar radiation in near-century by 0.05MJ/m^2. During mid-century there was a slight decrease in solar radiation (-0.1MJ/m^2). By end of the century there was an increase in solar radiation in all districts of the northern zone.

In the central zone of Kerala, Palakad district showed a reduction in solar radiation by -0.76, -0.92 and -0.45MJ/m^2 in near, mid and end of century respectively. In Thrissur and Ernakulam an increase in solar radiation was expected in all simulations. In the high range zone solar radiation showed a small reduction of 0.02 MJ/m^2 in near-century in Idukki. In the mid and late centuries, solar radiation increased by 0.29 and 0.49 MJ/m^2. In Wayanad, the solar radiation is expected to increase by 1.65, 2.00 and 2.19MJ/m^2 in near, mid and end of century respectively. In the problematic zone, solar radiation showed an increase during all future simulations. Maximum deviation was found to be in Kottayam (1.25MJ/m^2) during the end of century and minimum variation was found in Alappuzha (0.28MJ/m^2) in near-century.

Table 4.37. Annual normal and projected weather data under RCP 4.5

	SRAD (MJ/m^{-2})				TMAX (°C)				TMIN (°C)				RAIN (mm)			
Districts	Normal	NC	MC	LC	Normal	NC	MC	LC	Normal	NC	MC	LC	Normal	NC	MC	LC
	Northern zone															
Kasar	17.0	16.9	17.0	17.7	29.0	32.0	32.4	33.4	19.5	25.1	25.5	26.2	3833.4	4263.5	4338.6	4116.4
Kannur	17.0	17.1	16.9	17.5	28.7	32.1	32.6	33.5	19.3	25.2	25.7	26.3	2963.0	4054.9	4204.6	3920.5
Kkd	17.1	16.7	16.9	17.5	28.3	32.1	32.5	33.5	18.9	25.2	25.5	26.2	2670.6	4100.6	3930.3	3753.9
Mala	17.3	18.6	18.7	18.8	28.5	32.4	32.9	33.8	19.0	24.9	25.4	26.1	2188.4	3390.2	3319.7	3326.1
	Central zone															
Pala	19.7	19.0	18.8	19.3	29.0	32.7	33.2	34.1	19.7	25.1	25.6	26.3	2133.6	3142.1	3379.7	2999.7
Tsr	16.9	19.2	19.1	19.3	29.1	32.6	33.1	34.1	20.0	25.0	25.5	26.2	2349.1	3301.2	3434.4	3422.9
Ekm	16.8	17.8	18.0	18.3	29.8	32.1	31.6	33.5	20.9	25.1	25.6	26.3	2687.2	3718.7	3617.7	3707.7
	High range zone															
Idukki	16.8	16.8	17.1	17.3	30.3	28.0	28.6	29.5	21.5	20.0	20.5	21.2	1891.0	2215.5	2079.1	1983.8
Waya	17.1	18.8	19.1	19.3	28.3	27.8	28.2	29.2	18.9	19.5	20.0	20.7	2071.1	3434.6	2938.7	3030.1
	Problematic zone															
Alp	16.5	16.8	16.8	17.2	30.4	31.7	32.2	33.2	21.9	25.1	25.7	26.4	2928.5	3315.6	3361.1	3314.6
Ktm	16.5	17.3	17.4	17.7	30.4	32.0	32.5	33.4	21.9	25.2	25.7	26.4	2703.3	3327.3	3308.4	3195.1
	Southern zone															
Ptn	16.3	17.3	17.3	17.5	31.0	32.0	32.6	33.5	22.7	25.0	25.6	26.3	1868.4	3052.5	2858.6	2746.9
Kollam	16.3	16.2	16.1	16.4	31.2	31.4	31.9	32.8	22.9	25.1	25.6	26.4	1702.2	2868.5	2860.0	2572.8
Tvm	16.2	15.2	15.3	15.6	31.6	31.1	31.6	32.5	23.5	25.1	25.6	26.4	1505.9	1991.4	1870.4	1836.5

*Normal- 1980-2020 *NC- Near century- 2010-30 *MC- Mid century- 2021-50 * LC- End of century- 2051-80

Table 4.38. Annual normal and projected weather data under RCP 8.5

	SRAD (MJ/m^{-2})				TMAX (°C)				TMIN (°C)				RAIN (mm)			
Districts	Normal	NC	MC	LC	Normal	NC	MC	LC	Normal	NC	MC	LC	Normal	NC	MC	LC
	Northern zone															
Kasar	17.0	17.1	17.2	16.7	29.0	31.8	32.5	34.2	19.5	24.9	25.6	27.3	3833.4	4401.6	4311.4	4047.4
Kannur	17.0	17.2	17.0	16.5	28.7	31.9	32.6	34.4	19.3	25.0	25.8	27.4	2963.0	4069.4	4059.2	3739.7
Kkd	17.1	16.9	16.8	16.3	28.3	31.9	32.6	34.3	18.9	25.0	25.7	27.4	2670.6	4017.1	3708.9	3740.1
Mala	17.3	18.9	18.7	18.1	28.5	32.2	32.9	34.7	19.0	25.1	25.7	27.2	2188.4	3349.6	3251.8	3287.7
	Central zone															
Pala	19.7	18.9	18.8	18.6	29.0	32.5	33.2	35.0	19.7	24.8	25.6	27.2	2133.6	3315.4	3288.2	3106.0
Tsr	16.9	19.1	19.0	18.7	29.1	32.4	33.1	34.9	20.0	25.0	25.7	27.4	2349.1	3444.3	3461.0	3303.6
Ekm	16.8	17.9	17.8	17.5	29.8	32.0	32.6	34.3	20.9	25.0	25.7	27.3	2687.2	3823.6	3690.0	3651.5
	High range zone															
Idukki	16.8	16.9	16.9	16.7	30.3	27.9	28.6	30.3	21.5	19.9	20.7	22.3	1891.0	2074.6	2087.3	2053.4
Waya	17.1	19.2	19.2	18.5	28.3	27.5	28.2	30.1	18.9	19.4	20.2	21.9	2071.1	2728.0	2821.9	3028.7
	Problematic zone															
Alp	16.5	17.0	16.8	16.6	30.4	31.6	32.3	34.0	21.9	25.1	25.8	27.3	2928.5	3288.8	3329.5	3348.7
Ktm	16.5	17.5	17.4	17.0	30.4	31.9	32.6	34.2	21.9	25.1	25.8	27.4	2703.3	3390.4	3270.5	3428.5
	Southern zone															
Ptn	16.3	17.1	17.2	17.1	31.0	32.0	32.6	34.3	22.7	25.0	25.7	27.2	1868.4	3001.5	2799.7	2855.2
Kollam	16.3	16.0	16.1	15.9	31.2	31.3	31.9	33.5	22.9	25.1	25.7	27.3	1702.2	2964.9	2699.6	2707.2
Tvm	16.2	15.4	15.4	15.2	31.6	31.0	31.7	32.7	23.5	25.1	25.7	27.2	1505.9	1678.1	1701.4	1835.2

*Normal- 1980-2020 *NC- Near century- 2010-30 *MC- Mid century- 2021-50 * LC- End of century- 2051-80

In the southern zone solar radiation was expected to increase in Pathanamthitta by 1, 1.04 and 1.23 MJ/m^2 in near, mid and end of century respectively. In Kollam, the solar radiation decreased by 0.15 and 0.25MJ/m^2 in the near and mid-century by end of century the solar radiation is expected to increase in Kollam by 0.12 MJ/m^2 at end of century. In Thiruvananthapuram, there was a decrease in the amount solar radiation by 1.05, 0.97 and 0.65 MJ/m^2 during near, mid and end of century. Under RCP 8.5 in northern zone of Kerala, a reduction in solar radiation was observed in Kozhikode during all future simulations. In the Malappuram district, an increase in solar radiation was observed during all future simulations. In Kasargod, an increase in solar radiation was observed during the near and mid-century while by end of century the solar radiation was reduced by 0.37 MJ/m^2. In Kannur, the solar radiation showed an increase of 0.15MJ/m^2 in the near century then a reduction in solar radiation was observed. Maximum deviation was observed in the Malappuram district (1.62 MJ/m^2 in near-century). The highest negative deviation was observed in Kozhikode (-0.8 MJ/m^2). In central zone of Kerala trend was similar as in RCP 4.5 scenario. In Palakkad there was reduction solar radiation while in Thrissur and Ernakulam there was an increase in solar radiation. Maximum positive and negative deviation was found in Thrissur (2.14MJ/m^2 during near century) and Palakkad (-1.15MJ/m^2 during end of century) respectively. In the high range zone the solar radiation was expected to increase in different future simulations except in end of century in Idukki where the solar radiation was expected to decrease by 0.06MJ/m^2. Maximum deviation was found to be in Wayanad in the near century by 2.12 MJ/m^2. In problematic zone, an increase in annual solar radiation was observed. Maximum deviation was found to be in Kottayam by 1.03MJ/m^2 during the near century and the least deviation was found to be in 0.16MJ/m^2. In the southern zone Pathanamthitta showed an increase in solar radiation (by 0.79, 0.85 and 0.81MJ/m^2 during near, mid and end of century respectively). While in Kollam and Thiruvananthapuram there was a reduction in solar radiation in all future simulations. The maximum negative deviation was found to be during the end of century (-1.03MJ/m^2) in Thiruvananthapuram.

4.7.1.2. Maximum temperature

There was a mean change in the annual temperature projected by GFDL CM3 regional climate model for all the time series near, mid and late centuries under RCPs 4.5 and 8.5.

Under RCP 4.5 in the northern zone of Kerala, an increase in annual temperature was expected in all districts. A maximum increase in temperature was found in Malappuram district during the end of century by 5.32℃. Minimum increase in temperature was found to be during near century (3℃) in Kasargod. The temperature increase was high in the Malappuram district in the northern zone of Kerala. In the central zone of Kerala, annual maximum temperature was found to be increased and the maximum and minimum increase in temperature was found to be during the late (5.11℃) and near (2.35℃) century in Palakkad and Ernakulam respectively. The temperature increase was high in Palakkad . In the high range zone, a decrease in solar radiation was observed. In Wayanad, the temperature decreased by 0.57℃ and 0.1℃ in near and mid century while at end of century there was a small increase in maximum temperature by 0.91℃. In Idukki the maximum temperature decreased by 2.29℃, 1.74℃ and 0.81℃ during near, mid and end of century. The maximum temperature was expected to increase in the problematic zone. Compared to Alappuzha warming was found to be higher in Kottayam. The temperature increase was found to be higher in Kottayam (3.02℃) at end of century. In the southern zone of Kerala temperature was expected to increase in Pathanamthitta and Kollam. In Thiruvananthapuram, a decrease in maximum temperature was found during near and mid century by 0.53℃and 0.01℃ respectively and by end of century the temperature was found to be increased by 0.84℃.

Under RCP 8.5 variation of temperature was similar to the variation observed under RCP 4.5. Temperature increase in near-century was found to be greater under RCP 4.5 while in mid and end of century temperature increase was found to be higher under RCP 8.5. In the northern zone an increasing trend in maximum temperature was observed. Malappuram district showed a higher increase in maximum temperature. Maximum deviation was found from normal in Malappuram (3.68℃, 4.37℃ and 6.16℃

during near-century, mid century and end of century respectively) and minimum deviation was found in Kasargod (2.76°C, 3.47°C and 5.23°C during near-century, mid century and end of century respectively). An increasing trend in maximum temperature was observed in the central zone of Kerala. Maximum deviation from normal was found in Palakkad district (3.46°C, 4.15°C and 5.92°C during near-century, mid-century and end of century respectively) and the least deviation was observed in Ernakulam (2.2°C, 2.86°C and 4.57°C during near-century, mid century and end of century respectively). In the high range zone decrease in maximum temperature was observed. In Idukki, temperature decreased by 2.43°C, 1.76°C and 0.05°C during near-century, mid century and end of century respectively. While in Wayanad temperature decreased in near and mid-century by 0.82°C and 0.11°C respectively and then in end of century an increase in temperature by 1.73°C was found. In the problematic zone, an increasing trend in maximum temperature was found. Compared to Alappuzha temperature increase was found to be high in Kottayam. In Kottayam, by end of the century maximum temperature was found to be higher by 3.79°C. In southern zone of Kerala, an increase in temperature was observed except during near-century in Thiruvananthpuram where the temperature decreased by 0.59°C and then increased in the mid and end of century. In Kollam and Pathanamthitta the temperature increased by 2.31°C and 3.3°C in end of century respectively.

4.7.1.3. Minimum temperature

From the analysis, a mean change in minimum temperature was observed. The annual minimum is expected to increase in most parts of Kerala.

Under RCP 4.5, in the northern zone of Kerala, the minimum temperature was expected to increase in all districts. The maximum increase in minimum temperature was expected in Kozhikode (6.27°C, 6.66°C and 7.36°C during near-century, mid-century and end of century respectively) and a minimum increase was expected in Kasargod (5.64°C, 6.02°C and 6.67°C during near-century , mid-century and end of century respectively). An increasing trend in minimum temperature was observed in the central zone of Kerala. Increase in minimum temperature was found to be higher in Palakkad (5.33°C, 5.82°C and 6.51°C during near-century, mid-century and end of century respectively) and least in Ernakulam (4.2°C, 4.7°C and 5.42°C during near-century, mid-century and end of century respectively). In high ranges, a reduction in minimum temperature was observed in near, mid and end of century by 1.49°C, 0.98°C and 0.26°C respectively. In Wayanad minimum temperature increased by 0.65°C, 1.14°C and 1.86°C in the near, mid and end of century respectively. An increasing trend was observed in the minimum temperature of the problematic zone of Kerala. The minimum temperature expected to increase by end of the century was 4.47°C and 4.51°C in Alappuzha and Kottayam respectively. In the southern zone of Kerala, an increasing trend in minimum temperature was observed. Pathanamthitta showed a greater deviation followed by Kollam and Thiruvananthapuram respectively. By end of the century minimum temperature is expected to increase by 3.63°C, 3.41°C and 2.9°C in Pathanamthitta, Kollam and Thiruvananthapuram respectively.

Under RCP 8.5, in the northern zone of Kerala an increase in annual minimum temperature was expected to increase in all districts. A maximum increase in minimum temperature was found in Kozhikode district during the end of century by 8.48°C. Minimum increase in temperature was found to be during near-century (5.46°C) in Kasargod. In the central zone of Kerala, minimum temperature was found to be increased maximum in Palakkad and the minimum increase was observed in Ernakulam. In the high range zone, a decrease in minimum temperature was observed. In Wayanad, the temperature increased by 0.56°C, 1.3°Cand 3.02°C in near, mid-century and end of century respectively. An increasing trend in minimum temperature was observed during al simulations in problematic zones. In the southern zone of Kerala minimum temperature was expected to increase during all future simulations. The maximum deviation in minimum temperature was observed in Pathanamthitta and the minimum deviation was found in Thiruvananthapuarm. By end of century the temperature is expected to increase by 4.57°C, 4.31°C and 3.76°C in Pathanamthitta, Kollam and Thiruvananthapuram respectively.

4.7.1.4. Rainfall

Rainfall data obtained from the GFDL CM3 model was compared with the current climate. A mean change in annual rainfall was observed. Annual rainfall was expected to increase from normal in all districts of Kerala. Rainfall has been according to IMD classification based on deviation *i.e.*large excess (60%or more), excess (20%to50%), normal (-19% to 19%), deficient (-20%to -50%), large deficient (-60% to -90%).

Under RCP 4.5, in the northern zone of Kerala normal rainfall was expected in Kasargod while in all other districts an excess amount of rainfall is predicted. The maximum deviation of rainfall from normal was observed in near-century in Malappuram (55%) and Kozhikode (54%). The least deviation of 7% was found during end of century in Kasargod. In central zone an excess rainfall is expected in future. Maximum deviation was found in Palakkad (58%) in mid-century and minimum deviation was expected during mid-century in Ernakulam. In high range zone, a large excess rainfall was observed during near-century. While in Idukki a normal rainfall is expected. Minimum deviation in rainfall was found in Idukki (5%) in the end of century. In the problematic zone, an excess rainfall was expected in Kottayam during the near and mid centuries. In the end of the century normal rainfall has been predicted in Kottayam. In Alappuzha, a normal rainfall was predicted in all the future simulations. In the southern zone excess and large excess rainfall has been predicted. In Kollam, a large excess rainfall has been predicted during the near and mid century while in end of century an excess rainfall has been predicted. In Pathanamthitta district large excess rainfall has been predicted during near-century while in mid and end of century normal rainfall has been expected. An excess amount of rainfall has been predicted in Thiruvanthapuram.

Under RCP 8.5, a similar trend of RCP 4.5 was observed. In the northern zone of Kerala, normal rainfall has been expected in Kasargod while in all other districts an excess amount of rainfall is predicted. Maximum deviation was expected in Malapuram (53%) in the near century and the least deviation was found in Kasargod (6%) in the far century. In the central zone of Kerala, an excess rainfall has been predicted under all simulations. Maximum deviation was found in Palakkad (55%) in the near century and the minimum deviation was observed in Ernakulam (36%) in the end of century. In the high range zone, normal rainfall was expected in Idukki and excess rainfall in Wayanad. Maximum deviation was expected in Wayanad during the end of century (46%) and minimum in Idukki (9%) by the end of century. In the problematic zone, a normal rainfall was expected in Alappuzha and excess rainfall in Kottayam. The maximum deviation was 27% during the end of century in Kottayam. In the southern zone excess and large excess rainfall has been predicted. In Kollam, a large excess rainfall has been predicted during near-century while in mid and end of century an excess rainfall has been predicted. In Pathanamthitta district large excess rainfall has been predicted during near-century while in the mid and end of the century normal rainfall has been expected. An excess amount of rainfall has been predicted in Thiruvanthapuram in the near and mid-century and by end of the century excess rainfall has been predicted.

4.7.2. Seasonal analysis

Seasonal analysis of climate change has been also done for the various seasons classified according to IMD:

South-West Monsoon	(June – September)
North-East Monsoon	(October – December)
Winter	(January – February)
Summer or Pre-monsoon	(March – May)

Variation of weather parameters in each season has been explained below.

4.7.2.1. South West Monsoon (June – September)

Variation of weather parameters (Solar radiation, maximum temperature, minimum temperature, and rainfall) in southwest monsoon season for the 14 districts of Kerala under RCP 4.5 and 8.5 has been shown in Table 4.39 and 4.40 respectively. Variation of each weather parameter has been discussed below

4.7.2.1.1. Solar radiation

Solar radiation showed greater variability in Kerala. Under RCP 4.5, in the northern zone of Kerala, an increase in solar radiation was observed in Kozhikode, Malappuram during all future simulations. In the near and mid-century of Kasargod also an increase in solar radiation was observed. By the end of century of Kasargod and all the future simulations of Kannur a reduction in solar radiation was observed. The increase of solar radiation was found to the higher in Malappuram (2.29MJ/m^2) in the near century and the decrease of solar radiation was found to be greater in the mid-century of Kannur district (-1.07MJ/m^2). In the central zone of Kerala, an increase of solar radiation was observed in Palakkad by 3.09, 2.32 and 1.68 MJ/m^2 during the near, mid and end of century respectively. In Thrissur, solar radiation decreased from normal in near and mid-century and then increased at end of century. In all future simulations a decrease in solar radiation by 1.58, 1.29 and 0.55MJ/m^2 in near, mid and end of century respectively was observed. In the high range zone, a reduction in solar radiation in the near and mid-century was observed and then increased in end of century by 0.01MJ/m^2 in Idukki while in Wayanad an increase in solar radiation was observed. In the problematic zone, an increased amount of solar radiation was found, the maximum increase was found in Kottayam in the end of century (3.07MJ/m^2) and least deviation was observed in Alappuzha in mid-century (2.17MJ/m^2). In the southern zone of Kerala, an increase in solar radiation was observed in Pathanamthitta and Kollam While in Thiruvanthapuarm a decrease in solar radiation was observed. In mid century there was greater reduction in the amount of solar radiation when compared with near and mid century.

Under RCP 8.5, in northern zone of Kerala the solar radiation showed an increase in Malappuaram district and in the near-century of Kasargod district. In the mid and end of century of Kasargod and all simulations of Kannur and Kozhikode the solar radiation was observed to decrease. In the central zone, the solar radiation decreased in Ernakulam and increased in Palakkad in all the future simulations. In Thrissur, solar radiation decreased in the near century by 0.34MJ/m^2 and then increased in the mid and end of the century. In the high range zone, solar radiation decreased in the near and mid-century and increased in end of century by 0.17 MJ/m^2 in Idukki. While in Wayanad the solar radiation increased in near-century by 0.59MJ/m^2 and then decreased in the mid and end of the century. In the problematic zone, an increase in solar radiation was observed in Kottayam and Alappuzha. Kottayam showed an increase in solar radiation compared to

Alappuzha. In the southern zone of Kerala, an increase in solar radiation was observed in Pathanamthitta and a decrease in solar radiation was observed in Thiruvananthpuram. In Kollam in near there was an increase in solar radiation and then decreased in mid-century.

4.7.2.1.2. Maximum temperature

An increasing trend of maximum temperature was observed in most parts of Kerala under both RCPs during the southwest monsoon season. Under RCP 4.5, in the northern zone of Kerala, an increasing trend of maximum temperature was observed. Temperature rise was found to be higher in Kannur (4.02°C, 4.46°C and 5.29°C during near-century, mid-century and end of century respectively). In the central zone an increasing trend has been observed of maximum temperature was found. The temperature increase was found to be higher in end of century followed by the mid and near centuries. In the high range zone, a decrease in maximum temperature was observed in Idukki in the near and mid-century and the near-century of Wayanad district. In the end of century the maximum temperature showed an increase by 0.17°C and 1.28°C in Idukki and Wayanad districts respectively. In the problematic zone, an increase in maximum temperature was found. By end of the century the temperature increased by 2.5°C and 2.8°C in Alappuzha and Kottayam respectively. In the southern zone the temperature showed a decrease during near-century in Kollam and Thiruvananthpuram. In the mid and end of century an increase in maximum temperature was found.

A similar trend was observed under RCP 8.5. An increasing trend in maximum temperature has been found in most parts of Kerala during the southwest monsoon season. In the high range zone, a reduction in maximum temperature was observed in near future and it continued to decrease in Idukki by 0.66°C in the mid-century. By end of the century there was an increase in maximum temperature in all parts of Kerala. A small reduction in maximum temperature was found in Kollam (by 0.03°C) in the near-century. A maximum increase in minimum temperature was found in Kozhikode (by 3.68°C, 4.52°C and 6.55°C in near, mid and end of century respectively) in all future simulations.

Table 4.39. Normal and projected weather data under RCP 4.5 during southwest monsoon

	SRAD (MJ/m^2)				TMAX (°C)				TMIN (°C)				RAIN (mm)			
Districts	Normal	NC	MC	LC	Normal	NC	MC	LC	Normal	NC	MC	LC	Normal	NC	MC	LC
	Northern zone															
Kasar	17.9	18.4	18.1	17.8	26.5	30.5	30.8	31.7	20.1	25.3	25.7	26.3	3212.6	3414.7	3618.0	3451.5
Kannur	15.4	14.7	14.3	14.9	26.6	30.6	31.0	31.9	19.9	25.4	25.8	26.4	2348.1	3251.7	3494.3	3229.9
Kkd	17.6	18.4	17.7	17.9	26.7	30.6	31.0	31.9	19.6	25.2	25.6	26.3	2021.8	3198.6	3161.6	3047.3
Mala	17.6	19.9	19.5	18.6	27.1	30.5	31.0	32.0	19.6	24.9	25.4	26.1	1507.1	2633.0	2669.1	2620.7
	Central zone															
Pala	17.3	20.4	19.6	19.0	27.7	30.6	31.1	32.1	20.2	25.0	25.5	26.2	1433.1	2433.0	2606.4	2199.7
Tsr	16.1	15.9	16.0	16.8	28.9	31.6	31.8	32.9	22.2	25.1	25.6	26.3	1587.2	2303.2	2299.4	2411.7
Ekm	16.0	14.5	14.7	15.5	28.6	30.6	30.5	32.0	21.2	25.2	25.7	26.4	1818.8	2606.9	2501.3	2419.9
	High range zone															
Idukki	16.7	15.4	16.0	16.7	29.6	27.9	28.7	29.7	22.0	21.1	21.8	22.5	1053.3	1652.7	1502.6	1409.7
Waya	17.5	18.4	18.3	17.9	26.6	26.3	26.9	27.9	19.5	20.3	20.8	21.5	1486.6	2883.8	2470.7	2363.9
	Problematic zone															
Alp	16.6	19.0	18.8	19.0	29.4	30.4	31.0	31.9	22.2	25.1	25.6	26.3	1831.6	2278.3	2321.3	2133.6
Ktm	16.6	19.4	19.3	19.7	29.4	30.8	31.3	32.2	22.2	25.3	25.8	26.5	1698.9	2297.1	2326.6	2234.6
	Southern zone															
Ptn	16.3	17.9	17.0	17.1	30.4	31.4	32.1	33.0	23.0	25.4	25.9	26.7	980.5	2152.1	2027.5	2012.0
Kollam	16.3	17.8	16.9	16.8	30.7	30.7	31.2	32.1	23.3	25.3	25.8	26.5	818.5	1957.2	1934.4	1846.9
Tvm	16.3	15.5	15.1	15.7	31.2	31.2	31.9	32.8	23.8	25.6	26.3	27.0	650.0	1266.1	1083.9	1043.0

*Normal- 1980-2020 *NC- Near century- 2010-30 *MC- Mid century- 2021-50 * LC- End of century- 2051-80

Table 4.40. Normal and projected weather data under RCP 8.5 during southwest monsoon

	SRAD (MJ/m^2)				TMAX (°C)				TMIN (°C)				RAIN (mm)			
Districts	Normal	NC	MC	LC	Normal	NC	MC	LC	Normal	NC	MC	LC	Normal	NC	MC	LC
	Northern zone															
Kasar	17.9	18.1	17.2	15.1	26.5	30.3	31.0	33.0	20.1	25.1	25.8	27.3	3212.6	3535.1	3470.2	3359.6
Kannur	15.4	14.7	14.7	14.8	26.6	30.4	31.2	33.1	19.9	25.3	25.9	27.4	2348.1	3321.7	3387.3	3141.0
Kkd	17.6	17.6	16.6	16.2	26.7	30.3	31.2	33.2	19.6	25.1	25.7	27.3	2021.8	3281.9	3019.7	2968.7
Mala	17.6	19.5	19.0	18.3	27.1	30.4	31.2	33.3	19.6	24.9	25.5	27.1	1507.1	2651.5	2625.7	2538.5
	Central zone															
Pala	17.3	20.0	18.9	18.3	27.7	30.4	31.3	32.2	20.2	25.0	25.6	27.2	1433.1	2626.1	2544.2	2290.6
Tsr	16.1	15.7	16.2	16.4	28.9	30.8	31.4	33.1	22.2	25.1	25.8	27.3	1587.2	2721.5	2794.4	3007.0
Ekm	16.0	14.4	14.9	15.4	28.6	30.5	31.3	33.2	21.2	25.2	25.8	27.4	1818.8	2705.7	2564.7	2392.5
	High range zone															
Idukki	16.7	15.1	15.6	16.9	29.6	28.0	28.9	31.1	22.0	21.2	21.9	23.7	1053.3	1496.4	1471.1	1396.2
Waya	17.5	18.1	17.1	16.5	26.6	26.2	27.1	29.2	19.5	20.3	20.9	22.6	1486.6	2301.8	2370.4	2473.0
	Problematic zone															
Alp	16.6	18.5	18.4	17.2	29.4	30.5	31.2	33.1	22.2	25.1	25.8	27.3	1831.6	2234.0	2206.7	2223.8
Ktm	16.6	19.0	18.9	17.5	29.4	30.8	31.5	33.4	22.2	25.3	25.9	27.5	1698.9	2364.8	2318.9	2391.1
	Southern zone															
Ptn	16.3	16.4	16.4	17.0	30.4	31.4	32.2	34.4	23.0	25.4	26.1	27.8	980.5	2229.3	2070.4	1900.7
Kollam	16.3	16.5	16.3	16.3	30.7	30.7	31.4	33.5	23.3	25.3	25.9	27.6	818.5	2010.7	1892.1	1766.4
Tvm	16.3	15.5	15.0	13.9	31.2	31.3	32.1	33.1	23.8	25.7	26.4	28.0	650.0	1033.7	950.3	1110.7

*Normal- 1980-2020 *NC- Near century- 2010-30 *MC- Mid century- 2021-50 * LC- End of century- 2051-80

4.7.2.1.3. Minimum temperature

An increasing trend was observed in minimum temperature in most parts Kerala during the southwest monsoon season. Under RCP 4.5 in the northern zone, the minimum temperature was expected to increase by 6.65℃ in Kozhikode by end of century. The increase was greater than 5℃ during all future simulations in the northern zone of Kerala. In the central zone of Kerala, minimum temperature was expected to increase from normal in all districts. In the high range zone, the minimum temperature is expected to decrease in Idukki in the near and mid-century by 0.82℃ and 0.19℃ respectively. In end of century and all future simulations of Wayanad an increase in minimum temperature was expected. In the problematic zone, the minimum temperature showed an increase of near about 3℃, 3.5℃ and 4℃ in the near, mid and end of century. In the southern zone of Kerala, an increase in minimum temperature was found to be greater in Pathanamthitta and the least deviation was found in Thiruvananthapuram.

Under RCP 8.5 the trend was similar to as observe in 4.5. The maximum increase in minimum temperature was found in end of century in all districts. Maximum deviation was observed in Kozhikode districts with an increase in minimum temperature by 5.42℃, 6.06℃ and 7.62℃ in near, mid and end of century. In the high range zone the minimum temperature decreased in Idukki in the near and mid-century by 0.75℃ and 0.19℃ respectively increased in end of century by 1.75℃.

4.7.2.1.4. Rainfall

During southwest monsoon, a large excess and excess rainfall was expected in Kerala except in Kasargode where a normal rainfall was expected with the least deviation of 6%, 13% and 7% in near, mid and end of century respectively and the highest deviation was found in Kollam *i.e.* 139%, 136% and 126% in near, mid, and end of century respectively under RCP 4.5 scenarios.The increase southwest monsoon was high in mid century when compared to near and end of century.

A similar condition was observed under the RCP 8.5 scenario where the least deviation was found in Kasargod as 10%, 8%, and 5% in near, mid, and end of century respectively. scenarios and the highest deviation was observed in Kollam as 146%, 131% and 116% in near, mid and end of century respectively.

4.7.2.2. North East Monsoon (October – December)

Variation of weather parameters (Solar radiation, maximum temperature, minimum temperature and rainfall) in northeast monsoon season for the 14 districts of Kerala under RCP 4.5 and 8.5 has been shown in Table 4.41 and 4.42 respectively. Variation of each weather parameters has been discussed below

4.7.2.2.1. Solar radiation

During the north-east monsoon under RCP 4.5 the amount of solar radiation was expected to increase in most of the districts. In the northern zone, Kasargod and Kozhikode districts showed a small increase in solar radiation from normal during near-century while by mid and end of century the amount of solar radiation was expected to be reduced. In Kannur and Malappuram the solar radiation was found to be increased from normal. The amount of solar radiation received was less in end of century when compared with the mid and near century. In central zone and problematic the zone the solar radiation was expected to increase. In high range zone the amount of solar radiation decreased by 0.66, 1.11 and 0.72MJ/m^2 in near, mid and end of century respectively. While in Wayanad the solar radiation was expected to increase from normal. In southern zone the solar radiation was expected increase in Pathanamthitta and Kollam, while in Thiruvanthapuramit was predicted to decrease from normal. The maximum increase in solar radiation was found to be in Thrissur by 3.84, 3.48 and 3.16 MJ/m^2 in near, mid and end of centuryrespectively.

Under RCP 8.5 the amount of solar radiation was expected to increase from normal in most of the districts. Although in districts like Kasargod, Kozhikode, Idukki, Thiruvanthapuram it was predicted to decrease from normal. In Wayanad, there was a small increase during near-century while in the mid and late-century the amount of solar radiation was found to be reduced during the northeast monsoon season. Maximum deviation in solar radiation was found to be in Thrissurby 3.4, 3.3 and 2.7 MJ/m^2 in near, mid and end of century respectively.

Table 4.41. Normal and projected weather data under RCP 4.5 during northeast monsoon

	SRAD (MJ/m^2)				TMAX (°C)				TMIN (°C)				RAIN (mm)			
Districts	Normal	NC	MC	LC	Normal	NC	MC	LC	Normal	NC	MC	LC	Normal	NC	MC	LC
	Northern zone															
Kasar	18.1	18.2	17.9	17.5	28.6	32.4	32.8	33.7	18.6	24.4	24.8	25.6	331.2	320.5	268.2	254.6
Kannur	15.7	16.8	16.9	17.7	28.2	32.4	32.8	33.6	18.5	24.5	25.0	25.7	314.8	307.1	288.3	304.0
Kkd	17.8	18.2	17.4	17.5	27.4	32.5	32.8	33.7	18.1	24.5	24.8	25.6	345.8	304.9	293.4	341.4
Mala	17.8	19.9	19.5	18.5	27.4	32.4	32.8	33.6	18.3	24.2	24.7	25.4	387.7	320.9	301.0	321.8
	Central zone															
Pala	17.5	20.5	19.6	19.0	27.9	32.7	33.0	33.8	19.0	24.4	24.9	25.6	403.9	331.8	412.2	425.4
Tsr	15.3	19.1	18.8	18.4	29.1	31.9	32.3	33.3	21.3	24.6	25.1	25.8	419.3	535.3	473.6	433.7
Ekm	15.2	18.0	17.9	18.0	28.8	32.3	31.6	33.6	20.3	24.6	25.1	25.8	465.0	440.3	525.0	618.4
	High range zone															
Idukki	17.0	16.3	15.9	16.2	29.2	26.9	27.1	27.8	20.8	19.1	19.5	20.2	456.4	292.3	342.9	341.2
Waya	17.8	18.6	18.7	18.0	27.4	27.1	27.3	28.2	18.1	18.6	19.1	19.9	319.5	179.4	126.4	273.5
	Problematic zone															
Alp	16.9	18.7	18.4	18.6	29.5	31.7	32.1	33.0	21.3	24.6	25.1	25.8	556.2	430.7	507.4	607.2
Ktm	16.8	19.2	19.2	19.6	29.5	31.9	32.3	33.2	21.3	24.6	25.1	25.8	525.0	406.4	420.0	463.1
	Southern zone															
Ptn	16.5	18.4	17.8	18.0	30.0	31.4	31.8	32.6	22.0	24.4	24.8	25.5	492.4	410.7	395.4	392.8
Kollam	16.5	17.7	17.5	17.6	30.2	30.9	31.3	32.1	22.3	24.5	25.0	25.7	495.8	418.3	494.2	385.4
Tvm	16.5	15.0	15.4	16.1	30.6	30.0	30.4	31.2	22.8	24.3	24.8	25.5	502.9	402.7	516.0	569.3

*Normal- 1980-2020 *NC- Near century- 2010-30 *MC- Mid century- 2021-50 * LC- End of century- 2051-80

Table 4.42. Normal and projected weather data under RCP 8.5 during northeast monsoon

	SRAD (MJ/m^2)				TMAX (°C)				TMIN (°C)				RAIN (mm)			
Districts	Normal	NC	MC	LC	Normal	NC	MC	LC	Normal	NC	MC	LC	Normal	NC	MC	LC
	Northern zone															
Kasar	18.1	17.8	16.9	17.4	28.6	32.1	32.8	34.5	18.6	24.3	25.0	26.5	331.2	354.6	261.9	289.3
Kannur	15.7	16.6	17.2	17.6	28.2	32.1	32.8	34.6	18.5	24.4	25.1	26.6	314.8	314.8	283.2	255.0
Kkd	17.8	17.2	16.1	15.6	27.4	32.2	32.9	34.5	18.1	24.4	25.1	26.6	345.8	355.1	300.8	384.5
Mala	17.8	19.4	18.9	18.4	27.4	32.2	32.9	34.4	18.3	24.2	24.9	26.4	387.7	344.7	312.7	358.3
	Central zone															
Pala	17.5	20.0	18.8	18.2	27.9	32.5	33.1	33.5	19.0	24.4	25.1	26.6	403.9	351.9	419.2	456.9
Tsr	15.3	18.7	18.6	18.2	29.1	31.2	31.8	33.4	21.3	24.6	25.2	26.7	419.3	340.4	274.5	333.4
Ekm	15.2	18.3	18.1	17.9	28.8	32.2	32.8	34.3	20.3	24.6	25.3	26.7	465.0	512.1	567.1	631.1
	High range zone															
Idukki	17.0	15.2	15.1	15.8	29.2	26.6	27.1	28.3	20.8	19.0	19.6	20.9	456.4	317.8	376.9	432.5
Waya	17.8	18.4	17.3	16.8	27.4	26.7	27.3	29.1	18.1	18.6	19.3	20.9	319.5	87.6	126.6	296.1
	Problematic zone															
Alp	16.9	18.4	18.2	17.9	29.5	31.6	32.3	33.8	21.3	24.6	25.2	26.7	556.2	463.8	582.9	686.6
Ktm	16.8	18.9	18.8	18.3	29.5	31.8	32.5	34.0	21.3	24.6	25.2	26.7	525.0	436.7	406.5	544.4
	Southern zone															
Ptn	16.5	17.3	17.2	16.1	30.0	31.4	31.9	33.1	22.0	24.4	25.0	26.3	492.4	404.0	384.5	601.5
Kollam	16.5	16.3	16.9	15.7	30.2	30.9	31.5	32.7	22.3	24.5	25.1	26.4	495.8	481.3	449.6	595.1
Tvm	16.5	15.1	15.4	14.2	30.6	29.8	30.5	31.6	22.8	24.2	24.9	26.5	502.9	434.4	526.7	512.1

*Normal- 1980-2020 *NC- Near century- 2010-30 *MC- Mid century- 2021-50 * LC- End of century- 2051-80

4.7.2.2.2. Maximum temperature

During the north east monsoon season an increasing trend of maximum temperature was observed in most parts of Kerala under both RCPs. Under RCP 4.5, in northern zone of Kerala an increasing trend of maximum temperature was observed. Temperature rise was found to be higher in Kozhikode (5.07℃, 5.37℃ and 6.26℃ during near-century, mid century and end of century respectively). In central zone an increasing trend has been observed of maximum temperature was found. The temperature increase was found to be higher in end of century followed by mid and near century. In high range zone a decrease in maximum temperature was observed in Idukki during all future simulations and in near and mid century of Wayanad district. In the end of century the maximum temperature showed an increase by 0.79℃ in Wayanad. In problematic zone an increase in maximum temperature was found. By end of century the temperature increased by 3.47℃ and 3.68℃ in Alappuzha and Kottayam respectively. In southern zone the maximum temperature showed a decrease in Thiruvananthpuram during near and mid century by 0.64℃ and 0.22℃ respectively. In Kollam and Pathanamthitta districts an increasing trend in temperature was observed.

Under RCP 8.5a similar trend was observed. An increasing trend in maximum temperature has been found most parts of Kerala during the northeast monsoon season. In high range a reduction in maximum temperature was observed in near, mid and future century in Idukki and in Wayanad reduction was expected during near and mid century by 0.71℃ and 0.05℃ respectively. By end of century there was an increase in maximum temperature in all parts of Kerala except Idukki. A small reduction in maximum temperature was found in Thiruvananthapuram (by 0.79℃) in near century and mid century (0.19℃). Maximum increase in minimum temperature was found in Kozhikode (4.78℃, 5.49℃ and 7.05℃ in near, mid and end of century respectively) in all future simulations.

4.7.2.2.3. Minimum temperature

An increasing trend was observed in minimum temperature in most parts Kerala under northeast monsoon season. Under RCP 4.5 in northern zone the minimum temperature was expected to increase by 8.47℃ in Kozhikode by end of century. The increase was greater than 5.5℃ during all future simulation in northern zone of Kerala. In central zone of Kerala minimum temperature was expected to increase from normal in all districts. In high range zone the minimum temperature is expected to decrease in Idukki in all future simulation and in Wayanad minimum temperature was expected to increase. In problematic zone the minimum temperature showed an increase of near about 3.3℃, 3.9℃ and 5.3℃ in near, mid and end of century. In southern zone of Kerala an increase in minimum temperature was found to be greater in Pathanamthitta and the least deviation was found in Thiruvananthapuram.

Under RCP 8.5 the trend was similar to as observe in 4.5. The maximum increase in minimum temperature was found in end of century in all districts. Maximum deviation was observed in Kozhikode districts with an increase in minimum temperature by 6.29℃, 6.97℃ and 8.47℃ in near, mid and end of century respectively. In high range zone the minimum temperature decreased in Idukki in near and mid century by 1.82℃ and 1.22℃ respectively, in end of century and in all future simulation of Wayanad increase in minimum temperature was expected to increase. In problematic and southern zone the minimum temperature was expected to increase from normal in all future simulations

4.7.2.2.4. Rainfall

Northeast monsoonwas predicted to decrease from normal in almost all parts of Kerala. Under RCP 4.5 in northern zone of Kerala northeast monsoon decreased In central zone of Kerala a reduction in northeast monsoon has been predicted during near century in Palakkad and Ernakulam while in mid and end of century the northeast monsoon was found to be increased. In Thrissur northeast monsoon was predicted to increase. In high range zone a deficient northeast monsoon has been predicted. In problematic zone a reduction in north east monsoon has been predicted except in end of century in Alappuzha where the rainfall was expected to increase by 9%. In southern zone of Kerala the northeast monsoon has been predicted to decrease in Pathanamthitta and Kollam. In Thiruvananthpuram the rainfall decreased during near century and then increased in mid and late cemtury.

Under RCP 8.5, in northern zone of Kerala northeast monsoon decreased, in mid and end of century but in near century an increase in northeast monsoon has been predicted for the district like Kasargod, Kannur and Kozhikode. In Malappuram a decrease in north east monsoon has been observed. In central zone of Kerala a reduction in northeast monsoon has been predicted during near century in Palakkad and Thrissur while in mid and end of century the northeast monsoon was found to be increased. In Thrissur northeast monsoon was predicted to increase. In high range zone a deficient northeast monsoon has been predicted. In problematic zone a reduction in north east monsoon has been predicted except in end of century in Alappuzha where the rainfall was expected to increase by 9%. In southern zone of Kerala the northeast monsoon has been predicted to decrease in Pathanamthitta and Kollam. In Thiruvananthpuram the rainfall decreased during near century and then increased in mid and late cemtury.

4.7.2.3. *Winter season*

Variation of weather parameters (solar radiation, maximum temperature, minimum temperature and rainfall) in winter season for the 14 districts of Kerala under RCP 4.5 and 8.5 has been show in Table 4.43 and 4.44 respectively. Variation of each weather parameters has been discussed below

4.7.2.3.1. Solar radiation

During the winter season under RCP 4.5 the amount of solar radiation was expected to increase in most of the districts. In northern zone Kasargod and Kannur districts showed a small increase in solar radiation from normal during near and mid-centurywhile by end of century the amount of solar radiation was found to be reduced. In Kozhikode and Malappuram the solar radiation was found to be increased from normal. The amount of solar radiation received was less in end of century when compared with the mid and near century. In central zone the solar radiation was expected to increase. In high range zone the amount of solar radiation is expected to decrease by 0.09, 0.16 and 0.28MJ/m^2 in near, mid and end of century respectively in Wayanad. While in Idukki the solar radiation was expected to increase from normal. In problematic zone the solar radiation was expected to increase from normal. In southern zone the solar radiation was expected increase in Pathanamthitta and Kollam, while in Thiruvanthapuramit was predicted to decrease from normal.

Table 4.43. Normal and projected weather data under RCP 4.5 during winter season

	SRAD (MJ/m^2)				TMAX (°C)				TMIN (°C)				RAIN (mm)			
Districts	Normal	NC	MC	LC	Normal	NC	MC	LC	Normal	NC	MC	LC	Normal	NC	MC	LC
	Northern zone															
Kasar	17.6	18.3	17.9	17.3	30.1	31.1	31.5	32.7	17.3	22.6	23.0	23.8	5.1	1.3	2.0	15.2
Kannur	18.2	18.3	18.3	18.2	29.6	31.2	31.6	32.7	17.2	22.8	23.2	23.9	7.5	3.1	3.2	23.6
Kkd	17.2	18.4	17.4	17.3	28.8	31.3	31.7	32.9	16.7	22.9	23.3	24.0	9.4	2.0	6.0	18.4
Mala	17.2	19.3	18.5	17.9	28.8	32.0	32.6	33.8	16.8	22.8	23.4	24.0	17.2	4.0	5.0	17.2
	Central zone															
Pala	17.0	19.8	18.9	18.4	29.3	32.6	33.1	34.3	17.7	23.0	23.7	24.3	21.1	4.2	8.7	12.6
Tsr	17.7	20.8	20.2	20.4	28.6	31.1	31.8	33.0	20.4	23.5	24.1	24.8	20.8	13.8	10.3	8.1
Ekm	17.5	19.7	19.7	20.1	30.1	31.6	30.7	33.1	19.2	22.9	23.5	24.2	28.5	28.4	26.7	48.6
	High range zone															
Idukki	16.4	16.7	17.3	18.3	30.3	26.6	27.3	28.3	19.8	17.4	18.0	18.7	37.7	39.0	30.3	30.7
Waya	17.2	17.1	17.0	16.9	28.8	26.9	27.5	28.7	16.7	16.7	17.2	17.9	12.3	2.1	3.5	8.7
	Problematic zone															
Alp	16.3	18.0	17.7	18.1	30.7	31.5	32.1	33.2	20.4	23.5	24.1	24.8	44.6	38.0	37.3	83.4
Ktm	16.3	18.2	18.1	18.8	30.7	31.8	32.4	33.4	20.4	23.5	24.1	24.8	42.1	35.5	27.2	30.1
	Southern zone															
Ptn	16.0	17.4	17.9	18.6	30.9	31.3	31.8	32.8	21.2	23.2	23.9	24.6	47.9	40.0	44.6	34.8
Kollam	21.4	23.4	24.0	24.7	31.2	30.7	31.2	32.1	21.4	23.4	24.0	24.7	52.9	28.1	33.1	30.0
Tvm	16.0	15.1	14.1	14.6	31.5	30.4	30.8	31.7	22.0	23.4	23.9	24.7	53.4	44.8	40.9	50.5

*Normal- 1980-2020 *NC- Near century- 2010-30 *MC- Mid century- 2021-50 * LC- End of century- 2051-80

Table 4.44. Normal and projected weather data under RCP 8.5 during winter season

	SRAD (MJ/m^2)				TMAX (°C)				TMIN (°C)				RAIN (mm)			
Districts	Normal	NC	MC	LC	Normal	NC	MC	LC	Normal	NC	MC	LC	Normal	NC	MC	LC
	Northern zone															
Kasar	17.6	18.1	17.2	16.3	30.1	30.6	31.3	33.3	17.3	22.4	23.2	25.2	5.1	3.0	7.9	9.0
Kannur	18.2	18.1	17.3	16.0	29.6	30.6	31.3	33.3	17.2	22.5	23.4	25.4	7.5	1.4	12.4	11.8
Kkd	17.2	17.7	16.4	15.9	28.8	30.7	31.4	33.4	16.7	22.6	23.5	25.4	9.4	3.4	16.0	8.6
Mala	17.2	18.8	18.2	17.5	28.8	31.6	32.3	34.3	16.8	22.6	23.6	25.4	17.2	0.5	2.2	4.9
	Central zone															
Pala	17.0	19.4	18.3	17.5	29.3	32.1	32.9	33.8	17.7	22.9	23.9	25.7	21.1	9.1	12.9	11.4
Tsr	17.7	20.4	19.8	19.3	28.6	30.7	31.5	33.9	20.4	23.5	24.3	25.9	20.8	16.7	20.4	8.7
Ekm	17.5	19.5	19.2	18.2	30.1	31.0	31.8	33.8	19.2	22.7	23.6	25.5	28.5	26.5	39.5	35.0
	High range zone															
Idukki	16.4	17.2	17.1	16.7	30.3	26.2	27.0	28.9	19.8	17.4	18.2	19.7	37.7	36.6	31.4	34.7
Waya	17.2	17.0	16.1	15.7	28.8	26.4	27.1	28.9	16.7	16.5	17.4	19.2	12.3	10.6	5.2	8.0
	Problematic zone															
Alp	16.3	17.8	17.7	18.5	30.7	31.3	32.0	33.6	20.4	23.5	24.3	25.9	44.6	48.1	59.0	56.6
Ktm	16.3	18.0	18.1	18.8	30.7	31.5	32.2	33.8	20.4	23.5	24.3	25.9	42.1	28.0	25.7	45.3
	Southern zone															
Ptn	16.0	17.4	18.1	17.5	30.9	30.9	31.7	33.6	21.2	23.2	24.1	25.6	47.9	31.5	32.1	40.3
Kollam	21.4	23.3	24.1	25.8	31.2	30.5	31.1	33.0	21.4	23.3	24.1	25.8	52.9	38.7	32.5	39.3
Tvm	16.0	14.9	14.3	14.1	31.5	30.2	30.7	31.8	22.0	23.4	24.0	25.6	53.4	50.9	56.8	51.3

*Normal- 1980-2020 *NC- Near century- 2010-30 *MC- Mid century- 2021-50 * LC- End of century- 2051-80

Under RCP 8.5 the amount of solar radiation is expected to increase from normal in most of the districts. In northern zone except in Kannur the solar radiation is expected to rise in Kanuur it decreased by 0.7MJ/m^2 in near century. In mid and end of century the solar radiation is expected to decrease in all districts of northern zone except in Malappuarm district. In central zone and problematic zone solar radiation is expected to increase. A reduction in solar radiation was observed in Wayanad and Thiruvananthapuram. Maximum deviation was observed in end of century in Kollam district (4.4MJ/m^2).

4.7.2.3.1. Solar radiation

During the winter season under RCP 4.5 the amount of solar radiation was expected to increase in most of the districts. In northern zone Kasargod and Kannur districts showed a small increase in solar radiation from normal during near and mid-centurywhile by end of century the amount of solar radiation was found to be reduced. In Kozhikode and Malappuram the solar radiation was found to be increased from normal. The amount of solar radiation received was less in end of century when compared with the mid and near century. In central zone the solar radiation was expected to increase. In high range zone the amount of solar radiation is expected to decrease by 0.09, 0.16 and 0.28MJ/m^2 in near, mid and end of century respectively in Wayanad. While in Idukki the solar radiation was expected to increase from normal. In problematic zone the solar radiation was expected to increase from normal. In southern zone the solar radiation was expected increase in Pathanamthitta and Kollam, while in Thiruvanthapuramit was predicted to decrease from normal.

Under RCP 8.5 the amount of solar radiation is expected to increase from normal in most of the districts. In northern zone except in Kannur the solar radiation is expected to rise in Kanuur it decreased by 0.7MJ/m^2 in near century. In mid and end of century the solar radiation is expected to decrease in all districts of northern zone except in Malappuarm district. In central zone and problematic zone solar radiation is expected to increase. A reduction in solar radiation was observed in Wayanad and Thiruvananthapuram. Maximum deviation was observed in end of century in Kollam district (4.4MJ/m^2).

4.7.2.3.2. Maximum temperature

An increasing trend in maximum temperature was found during winter season in most parts of Kerala. Under RCP 4.5, in northern zone of Kerala an increasing trend of maximum temperature was observed. Temperature rise was found to be higher in Malappuram (3.22℃, 3.79℃ and 5.01℃ during near-century, mid century and end of century respectively). In central zone an increasing trend has been observed of maximum temperature was found. The temperature increase was found to be higher in end of century followed by mid and near century. In high range zone a decrease in maximum temperature is expected in Idukki and Wayanad during all future simulations. In problematic zone an increase in maximum temperature was found. By end of century the temperature increased by 2.52℃ and 2.76℃ in Alappuzha and Kottayam respectively. In southern zone the maximum temperature showed a decrease in Thiruvananthpuram during near and mid century by 1.11℃ and 0.74℃ respectively. In Kollam and Pathanamthitta districts an increasing trend in temperature is expected.

Under RCP 8.5 the maximum temperature showed an increase in northern zone, central zone and problematic zone of Kerala. High range zone a decrease in maximum temperature was found in all future simulation except during end of century of Wayanad where the temperature showed a small increase of 0.14℃. In southern zone of Kerala maximum temperature is expected to decrease in near century. In mid century, increase is found only in Pathanamthitta in southern zone. By end of century the temperature was expected to rise in southern zone. Maximum increase in maximum temperature was observed in Malappuram (2.79℃, 3.48℃ and 5.49℃ during near-century, mid century and end of century respectively)

4.7.2.3.3 Minimum temperature

An increasing trend was observed in minimum temperature in most parts Kerala under winter season. Under RCP 4.5 in northern zone the minimum temperature was expected to increase by 7.33℃ in Kozhikode by end of century. The increase will be greater than 5 ℃ during all future simulation in northern zone of Kerala. In central zone of Kerala minimum temperature is expected to increase from normal in all districts. In high range zone the minimum temperature decreased in Idukki in all future simulation and in Wayanad minimum temperature was expected to increase. In problematic zone the minimum temperature showed an increase of near about 3℃, 3.7℃ and 4.4℃ in near, mid and end of century. In southern zone of Kerala an increase in minimum temperature was found to be greater in Pathanamthitta and the least deviation was found in Thiruvananthapuram.

Under RCP 8.5 the trend was similar to as observe in 4.5. The maximum increase in minimum temperature was found in end of century in all districts. Maximum deviation was observed in Kozhikode districts with an increase in minimum temperature by 5.86℃, 6.79℃ and 8.74℃ in near, mid and end of century respectively. In high range zone the minimum temperature is expected to decrease in Idukki during all future simulation. In Wayanad increase in minimum temperature is expected during mid and end of century. In problematic and southern zone the minimum temperature was expected to increase from normal in all future simulations.

4.7.2.3.4 Rainfall

Winter rainfall was predicted to decrease from normal in almost all parts of Kerala. Under RCP 4.5 in northern zone of Kerala winter rainfall decreased. In end of century an increase in winter rainfall was expected except in Malappuaram. In central zone of Kerala a reduction in winter rainfall has been predicted in all the future simulations. In Ernakulam by end of century an increase in winter rainfall is predicted. In high range zone a deficient northeast monsoon has been predicted. In problematic zone a reduction in winter rain has been predicted except in end of century in Alappuzha where the rainfall was expected to increase by 38mm. In southern zone of Kerala the winter rain has been predicted to decrease in all the future simulations.

Under RCP 8.5 a decrease in rainfall has been predicted in almost all districts expect in Alappuzha, where an normal to excess rainfall has been predicted. Greater reduction in winter rainfall has been observed in Malappuarm district.

4.7.2.4. Summer season

Variation of weather parameters (solar radiation, maximum temperature, minimum temperature and rainfall) in summer season for the 14 districts of Kerala under RCP 4.5 and 8.5 has been show in Table 4.45 and 4.46 respectively. Variation of each weather parameters has been discussed below

4.7.2.4.1. Solar radiation

During the summer season under RCP 4.5 the amount of solar radiation was expected to increase in most of the districts. In northern zone Kannur districts showed a small decrease in solar radiation from normal during near and mid-century while by end of century the amount of solar radiation was found to be increased. In Kasargode, Kozhikode and Malappuram the solar radiation is expected to increase from normal. The amount of solar radiation received was less in end of century when compared with the mid and near century. In central zone the solar radiation was expected to increase. In high range zone the amount of solar radiation decreased in near century by 0.76MJ/m^2 in Idukki. In Wayanad, solar radiation is expected to reduce by end of century. In problematic zone the solar radiation was expected to increase from normal. In southern zone the solar radiation is expected to increase in Pathanamthitta and Kollam , while in Thiruvanthapuramit is predicted to decrease from normal.

Under RCP 8.5 the amount of solar radiation was expected to increase from normal in most of the districts. In northern zone solar radiation was expected to increase in near century and then decreased in mid and end of century except in Malappuarm district where the solar radiation was expected to rise by 1.90, 1.34 and 0.46 MJ/m^2 in near, mid and end of century. In central zone and problematic zone solar radiation was expected to increase. A reduction in solar radiation was observed in Wayanad and Thiruvananthapuram. Maximum deviation was observed in end of century in Kollam district (4.42MJ/m^2).

Table 4.45. Normal and projected weather data under RCP 4.5 during summer season

	SRAD (MJ/m^2)				TMAX (℃)				TMIN (℃)				RAIN (mm)			
Districts	Normal	NC	MC	LC	Normal	NC	MC	LC	Normal	NC	MC	LC	Normal	NC	MC	LC
	Northern zone															
Kasar	17.7	18.5	18.1	17.8	32.0	34.3	34.7	35.8	20.9	27.2	27.6	28.3	284.7	527.0	450.4	395.1
Kannur	19.7	19.7	19.6	20.3	31.7	34.4	35.0	35.9	20.8	27.3	27.8	28.3	292.8	493.1	419.0	362.9
Kkd	17.4	18.5	17.8	18.0	31.2	34.4	34.8	35.8	20.4	27.3	27.7	28.3	293.7	595.1	469.4	346.8
Mala	17.4	19.7	19.1	18.6	31.4	35.0	35.6	36.6	20.4	27.0	27.4	28.0	276.6	432.3	344.6	366.5
	Central zone															
Pala	17.1	20.2	19.5	19.0	31.7	35.5	36.0	37.0	21.1	27.1	27.6	28.2	275.7	373.1	352.0	303.8
Tsr	19.2	22.8	22.8	23.1	28.7	31.1	31.5	32.6	23.1	26.7	27.2	27.9	321.9	468.0	431.4	484.6
Ekm	18.9	21.0	21.2	21.1	32.1	34.4	33.6	35.7	22.1	26.9	27.4	28.0	375.0	643.1	564.7	621.0
	High range zone															
Idukki	16.5	15.8	17.1	18.1	32.5	30.3	30.8	31.7	22.7	21.0	21.5	22.2	295.8	231.5	203.4	201.6
Waya	17.3	17.8	17.4	17.2	31.2	30.8	31.4	32.4	20.3	21.3	21.7	22.4	252.9	369.4	338.1	384.0
	Problematic zone															
Alp	16.5	18.7	17.9	18.1	32.5	33.6	34.0	35.0	23.1	26.7	27.2	27.9	496.2	566.4	493.9	490.4
Ktm	16.4	18.9	18.3	18.7	32.5	33.8	34.3	35.3	23.1	26.7	27.2	27.9	437.4	588.3	534.7	470.1
	Southern zone															
Ptn	16.1	17.1	17.1	17.5	32.8	33.9	34.5	35.4	23.8	26.4	26.8	27.6	347.9	449.6	391.1	307.4
Kollam	24.1	26.5	27.0	27.7	33.0	33.2	33.7	34.6	24.1	26.5	27.0	27.7	335.7	464.9	399.2	310.6
Tvm	16.1	15.5	14.5	15.0	33.3	32.6	33.0	33.9	24.6	26.1	26.6	27.4	300.7	277.8	229.6	173.8

*Normal- 1980-2020 *NC- Near century- 2010-30 *MC- Mid century- 2021-50 * LC- End of century- 2051-80

Table 4.46. Normal and projected weather data under RCP 8.5 during summer season

	SRAD (MJ/m^2)				TMAX (°C)				TMIN (°C)				RAIN (mm)			
Districts	Normal	NC	MC	LC	Normal	NC	MC	LC	Normal	NC	MC	LC	Normal	NC	MC	LC
	Northern zone															
Kasar	17.7	18.2	17.3	18.2	32.0	34.3	34.8	36.3	20.9	27.0	27.7	29.5	284.7	509.0	571.4	389.4
Kannur	19.7	20.3	19.7	18.0	31.7	34.5	35.0	36.5	20.8	27.1	27.8	29.6	292.8	431.5	376.3	331.8
Kkd	17.4	17.8	16.8	16.3	31.2	34.3	34.8	36.3	20.4	27.0	27.8	29.6	293.7	376.7	372.5	378.3
Mala	17.4	19.3	18.7	17.8	31.4	35.1	35.6	37.0	20.4	26.7	27.5	29.4	276.6	352.9	311.2	386.0
	Central zone															
Pala	17.1	19.8	18.8	17.8	31.7	35.5	36.0	36.3	21.1	26.9	27.7	29.5	275.7	330.7	307.4	346.6
Tsr	19.2	23.1	22.8	22.1	28.7	30.4	31.2	33.4	23.1	26.6	27.3	28.9	321.9	401.4	474.6	379.7
Ekm	18.9	21.0	20.5	19.5	32.1	34.3	34.8	36.2	22.1	26.8	27.5	29.1	375.0	579.4	518.8	592.9
	High range zone															
Idukki	16.5	16.4	16.9	16.9	32.5	30.1	30.6	31.9	22.7	20.8	21.5	23.3	295.8	223.9	207.9	190.0
Waya	17.3	17.5	16.4	15.7	31.2	30.8	31.3	32.9	20.3	21.0	21.8	23.8	252.9	328.2	319.8	251.7
	Problematic zone															
Alp	16.5	18.1	17.7	17.5	32.5	33.5	34.0	35.5	23.1	26.6	27.3	28.9	496.2	543.0	480.9	381.6
Ktm	16.4	18.2	18.0	17.8	32.5	33.7	34.3	35.8	23.1	26.6	27.3	28.9	437.4	560.9	519.4	447.7
	Southern zone															
Ptn	16.1	16.4	17.0	17.7	32.8	33.9	34.4	35.7	23.8	26.3	26.9	28.5	347.9	336.7	312.6	312.7
Kollam	24.1	26.4	27.0	28.5	33.0	33.1	33.7	34.9	24.1	26.4	27.0	28.5	335.7	434.3	325.3	306.4
Tvm	16.1	15.2	14.5	13.9	33.3	32.4	33.0	33.8	24.6	26.0	26.7	28.0	300.7	159.1	167.6	161.2

*Normal- 1980-2020 *NC- Near century- 2010-30 *MC- Mid century- 2021-50 * LC- End of century- 2051-80

4.7.2.4.2. Maximum temperature

An increasing trend in maximum temperature was found during summer season in most parts of Kerala. Under RCP 4.5, in northern zone of Kerala an increasing trend of maximum temperature was observed. Temperature rise was found to be higher in Malappuram (3.66℃, 4.21℃ and 5.2℃ during near-century , mid century and end of century respectively). In central zone an increasing trend has been observed of maximum temperature was found. The temperature increase was found to be higher in end of century followed by mid and near century. In high range zone a decrease in maximum temperature was observed in Idukki during all future simulations. In Wayanad an increase was observed during mid and end of century. In problematic zone an increase in maximum temperature was found. By end of century the temperature increased by 2.49℃ and 2.77℃ in Alappuzha and Kottayam respectively. In southern zone the maximum temperature showed a decrease in Thiruvananthpuram during near and mid century by 0.74℃ and 0.32℃ respectively. In Kollam and Pathanamthitta districts an increasing trend in temperature was observed.

Under RCP 8.5 the maximum temperature showed an increase in northern zone, central zone and problematic zone of Kerala. High range zone a decrease in maximum temperature was found in all future simulation except during mid and end of century of Wayanad where the temperature showed a small increase. In southern zone of Kerala maximum temperature was expected to increase except in near and mid century of Thiruvananthapuram.

4.7.2.4.3 Minimum temperature

An increasing trend was observed in minimum temperature in most parts Kerala under summerseason. Under RCP 4.5 the increase was greater than 5 ℃ during all future simulation in northern zone of Kerala. In central zone of Kerala minimum temperature was expected to increase from normal in all districts. In high range zone the minimum temperature decreased in Idukki in all future simulation and in Wayanad minimum temperature was expected to increase. In problematic zone the minimum temperature showed an increase of near about 3.5℃, 4℃ and 4.5℃ in near, mid and end of century respectively. In southern zone of Kerala an increase in minimum temperature was found to be greater in Pathanamthitta and the least deviation was found in Thiruvananthapuram.

Under RCP 8.5 the trend was similar to as observe in 4.5. The maximum increase in minimum temperature was found in end of century in all districts. Maximum deviation was observed in Kozhikode districts with an increase in minimum temperature by 6.61℃, 7.38℃ and 9.30℃ in near, mid and end of century respectively. In high range zone the minimum temperature decreased in Idukki in near and mid century while in Wayanad it increased in during all future simulations. In problematic and southern zone the minimum temperature was expected to increase from normal in all future simulations.

4.7.2.4.4 Rainfall

Under RCP 4.5large excess and excess rainfall was expected in northern zone and central zone Kerala during summer season. In high range zone, a reduction in rainfall is expected in Idukki while it showed an increase in Wayanad during all future simulations. In problematic zone normal summer showers are expected. In southern zone there was a decrease in rainfall during end of century and in Thiruvananthapuram it decreased in all future simulation.

A similar condition was observed under the RCP 8.5 scenario. In northern zone and central an increase in summer rainfall has been expected and in southern zone a reduction in summer rainfall has been predicted.

4.8. IMPACT OF CLIMATE CHANGE ON DURATION OF RICE VARIETIES

The duration of phenophase had been predicted using DSSAT- CERES model. Table 4. 47 shows the duration of short duration rice variety, Jyothi in base period, near century, mid century and end of century. The duration of crop showed is expected to decrease in future simulation under both the RCPs in all most of the districts with an exception in Idukki, where the duration is expected to increase in future simulations. Similarly in medium duration variety, Jaya also the duration is expected to decrease in future except inIdukki, where the duration is expected to increase in future simulations (Table 4.48)

Table 4.47. Duration of Jyothi in future simulation under RCP 4.5 and 8.5

Districts	Base period	RCP 4.5			RCP 8.5		
		Near century	Mid century	End of century	Near century	Mid century	End of century
Kasar	122	97	96	94	107	100	92
Kannur	122	97	95	94	97	95	92
Kkd	124	97	95	94	97	95	92
Mala	122	97	95	94	98	95	93
Pala	117	97	95	95	98	95	92
Tsr	115	95	95	97	97	96	92
Ekm	109	96	95	93	97	92	92
Idukki	105	115	112	107	115	110	101
Alp	104	96	96	94	96	94	91
Ktm	104	95	94	92	95	94	91
Ptn	101	95	93	92	95	93	91
Kollam	99	96	93	91	96	93	91
Tvm	97	95	93	91	94	92	90

Table 4.48. Duration of Jaya in future simulation under RCP 4.5 and 8.5

Districts	Base period	RCP 4.5			RCP 8.5		
		Near century	Mid century	End of century	Near century	Mid century	End of century
Kasar	134	106	106	104	134	106	106
Kannur	134	106	105	104	134	106	105
Kkd	136	106	105	104	136	106	105
Mala	134	107	106	103	134	107	106
Pala	127	107	106	103	127	107	106
Tsr	117	107	105	103	117	107	105
Ekm	120	106	105	102	120	106	105
Idukki	115	125	123	118	116	125	123
Alp	115	106	104	102	115	106	104
Ktm	115	106	103	102	115	106	103
Ptn	110	104	103	102	110	104	103
Kollam	109	104	103	101	109	104	103
Tvm	107	104	102	100	107	104	102

4.9. IMPACT OF CLIMATE CHANGE ON THE YIELD OF SHORT DURATION RICE VARIETY UNDER RCP 4.5 AND 8.5

The study was conducted to recognize the changes in yield ofshort duration variety Jyothi in all districts of Kerala where riceis cultivated in *Kharif* season under the climate change scenarios using Representative Concentration Pathway (RCP) 4.5 and 8.5. The Decision Support System for Agro technology Transfer (DSSAT) software has been used to simulate the future yield under different simulations *i.e.* near century (2010-30), mid century (2021-50) and end of century (2051-80). The predicted potential yield had been depicted in Table 4.49.

4.9.1. Kasargod

In Jyothi, during the base period maximum potential yield has been observed in July 5th planting (8094kg ha^{-1}). In future simulations highest yield was found to be in July 20th planting except in near century under RCP 8.5 in near century were the maximum yield has been observed in July 5th planting. The maximum deviation from normal has been observed in during June 5th in near (-48%), mid (-51%) and end of century (-52%) under RCP 4.5. The least deviation was found in July 20th planting in all the future simulations. Under RCP 8.5 in near century a maximum deviation of -47% was observed during August 5th planting and the least deviation of -6% was observed during July 5th planting. In the mid and end of century the maximum deviation was observed June 5th (-49%) and June 20th planting (-55%) respectively. The least deviation was observed in July 20th planting in mid and near century.

4.9.2. Kannur

In Jyothihighest potential yield has been observed in June 20th planting (8199 kg ha^{-1}) during the base period. Under RCP 4.5 the highest potential yield of Jyothi has been observed in July 20th planting (6506kg ha^{-1}) in near century, mid (6197 kg ha^{-1}) and end of century (6048 kg ha^{-1}) highest potential yield has been observed in July 20th planting. Maximum deviation has been observed during June 5th planting in all the future simulations. Under RCP 8.5 also the same trend which was observed under RCP 4.5 has been observed.Maximum deviation has been observed during June 5th planting in near and mid century while by the end of century maximum deviation has been observed in June 20th planting.

Table. 4.49. Yield of Jyothi in future simulation under RCP 4.5 and 8.5

Districts	Date of planting	Base	RCP 4.5			RCP 8.5		
		2020	NC	MC	LC	NC	MC	LC
Kasar	D1	7766	4059	3828	3741	5598	3969	3531
	D2	7971	5037	4762	4266	6394	4926	3448
	D3	8094	5558	5160	5020	7604	5345	4823
	D4	7886	6574	6192	6257	6504	6448	5723
	D5	7669	5978	5989	6096	4074	6184	4701
Kannur	D1	8038	3969	3682	3571	3963	3790	3436
	D2	8199	4403	4388	4021	4004	4570	3336
	D3	8065	5814	5220	4859	5885	5418	4703
	D4	8042	6506	6197	6048	6464	6387	5603
	D5	7851	5763	5681	4978	5783	5792	3747
Kkd	D1	8402	3569	3085	3329	3212	3334	2996
	D2	8300	4589	4105	3985	4425	4183	3146
	D3	8341	5636	5216	5207	5306	5203	3863
	D4	8232	6318	6339	6274	6454	6421	5520
	D5	8005	5835	6045	5381	5885	6100	4612
Mala	D1	8277	4421	4171	3926	3950	4048	3528
	D2	8297	5393	4922	4670	5424	4841	3253
	D3	8105	6128	5784	5789	6148	5826	4120
	D4	8105	6891	6951	6196	7142	7018	5784
	D5	8150	6443	6579	6579	6656	6696	5260
Pkd	D1	7908	4274	3774	4071	3999	3780	3687
	D2	7991	5332	4575	4013	5346	4600	3198
	D3	7943	6132	5785	5689	6026	5876	3770
	D4	7656	7013	6912	6652	7136	7009	5384
	D5	7719	6564	6671	6813	6783	6736	5385

Table. 4.49. Yield of Jyothi in future simulation under RCP 4.5 and 8.5 (Contd.)

Districts	Date of planting	Base	RCP 4.5			RCP 8.5		
		2020	NC	MC	LC	NC	MC	LC
Trs	D1	7766	4079	3769	4668	5525	3840	3622
	D2	7612	5320	4758	5667	5344	4836	3393
	D3	7683	6025	5967	6799	5287	6093	3653
	D4	7511	7222	7158	8111	5557	6989	6085
	D5	7423	6877	6955	7142	5681	6969	5494
Ekm	D1	7146	3691	3538	3642	3633	3597	3512
	D2	7387	4867	4694	4427	4622	4490	3187
	D3	7229	5769	5415	5452	5429	5459	4019
	D4	7049	6653	6622	6522	6683	6600	5798
	D5	6796	6189	6489	5498	6200	6301	5034
Idukki	D1	6831	5731	5407	4769	6106	5218	4279
	D2	6950	6579	6454	5851	6719	6398	5062
	D3	6814	8308	7659	6690	8193	7162	6008
	D4	6839	9183	8777	8397	9458	8727	6688
	D5	6830	8227	8484	8170	8414	8438	7654
Ktm	D1	6580	3315	2924	3098	3300	2925	2787
	D2	6814	4159	3981	3399	4067	4158	3215
	D3	6805	5584	5218	4214	5456	5260	2859
	D4	6653	6616	6220	5888	6298	6121	5266
	D5	6594	6686	6668	6301	6529	6423	5779
Alap	D1	6574	3293	2930	2902	2973	3083	2962
	D2	6810	4127	3851	3311	4081	3907	3340
	D3	6801	5397	5296	4982	5286	5084	2995
	D4	6653	6457	6151	5810	6102	6031	5300
	D5	6599	6495	6508	6166	6407	6458	5682

Table. 4.49. Yield of Jyothi in future simulation under RCP 4.5 and 8.5 (Contd.)

Districts	Date of planting	Base	RCP 4.5			RCP 8.5		
		2020	NC	MC	LC	NC	MC	LC
Ptn	D1	6289	3213	3427	3454	2981	3456	3193
	D2	6373	4139	3917	3860	4112	4016	2898
	D3	6531	5364	3853	3452	4489	3720	2860
	D4	6299	6561	5996	5754	6445	5967	4433
	D5	6303	6889	6320	6209	6565	6400	5926
Kollam	D1	6266	2800	2732	2810	2631	2800	2714
	D2	6109	4038	3576	3598	3741	3520	2513
	D3	6290	5268	4182	3553	5121	4070	2769
	D4	6160	6388	5762	5460	6143	5674	5056
	D5	6143	6745	6245	5891	6321	5998	5636
Tvm	D1	5186	2559	2760	2269	2477	2346	2873
	D2	6099	3560	3060	2439	3022	2563	2607
	D3	5928	4509	4302	3346	4112	3738	2911
	D4	6052	5476	4416	3688	5610	4316	3165
	D5	5942	6436	6112	5909	6367	6165	4152

4.9.3. Kozhikode

In Jyothi during the base period potential yield ranged from 8005 to 8402kg ha^{-1}. The highest potential yield has been observed in June 5th planting (8402 kg ha^{-1}). Under RCP 4.5 in future simulations highest yield was found to be in July 20th in near century (6318 kg ha^{-1}), mid century (6339 kg ha^{-1}) and end of century (6274 kg ha^{-}1. The maximum deviation from has been observed in during June 5th in near (-58%), mid (-63%) and end of century (-60%) under RCP 4.5. The least deviation was found in July 20th planting in all the future simulations.

Under RCP 4.5 in future simulations highest yield was found to be in July 20th in near century (6454 kg ha^{-1}), mid century (6421 kg ha^{-1}) and end of century (5520 kg ha^{-1})

.The maximum deviation from normal has been observed in during June 5th in near (-62%), mid (-60%) and end of century (-64%) under RCP 8.5. The least deviation was found in July 20th planting in all the future simulations.

4.9.4. Malappuram

In Jyothi during the base period potential yield ranged from 8105 to 8297kg ha^{-1}. The highest potential yield has been observed in June 5th planting (8297kg ha^{-1}). Under RCP 4.5 in future simulations highest yield was found to be in July 20th in near century (6891kg ha^{-1}), mid century (6951kg ha^{-1}) and end of century (6196kg ha^{-1}). The maximum deviation from has been observed in during June 5th in near (-47%), mid (-50%) and end of century (-53%) under RCP 4.5.

Under RCP 8.5 in future simulations highest potential yield was found to be in July 20th in near century (7142kg ha^{-1}), mid century (7018kg ha^{-1}) and end of century (5784 kg ha^{-1}) .The maximum deviation from has been observed in during June 5th in near (-52%), mid (-51%) and end of century (-57%) under RCP 8.5.

4.9.5. Palakkad

In Palakkad yield of Jyothi in base period potential yield ranged from 7656 to 7991 kg ha^{-1}. The highest potential yield has been observed in June 20th planting (7991kg ha^{-1}). Under RCP 4.5 in future simulations highest yield was found to be in July 20th in near century (7013 kg ha^{-1}), mid century (6912 kg ha^{-1}) and end of century (6652 kg ha^{-1}). The maximum deviation from has been observed in during June 5th in near (-46%) and mid century (-52%) and by the end of century maximum deviation of -50% has been expected in July 20th planting under RCP 4.5.

Under RCP 8.5 in future simulations highest potential yield was found to be in July 20th in near century (6652 kg ha^{-1}), mid century (7136kg ha^{-1}) and end of century (5384 kg ha^{-1}) .The maximum deviation from has been observed in during June 5th in near (-49%) and mid century (-52%) and by the end of century maximum deviation of -53% has been expected in July 20th planting under RCP 8.5.

4.9.6. Thrissur

In Thrissur, yield of Jyothi during the base period potential yield ranged from 7423 kg ha^{-1} to 7766 kg ha^{-1}. The highest potential yield has been observed in June 5th planting (7766 kg ha^{-1}). Under RCP 4.5 in future simulations highest yield was found to be in July 20th in near century (7222 kg ha^{-1}), mid century (7158 kg ha^{-1}) and end of century (8111 kg ha^{-1}). The maximum deviation from has been observed in during June 5th in near (-47%), mid (-51%) and end of century (-40%) under RCP 4.5.

Under RCP 8.5 in future simulations highest potential yield was found to be in July 20th in near century (5557 kg ha^{-1}), mid century (6989 kg ha^{-1}) and end of century (6085 kg ha^{-1}). The maximum deviation from has been observed during July 5th in near (-31%), June 5th in mid (-51%) and June 20th in the end of century (-55%) under RCP 8.5.

4.9.7. Ernakulam

In Jyothi, June 20th planting showed a highest potential yield in the base period (7387 kg ha^{-1}). In all the future simulations the higher potential yield has been predicted during July 20th planting *i.e.*6653 kg ha^{-1}, 6622 kg ha^{-1} and 6522 kg ha^{-1} in near, mid and end of century respectively under RCP 4.5. Maximum deviation was found in June 5th planting in near (-48%), mid (-50%) and end of century (-49%).

Under RCP 8.5 in future simulations highest potential yield was found to be in July 20th in near century (6683 kg ha^{-1}), mid century (6600 kg ha^{-1}) and end of century (5798 kg ha^{-1}). Maximum deviation was found in June 5th planting in near (-49%) and mid (-50%) century. By the end of century maximum deviation was found to be in June 20th planting (-57%).

4.9.8. Idukki

In Jyothi, yield in base period ranged from 6830 to 6950 kg ha^{-1}. Highest yield had been obtained in June 20th.Under RCP 4.5 in future simulations highest potential yield was found to be in July 20th in near century (9183 kg ha^{-1}), mid century (8777 kg ha^{-1}) and end of century (8397kg ha^{-1}). Maximum positive deviation was observed during July 20th planting *i.e.* 34% in near, 28% in mid century and by the end of century a deviation of 23% was observed. June 5th and 20th planting showed a negative deviation under both RCPs.

Under RCP 8.5 in future simulations highest potential yield was found to be in July 20th in near century (9458 kg ha^{-1}), mid century (8727kg ha^{-1}) and end of century (6688 kg ha^{-1}). Maximum deviation is observed during the end of century where June 5th planting showed a negative deviation of -31%. In July 20th planting higher yield has been observed and shows a positive deviation of 38%, 28% in near and mid century respectively. By the end of century yield is expected to decrease except in August 5th planting which showed a positive deviation of 12%.

4.9.9. Kottayam

In Kottayam yield ranged from 6580 kg ha^{-1} to 6814kg ha^{-1} and the highest potential yield has been observed in June 20th planting in base period. Under RCP 4.5 in future simulations highest potential yield was found to be in August 5thplanting in near century (6616 kg ha^{-1}), mid century (6220 kg ha^{-1}) and end of century (5888 kg ha^{-1}). Maximum deviation from base has been observed during in June 5th planting *i.e.* -50%, -56% , -53% in near, mid and end of century respectively under RCP 4.5

Under RCP 8.5 in future simulations highest potential yield was found to be in August 5thplanting in near century (6529 kg ha^{-1}), mid century (6423 kg ha^{-1}) and end of century (5779 kg ha^{-1}). Maximum deviation from base has been observed during in June 5th planting *i.e.* -50%, -56%, -58% in near, mid and end of century respectively under RCP 8.5.

4.9.10. Alappuzha

In Jyothi, potential yield was found to be in the range of 6574 kg ha^{-1} to 6810 kg ha^{-1}. Under RCP 4.5 in future simulations highest potential yield was found to be in August 5th planting in near century (6495 kg ha^{-1}), mid century (6508 kg ha^{-1}) and end of century (5810 kg ha^{-1}). The maximum deviation was found in June 5th planting *i.e.* -50%, -55% and -56% in near, mid and end of century respectively.

Under RCP 8.5 in future simulations highest potential yield was found to be in August 5thplanting in near century (6407 kg ha^{-1}), mid century (6458 kg ha^{-1}) and end of century (5682 kg ha^{-1}). The maximum deviation of -55, -53% and -55% was found in near, mid and end of century respectively in June 5th planting.

4.9.11. Pathanamthitta

In Jyothi , potential yield was found to be in the range of 6289 kg ha^{-1} to 6531 kg ha^{-1} . Under RCP 4.5 in future simulations highest potential yield was found to be in August 5thplanting in near century (6889 kg ha^{-1}), mid century (6320 kg ha^{-1}) and end of century (6209 kg ha^{-1}). The maximum deviation was found in June 5th planting *i.e.* -49%, -46% and -45% in near, mid and end of century respectively. Under RCP 8.5 in future simulations highest potential yield was found to be in August 5thplanting in near century (6565 kg ha^{-1}), mid century (6400 kg ha^{-1}) and end of century (5926 kg ha^{-1}). The maximum deviation of -53 and -45% was found in near and mid century respectively. By the end of century maximum negative deviation was observed in July 20th planting *i.e.* -55%.

4.9.11. Kollam

In Jyothi , potential yield was found to be in the range of 6109 kg ha^{-1} and6290 kg ha^{-1}. The highest yield was observed in June 20th planting. In all the future simulations highest yield has been recorded in August 5thplanting under both the RCPs. An increase in yield from the base period has been observed in July 20th in near, mid and end of the century. Yield is expected to increase in August 5th planting also in near and mid century under both RCPs. Under RCP 4.5 in future simulations highest potential yield was found to be in August 5thplanting in near century (6745 kg ha^{-1}), mid century (6245 kg ha^{-1}) and end of century (5891 kg ha^{-1}). The maximum deviation was found in June 5th planting in near (-55%) mid (-56%) and end of century (-55%) respectively. Under RCP 4.5 in future simulations highest potential yield was found to be in August 5thplanting in near century (6321 kg ha^{-1}), mid century (5998 kg ha^{-1}) and end of century (5636 kg ha^{-1}). The maximum deviation of -58% and -55% was found in near and mid century respectively. By the end of century maximum negative deviation was observed in July 20th planting *i.e.* -59%.

4.9.13. Thiruvananthapuram

In Jyothi , potential yield was found to be in the range of 5186 kg ha^{-1} and 6099 kg ha^{-1}. The highest yield was observed in June 20th planting. In all the future simulations highest yield has been recorded in August 5thplanting under both the RCPs. An increase in yield from the base period has been observed in August 5th planting in near, mid and end of the century. Under RCP 4.5 in future simulations highest potential yield was found to be in August 5thplanting in near century (6436 kg ha^{-1}), mid century (6112 kg ha^{-1}) and end of century (5909 kg ha^{-1}). The maximum deviation was found in June 5th planting in near (-51%), June 20th in mid (-50%) and end of century (-60%). Under RCP 8.5 in future simulations highest potential yield was found to be in August 5thplanting in near century (6367 kg ha^{-1}), mid century (6165 kg ha^{-1}) and end of century (4152 kg ha^{-1}). The maximum deviation was found in June 5th planting in near (-52%), June 20th in mid (-58%) and end of century (-57%).

4.10. IMPACT OF CLIMATE CHANGE ON THE YIELD OF MEDIUM DURATION RICE VARIETY UNDER RCP 4.5 AND 8.5

The study was conducted to recognize the changes in yield ofmedium duration variety Jaya in all districts of Kerala where riceis cultivated in *Kharif* season under the climate change scenarios using Representative Concentration Pathway (RCP) 4.5 and 8.5. The Decision Support System for Agro technology Transfer (DSSAT) software has been used to simulate the yield in future under different simulations *i.e.* near-century (2010-30), mid century (2021-50) and end of century (2051-80). The predicted potential yield had been depicted in Table 4.50.

4.10.1. Kasargod

In Jaya, during the base period July 5th recorded the highest potential yield (9013 kg ha^{-1}) in Kasargod. In future simulations highest yield was observed during July 20th planting under both the RCPs. A reduction in rice yield has been observed in near century, mid century and by the end of century under both the RCPs. Under RCP 4.5 in future simulations highest potential yield was found to be in July 20thplanting in near century (7225 kg ha^{-1}), mid century (7089 kg ha^{-1}) and end of century (6381 kg ha^{-1}). In near century maximum deviation of yield has been observed in June 5th planting with a percentage deviation of -38%. In mid century the maximum deviation was observed in August 5th planting with a percentage deviation of -39%. By the end of century the yield reduction increased when compared to near and mid century and the maximum deviation was observed in June 20th planting by -60%. Under RCP 8.5 in future simulations highest potential yield was found to be in July 20thplanting in near century (7645 kg ha^{-1}), mid century (7342 kg ha^{-1}) and end of century (6889 kg ha^{-1}). In near century maximum deviation was found in near century (-35%). In mid and end of century maximum deviation in the rice production has been observed in August 5th planting. Least deviation was observed in July 20th planting for all the future simulations.

Table. 4.50. Yield of Jaya in future simulation under RCP 4.5 and 8.5

Districts		Base	RCP 4.5			RCP 8.5		
		2020	NC	MC	LC	NC	MC	LC
Kasar	D1	8451	5272	5246	4623	5466	5326	5073
	D2	8599	6149	5787	3461	6486	6080	4512
	D3	9013	6714	6425	5822	6983	6866	6451
	D4	8803	7225	7089	6381	7645	7342	6889
	D5	8813	5956	5405	4202	5856	5037	4672
Kannur	D1	9229	5165	5066	4016	4894	5231	4499
	D2	9017	6171	5781	5636	6077	5938	3477
	D3	8850	7288	6604	6345	7168	6743	5686
	D4	8875	6876	6898	6689	7160	7071	6081
	D5	8335	6019	4883	4449	6010	4893	4006
Kkd	D1	9342	4745	4578	4632	4607	4694	4126
	D2	9262	5875	5678	4226	5550	5567	3276
	D3	9072	6928	6606	6396	6879	6606	5821
	D4	8982	6961	7188	6720	7056	7188	6190
	D5	8688	5959	4880	4549	6098	4880	4145

Table. 4.50. Yield of Jaya in future simulation under RCP 4.5 and 8.5 (Contd.)

Mala	D1	9308	5612	5755	5066	5579	4900	4630
	D2	9046	6580	6370	4287	6315	6345	3706
	D3	9031	7688	7086	6384	7199	7184	5987
	D4	8922	7597	7691	6930	7891	7769	6582
	D5	8616	6495	5619	5034	6965	5352	4033
Pkd	D1	8789	5520	5240	5788	5381	5226	4516
	D2	8751	6681	6197	4238	6467	5119	3745
	D3	8456	7689	7027	6746	7586	7020	6085
	D4	8393	7750	7593	7147	7709	7689	6787
	D5	8171	6772	5602	5285	5938	5308	4006
Trs	D1	7816	5691	4987	4933	5343	5030	4419
	D2	7761	6471	4849	4157	6308	4747	4068
	D3	7757	7422	7060	6590	7417	7056	6013
	D4	7861	7877	7677	7265	8008	7581	6876
	D5	7598	6084	5997	5558	6054	5933	4106
Ekm	D1	8067	4962	4739	4984	4582	4836	4214
	D2	8134	6090	5898	4803	5821	5884	3817
	D3	7964	7299	6830	6429	6588	6631	5565
	D4	7836	7358	7472	6939	7189	7125	6457
	D5	7853	6457	6566	4569	6331	5096	3920
Idukki	D1	7730	7243	7084	6015	7462	6835	5347
	D2	7695	7600	7161	6852	7947	7203	6001
	D3	7902	9510	9104	8465	9536	9180	7036
	D4	7590	9643	9631	9119	9620	9433	8346
	D5	7483	7912	8076	8151	8000	8235	8536

Table. 4.50. Yield of Jaya in future simulation under RCP 4.5 and 8.5 (Contd.)

Districts		Base	RCP 4.5			RCP 8.5		
		2020	NC	MC	LC	NC	MC	LC
Ktm	D1	7529	4637	4023	4253	4221	4096	3366
	D2	7545	4406	4303	4191	4333	4339	3520
	D3	7529	6776	6035	5880	6698	6091	4678
	D4	7424	7412	6921	6842	7257	7024	5890
	D5	7460	6544	6694	5510	6449	5927	5579
Alap	D1	7522	4656	4082	4059	4475	4046	3951
	D2	7541	5436	3992	3998	5617	4200	3647
	D3	7528	6770	6064	5849	6623	6060	5456
	D4	7427	7246	6957	6589	7113	6797	6390
	D5	7464	6290	6506	5408	5462	5773	5524
Ptn	D1	7254	4182	4364	4304	4212	4414	3472
	D2	7298	5389	5104	4307	5413	4154	3385
	D3	7086	6200	6190	6268	6268	6337	3532
	D4	6995	7450	7464	7107	7477	7299	6122
	D5	7020	7213	7279	6814	7091	7272	6452
Kollam	D1	6881	3910	3844	3680	3758	3803	3638
	D2	6927	4171	4935	4025	3923	4883	3441
	D3	6976	6221	5754	6490	6105	5739	3367
	D4	7013	7401	6981	6679	6832	6910	5668
	D5	6811	6686	6161	6511	6485	6882	6131
Tvm	D1	6689	3580	3458	2886	3393	3073	3299
	D2	6761	4804	4267	3497	4141	3675	3387
	D3	6846	5712	5176	4415	4427	4686	4098
	D4	6672	6462	6099	5808	6349	5974	3578
	D5	6550	6985	7070	6813	7381	7178	5595

4.10.2. Kannur

In Jaya highest potential yield has been observed in June 5th planting (9229 kg ha^{-1}) during the base period. Under RCP 4.5 the highest potential yield of Jaya has been observed in July 5th planting (7288kg ha^{-1}) in near century while in mid (6898 kg ha^{-1}) and end of century (6689 kg ha^{-1}) highest potential yield has been observed in July 20th planting. Maximum deviation has been observed during June 5th planting in the entire future simulations *i.e.* -44%, -45% and -56% in near, mid and end of century. Under RCP 8.5 the highest potential yield of Jaya has been observed in July 5th planting (7160kg ha^{-1}) in near century while in mid (7071 kg ha^{-1}) and end of century (6081 kg ha^{-1}) highest potential yield has been observed in July 20th planting. Maximum deviation has been observed during June 5th planting in the entire future simulations *i.e.* -47% and -43% in near and mid century respectively. By the end of century the maximum deviation was found to be -61% during June 20th planting.

4.10.3. Kozhikode

In Kozhikode, during the base period the highest potential yield has been observed during June 5th planting (9342 kg ha^{-1}) in Jaya. In all future simulations the potential yield has been found to be higher during July 20th planting under both the RCPs.Under RCP 4.5 in future simulations highest potential yield is found to be in July 20th planting in near century (6961 kg ha^{-1}), mid century (7188 kg ha^{-1}) and end of century (6720 kg ha^{-1}). Maximum deviation has been observed during June 5th planting in the entire future simulations *i.e.* -49% and -51% in near and mid century respectively. By the end of century the maximum deviation was found to be -54%. Under RCP 8.5 in future simulations highest potential yield was found to be in July 20th planting in near century (7056 kg ha^{-1}), mid century (7188 kg ha^{-1}) and end of century (6190 kg ha^{-1}). Maximum deviation has been observed during June 5th planting in the entire future simulations *i.e.* -51% and -50% in near and mid century respectively. By the end of century the maximum deviation was found to be -65%.

4.10.4. Malappuram

In Malappuram, during the base period the highest potential yield has been observed during June 5th planting (9308 kg ha^{-1}) in Jaya. In all future simulations the potential yield has been found to be higher during July 20th planting under both the RCPs.In near century highest potential yield has been recorded in July 5th planting *i.e.* 7688 kg ha^{-1} while in mid and end of the century the highest yield has been expected to be in July 20th planting *i.e.*7691 kg ha^{-1}and 6930kg ha^{-1}under RCP 4.5. Maximum deviation has been observed during June 5th planting in the entire future simulations *i.e.* -40% and -38% in near and mid century respectively. By the end of century the maximum deviation was found to be -53%. Under RCP 8.5 in future simulations highest potential yield was found to be in July20th planting in near century (7891 kg ha^{-1}), mid century (7769 kg ha^{-1}) and end of century (6582 kg ha^{-1}). Maximum deviation has been observed during June 5th planting in the entire future simulations *i.e.* -40% and -47% in near and mid century respectively. By the end of century the maximum deviation was found to be -59%.

4.10.5. Palakkad

In Palakkad highest potential yield in Jaya was observed in June 5th planting *i.e.* 8789 kg ha^{-1}. In future simulations highest potential yield is expected to be during July 20th planting *i.e.* 7750 kg ha^{-1}, 7593kg ha^{-1} and 7147kg ha^{-1} during near, mid and end of century respectively under RCP 4.5. The maximum deviation from base was found in June 5th planting in near (-37%) and mid (-40%) century while by the end of century June 5th showed a maximum deviation of -52% in June 20th planting. Under RCP 8.5 also maximum yield was expected to be in July 20th planting *i.e.* 7709 kg ha^{-1}, 7689 kg ha^{-1} and 6787 kg ha^{-1} during near, mid and end of century respectively. The trend of maximum deviation was found to similar to that of RCP 4.5. The maximum deviation from base was found in June 5th planting in near (-39%) and mid (-41%) century while by the end of century maximum deviation of -57% in June 20th planting.

4.10.6. Thrissur

In Thrissur highest potential yield in Jaya was observed in June 5th planting *i.e.* 7861 kg ha^{-1}. In future simulations highest potential yield is expected to be during July 20th planting *i.e.* 7877 kg ha^{-1}, 7877kg ha^{-1} and 7677kg ha^{-1} during near, mid and end of century respectively under RCP 4.5. The maximum deviation from base was found in June 5th planting in near (-28%) while in the mid century and end of century a maximum deviation of -38% and -46% respectively in June 20th planting. Under RCP 8.5 also maximum yield was expected to be in July 20th planting *i.e.*8008 kg ha^{-1}, 7581 kg ha^{-1} and 6876 kg ha^{-1} during near, mid and end of century respectively. The trend of maximum deviation was found to similar to that of RCP 4.5. The maximum deviation from base was found in June 5th planting in near century (-32%) while in mid (-39%) century and by the end of century maximum deviation of -48% in June 20th planting.

4.10.7. Ernakulam

In Jaya, June 20th planting showed highest potential yield in the base period (8134 kg ha^{-1}). In all the future simulations the higher potential yield has been predicted during July 20th planting under both RCP. Under RCP 4.5 in future simulations highest potential yield is found to be in July 20thplanting in near century (7359 kg ha^{-1}), mid century (7472 kg ha^{-1}) and end of century (6939 kg ha^{-1}). The maximum deviation was found in June 5th planting in near (-38%) and mid (-41%) century. By the end of century maximum deviation was found to be in June 20th planting (-41%). Under RCP 8.5 in future simulations highest potential yield is found to be in July 20thplanting in near century (7189 kg ha^{-1}), mid century (7125 kg ha^{-1}) and end of century (6457 kg ha^{-1}). Under RCP 8.5 maximum deviation was found in June 5th planting in near (-43%) and mid (-40%) century. By the end of century maximum deviation was found to be in June 20th planting (-53%).

4.10.8. Idukki

In Idukki an increase in yield from base period has been expected in last three dates of planting and also when compared with other districts the least deviation is shown in Idukki. In Jaya yield in base period ranged from 7483 to 7730 kg ha^{-1}. Under RCP 4.5

in future simulations highest potential yield was found to be in July 20th in near century (9643kg ha^{-1}), mid century (9631kg ha^{-1}) and end of century (9119 kg ha^{-1}). Under RCP 4.5 maximum positive deviation was observed during July 20th planting (27%) in near and mid century and by the end of century a deviation of 20% was observed. June 5th and 20th planting showed a negative deviation under both RCPs. Under RCP 8.5 in future simulations highest potential yield was found to be in July 20th in near century (9620 kg ha^{-1}), mid century (9433 kg ha^{-1}) and end of century (8346 kg ha^{-1}). The maximum deviation is observed during the end of century where June 5th planting showed a negative deviation of -31%. In July 20th planting higher yield has been observed and shows a positive deviation of 27%, 24% and 10% in near, mid and end of century respectively.

4.10.9. Kottayam

In Kottayam yield ranged from 7424 to 7545kg ha^{-1} and the highest potential yield has been observed in June 20th planting in base period. Under RCP 4.5 in future simulations highest potential yield was found to be in July 20thplanting in near century (7412 kg ha^{-1}), mid century (6921 kg ha^{-1}) and end of century (6842 kg ha^{-1}). Maximum deviation from base has been observed during in July 5th planting *i.e.* -42%, -43% , -44% in near, mid and end of century respectively under RCP 4.5

Under RCP 8.5 in future simulations highest potential yield was found to be in August 5thplanting in near century (7257 kg ha^{-1}), mid century (7024 kg ha^{-1}) and end of century (5890 kg ha^{-1}). Maximum deviation from base has been observed during in June 20th planting *i.e.* -44%, -46%, -55% in near, mid and end of century respectively under RCP 8.5.

4.10.10. Alappuzha

In Alappuzha, potential yield of Jaya ranges between 7427 kg ha^{-1} and7541 kg ha^{-1}. The highest yield was observed in June 20th planting. In all the future simulations highest yield has been recorded in July 20th planting under both the RCPs. Under RCP 4.5 in future simulations highest potential yield was found to be in July 20thplanting in near century (7246 kg ha^{-1}), mid century (6957 kg ha^{-1}) and end of century (6589 kg ha^{-1}).

The maximum deviation was found in June 5th planting *i.e.* -38% and in mid and end of century maximum deviation of -47% in June 20th planting. Under RCP 8.5 in future simulations highest potential yield was found to be in July 20thplanting in near century (7113 kg ha^{-1}), mid century (6797 kg ha^{-1}) and end of century (6390 kg ha^{-1}). The maximum deviation of -41 and -46% was found in near and mid century respectively in June 20th planting. By the end of century maximum deviation was found in June 20th planting *i.e.* 52%.

4.10.11. Pathanamthitta

In Pathanamthitta, potential yield of Jaya ranges between 6995 kg ha^{-1} and7298 kg ha^{-1}. The highest yield was observed in June 20th planting. In all the future simulations highest yield has been recorded in July 20th planting under both the RCPs. An increase in yield from the base period has been observed in July 20thin near, mid and end of the century. Yield is expected to increase in August 5th planting also in near and mid century under both RCPs. Under RCP 4.5 in future simulations highest potential yield was found to be in July 20thplanting in near century (7450 kg ha^{-1}), mid century (7464 kg ha^{-1}) and end of century (7107 kg ha^{-1}). The maximum deviation was found in June 5th planting in near (-42%) mid (-40%) and end of century (41%). Under RCP 8.5 in future simulations highest potential yield was found to be in July 20thplanting in near century (7477 kg ha^{-1}), mid century (7299 kg ha^{-1}) and by end of century highest yield has been recorded in August 5th planting (6122 kg ha^{-1}). The maximum deviation of was found in near (-42%) mid (-39%) and end of century (-52%).

4.10.12. Kollam

In Kollam, potential yield of Jaya ranges between 6811 kg ha^{-1} and7013 kg ha^{-1}. The highest yield was observed in June 5th planting. In all the future simulations highest yield has been recorded in June 5thplanting under both the RCPs. An increase in yield from the base period has been observed in July 20th in near, mid and end of the century. Yield is expected to increase in August 5th planting also in near and mid century under both RCPs. Under RCP 4.5 in future simulations highest potential yield was found to be in July 20thplanting in near century (7401 kg ha^{-1}), mid century (6981 kg ha^{-1}) and end of century (6679 kg ha^{-1}). The maximum deviation was found in June 5th planting in near (-44%) mid (-45%) and end of century (-48%). Under RCP 8.5 in future simulations highest potential yield was found to be in July 20thplanting in near century (6832 kg ha^{-1}), mid century (6910 kg ha^{-1}) and by end of century highest yield has been recorded in August 5th planting (6131 kg ha^{-1}). The maximum deviation of was found in near and mid century (-46%).By the end of century maximum deviation was observed in June 20th planting (-50%).

4.10.13. Thiruvanthapuram

In Thiruvanthapuram, potential yield of Jaya ranges between 6550 kg ha^{-1} and 6846 kg ha^{-1}. The highest yield was observed in June 5th planting. In all the future simulations highest yield has been recorded in June 5th planting under both the RCPs. Under RCP 4.5 an increase in yield from the base period has been observed in August 5th planting in near, mid and end of the century. In future simulations highest potential yield was found to be in August 5thplanting in near century (6985 kg ha^{-1}), mid century (7070 kg ha^{-1}) and end of century (6813 kg ha^{-1}). The maximum deviation was found in June 5th planting in near (-46%) mid (-48%) and end of century (-57%). Under RCP 8.5 yield is expected to increase from base in August 5th planting in near and mid century. In future simulations highest potential yield was found to be in July 20thplanting in near century (7381 kg ha^{-1}), mid century (7178 kg ha^{-1}) and end of century (5595 kg ha^{-1}). The maximum deviation of was found in June 5th planting in near, mid and end of the century -46%, -54% and -51% respectively.

Discussion

5. DISCUSSION

The spatial variability of the impacts of climate change on rice (*Oryza sativa* L.) yield in Kerala was analyzed and the results of the research were discussed in this chapter.

5.1 GROWTH AND DEVELOPMENT OF RICE VARIETIES

5.1.1. Weekly plant height

Among the two varieties a significant difference was found in heightduring all weeks. It was found that Jyothi was taller than Jaya (Fig 5.1). Haritharaj, 2019 and Harithalekshmi, 2020 reported a parallel result that higher plant height has been observed in Jyothi. In Jyothi, greater plant height was observed in June 20th planting while in Jaya it was observed on July 5th planting. Vysakh, 2015 reported that an increased maximum temperature may lead to a reduction in plant height. This was observed in this study. Figure 5.1 depicts the impact of maximum temperature on plant height.In this study, it was observed that rainfall had a positive effect on plant height. Figure 5.2 shows that an increased rainfall leads to an increase in plant height. Abbas and Mayo, 2021 also reported that precipitation had a positive correlation with plant height during the plant growth period

5.1.2 Dry matter accumulation

Maximum dry matter accumulation was achieved during 75 days after planting in Jaya and Jyothi. A similar observation has been observed by Harithalekshmi, 2020. Maximum dry matter accumulation has been observed during August 5th planting. The studies conducted by Singh *et al*., (2012) and Ravindran, (2018) showed that increase in maximum temperature lead to a decrease in dry matter accumulation. In this study also this has been observed. Figure 5.2 shows that an increase in maximum temperature leads to a decrease in dry matter accumulation. Relative humidity showed positive correlation with the dry matter production *i.e.* an increased relative humidity enhanced the dry matter production of rice varieties.

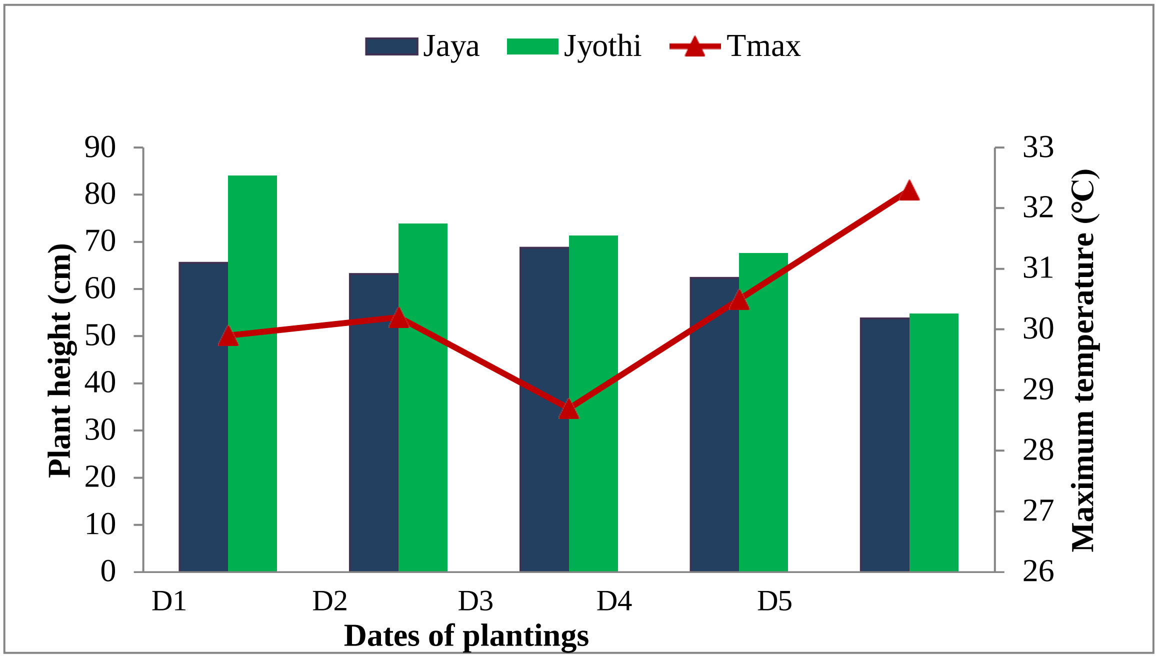


Fig 5.1. Impact of temperature on plant height during the vegetative phase

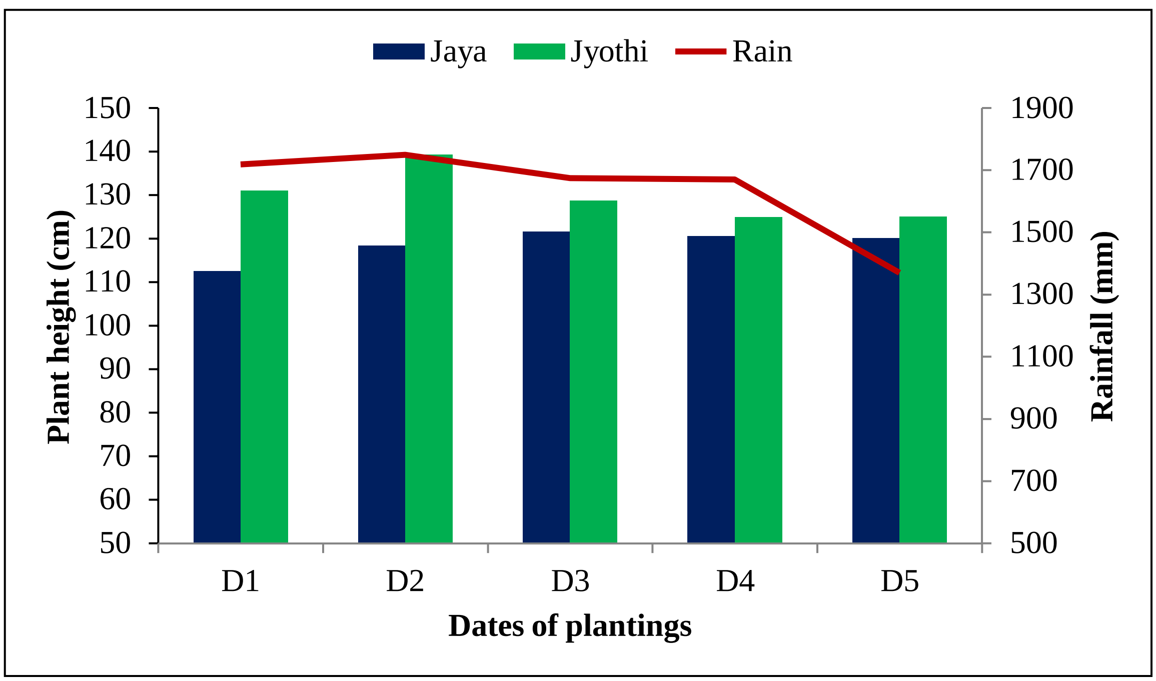


Fig 5.2. Impact of rainfall on plant height during the crop period

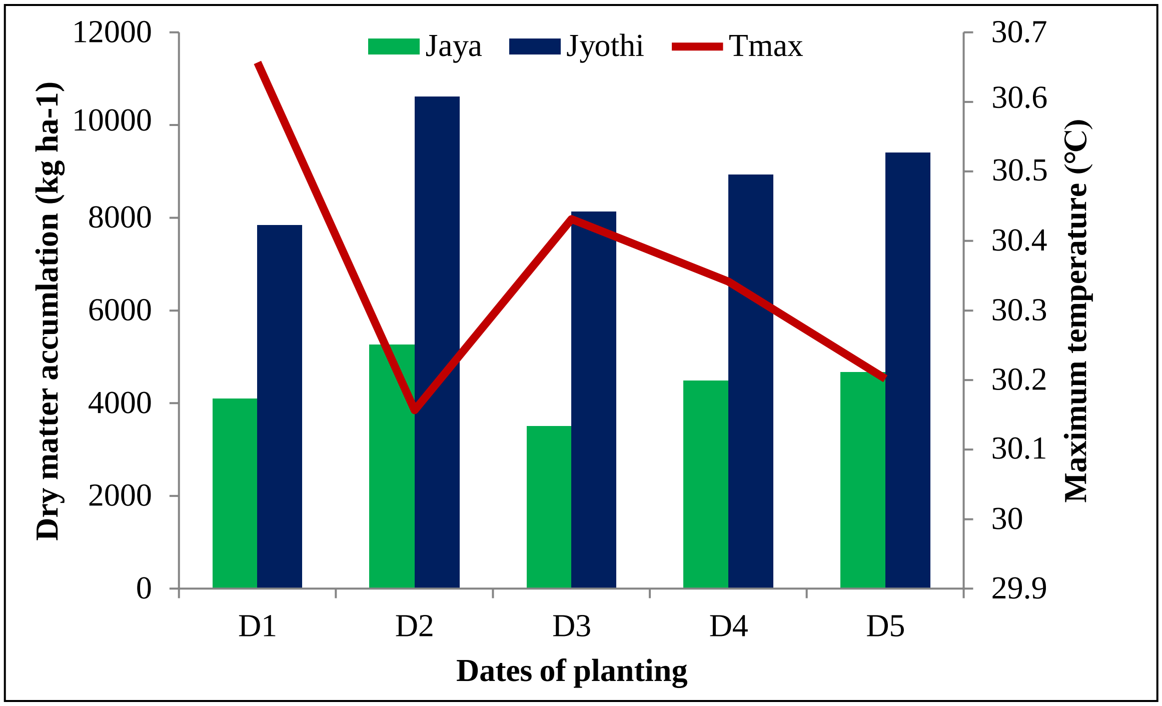


Fig. 5.3. Impact of maximum temperature on dry matter accumulation

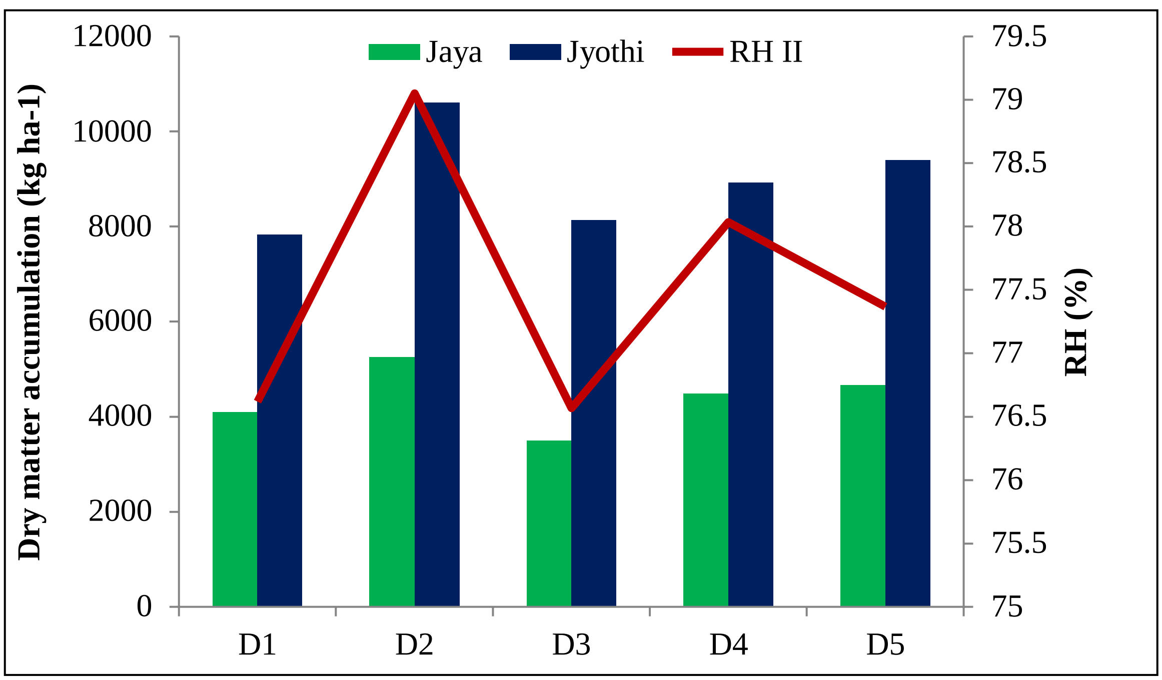


Fig. 5.4. Impact of relative humidity on dry matter accumulation

5.1.3. Number of filled grains

It was observed that rainfall during heading to 50% flowering had a negative correlation with number of filled grains. Figure 5.5 depicts the relationship between filled grains and rainfall received during heading to 50% flowering. Sreenivasan, 1985 reported that intense rainfall gave rise to blank florets that may be the reason for the reduced number of filled grains in rice with an increase in rainfall.

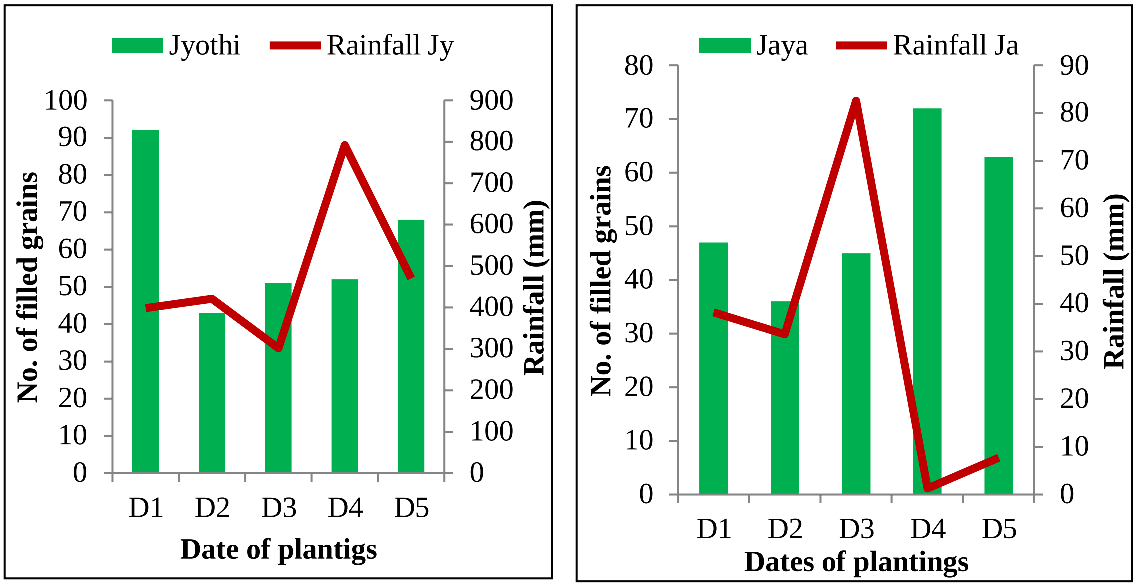


Fig. 5.5. Impact of rainfall on filled grains in Jyothi and Jaya

5.1.4. Grain yield

A reduction in rice yield was observed by Pradhan and Dixit, 1989 as a result of the combined effect of incessant rainfall and heavy wind.A similar condition was observed in during July 20th planting of Jyothi. Figure 5.6 shows the rainfall and wind speed that prevailed during 50 % flowering to physiological maturity. That may be the reason for the reduced yield during July 20th planting of Jyothi.

A detrimental effect was found between yield and number of rainy day during last phenophase of rice. Heavy rainfall events during this period had a significant negative impact on the grain yield (Narayanan, 2004). In this study also it was observed that rainfall during heading to 50% flowering had a negative correlation with yield (Figure 5.7).

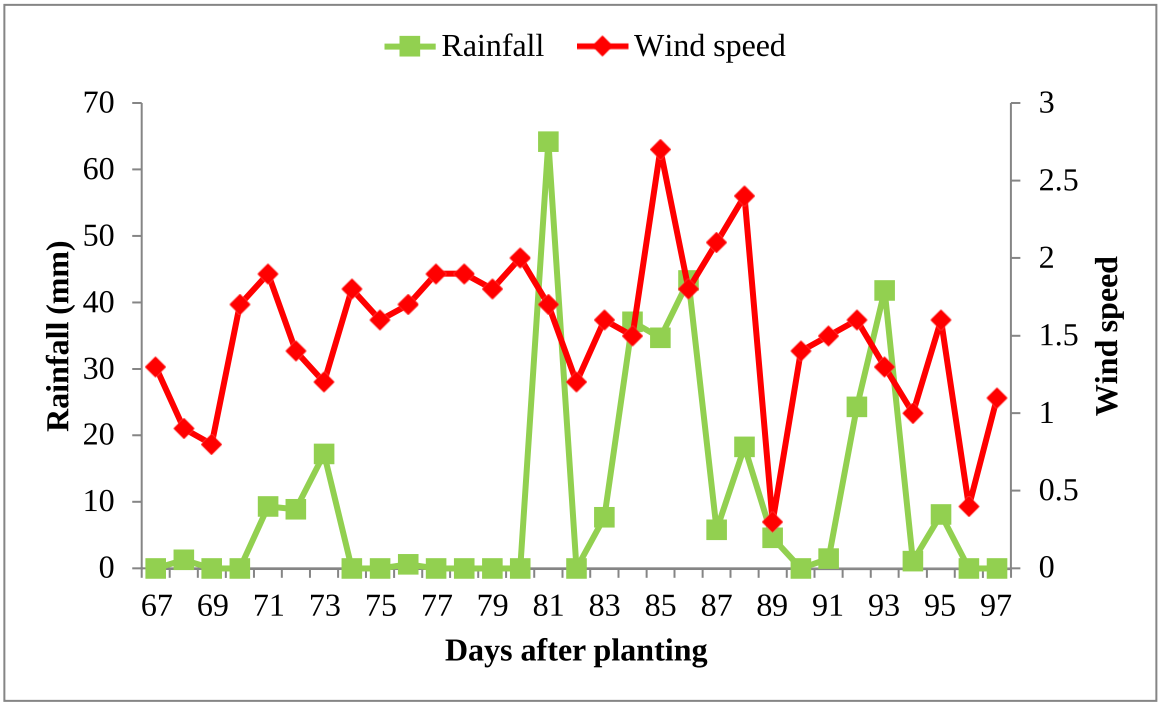


Fig. 5.6. Impact of rainfall and windspeed in July 20th planting of Jyothi

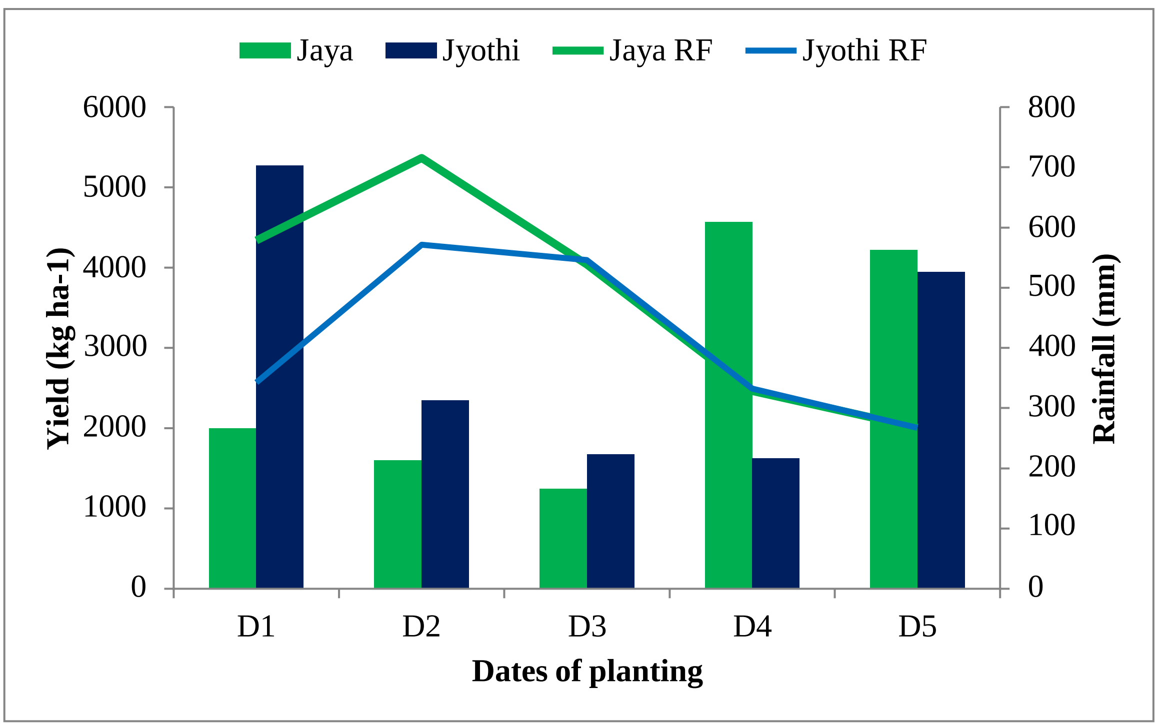


Fig. 5.7. Impact of rainfall on yield in Jyothi and Jaya

5.2 EFFECT OF WEATHER ON PHENOLOGY

Duration of rice varieties, Jaya and Jyothi was found to be different. Jaya is a medium duration while Jyothi is short duration crop. In Jaya the maximum duration was observed in July 20th planting and the duration of crop decreased towards the last planting. In Jyothi also similar result was observed. The duration of crop showed a negative correlation with maximum temperature.

The duration of transplanting to active tillering was found to be inversely proportional to the temperature (Figure 5.8). Decrease in temperature prolonged the days of tillering. This was found by Srideviand Chellamuthu**.** A parallel finding was observed in this study also. June 5th planting took less number of planting and July 20th planting took more number of days to reach active tillering. The maximum temperature was found to be higher in June 5th and lower in July 20th planting.

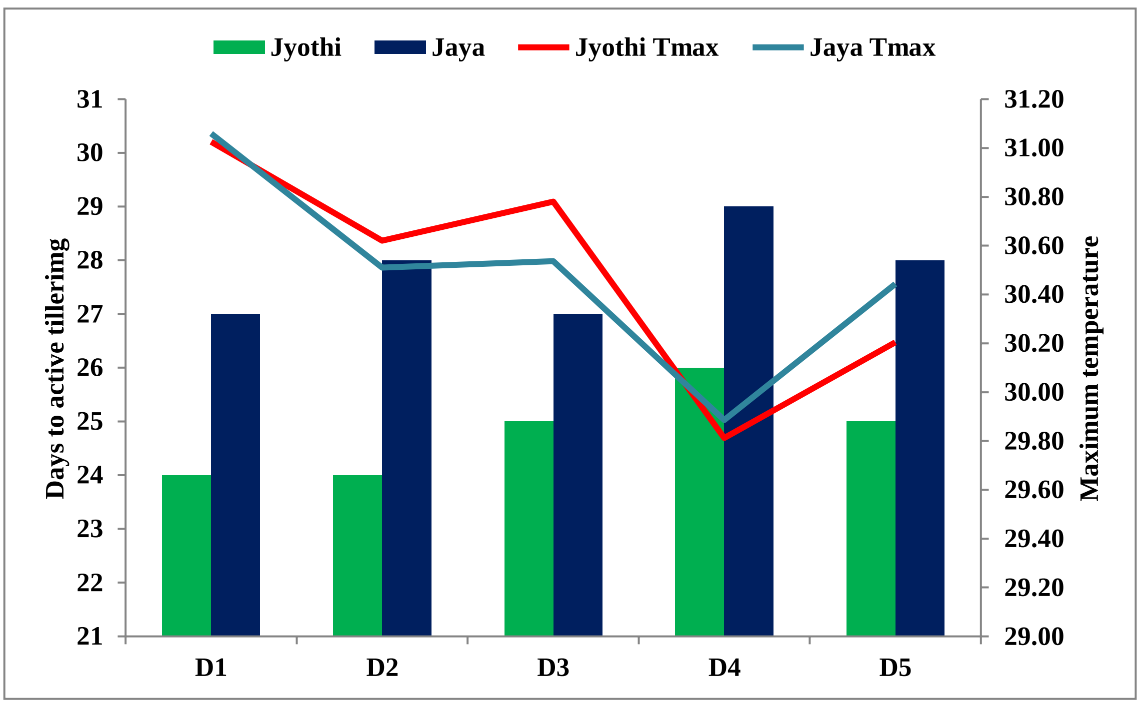


Fig. 5.8. Impact of temperature on duration of phenophase in Jyothi and Jaya

5.3. GROWTH INDICES

5.3.1. Leaf area index

Leaf area duration was observed maximum at 75 days after planting during all dates of planting. Leaf area index showed an increasing trend and then it decreased towards the end.Medhi *et al.* (2016) and Haritharaj (2019), reported a similar results. Sharma and Haloi (2001) stated that a decline in leaf area index towards the senescence. Figure 5.9 and 5.10 shows that there was reduction in leaf area index towards the senescence in both varities. Among both varieties leaf area was found to be higher in Jyothi than Jaya.

5.3.2. Leaf area duration

Maximum value of leaf area duration was observed during 75 days after planting in both varieties (Figure 5.11 and 5.12). Similar to leaf area index a reduction in leaf area duration was observed after 75 days after planting. The findings matched with Sadeghi and Bohrani (2001) Aswany (2016), Medhi *et al.* (2016) and Haritharaj (2019).

5.3.3. Crop growth rate

Crop growth rate of was found to be lower during the initial growth stages because reduced vegetative cover and light absorption. Later it increased and maximum crop growth rate was recorded during 45 -60 days after planting. After that a decline in crop growth rate was observed (Figure 5.13 and Figure 5.14). Due to increased leaf area index at 60- 75 days after planting lower leaves cannot absorb enough light. Hence the CGR decreases and becomes negative. In the report of Azarpour *et al.* (2014) a similar kind of observation was found. He also stated that a positive crop growth rate indicates an increased dry matter accumulation and reduction in the dry matter accumulation leads to a negative crop growth rate.

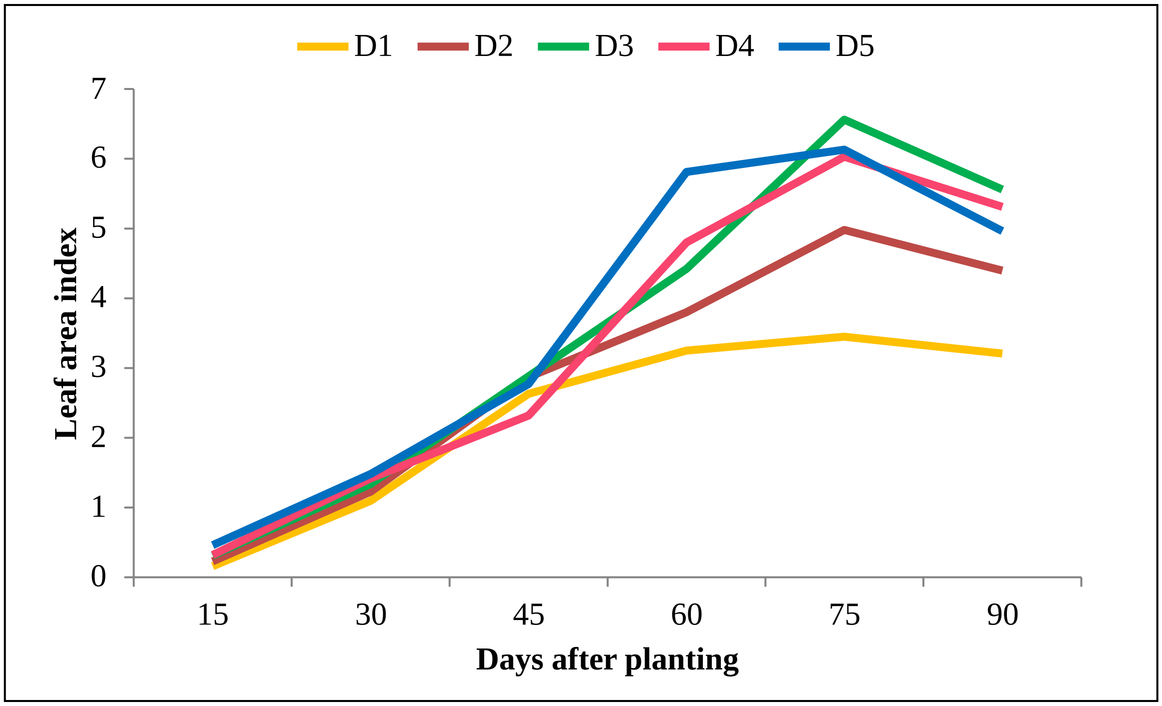


Fig. 5.9. Leaf area index of Jyothi

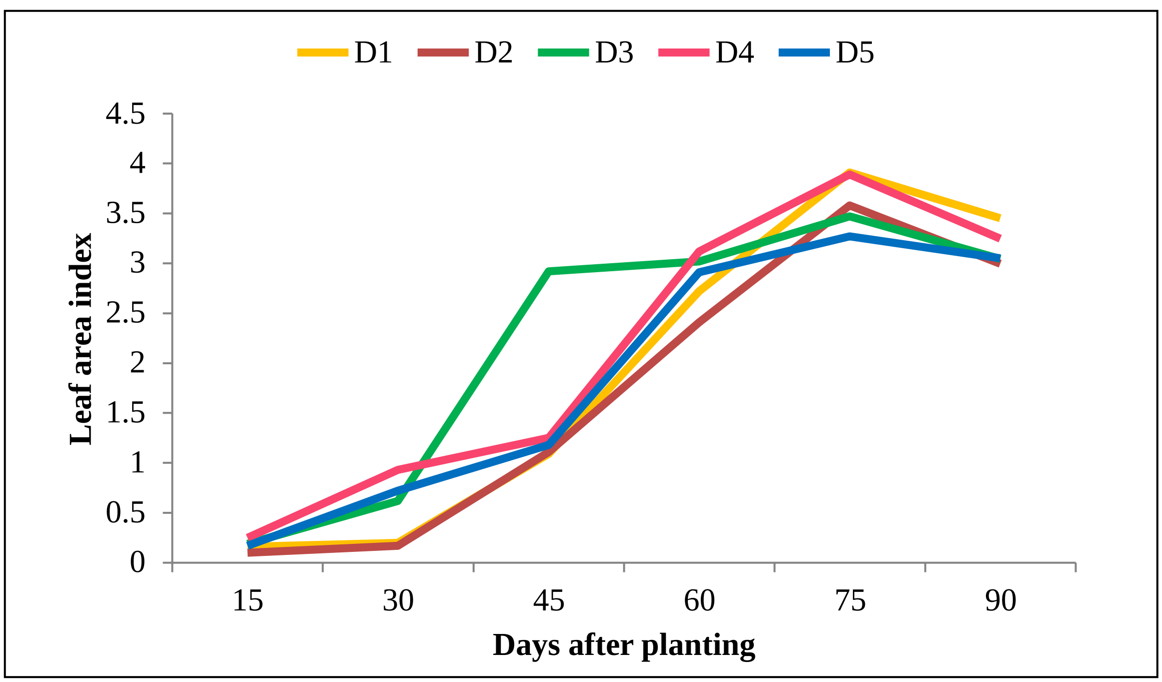


Fig 5.10. Leaf area index of Jaya

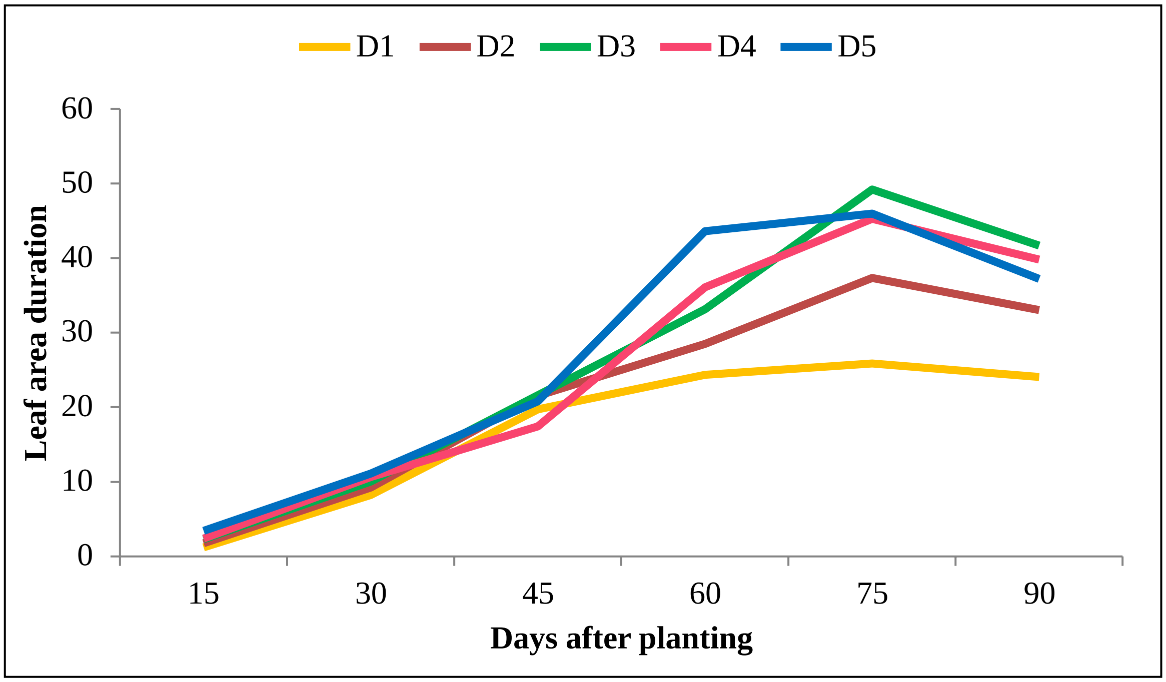


Fig 5.11. Leaf area duration of Jyothi

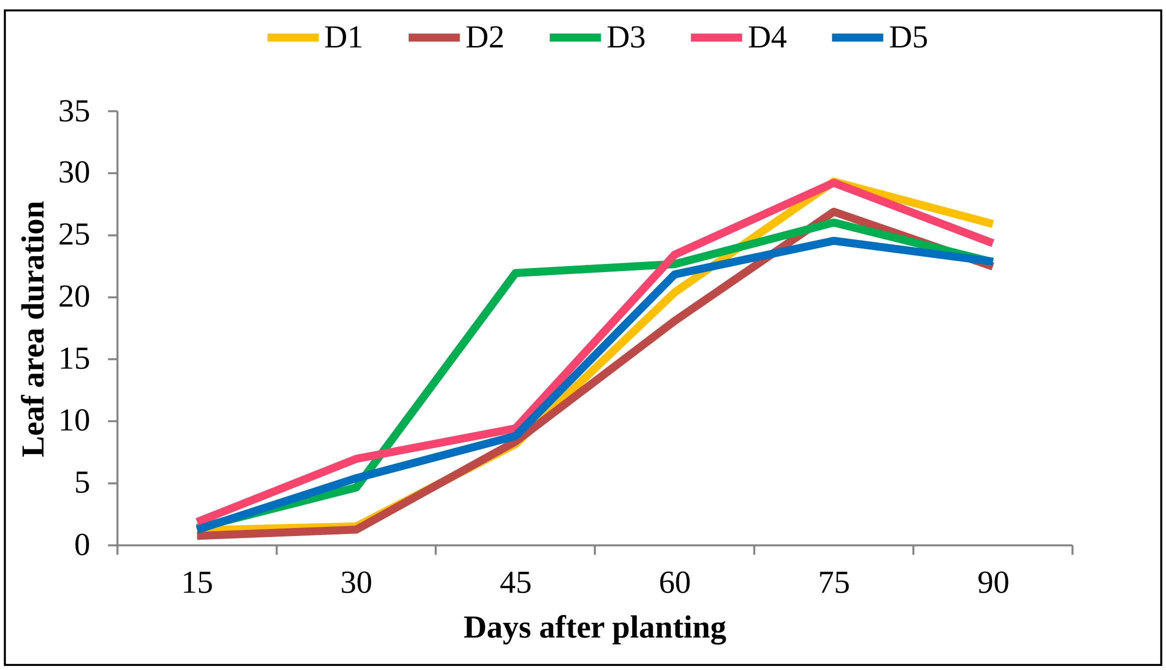


Fig 5.12. Leaf area duration of Jaya

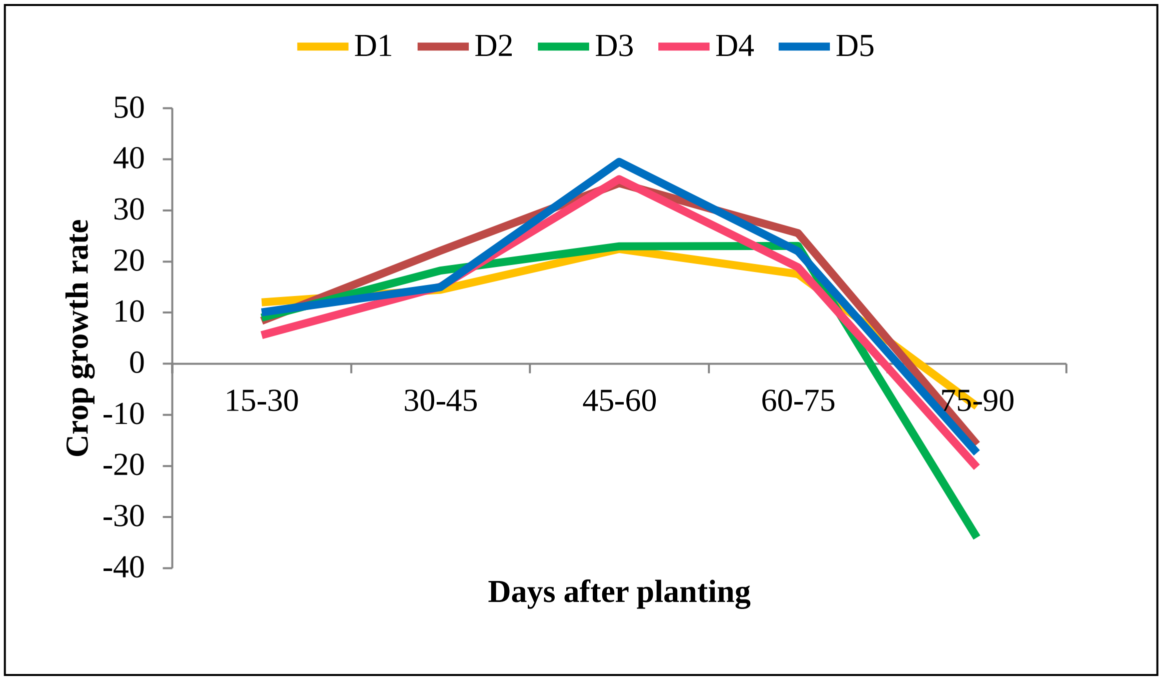


Fig. 5.13. Crop growth rate of Jyothi

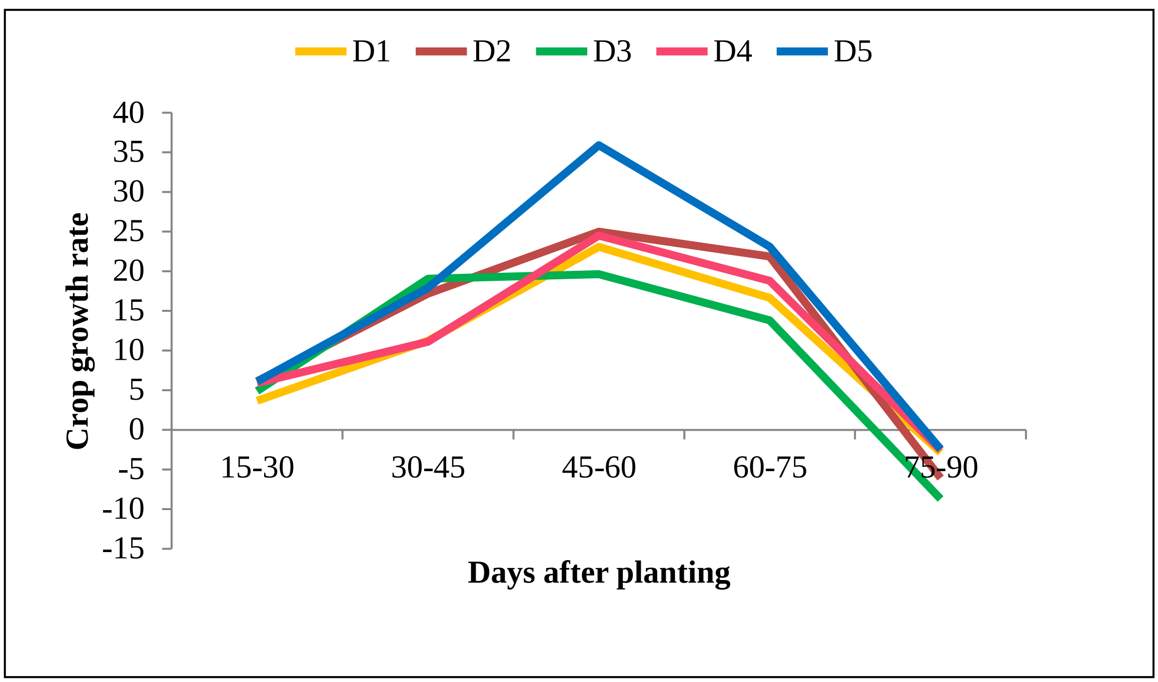


Fig. 5.14. Crop growth rate of Jaya

5.4 CERES RICE MODEL

DSSAT – CERES model has been used in this study. The model simulated the number of days to reach panicle initiation, anthesis and physiological maturity along with yield. These simulated data was compared with the observed yield. The performance of the model has been determined using RMSE (Root Mean Square Error) value and D stat index. Willmott, (1982) reported that a performance of a model is said to be good when its D stat index value is near to unity and RMSE value near to zero.

5.4.1 Simulation of Grain yield

The model predicted the grain yield of Jaya with a D stat value of 0.502 and RMSE value of 1612.52. In case Jyothi the model predicted the grain yield with D stat value of 0.505 and RMSE value of 1807.474. Table 5.1. shows the observed and simulated yield in each date of planting.

Table.5.1. Observed and simulated yield for Jaya and Jyothi

Variety		D1	D2	D3	D4	D5
Jyothi	Observed	5275	2350	1675	1625	3950
	Simulated	4393	4449	4208	3658	4238
Jaya	Observed	2000	1600	1245	4575	4225
	Simulated	3306	3702	3666	3701	3723

5.4.2 Simulation of Phenology

The model simulated the days to panicle initiation, anthesis and physiological maturity. In Jaya the days to panicle initiation was predicted with a D – stat value of 0.480 and RMSE value 3.286. Days to anthesis was predicted with a D- stat value of 0.390 and RMSE value of 4.539. Days to physiological maturity was predicted with a D- stat value of 0.416 and RMSE value of 5.329. In Jyothi, the days to panicle initiation, anthesis and physiological maturity has been predicted with a D- stat value of 0.775, 2.049 and 2.236 respectively and RMSE value of 4.539, 3.286 and 5.329 respectively.

Table.5.2. Observed and simulated phenophase for Jaya and Jyothi

Variety	Phenophases	Observed	Simulated	RMSE	d-Stat
Jaya	Anthesis	71	75	4.539	0.390
	Panicle initiation	38	41	3.286	0.480
	Physiological maturity	110	109	5.329	0.416
Jyothi	Anthesis	66	66	0.775	0.59
	Panicle initiation	34	33	2.049	0.425
	Physiological maturity	100	100	2.236	0.152

5.5. CLIMATE CHANGE STUDIES

In order to assess the change in the future climate of Kerala the current climate (1980 – 2020) was evaluated against the simulated weather data obtained from Mark Sim GCM-DSSAT weather file generator using the climate model GFDL CM3. The current climate (1980 – 2020) has been compared with three different future 2010-2030 (near-century), 2021-2050(mid-century), and 2051-2080 (end of century) simulations for the 14 districts of Kerala which has been divided into five agro-climatic zones *i.e.* northern zone, central zone, high range zone, problematic zone, and southern zone under RCP 4.5 and 8.5. The Annual and seasonal changes in weather parameters (solar radiation, maximum temperature, minimum temperature and rainfall) have been discussed.

5.5.1 Solar radiation

Annual and seasonal variation ofsolar radiation in different zones of Kerala has been discussed here.Table 5.3 shows the classification of departure of solar radiation from the normal.

Table 5.3.Classification of departure of solar radiation from normal

	>2MJ/m^{-2}	Markedly above normal
	1to 2 MJ/m^{-2}	Above normal
	-1to 1 MJ/m^{-2}	Normal
	-2 to -1 MJ/m^{-2}	Below normal
	< -2	Markedly below normal

5.5.1.1. Annual

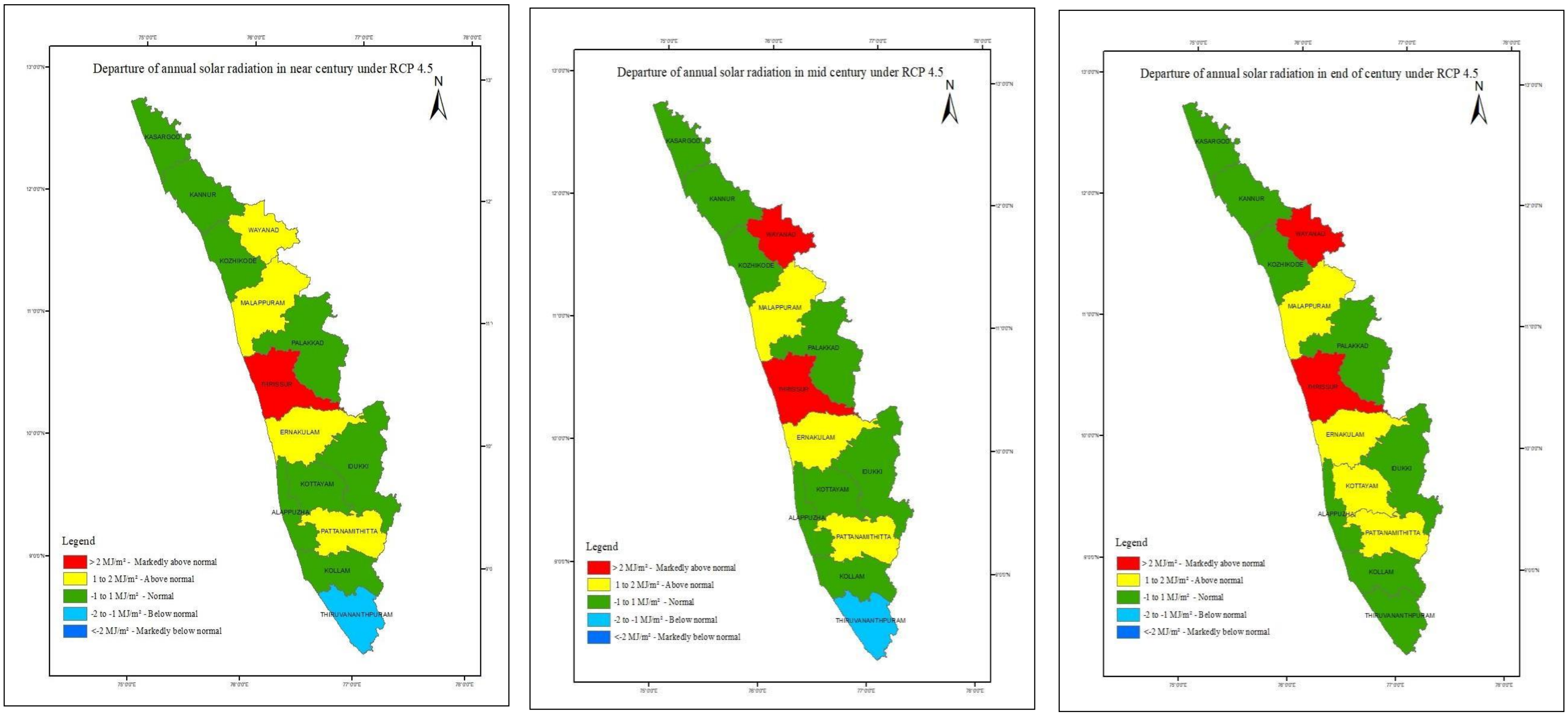
Departure of annual solar radiation under RCP 4.5 and 8.5 is shown in Figure 5.15 and 5.16. Under RCP 4.5 in near century solar radiation is expected to be normal in northern zone of Kerala except in Malappuram district where an above normal increase in solar radiation is expected. In central zone of Kerala an increase in solar radiation is expected. In Palakkad the departure was found to be normal, in Ernakulam it was found to be above normal and in Thrissur it was found to be markedly above normal. In high range zone the solar deviation showed an above normal departure from normal in Wayanad, while the departure was found to be normal in Idukki. In problematic zone also a normal departure was found. In southern zone solar radiation showed a wide variability. In Pathanamthitta an above normal increase in solar radiation is expected. Kollam showed a normal departure from normal while Thirivanathapuram showed a below normal departure from normal. In mid century the departure was similar to near century expect in Wayanad where the solar radiation showed a markedly above normal increase in solar radiation. In the end of century the departure was similar to the mid century but in Kottayam district an above normal increase in solar radiation is expected.

Under RCP 8.5 also in near century solar radiation is expected to be normal in northern zone of Kerala except in Malappuram district where an above normal increase in solar radiation is expected.In central zone of Kerala an increase in solar radiation is expected. In Palakkad the departure was found to be normal, in Ernakulam it was found to be above normal and in Thrissur it was found to be markedly above normal. In high range zone Wayanad showed a markedly above normal increase in solar radiation and in Idukki a normal departure is expected. In problematic zone Kottayam showed an above normal increase in solar radiation and in Alappuzha it was found to be normal. In southern zone of Kerala a normal departure of solar radiation is expected in near century. In mid century the departure was found to be normal in problematic zone while in other zones departure was found to be similar to be in near century. By the end of century the solar radiation showed a normal departure in almost all parts of Kerala except in Thrissur,Wayanad and Palakkad. In Thirssur and Wayanad an above normal increase in solar radiation is expected and in Palakkad a below normal departure of solar radiation is expected by the end of century.

5.5.1.2. Southwest monsoon season

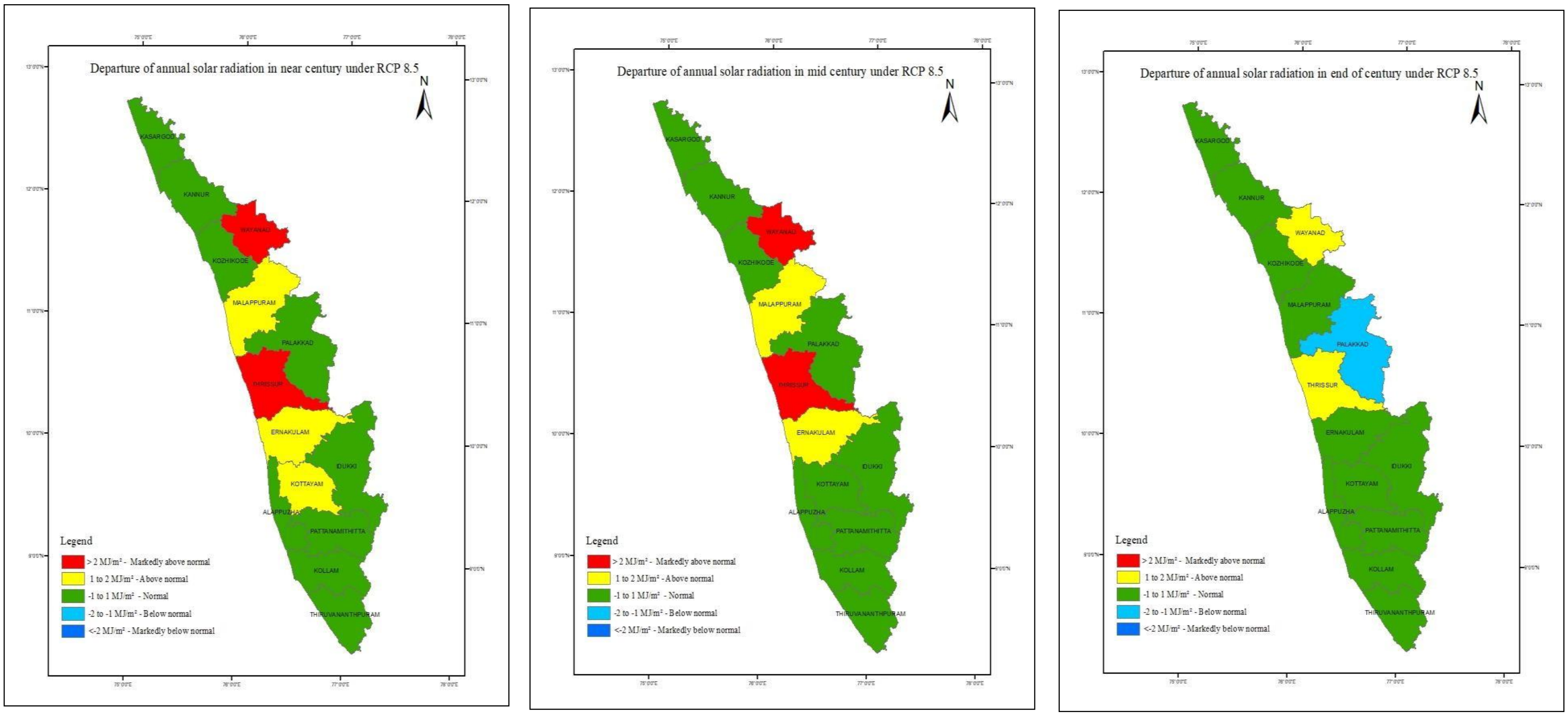
Departure of solar radiation during southwest monsoon under RCP 4.5 in near century showed a normal departure in the northern zone except in Malappuram district where a markedly above normal increase in solar radiation. In central zone there was no common trend it varied in different places. In Palakkad markedly above increase in solar radiation is expected while in Thrissur a normal departure is expected. In Ernakulam the solar radiation showed a negative departure. In high range zone below normal departure of solar radiation is expected in Wayanad and below normal departure in Idukki. In problematic zone the solar radiation showed markedly above normal departure of solar radiation. In southern zone solar radiation showed an above normal increase in solar radiation except in Thiruvananthapuram where the solar radiation is expected to be normal. In mid century the solar radiation showed an above normal departure in northern zone except in Kannur where the solar radiation is expected to be below normal. In Palakkad markedly above increase in solar radiation is expected while in Thrissur a above normal departure is expected. In Ernakulam the solar radiation showed a below normal departure.In high range zone above normal departure of solar radiation is expected. In problematic zone markedly above normal departure of solar radiation is expectedIn southern zone solar radiation showed an above normal increase in solar radiation except in Thiruvananthapuram where the solar radiation is expected to be below normal. By the end of century the solar radiation is expected to be normal in most parts of Kerala except in Palakkad and Malappuram where the solar radiation is expected to be above normal. In problematic zone of Kerala the solar radiation is expected to increase markedly above normal by the end of century (5.17).

In northern zone under RCP 8.5 except Malappuram all other districts showed a normal departure of solar radiation. In central zone, Palakkad showed above increase in solar radiation while in Thrissur a normal departure is expected. In Ernakulam the solar radiation showed a below normal departure. In high range zone below normal departure of solar radiation is expected in Wayanad and below normal departure in Idukki. In problematic zone the solar radiation is expected to increase markedly above normal. In southern zone of Kerala a normal departure of solar radiation is expected in near century. In the mid century solar radiation showed a similar trend which was observed in near



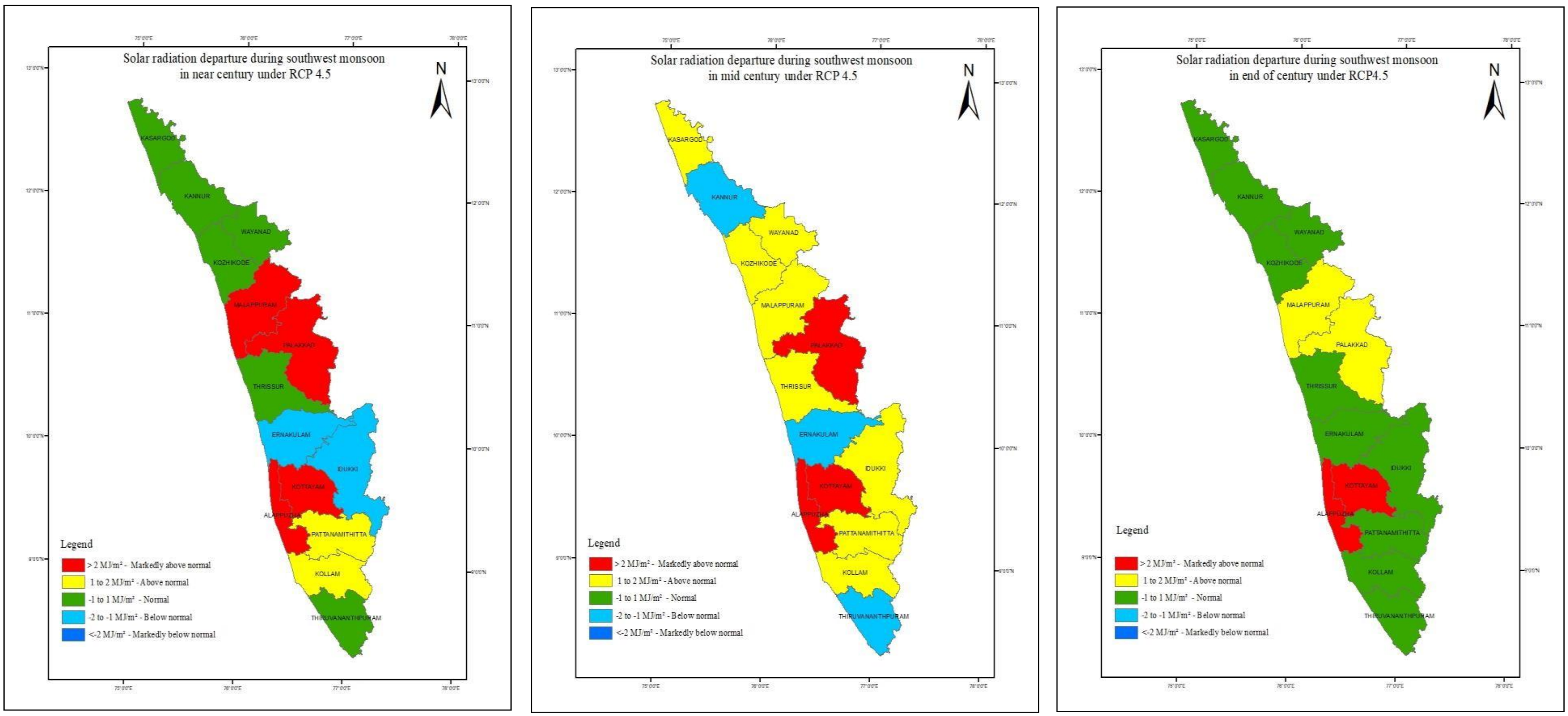
(a) (b) (c)

Fig. 5.15. Departure of annual solar radiation from normal under RCP 8.5 (a) near century (b) mid century (c) end of century



(a) (b) (c)

Fig. 5.16. Departure of annual solar radiation from normal under RCP 8.5 (a) near century (b) mid century (c) end of century



(a) (b) (c)

Fig. 5.17. Departure of solar radiation from normal during southwest monsoon under RCP 4.5 (a) near century (b) mid century (c) end of century

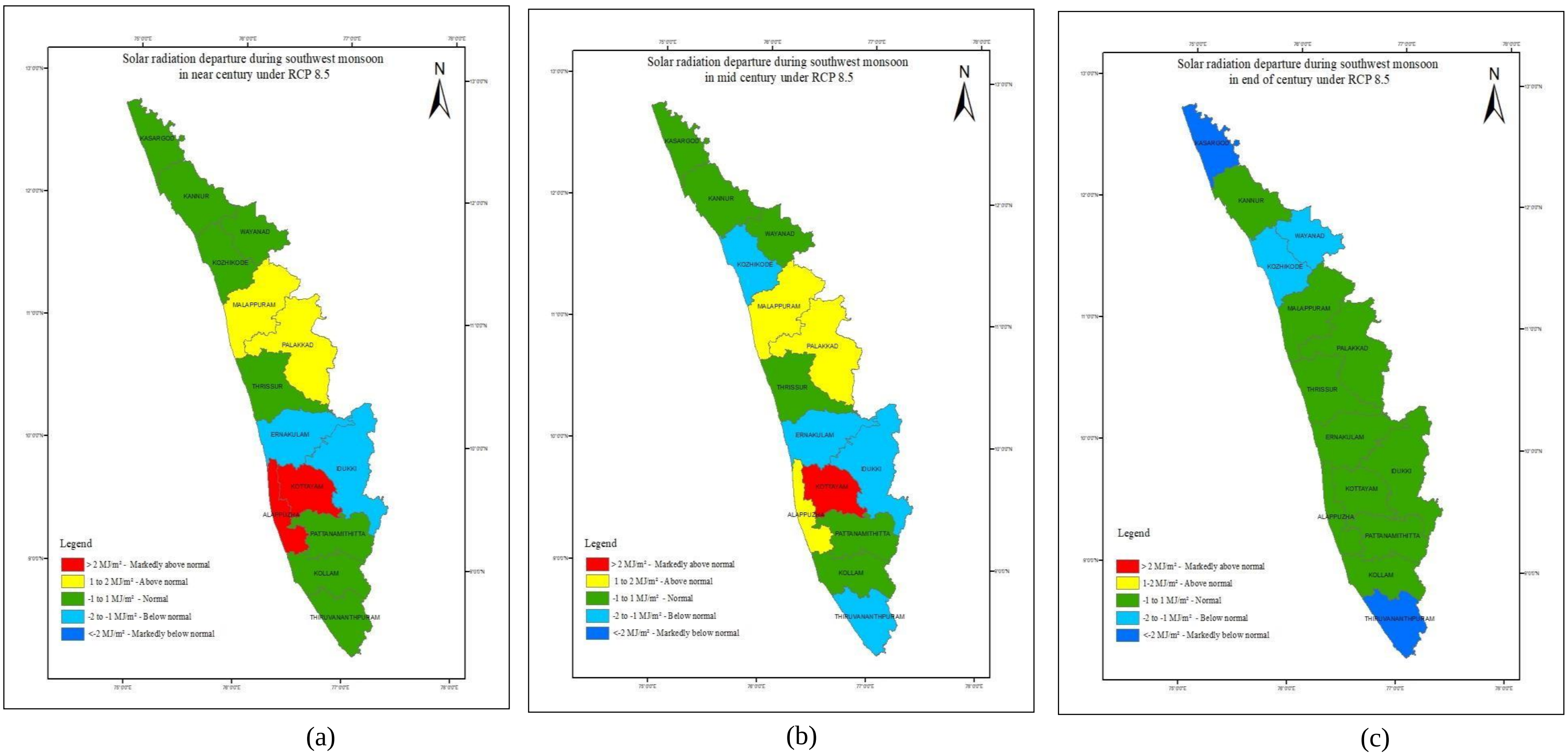


Fig. 5.18. Departure of solar radiation from normal during southwest monsoon under RCP 8.5 (a) near century (b) mid century (c) end of century

century expect the districts like Kozhikode, Thiruvanthapuram (where the solar radiation is expected show a below normal departure) and Alappuzha where it showed an above normal departure. In the end of century normal departure is expected in most parts of Kerala except in Kozhikode, Wayanad, Thiruvananthapura and Kasargod where there is a decrease in solar radiation (Fig. 5.18).

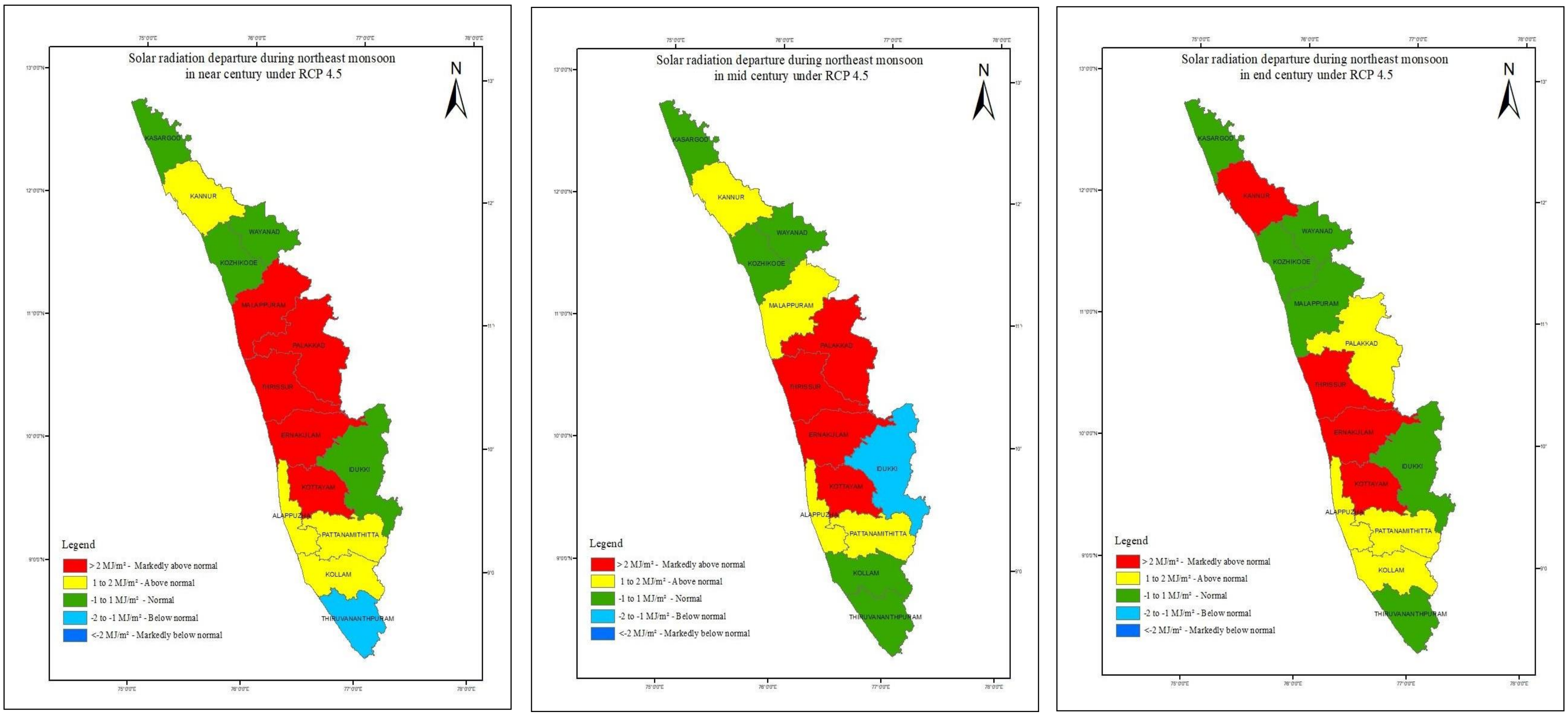
5.5.1.3. Northeast monsoon season

Departure of solar radiation from normal during northeast monsoon under RCP 4.5 and 8.5 is shown in Figure 5.19 and 5.20. Under RCP 4.5 solar radiation showed an increase in most places in all the future simulations. In the near century in northern zone of Kerala, districts like Kasargod, Kozhikode showed a normal departure. At the same time in Kannur and Malappuram an above normal and markedly above normal increase in solar radiation is expected respectively. In central zone of Kerala a markedly above normal increase in solar radiation is expected. In high ranges Wayanad and Idukki showed a normal departure in the near century. In the problematic zone solar radiation showed an above normal increase in Alappuzha and markedly above normal in Kottayam district. In southern zone of Kerala an above normal departure is expected except in Thiruvananthpuram where there is a below normal departure of solar radiation. In the mid century in the northern zone of Kerala Kasargod, Kozhikode showed a normal departure while in Kannur and Malappuram an above normal increase in solar radiation is expected. In central zone and problematic zone the departure was similar to that of in near century. In high ranges departure was found to be normal in Wayanad and below normal in Idukki. In southern zone was found to be normal departure except in Pathanamthitta, where an above normal increase in solar radiation is observed. By the end of century the solar radiation expected to increase in most parts of Kerala. In northern zone a normal departure is expected except in Kannur which showed a markedly above normal increase in solar radiation. In central and problematic zone also markedly above normal increase in solar radiation is observed except in Palakkad and Alappuzha where an above normal increase is expected. . In southern zone of Kerala an above normal departure is expected except in Thiruvananthpuram where there is a normal departure of solar radiation.

Under RCP 8.5 in near century, northern zone showed a normal departure of solar radiation except in Malappuram. In central zone of Kerala markedly above normal increase in solar radiation was observed. In high range zone Wayanad showed a normaldeparture in solar radiation while Idukki showed a below normal increase in solar radiation. In problematic zone markedly above normal departure in solar radiation is expected in Kottayam and above normal departure in Alappuzha. In the southern zone of Kerala Kollam and Pathanamthitta showed a normal departure while Thiruvananthpuram showed a below normal departure in solar radiation. In the mid century solar radiation in northern zone of Kerala showed a below normal departure in districts like Kasargod and Kozhikode and above normal in Kannur and Malappuram. In central zone a markedly above normal increase in solar radiation is expectedand an above normal is expected in Palakkad. In high ranges, problematic zone, and southern zone the departure was found to be similar to that of in near century. By the end of century departure was found be normal in most places with few exceptions. Kannur and Kottayam showed an above normal increase in solar radiation. Kozhikode and Thiruvanthpuram showed a markedly below normal departure in solar radiation.

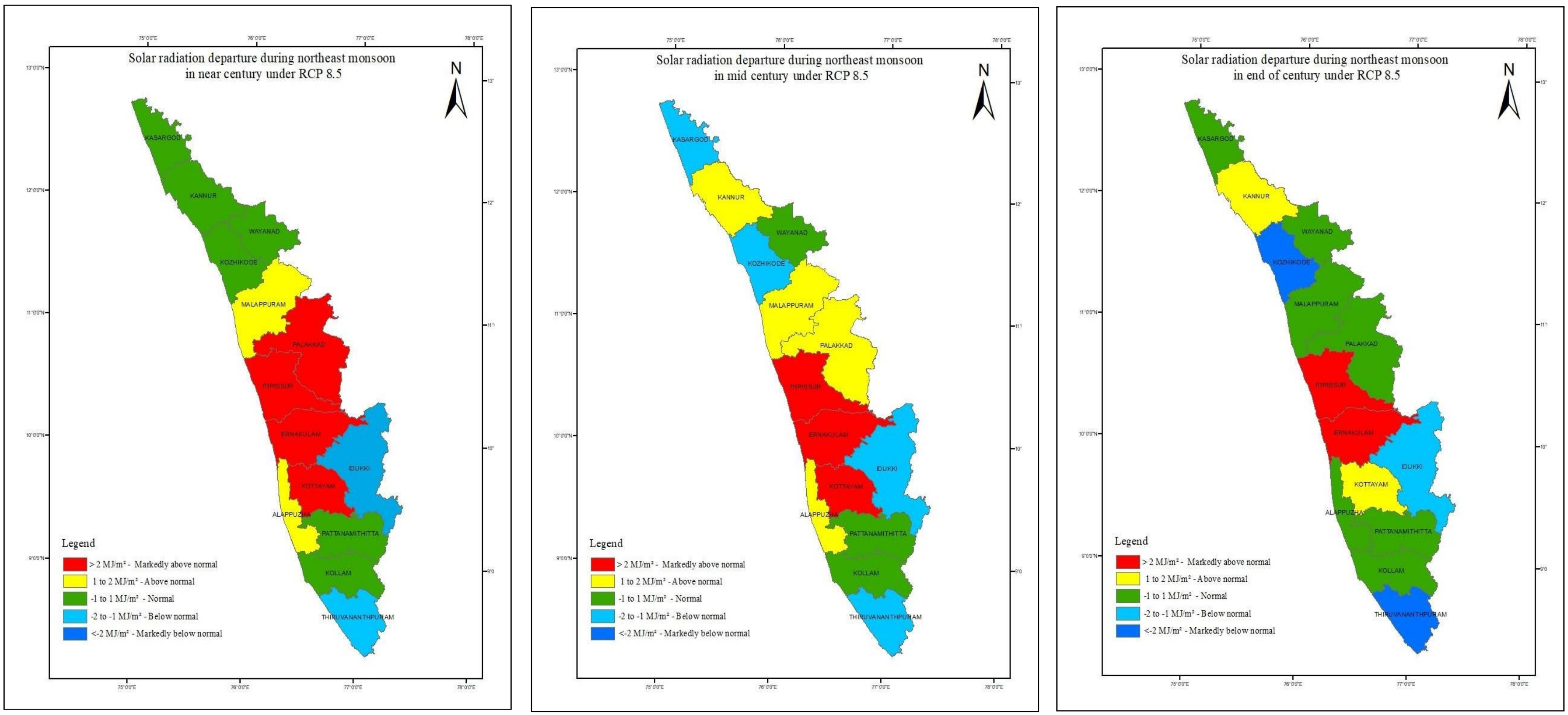
5.5.1.4. Winter season

Under RCP 4.5 solar radiation in northern zone of Kerala shows a normal departure in near century, mid century and the end of century with few exceptions. In near century Kozhikode shows an above normal departure while Malappuram showed a markedly above normal in solar radiation. In mid century Malappuram district showed an above normal increase in solar radiation. Central zone of Kerala showed a markedly above normal increase in solar radiation during all future simulations except in Palakkad district where the solar radiation is expected to show an above normal departure from normal. In high range zone an normal deviation is expected in near and mid century. By the end of century in Idukki an above normal departure has been expected. In problematic zone solar radiation is expected to show an above normal departure in near and mid century. During the end century Kottayam showed a markedly above normal increase in solar radiation. In southern zone of Kerala Kollam, Pathanamthitta showed an above normal increase in solar radiation



(a) (b) (c)

Fig.5.19. Departure of solar radiation from normal during northeast monsoon under RCP 4.5 (a) near century (b) mid century (c) end of century



(a) (b) (c)

Fig. 5.20. Departure of solar radiation from normal during northeast monsoon under RCP 8.5 (a) near century (b) mid century (c) end of century

and in Thiruvananthpuram a normal departure has nbeen observed. Kollam showed a markedly above normal increase in solar radiation in mid and end of century. Pathanamthitta showed an above normal and markedly above normal in mid and end of century respectively. In Thiruvananthapuram below normal departure od solar radiation has been expected (Fig. 5.21) .

Under RCP 8.5 in northern zone of Kerala a normal departure in solar radiation is expected in near and mid century with an exception of Malappuram in near century with an above normal departure. By the end of century there is reduction in solar radiation in northern zone of Kerala. In the central zone of Kerala a markedly above normal increase in solar radiation is observed in near century. In mid century Palakkad and Ernakulam showed an above normal increase in solar radiation. By the end of century Palakkad and Ernakulam showed a normal departure while Thrissur showed an above normal increase in solar radiation. In high range zone a normal departure has been expected in near century. While in mid and end century a below normal departure has been found in Wayanad.In problematic zone in near and mid century there is an above average departure in solar radiation and by the end of century solar radiation is expected to increase by markedly above normal departure. In southern zone of Kerala in Thiruvananthapuram a below normal departure of solar radiation is expected during all the future simulations. In Kollam and Pathanamthitta an above normal departure is expected in near century and markedly above normal departure in mid century. By the end of century in Pathanamthitta district an above normal increase and in Kollam markedly above normal increase in solar radiation is expected (Fig.5.22).

5.5.1.5. Summer season

Under RCP 4.5 in northern zone of Kerala Kasargod, Kannur showed a normal departure while in Kozhikode an above normal and in Malappuram markedly above normal increase in solar radiation has been observed in near century. In mid and end of century the solar radiation showed a normal departure except in Malappuram district where the solar radiation was expected to increase above normal. In central zone of Kerala a markedly above normal increasein solar radiation has been expected in near and mid century. By the end of century in Palakkad an above normal increase in solar radiation is expected. In high range zone a normal departure has been expected in near and mid century. While end century an above normal departure has been found in Idukki. In problematic zone markedly above normal departure has been expected in near century and above normal departure in the mid century. By the end of century in Kottyam markedly above normal departure has been expected and in Alappuzhaabove normal departurehas been expected. In southern zone of Kerala Pathanamthitta showed an above normal departure and Kollam showed an markedly above normal increase in solar radiation in all the future simulations. In Thiruvananthapuram a normal departure has been expected in near century and a below normal departure has been expected in mid and end of the century (Fig.5.23).

Under RCP 8.5 in northern zone of Kerala a normal departure of solar radiation has been expected except in Malappuram where an above normal increase in solar radiation is expected in near and mid century. By the end of century a below normal deviation in solar radiation has been observed. In central zone of Kerala in near century a markedly above normal departure has been observed in near century. It continued to be the same in Thissur while in Palakkad and Ernakulam it showed an decreasing trend in mid and late century.In high range zone a normal departure has been expected in near century. While in mid and end century a below normal departure has been found in Wayanad. In problematic zone in near and mid century there is an above average departure in solar radiation in near, mid and end of century. In southern zone a nomal departure has been predicted in Pathanamthitta in near and mid century and by the end of century an above average increase has been expected. In Kollam in all the future simulations the solar radiation was found to be markedly above normal. While in Thiruvananthapuram a decreasing trend in solar radiation has been observed in near mid and end of century (Fig.5.24).

5.5.2. Maximum temperature

Annual and seasonal variation of solar radiation in different zones of Kerala has been discussed here. Table 5.4 shows the classification of departure of temperatures from the normal.

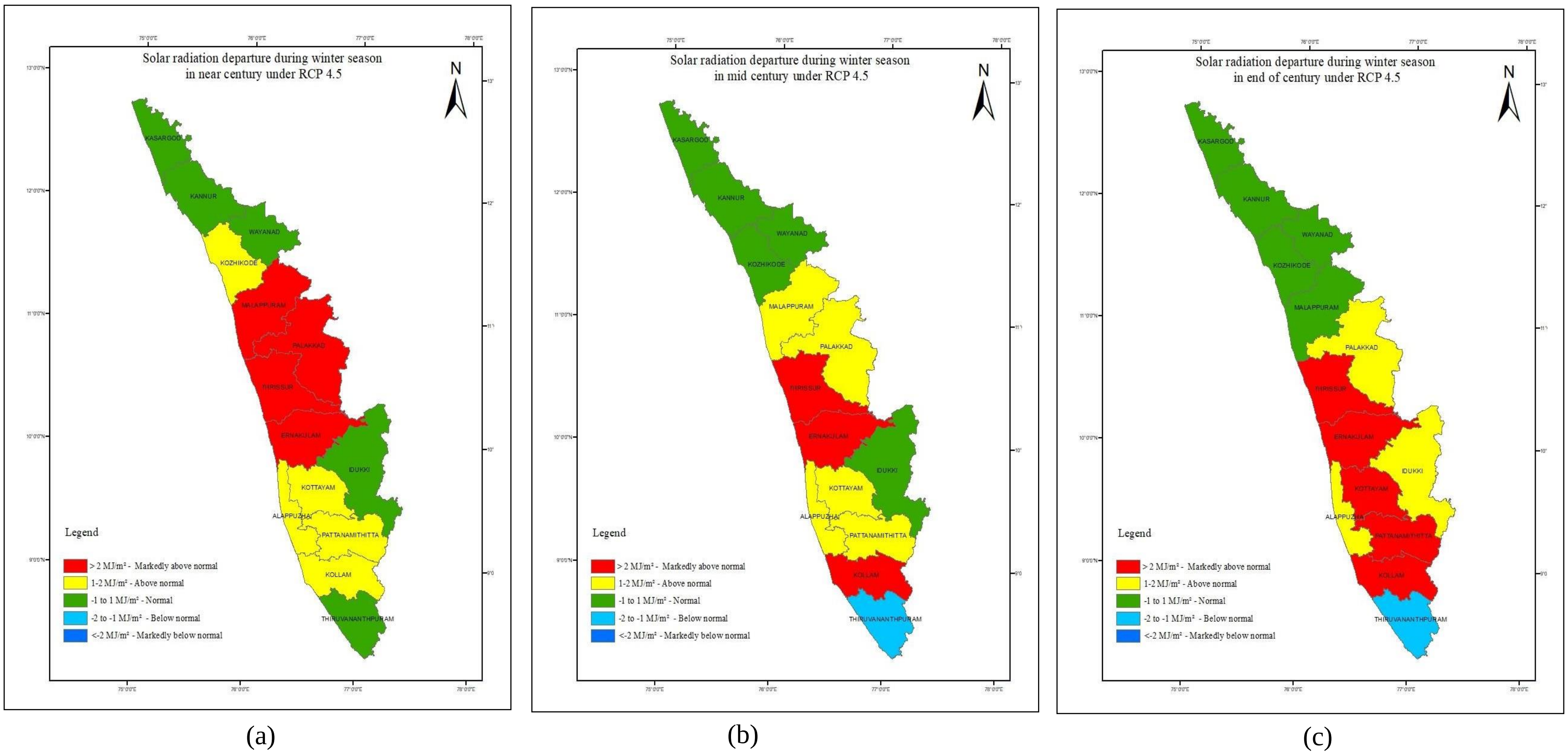
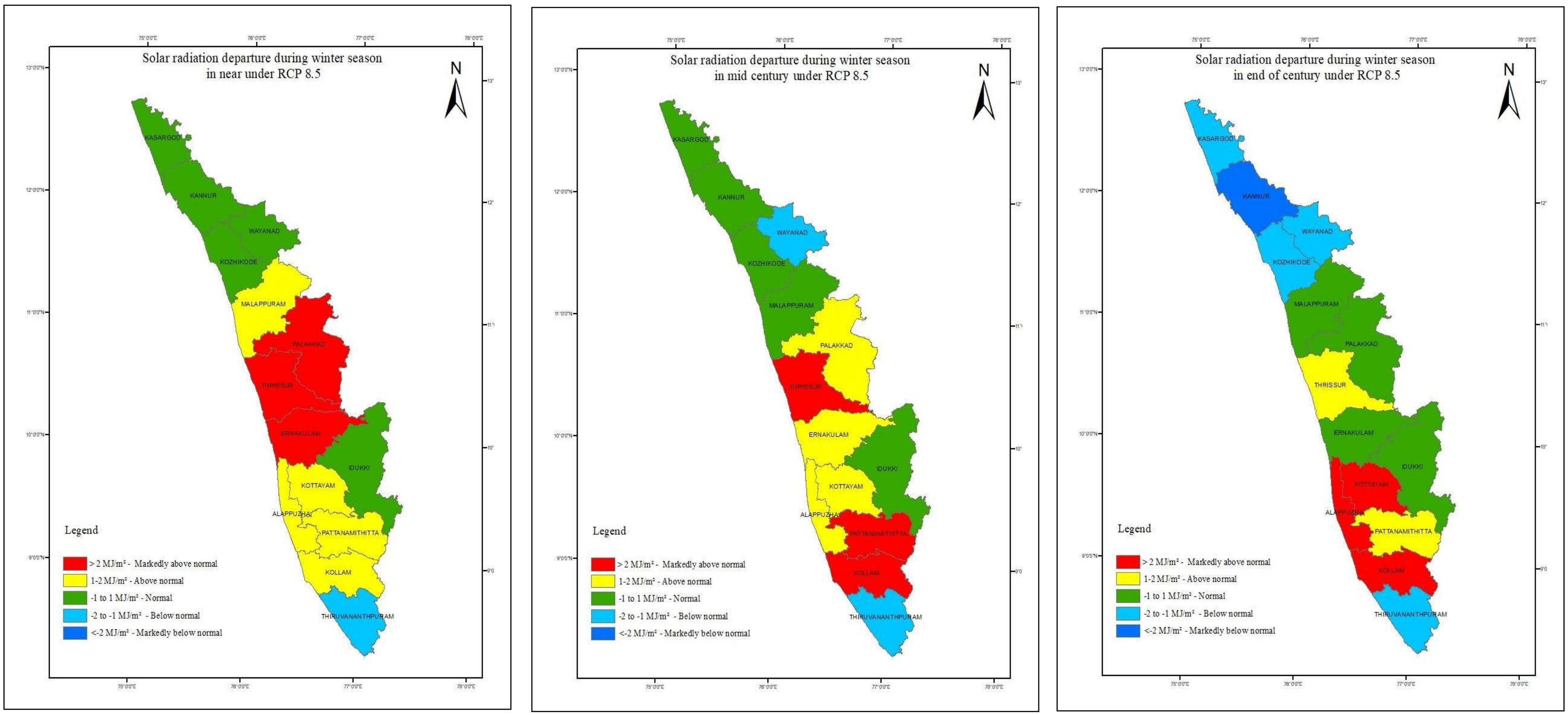
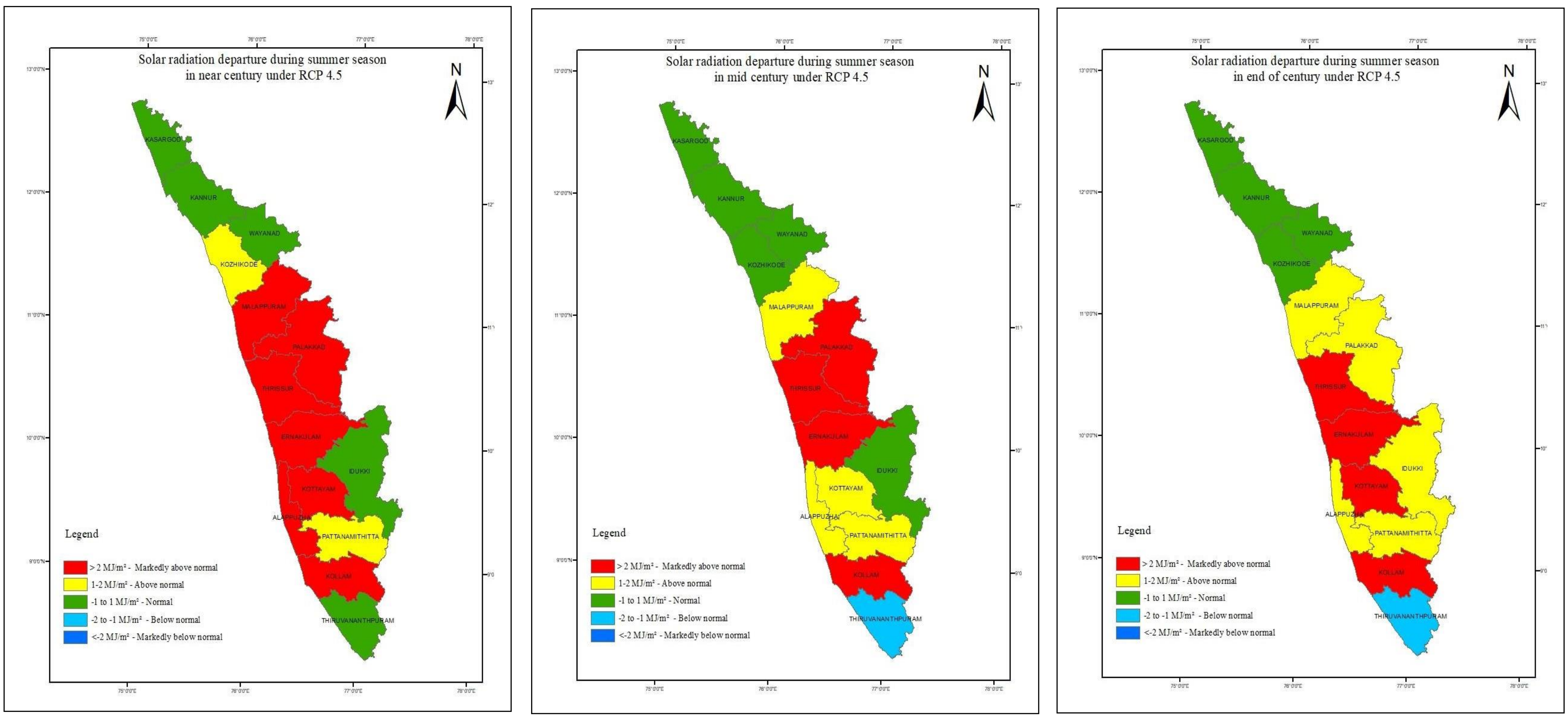


Fig. 5.21. Departure of solar radiation from normal during winter season under RCP 4.5 (a) near century (b) mid century (c) end of century



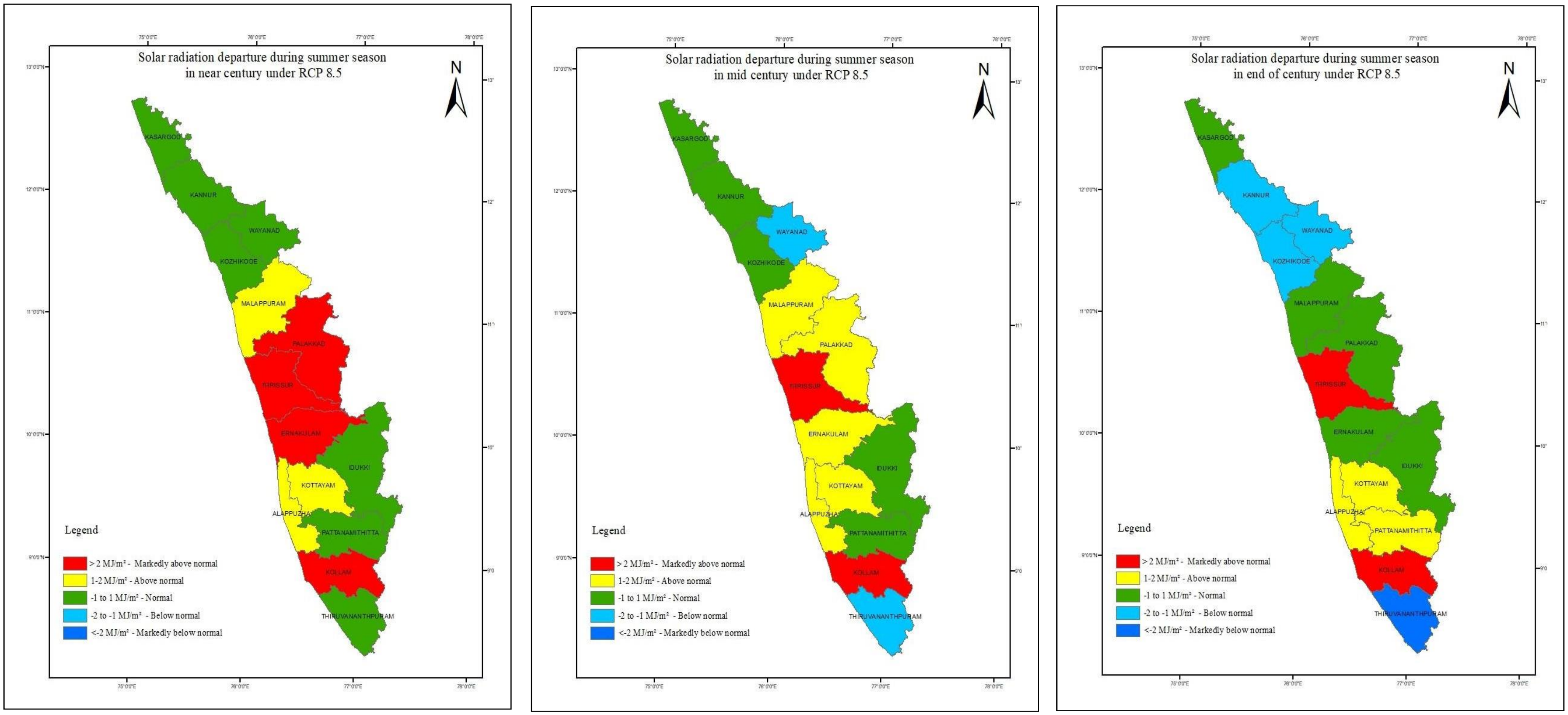
(a) (b) (c)

Fig. 5.22. Departure of solar radiation from normal during winter season under RCP 8.5 (a) near century (b) mid century (c) end of century



(a) (b) (c)

Fig. 5.23. Departure of solar radiation from normal during summer season under RCP 4.5 (a) near century (b) mid century (c) end of century



(a) (b) (c)

Fig. 5.24. Departure of solar radiation from normal during summer season under RCP 8.5 (a) near century (b) mid century (c) end of century

Table 5.4. Classification of departure of temperature from normal

	>5°C	Markedly above normal
	3.1 to 5°C	Appreciably above normal
	1.6 to 3°C	Above normal
	1.5 to -1.5°C	Normal
	-1.6 to -3°C	Below normal
	-3.1 to -5°C	Appreciably below normal
	<-5°C	Markedly below normal

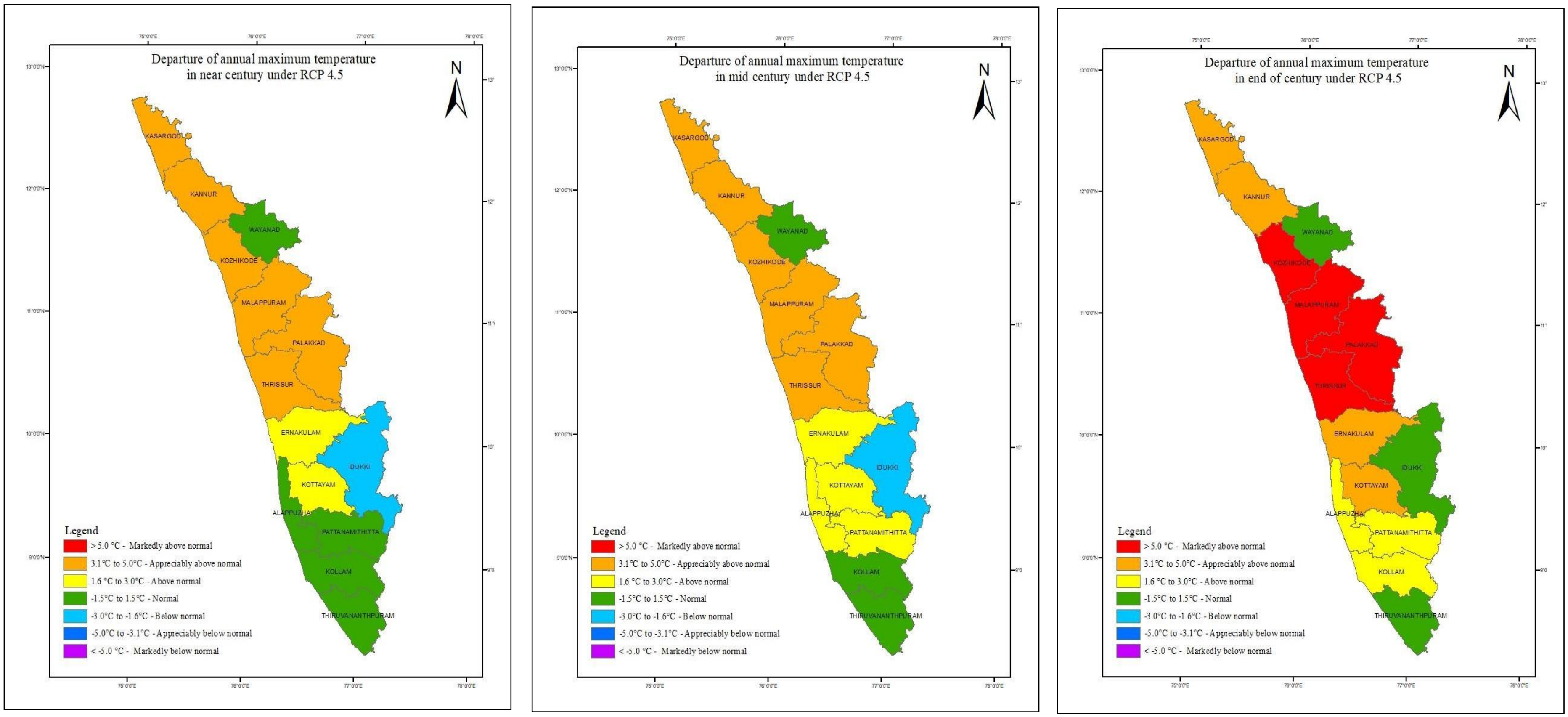
5.5.2.1. Annual

Under RCP 4.5, during all the time periods in the northern zone of Kerala the maximum temperature, showed anappreciably above normal departure in near and mid century. By the end of century a markedly above normal increase is observed in districts like Kozhikode and Malappuram (Fig. 5.25). In the central zone of Kerala maximum temperature showed a positive deviation. In Palakkad and Thrissur the deviation was appreciably above normal during the near and mid-century at the same time, during this period, in Ernakulam the temperature rise was expected to be above normal. By the late century, the maximum temperature in the central zone of Kerala is expected be markedly above normal and appreciably above normal in Ernakulam.In the High range zone, the maximum temperature showedbelow departure normal departure in Idukki in near and mid future and by end of century a normal departure has been expected. The departure is expected to be normal in Wayanad. In the Problematic zone of Kerala, the maximum temperature showed an above normal increase in Kottyam and normal departure in Alappuzha in near century. In mid century the maximum temperature showed an above normal increase. By the end of century an appreciably above normal increase in maximum temperature is expected. In southern zone departure of maximum temperature is found to be normal in near century but in mid and end of century maximum temperature showed an above normal increase in Pathanamthitta. By the end of century in Kollam also the temperature showed an above normal increase in solar radiation.

Under RCP 8.5 an appreciably above normal increase in solar radiation has been expected in northern and central zone of Kerala in near and mid centurywith an exception of Kasargod and Ernakulam where an above normal increase in temperature has been expected in near century. By the end of century a markedly above normal departure has been expected in northern and central zone of Kerala except in Ernakulam. In high range zone temperature showed a normal deviation in Wayanad and below normal deviation in Idukki during near and mid century. By the end of century Wayanad showed an above normal increase and Idukki showed a normal deviation. In problematic zone temperature showed a increasing trend towards the end of century. In near century the departure was normal, in mid century the departure was found to be above normal and by the end of century an appreciably above normal departure in maximum temperature is expected. In southern zone the temperature departure was found to be normal in near century. In mid and end of century Pathanamthitta showed an above normal and appreciably above normal departure of maximum temperature respectively. In Kollam an above normal deviation has been expected (Fig. 5.26).

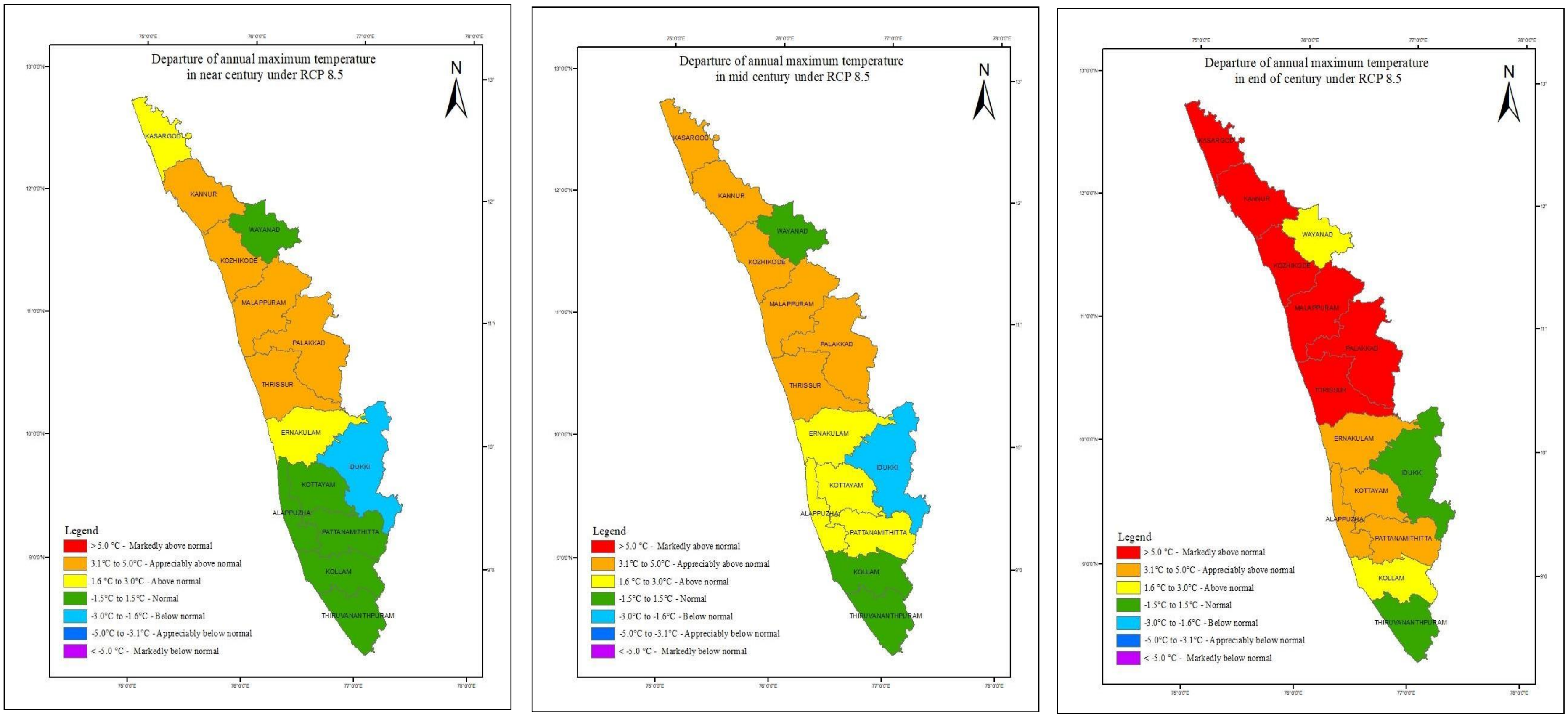
5.5.2.2.Southwest monsoon season

Under RCP 4.5 in near century maximum temperature showed an appreciably above normal departure in northern zone and above normal departure in central zone of Kerala. The departure of maximum temperature was found to be normal in problematic, southern and high range zone with an exception in Idukki where the temperature showed a below normal departure. In mid century maximum temperature showed anappreciably above normal departure in northern and central zone of Kerala except in Ernakulam. In high range zone the maximum temperature showed a normal departure. In problematic zone above normal departure is expected in mid century. In southern zone the temperature departure has been found to be normal except in Pathanamthitta. By the end of century in northern zone the maximum temperature showed a markedly above normal increase in maximum temperature except in Malappuram. In central zone an appreciably above normal increase in maximum temperature is expected.



(a) (b) (c)

Fig. 5.25. Annual departure of maximum temperature from normal under RCP 8.5 (a) near century (b)mid century (c) end of century



(a) (b) (c)

Fig. 5.26. Annual departure of maximum temperature from normal under RCP 8.5 (a) near century (b)mid century (c) end of century

In high range zone the maximum temperature showed a normal departure. In problematic zone above normal departure is expected in mid century. In southern zone the temperature departure has been found to be above normal except in Kollam (Fig. 5.27).

Under RCP 8.5 in near century the temperature change was similar to that of under RCP 4.5 in near century except in Idukki where there is a normal departure in maximum temperature. In the mid century in northern zone the maximum temperature showed an appreciably above normal departure in northern zone and above normal departure in central zone of Kerala except in Palakkad where an appreciably above normal departure is observed. In high range zone, problematic zone and southern zone a normal departure of maximum temperature is expected with an exception of Kottayam where an above normal departure of solar radiation is expected. By the end of century in northern zone the maximum temperature is expected to increase markedly above normal. In central and problematic zone the maximum temperature is expected to show an appreciably above normal increase. In high range zone and souther zone an above normal departure has been expected (Fig. 5.28).

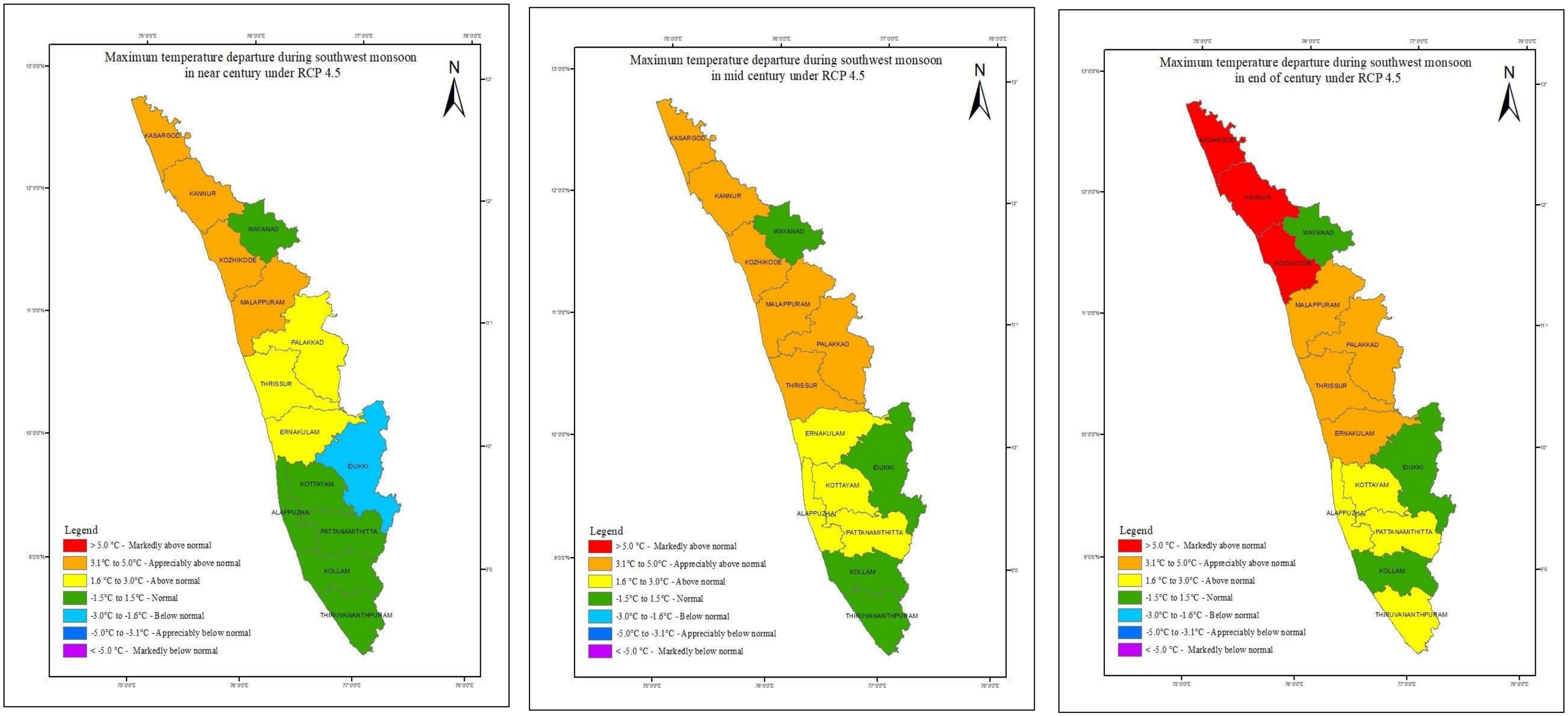
5.5.2.3. Northeast monsoon season

.Departure of maximum temperature from normal during northeast monsoon under RCP 4.5 and 8.5 is shown in Figure 5.29 and 5.30. Under RCP 4.5 in northern zone of Keralain near century an appreciably above normal increase in maximum temperature is expected but in Kozhikode the increase was found to be higher. In central zone of Kerala also an appreciably above normal increase in maximum temperature is expected except in Thrissur. In the High range zone, the maximum temperature showedbelow departure normal departure in Idukki and normal departure in Wayanad. In problematic zone an above normal departure is expected in maximum temperature. In southern zone of Kerala A normal departure of maximum temperature has been expected in near century. In mid century northern zone of Kerala showed a markedly and appreciably above normal increase in maximum temperature. In central zone Palakkad showed a markedly above normal increase in maximum temperature, Thrissur showed an appreciably above normal and Ernakulam showed an above normal increase in maximum temperature. In problematic zone maximum temperature showed an above normal increase in maximum temperature and in southern zone departure is expected to be normal except in Pathanamthitta. By the end of century a markedly above normal increase has been observed in northern zone and Palakkad district. An appreciably above normal increase in maximum temperature has been expected in central zone and problematic zone. An above normal increase is expected in southern zone except in Thiruvananthapuram. In high range zone and Thiruvananthapuram the departure of maximum temperature has been found to be normal.

Under RCP 8.5 in near century an appreciably above normal increase in maximum temperature has been expected in northern and central zone except in Thrissur.In the High range zone, the maximum temperature showedbelow departure normal departure in Idukki and normal departure in Wayanad. In problematic zone an above average increase in maximum temperature is expectedand a normal departure is expected in southern zone. In mid century the departure was similar to that of in RCP 4.5. By the end of century a markedly above normal increase has been observed in northern zone and central zone except in Thrissur. An appreciably above normal increase in maximum temperature has been expected in problematic zone and Pathanamthitta.

5.5.2.4.Winter season

Under RCP 4.5 during winter season in northern zone increase in temperature is expected. In Kasargod a normal departure in Kannur and Kozhikode an above normal increase and in Malappuram an appreciably above normal increase in maximum temperature has been expected. In centalxone there is no typical trend it is different in three districts. In high range zone maximum temperature is expected to show an normal and below normal departure. In problematic and southern zone a normal departure of maximum temperature has been expected. In mid century departure is similar to near century except im Kottayam and Thrissur. By the end century maximum temperature is expected to increase markedly above normal, appreciably above normal and above normal in northern zone. In central zone an appreciably above normal increase in maximum temperature is expected except in Palakkad. In problematic zone an above normal increase in maximum temperature is expected. In high range zone maximum temperature is expected to show a



(a) (b) (c)

Fig. 5.27. Departure of maximum temperature from normal during southwest monsoon under RCP 4.5 (a) near century (b) mid century (c) end of century

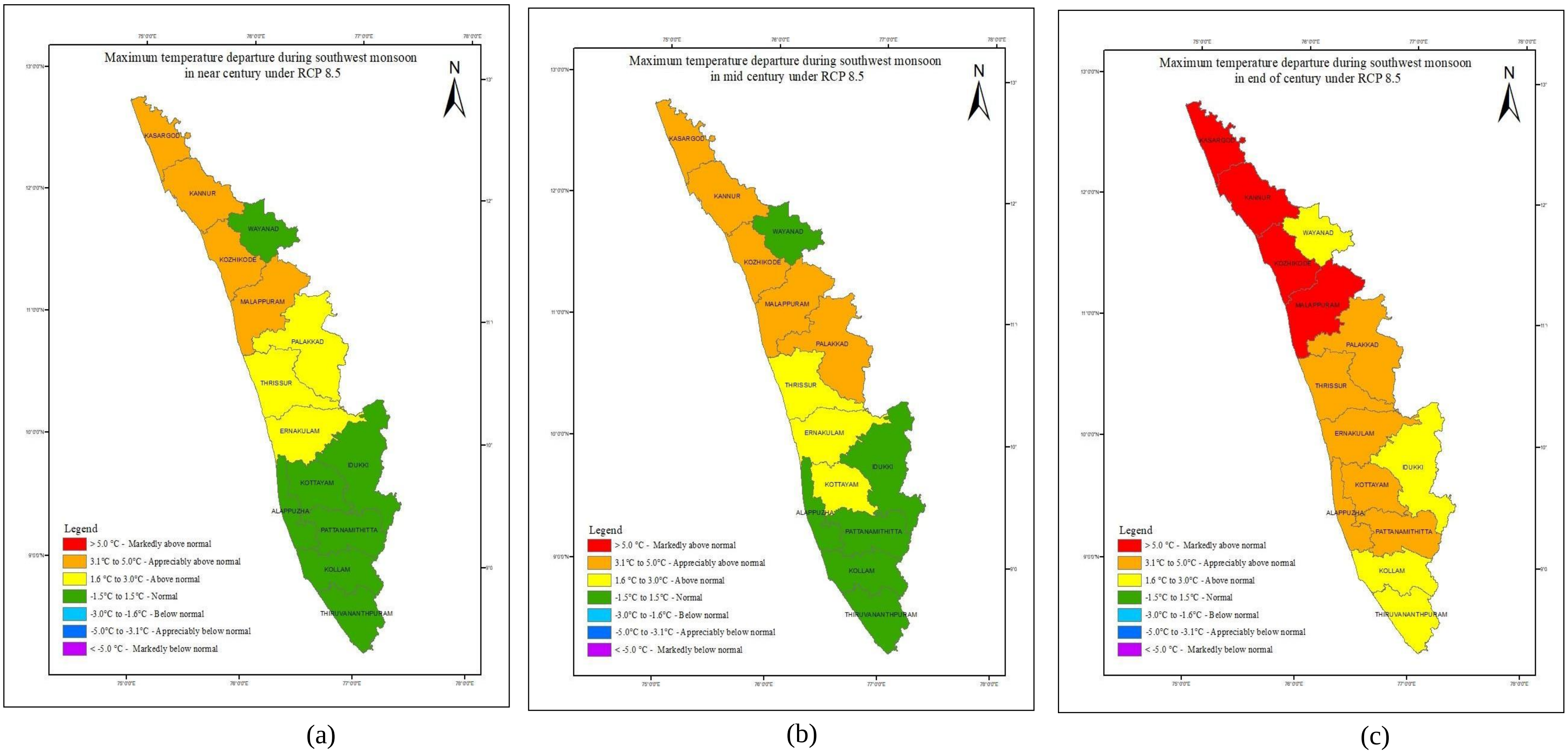
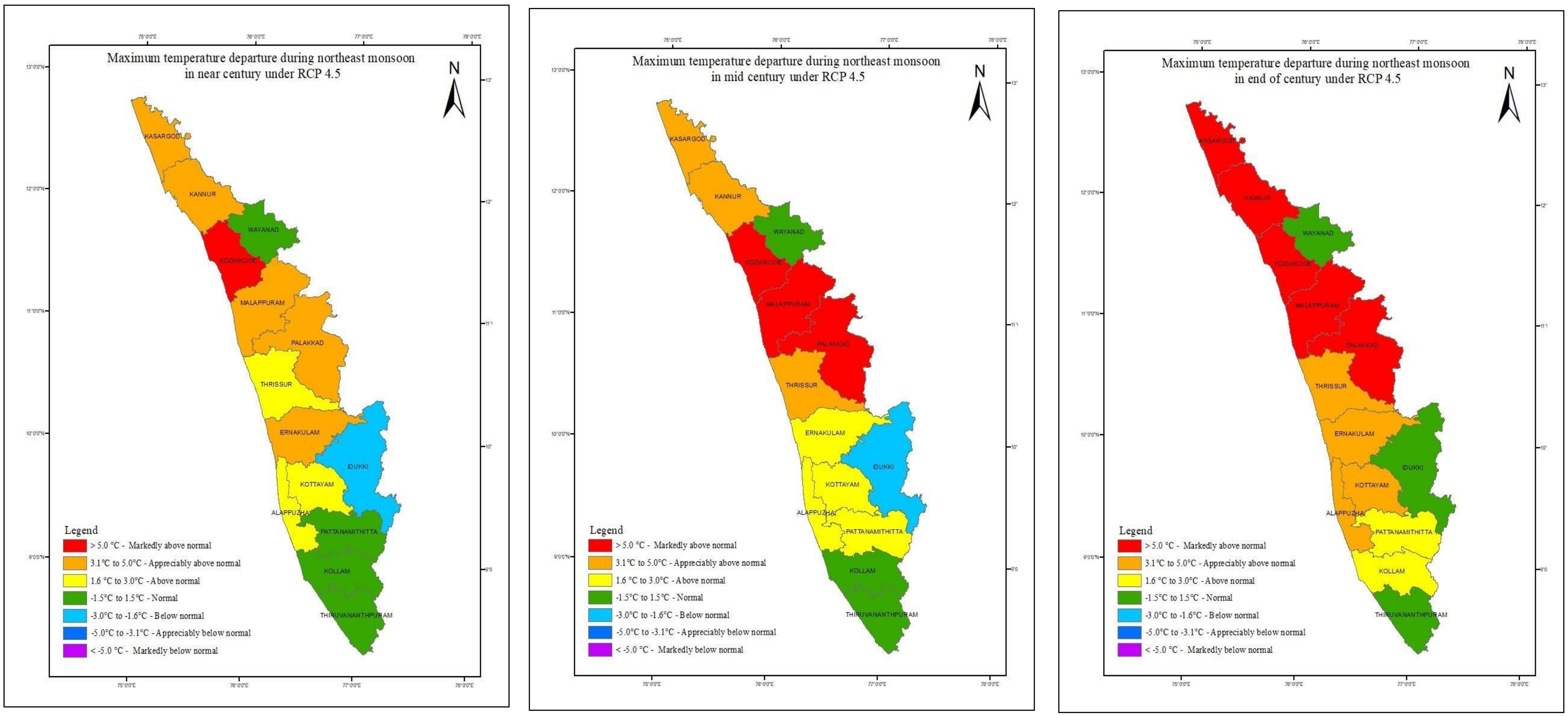
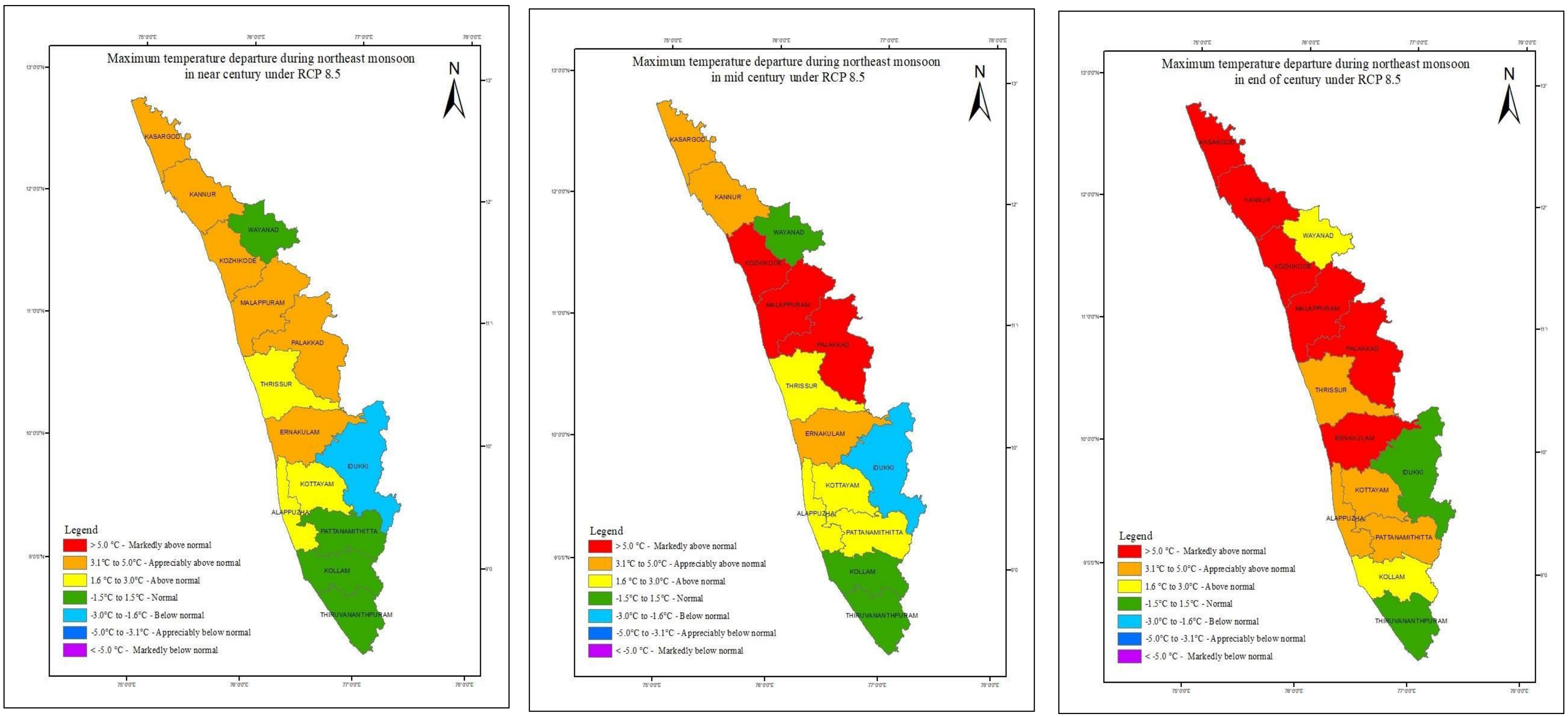


Fig. 5.28. Departure of maximum temperature from normal during southwest monsoon under RCP 8.5 (a) near century (b) mid century (c) end of century



(a) (b) (c)

Fig. 5.29. Departure of maximum temperature from normal during northeast monsoon under RCP 4.5 (a) near century (b) mid century (c) end of century



(a) (b) (c)

Fig. 5.30. Departure of maximum temperature from normal during northeast monsoon under RCP 8.5 (a) near century (b) mid century (c) end of century

normal and below normal departure. In southern zone a normal departure is expected during winter season except in Pathanamthitta (Fig. 5.31).

Under RCP 8.5 in near century northern zone and central zone of Kerala showed a normal and above normal increase in maximum temperature, In high range zone a below normal and appreciably below normal departure is observed in near, mid and end of century. In problematic and southern zone a normal departure of maximum temperature is expected. In mid century an increase in temperature is expected in northern except in Kasargod where a normal departure is expected. In central zone an appreciably above normal and above normal departure is expected. In southern zone a normal departure is expected. By the end of century the warming is expected to increase in Kerala under RCP 8.5. In northern and central zone anappreciably and markedly above normal increase in maximum temperature is expected. In problematic zone Alappuzha showed a markedly above normal increase and Kottayam showed an appreciably above normal departure. In southern zone an above average increase is expected except in Thiruvananthpuram (Fig. 5.32).

5.5.2.5.Summer season

In summer season under RCP 4.5 maximum temperature showed an above normal and appreciably above increase in temperature in northern and central zone in near and mid century. In high range zone a below normal and appreciably below normal departure is observed in near near and mid century In problematic and southern zone a normal departure is expected in problematic and southern zone of Kerala in near century and in mid century an above normal departure has been expected in problematic zone and Pathanamthitta. By the end of century a markedly above and appreciably above normal temperature has been expected in northern zone and central zone. In problematic and southern zone an above normal increase in temperature is expected. Inhigh range zone and Thiruvananthpuram a normal departure is expected.

Under RCP 8.5 a similar trend in RCP 4.5 has been observed. An increase in temperature from has been observed in all the districts of Kerala (Fig. 5.33 and 5.34).

5.5.3 Minimum temperature

Departure of minimum temperature has been classified same as maximum temperature.

5.5.3.1. Annual

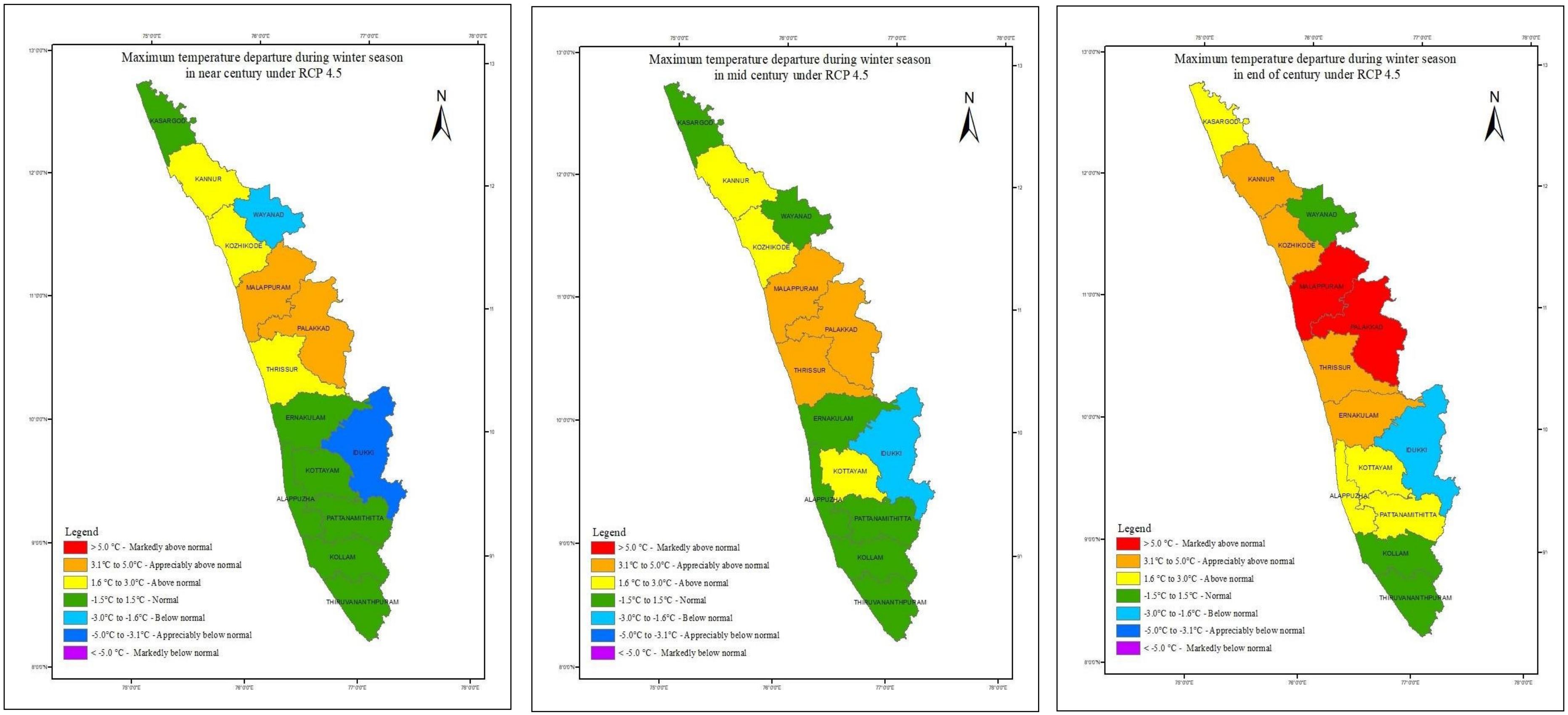
Under RCP 4.5 a markedly above normal increase in annual minimum temperature is expected in northern zone and central zone in near, mid and end of the century with an exception of Ernakulam which showed an above normal departure in near and mid century. In high range zone a normal departure has been expected in all future simulations. But by the end of century in Wayanad an above normal departure is expected. An above normal increase in minimum temperature is expected in problematic and southern zone in all the future simulations (Fig. 5.35).

Under RCP 8.5 also a similar departure as under RCP 4.5 is expected. But in high range zone a below normal departure of minimum temperature has been expected in near and mid century (Fig. 5.36).

5.5.3.2. Southwest monsoon season

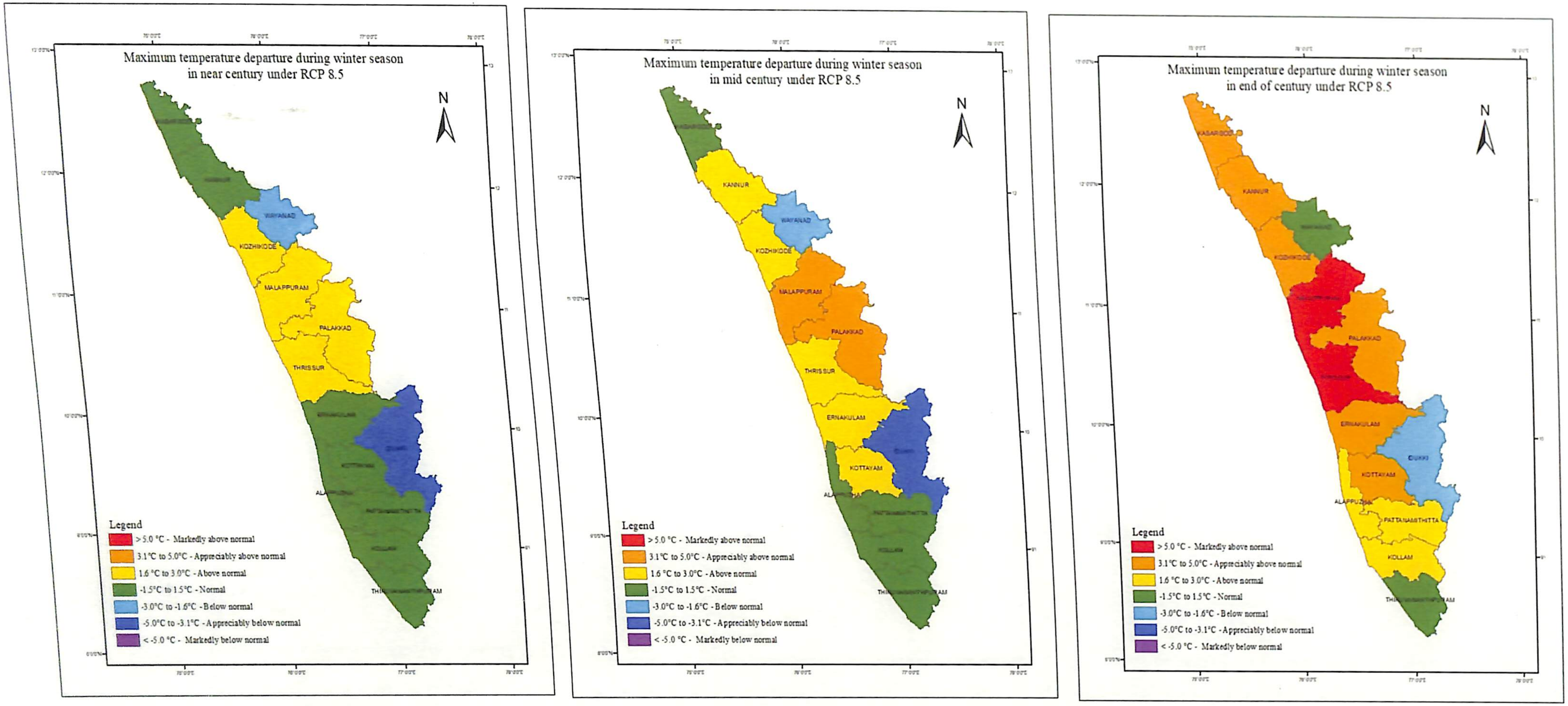
Under RCP 4.5 a markedly above normal increase in minimum temperature during the southwest monsoon is expected in northern zone of Kerala in near, mid and end of century. In central zone Kerala an appreciably above normal increase in minimum temperature is expected in all future simulations. In Palakkad the minimum temperature departure is expected to increase appreciably above normal by mid and end of century. In high range zone a normal departure of minimum temperature is expected in near and mid century. But by the end of century in Wayanad an above normal increase in minimum temperature is expected. In problematic zone of Kerala an appreciably above normal increase in minimum temperature is expected in all future simulations In southern zone of Kerala an above normal increase in minimum temperature is expected in near and mid century. By the end of century the minimum temperature is expected to show an appreciably above normal increase . (Fig. 5.37).

Under RCP 8.5 in northern zone a minimum temperature is expected to show an markedly above normal increase in minimum temperature in all the future simulations. In central zone departure of minimum temperture was found to be same as that of in RCP 4.5.



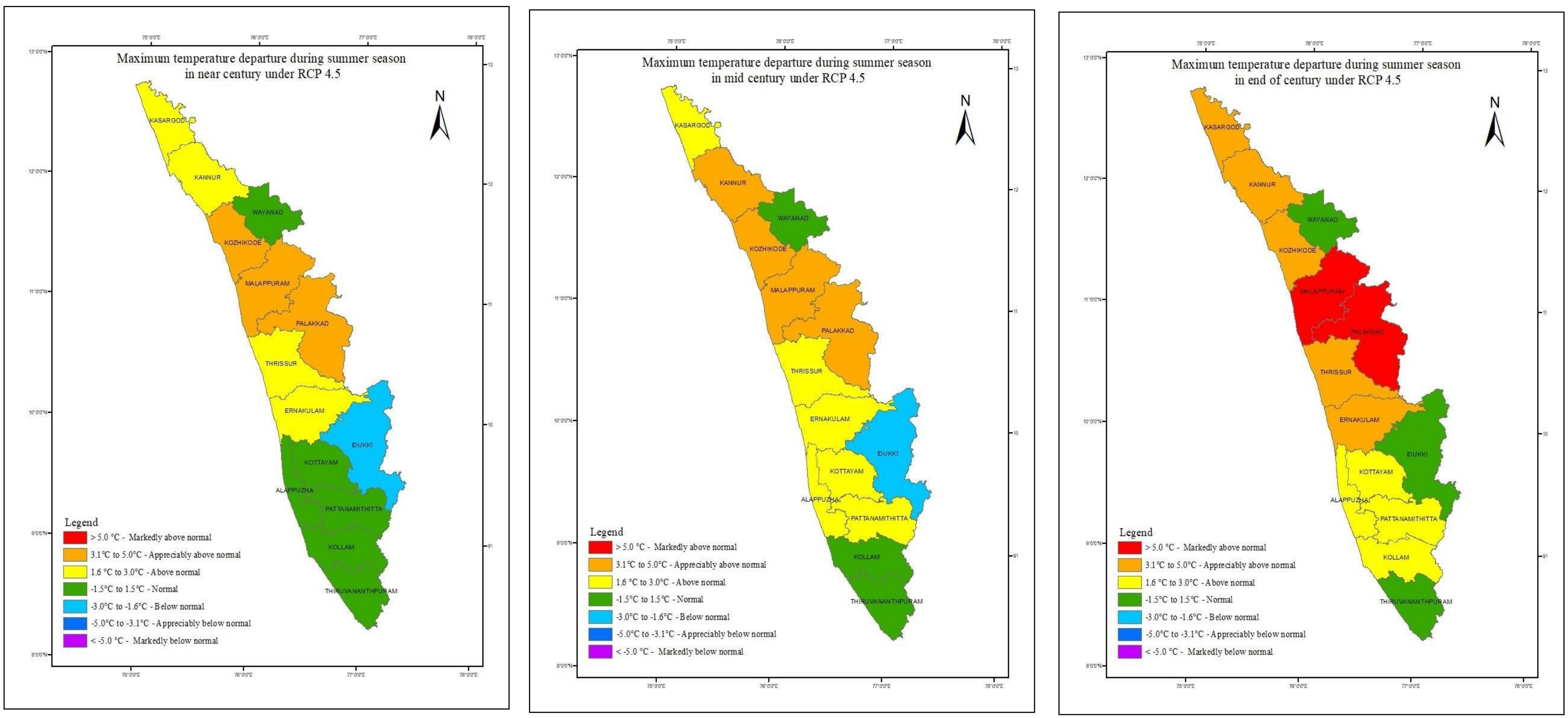
(a) (b) (c)

Fig. 5.31. Departure of maximum temperature from normal during winter season under RCP 8.5 (a) near century (b) mid century (c) end of century



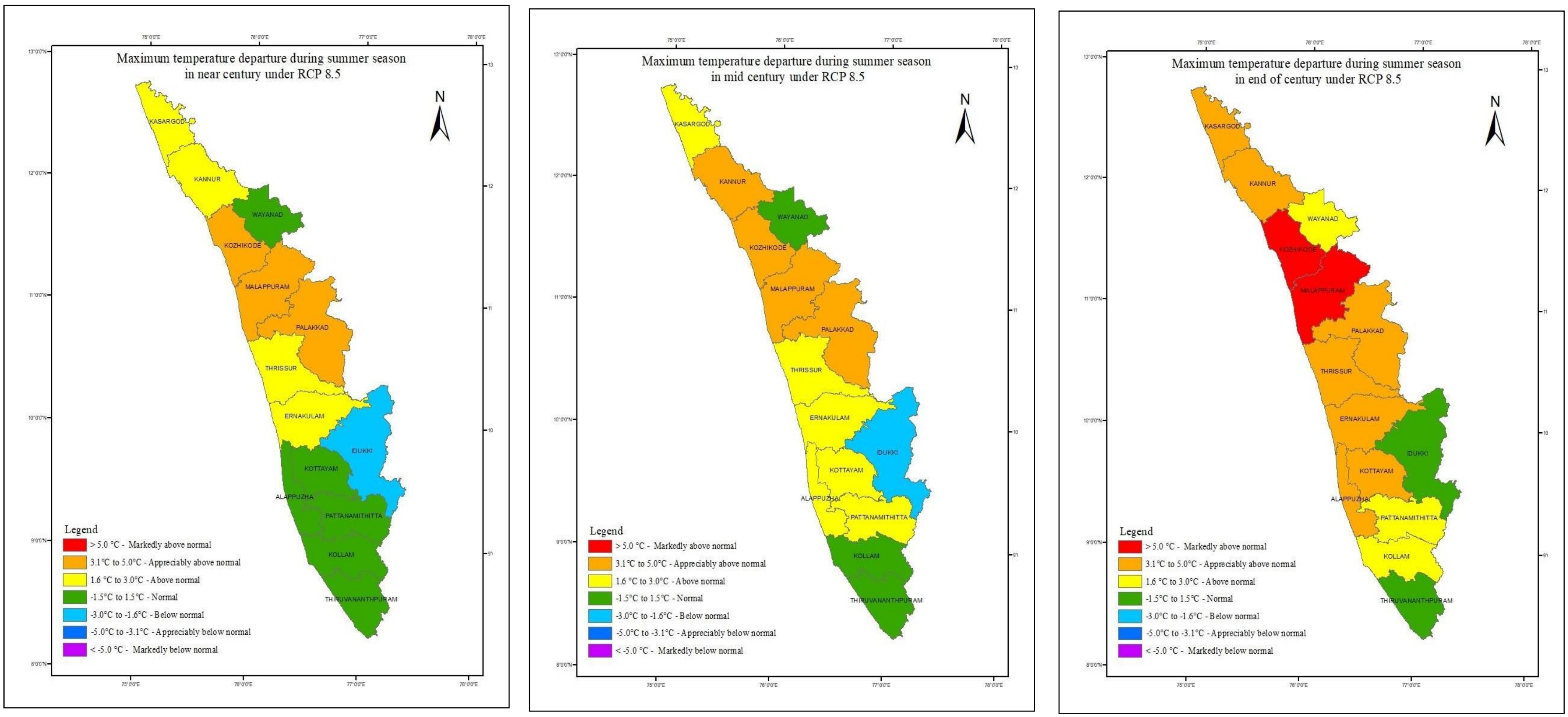
(a) (b) (c)

Fig. 5.32. Departure of maximum temperature from normal during winter season under RCP 8.5 (a) near century (b) mid century (c) end of century



(a) (b) (c)

Fig. 5.33. Departure of maximum temperature from normal during summer season under RCP 4.5 (a) near century (b) mid century (c) end of century



(a) (b) (c)

Fig. 5.34. Departure of maximum temperature from normal during summer season under RCP 8.5 (a) near century (b) mid century (c) end of century

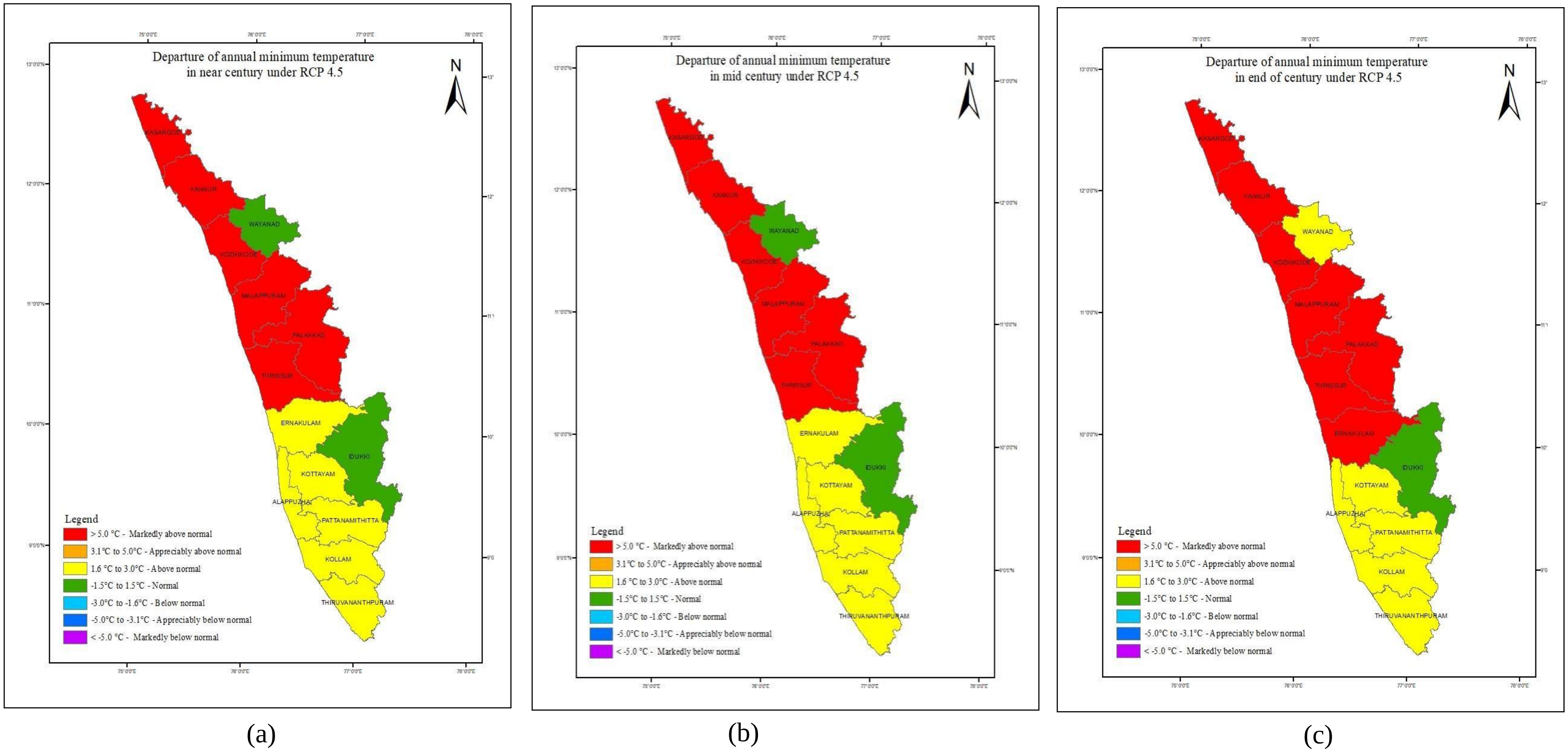
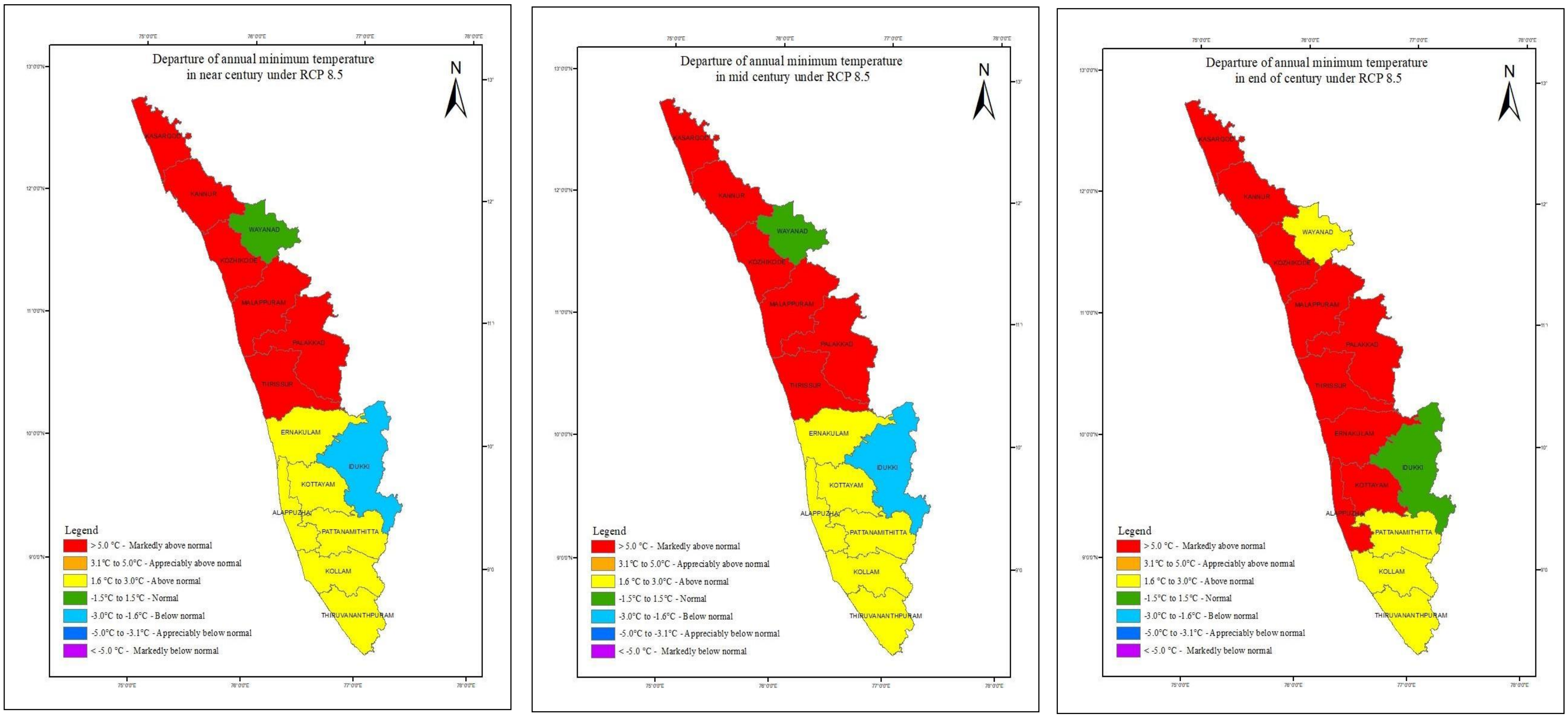
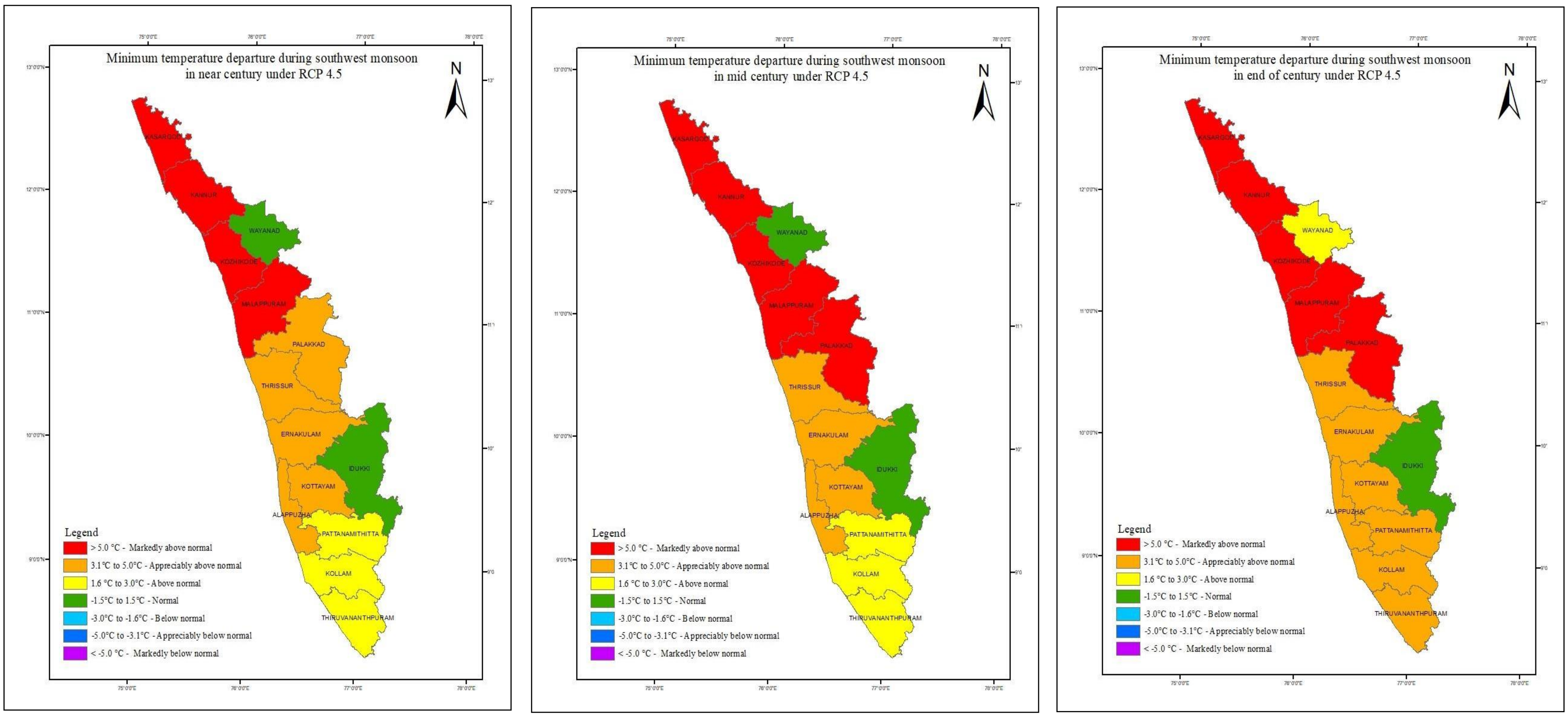


Fig. 5.35. Departure of annual minimum temperature from normal under RCP 4.5 (a) near century (b) mid century (c) end of century



(a) (b) (c)

Fig. 5.36. Departure of annual minimum temperature from normal under RCP 8.5 (a) near century (b) mid century (c) end of century



(a) (b) (c)

Fig.5.37. Departure of minimum temperature from normal during southwest monsoon under RCP 4.5 (a) near century (b) mid century (c) end of century

In high range zone a normal departure of minimum temperature is expected in near and mid century. But by the end of century in Wayanad an appreciably above normal increase and above normal increase in minimum temperature is expected in Idukki. In problematic zone an above normal increase is found to be in mid century and by the end of century an appreciably above normal increase is found. In southern zone an above normal departure of minimum temperature is expected in near century and mid century. By the end of century an appreciably above normal increase in minimum temperature is expected (Fig. 5.38).

5.5.3.3. Northeast monsoon season

Under RCP 4.5 in northern zone a markedly above normal increase in minimum temperature is expected in near, mid and end of the century. In central zone Palakkad district showed an markedly above normal departure while in other two districts an appreciably above normal increase in minimum temperature increase in minimum temperature is expected in all the future simulations. In high range zone minimum temperature is expected to show a normal departure in near and mid century and then an above normal increase in Wayanad. While in Idukki the temperature is decreasing in near and mid century and a normal departure is expected by the end of century. In problematic zone a markedly above normal increase in minimum temperature is expected in all the future simulations. In southern zone an above normal departure of minimum temperature is expected in near and mid century and by the end of century an appreciably above normal increase in minimum temperature is expected except in Thiruvananthapuram (Fig. 5.39).

Under RCP 8.5 the departure of minimum temperature is similar to that of under RCP 4.5 in most places. In southern zone an above normal departure of minimum temperature is expected in near and mid century and by the end of century an appreciably above normal increase in minimum temperature is expected (Fig. 5.40).

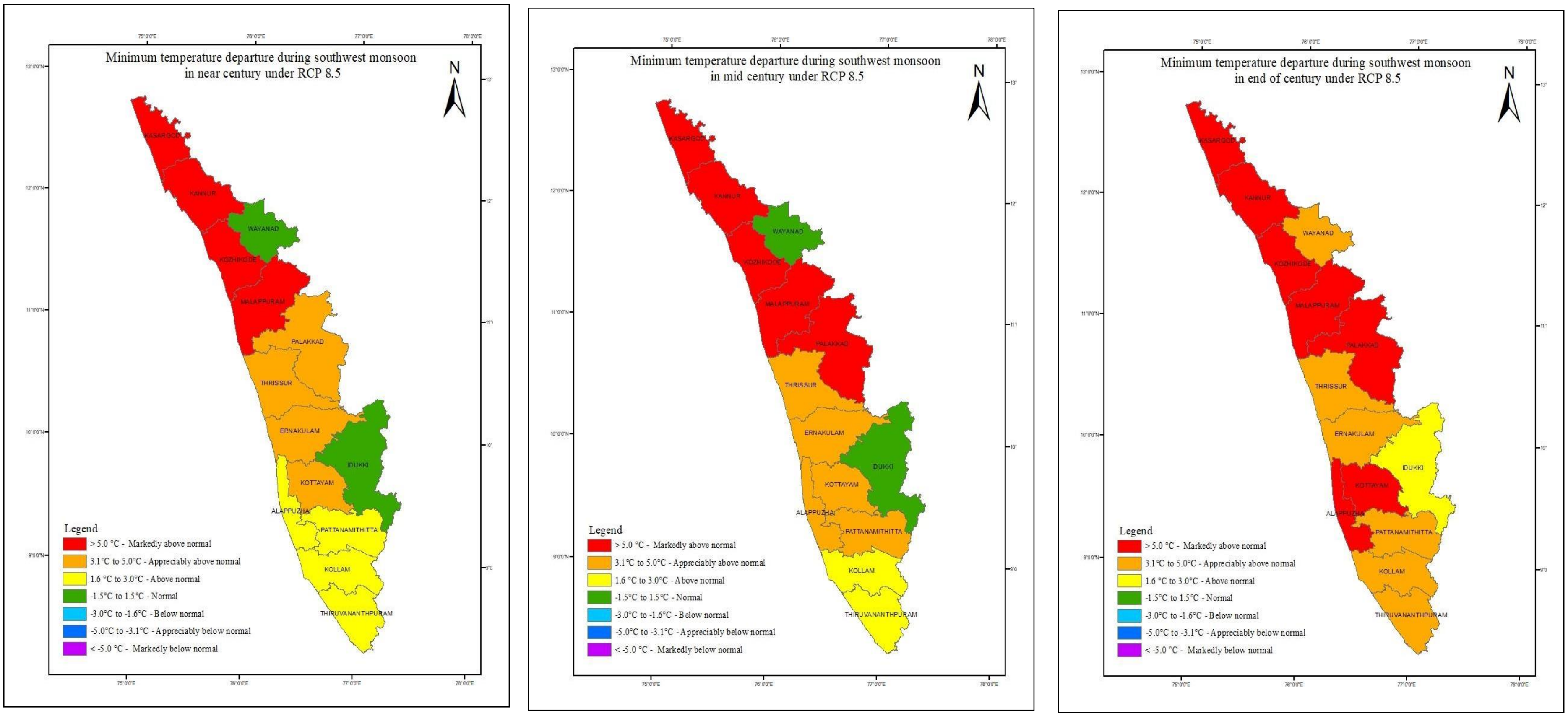
5.5.3.4.Winter season

Under RCP 4.5 minimum temperature shows a markedly above normal increase in northern zone in all the future simulations. In central zone an appreciably above normal increase in minimum temperature is expected in Thrissur and Ernakulam andmarkedly above normal increase is expected in Palakkad in near and mid century. By the end of century Ernakulam district also showed a markedly above normal increase in minimum temperature. In high range zone a decrease of minimum temperature is expected in near century. In mid and end of century a normal departure is expected in Wayanad and below normal departure in Idukki. In problematic zone an appreciably above normal increase in minimum temperature has been expected in all the future simulations. In southern zone Thiruvananthapuram showed a normal departure in near centure while other districts showed an above normal departure in near and mid century. An appreciably above normal departure in Kollam and Pattanamthitta and an above in normal departure in Thiruvananthapuram is expected by end of century (Fig. 5.41).

Under RCP 8.5 a markedly above normal increase in minimum temperature is expected in all the future simulations. In central zone an appreciably above normal increase in minimum temperature is expected in Thrissur and Ernakulam andmarkedly above normal increase is expected in Palakkad in near and mid century. In problematic zone an appreciably above normal increase in minimum temperature has been expected in near and mid century. In high range zone Wayanad shows a normal departure while in Idukki the minimum temperature is expected to decrease below in near and end century. In southern zone showed an above normal departure in near and mid century. By the endof century a markedly above normal increase in minimum temperature is observed in most places. In southern zone an appreciably above normal increase in minimum temperature is expected (Fig. 5.42).

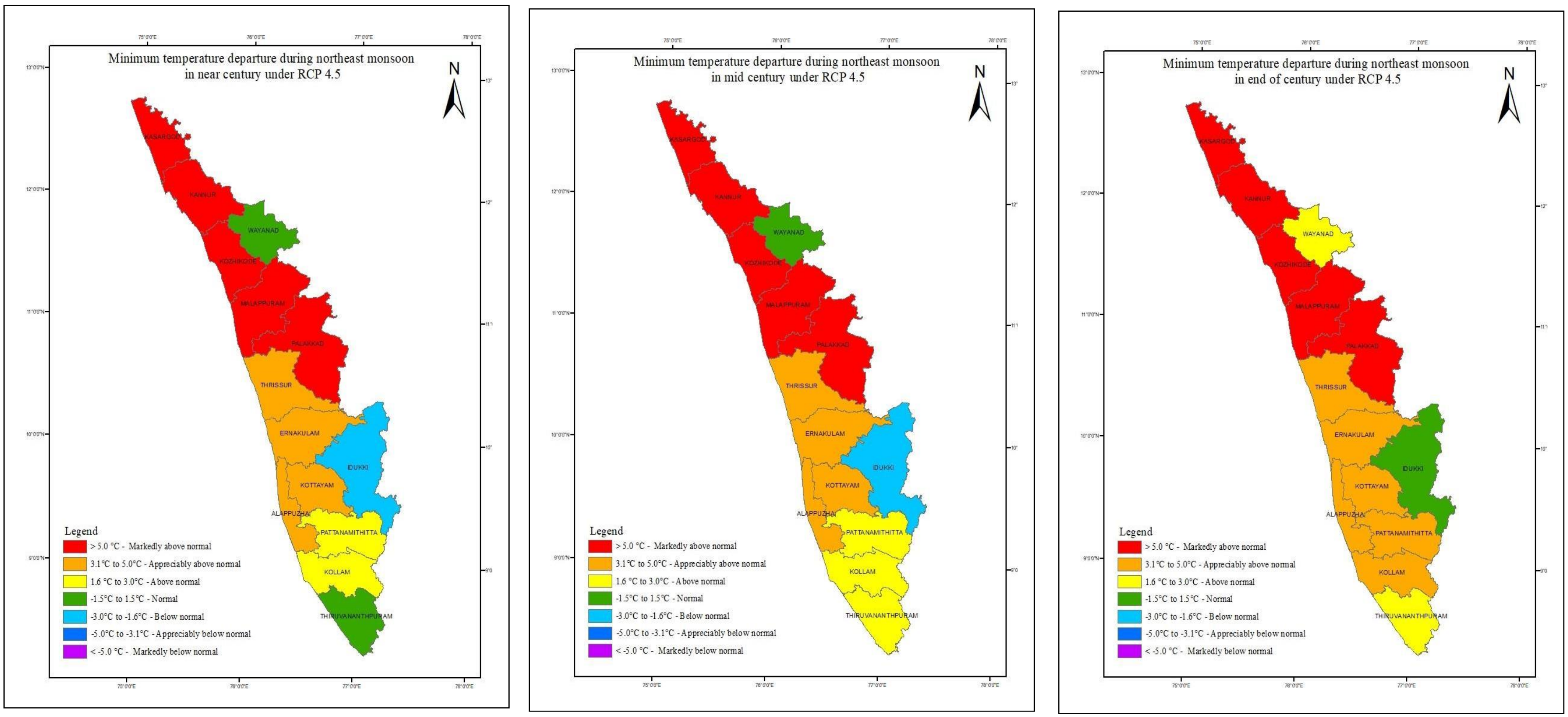
5.5.3.5. Summer season

Under RCP 4.5 minimum temperature shows a markedly above normal increase in northern zone in all the future simulations.In central zone an appreciably above normal increase in minimum temperature is expected in Thrissur and Ernakulam andmarkedly above normal increase is expected in Palakkad in near century. In mid and end centuryan appreciably above normal increase in minimum temperature is expected in Thrissur andmarkedly above normal increase is expected in Palakkadand Ernakulam. In problematic zone an appreciably above normal increase in minimum temperature has been expected in near and mid century. In high range zone Wayanad shows a normal departure while in



(a) (b) (c)

Fig. 5.38. Departure of minimum temperature from normal during southwest monsoon under RCP 8.5 (a) near century (b) mid century (c) end of century



(a) (b) (c)

Fig. 5.39. Departure of minimum temperature from normal during northeast monsoon under RCP 4.5 (a) near century (b) mid century (c) end of century

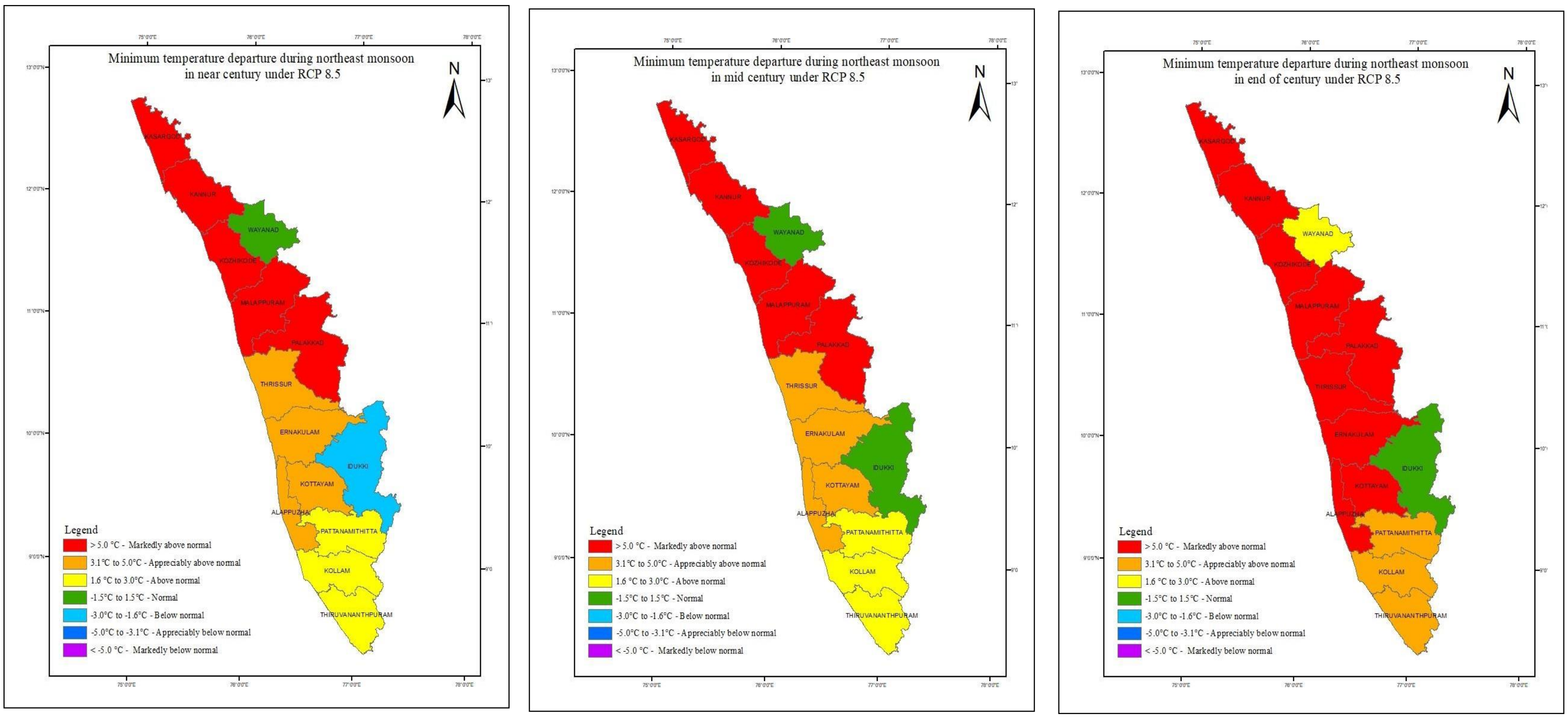


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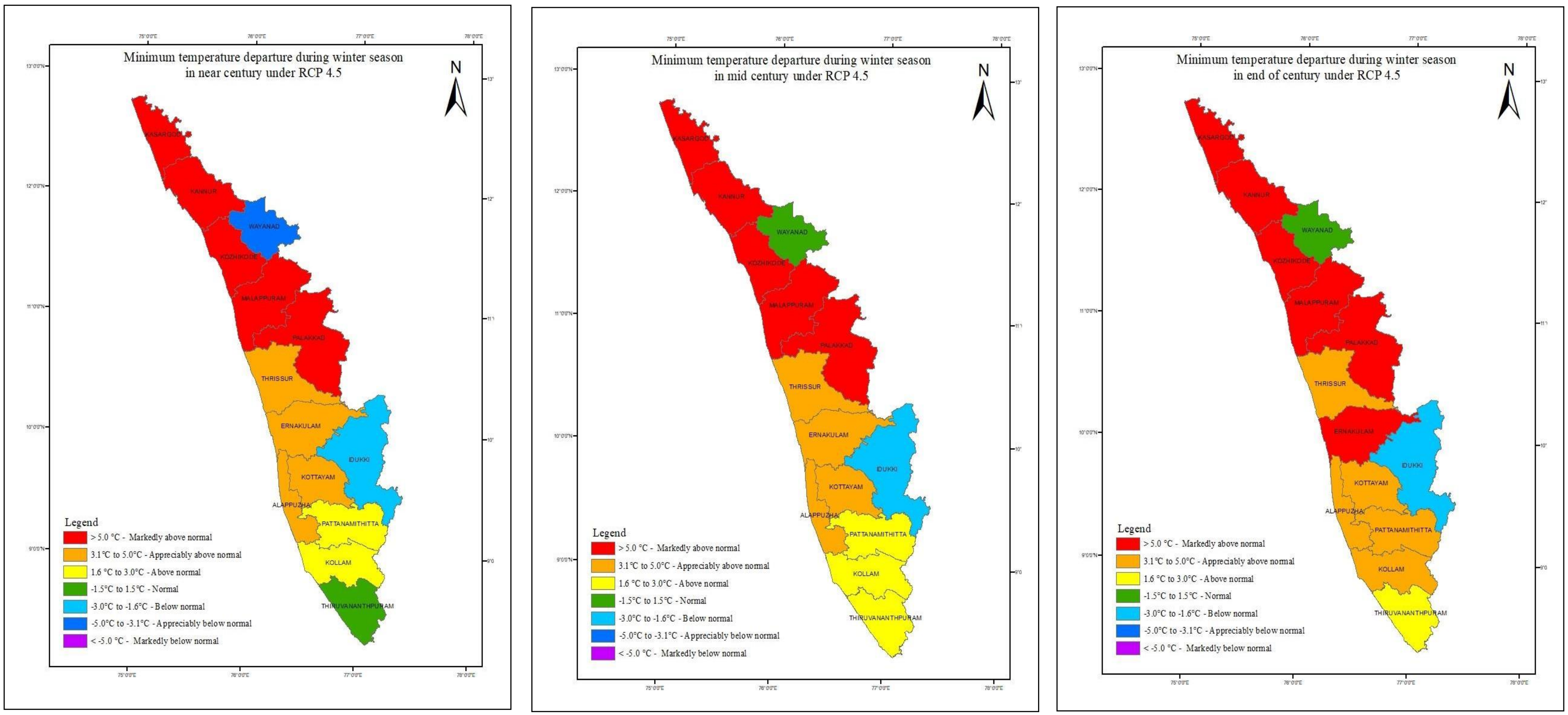
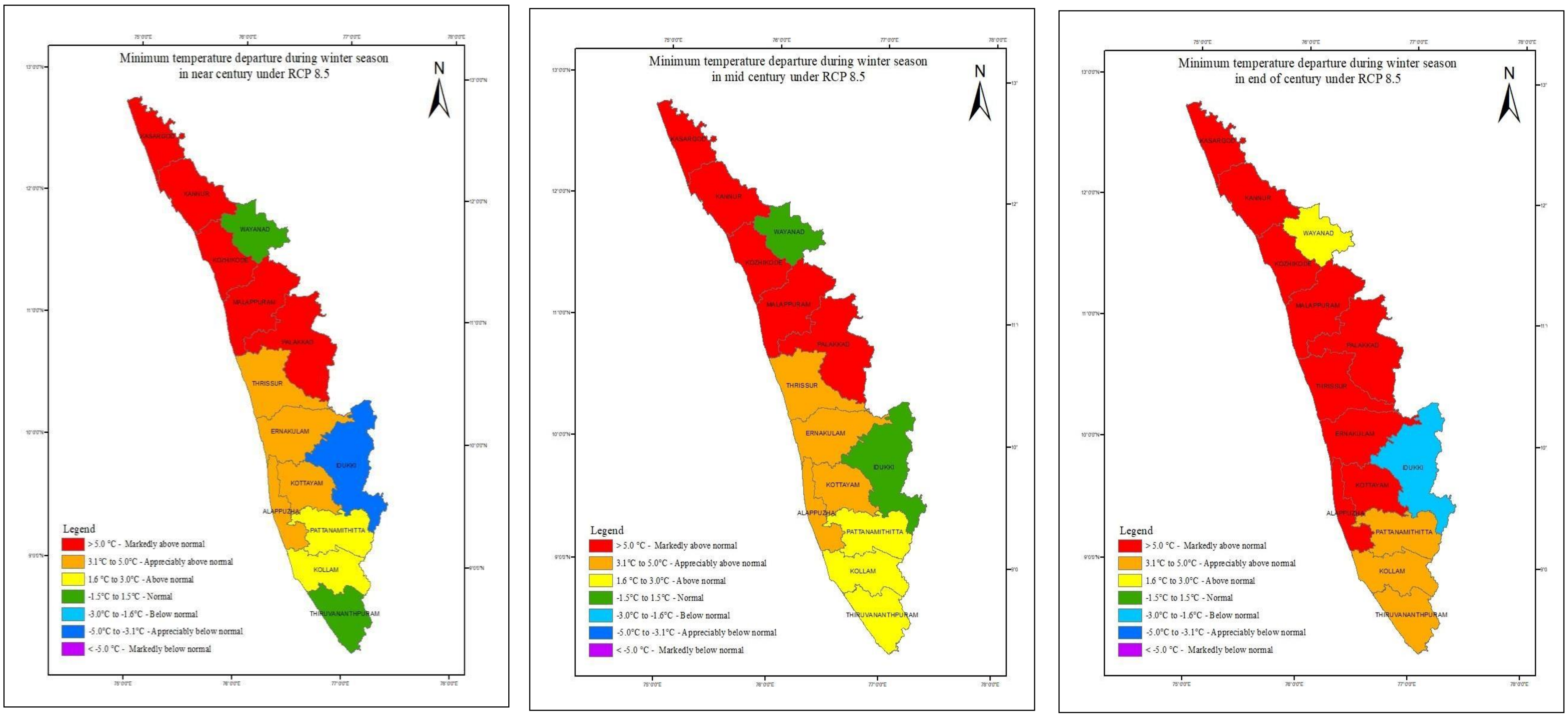
Fig.5.40. Departure of minimum temperature from normal during northeast monsoon under RCP 8.5 (a) near century (b) mid century (c) end of century



(a) (b) (c)

Fig. 5.41. Departure of minimum temperature from normal during winter season under RCP 4.5 (a) near century (b) mid century (c) end of century



(a) (b) (c)

Fig. 5.42. Departure of minimum temperature from normal during summer season under RCP 8.5 (a) near century (b) mid century (c) end of century

Idukki the minimum temperature is expected to decrease below in near century. In mid century both showed an normal departure. By the ed of century Idukki showed a normal departure and Wayanad showed an above normal increase. In southern zone an above normal increase in maximum temperature is expected (Fig. 5.43).

The departure of minimum temperature in near and mid century under RCP 8.5 was found to be similar to RCP 4.5 except in highranges where a normal departure has been predicted. By the end of century a markedly above normal increase in minimum temperature is observed in most places. In southern zone and Wayanad an appreciably above normal increase in minimum temperature is expected. In Idukki a normal departure of minimum temperature is expected (Fig. 5.44).

5.5.4. Rainfall

Annual and seasonal variation of rainfall in different zones of Kerala has been discussed here. Table 5.5 shows the classification of departure of rainfall from the normal.

Table 5.5. Classification of departure of rainfall

	≥60%	Large excess
	20 to 59%	Excess
	-19 to +19%	Normal
	-59 to -20%	Deficient
	-99 to -60%	Large deficient
	-100%	No rain

5.5.4.1. Annual

Figure 5.45 and 5.46 shows the departure of annual rainfall from the normal under RCP 4.5 and 8.5. Under RCP 4.5 large excess rainfall was expected in Kollam, Wayanad and Pathanamthitta. An excess rainfall is expected in northern zone and central zone. The rainfall was expected to be normal in Idukki, Alappuzha, and Kasargod during the near and mid centuries. By the end of century in almost all parts of Kerala, an excess rainfall was predicted except in the problematic zones of Kerala and in Idukki and Kasargode.

Under RCP 8.5 in near-century a large excess and excess rainfall is predicted over the northern zone and high ranges of Kerala except in few parts of Idukki and Karsarkod where the rainfall was expected to be normal in all the furure simulations. In the central zone of Kerala the annual rainfall was predicted to be in excess in near, mid and end of the century. In problematic zones, normal and excess rainfall has been predicted. In the southern zone of Kerala, Kollam and Pathanamthitta districts receive large excess rainfall in near century and excess rainfall in mid and end of the century. In Thiruvananthapuram normal deviation of rainfall is expected in near and mid century.

5.5.4.3. Southwest monsoon season

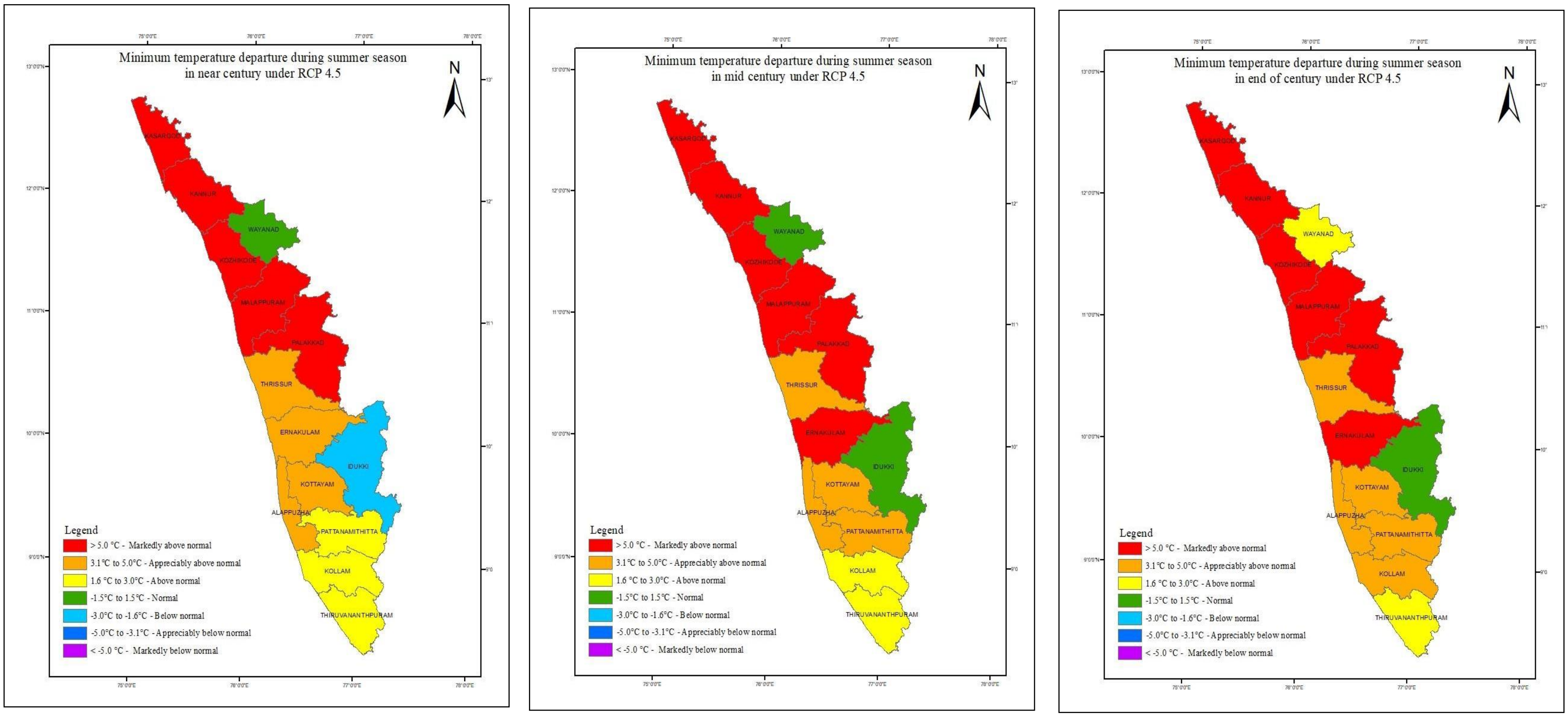
During the southwest monsoon under RCP 4.5 large excess and excess rainfall was expected in Kerala except in Kasargode where normal rainfall in near, mid and end of century. In Alappuzha by end of century the rainfall is expected to show an normal deviation (Fig. 5.47).

A similar condition was observed under the RCP 8.5 where large excess and excess rainfall was expected in Kerala except in Kasargode where normal rainfall in near, mid and end of century (Fig. 5.48).

5.5.4.3. Northeast monsoon season

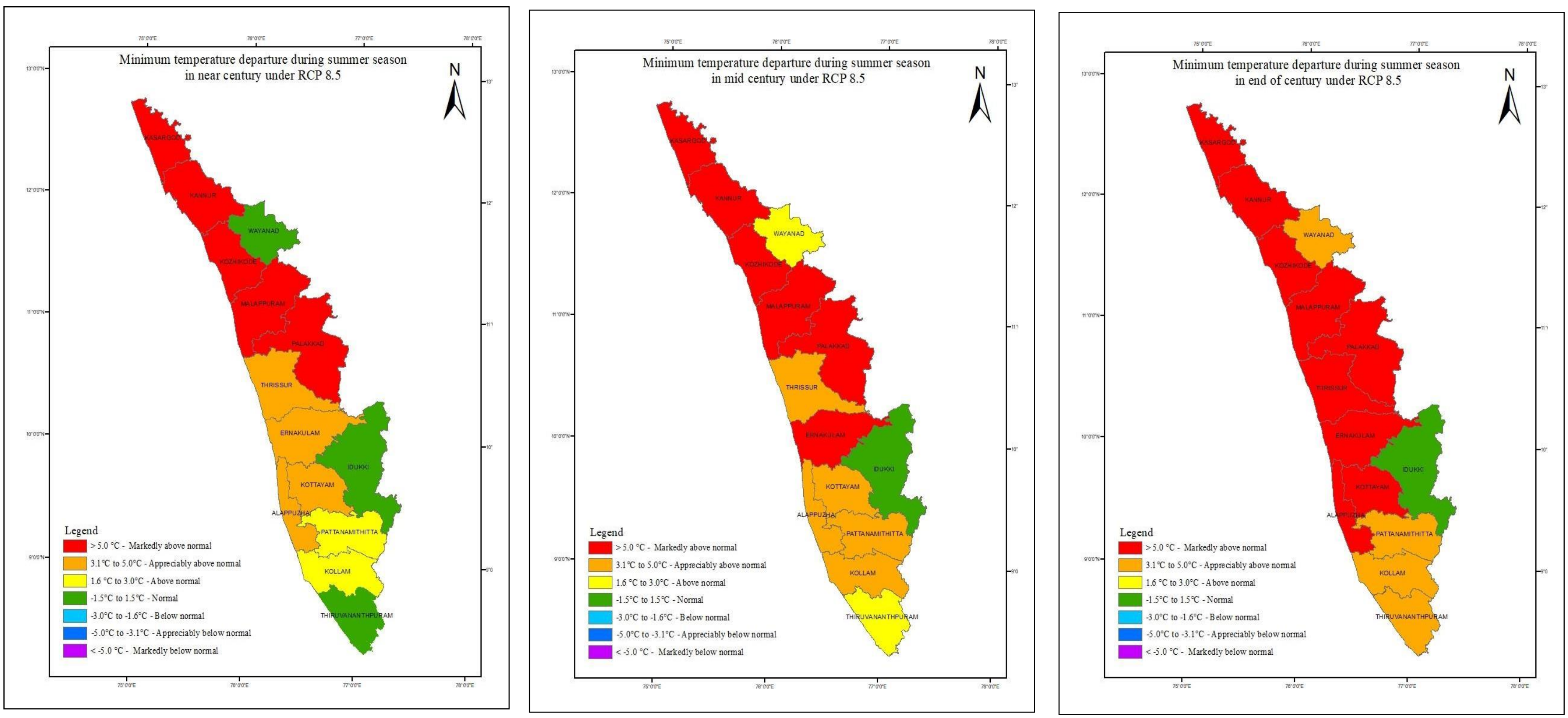
The Northeast monsoon is predicted to decrease from normal in almost all parts of Kerala under RCP 4.5. In the near-century northeast monsoon is expected to be excess in Thrissur. In northern zone and other parts of central zone a normal departure has been predicted. In problematic zone and high range zone a deficient rainfall has been predicted. In southern zone the rainfall is expected to be normal expect in Thiruvananthapuram. In mid century a normal rainfall is expected in most parts of Kerala except in Malapuram, Kottayam, Pathanamthitta and in high range zone where the rainfall is expected to be deficient. In end of century a deficient rainfall has been predicted in Kasargod, Idukki and southern zone except in Thiruvananthapuaram. In Enakulamnortheast monsoon is expected to be excess by the end of century (Fig. 5.49).

Under RCP 8.5 a normal departure of rainfall has been expected in most parts in near century. In high range zone, a deficient and large deficient rainfall has been expected in Idukki and Wayanad respectively. In mid century in Ernakulam district an excess amount of rainfall has been predicted. In Kasargode, Thrissur, Kottayam and Pattanamthitta a deficient in rainfall has been expected. A large deficient in northeast monsoon has been expected in Wayanad. By the end end of century In Ernskulsm, Alappuzha, Pathanamthitta and Kollam an excess rainfall is predicted while in Kannur and



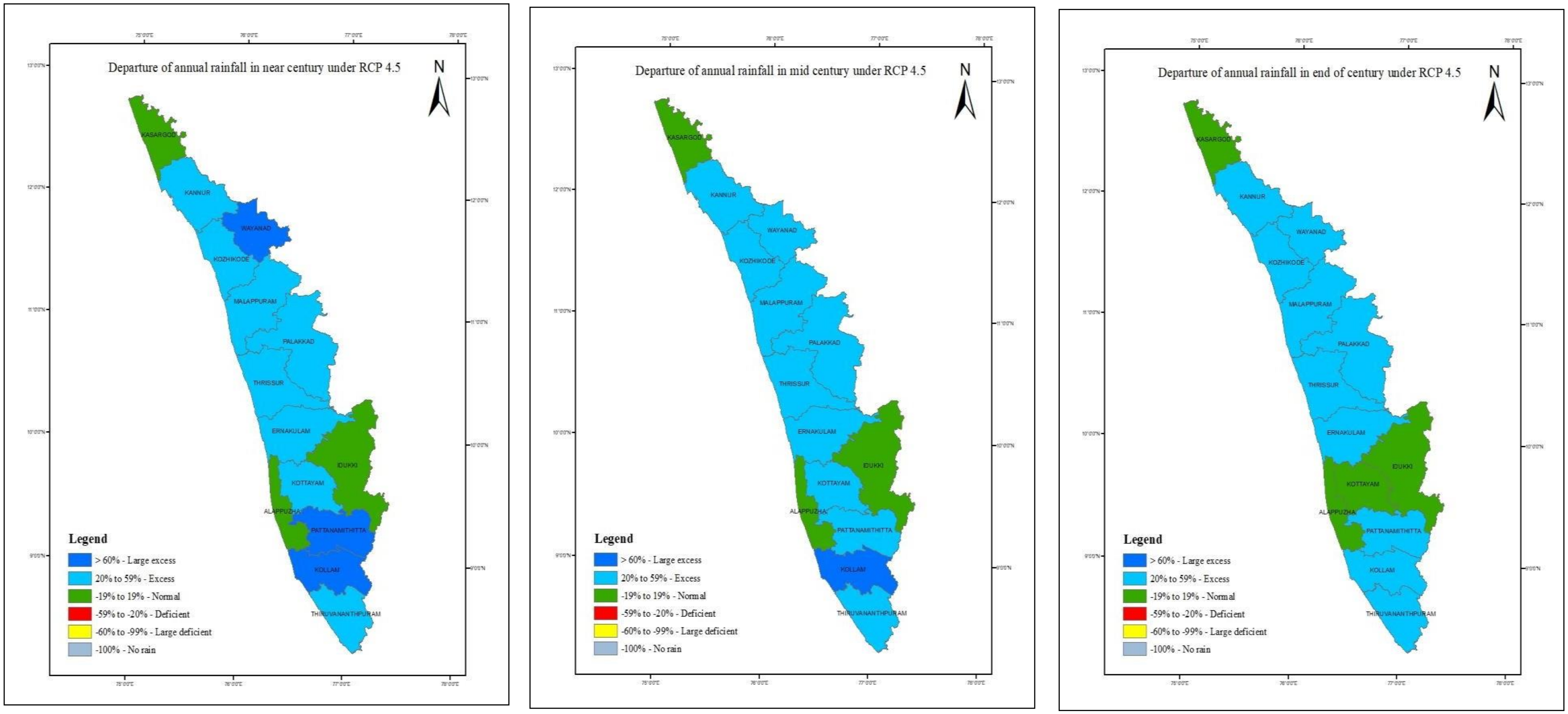
(a) (b) (c)

Fig. 5.43. Departure of minimum temperature from normal during summer season under RCP 4.5 (a) near century (b) mid century (c) end of century



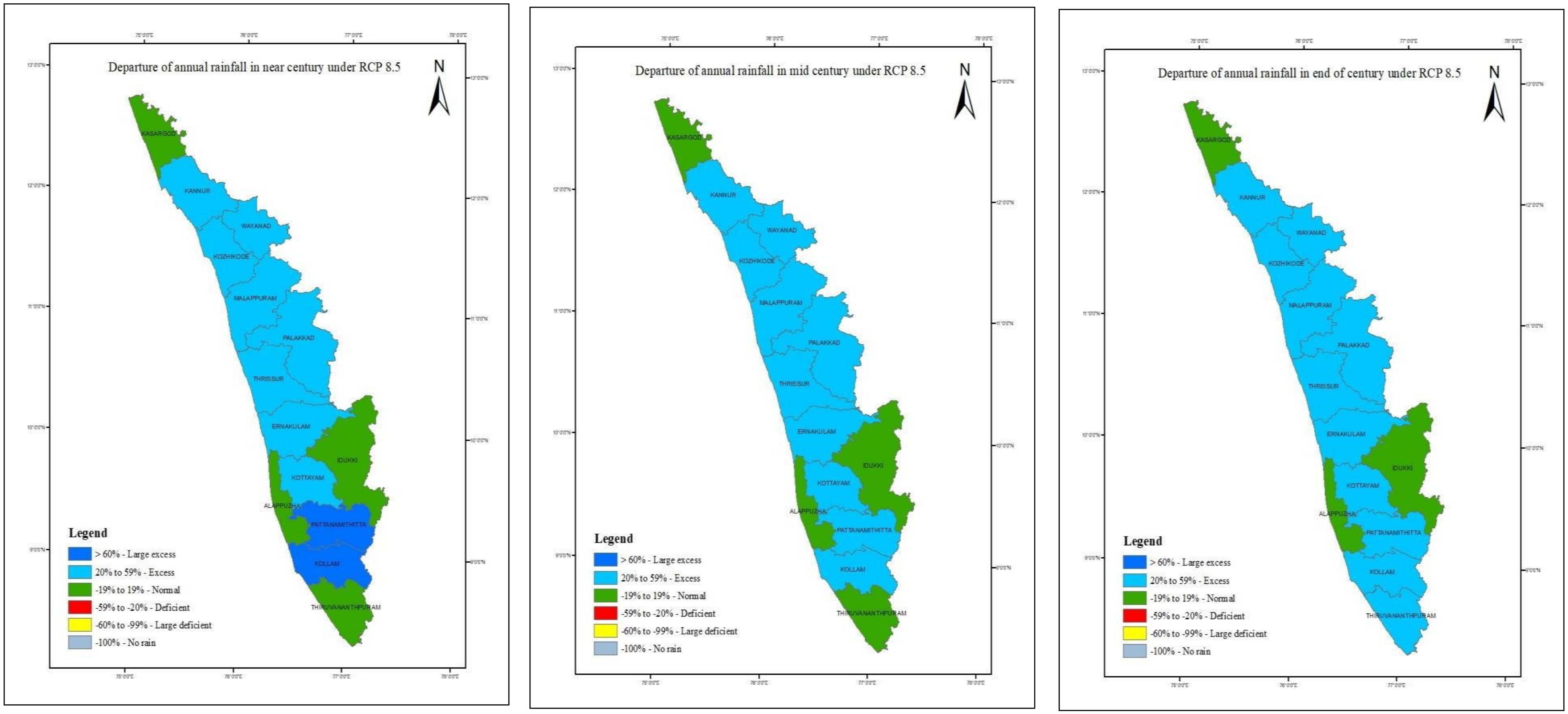
(a) (b) (c)

Fig. 5.44. Departure of minimum temperature from normal during summer season under RCP 8.5 (a) near century (b) mid century (c) end of century



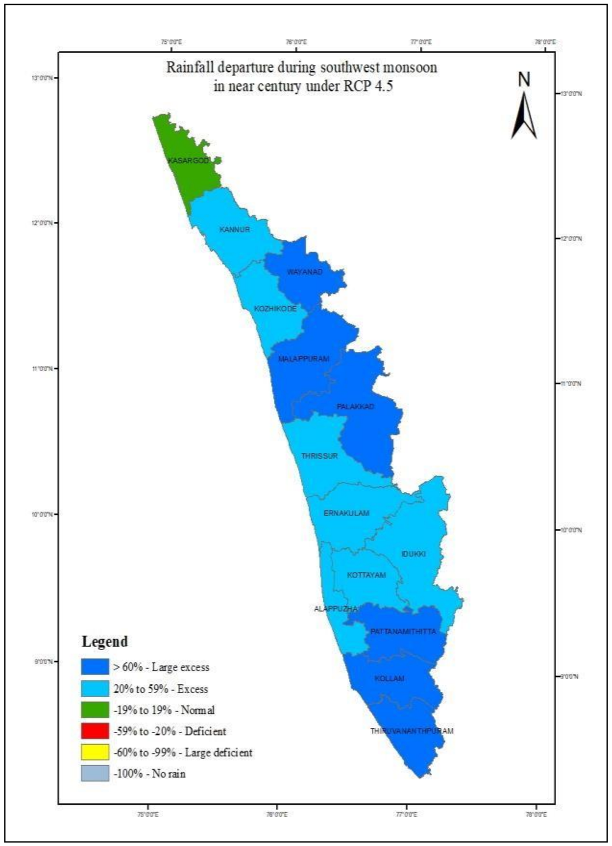
(a) (b) (c)

Fig. 5.45. Departure of annual rainfall from normal under RCP 4.5 (a) near century (b) mid century (c) end of century

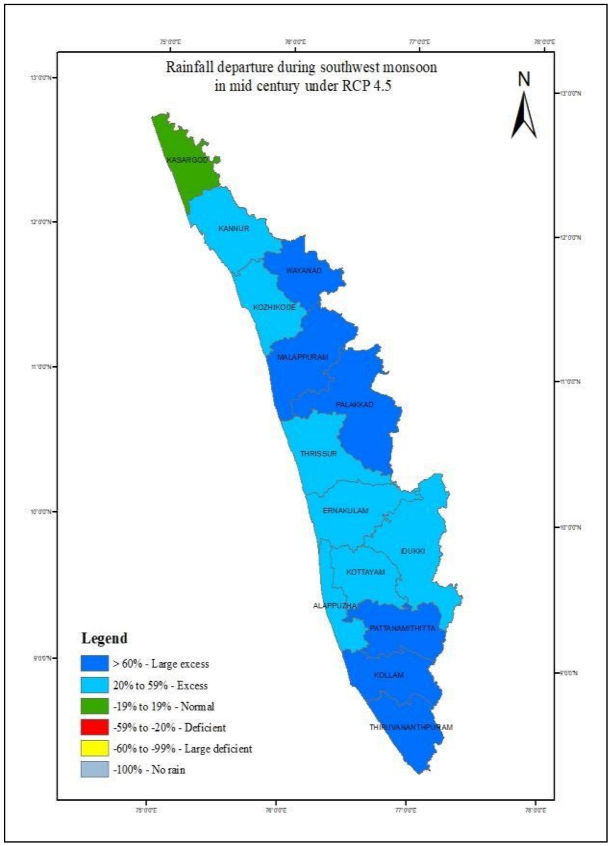


(a) (b) (c)

Fig. 5.46. Departure of annual rainfall from normal under RCP 8.5 (a) near century (b) mid century (c) end of century



(a)



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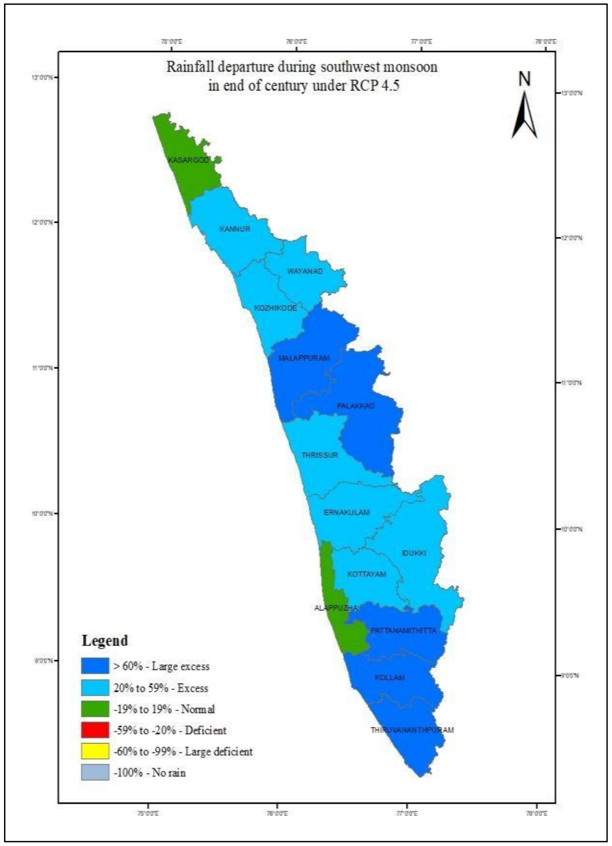
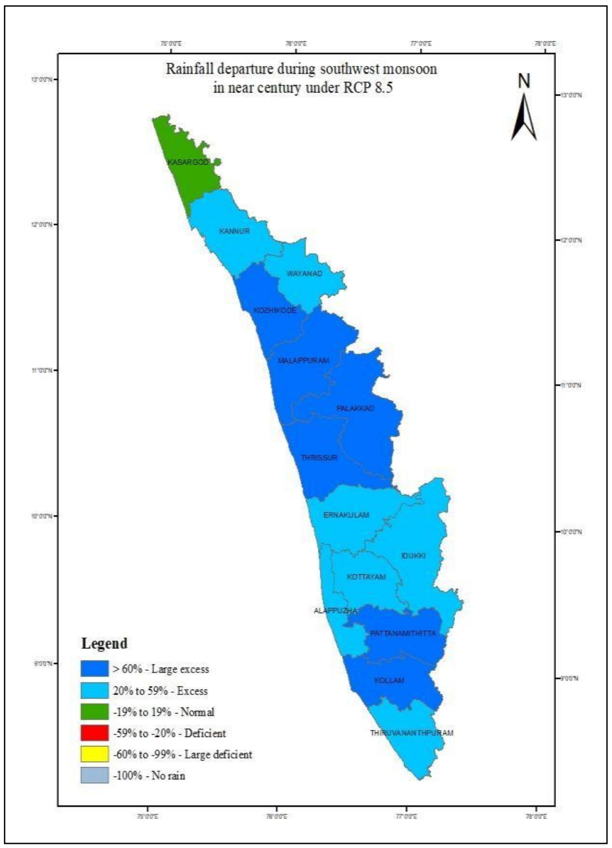
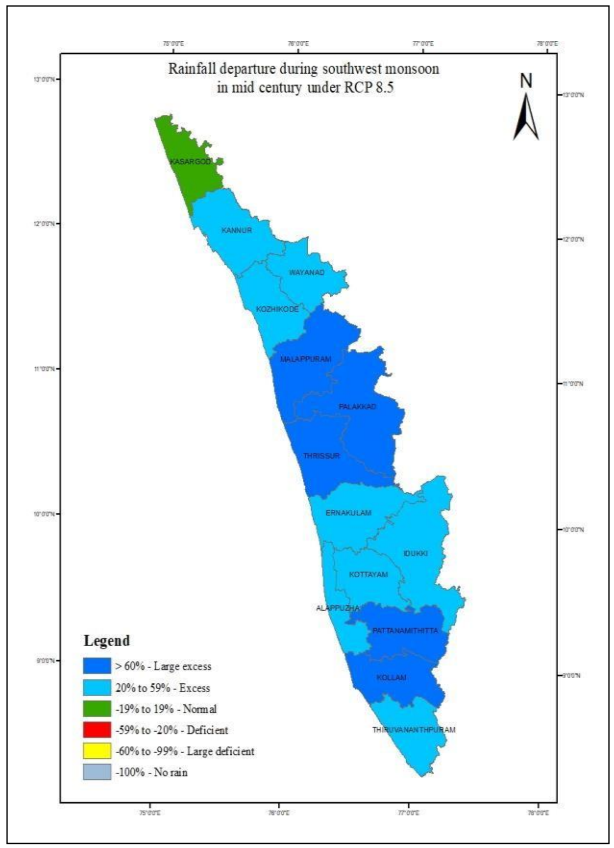


(c)

Fig. 5.47. Departure of rainfall from normal during southwest monsoon season under RCP 4.5 (a) near century (b) mid century (c) end of century



(a)



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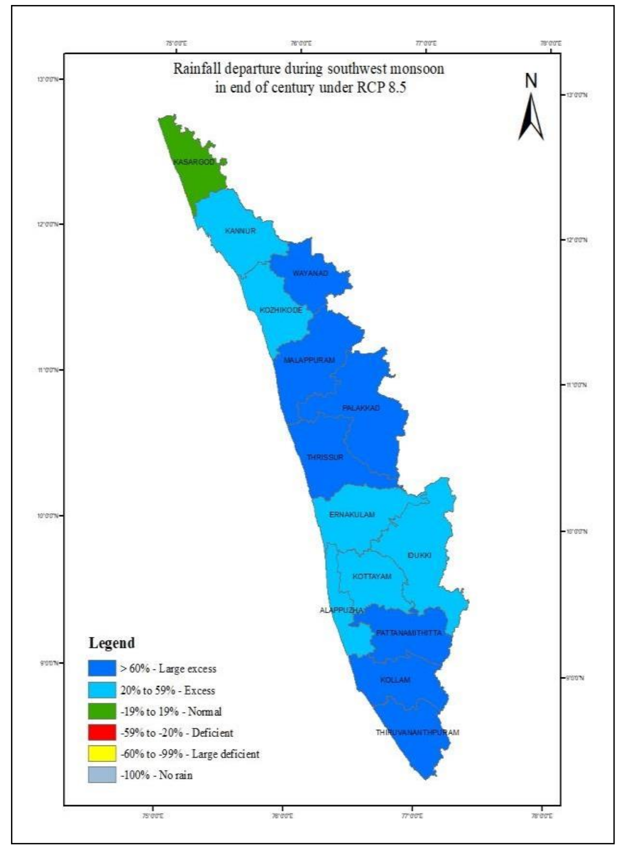
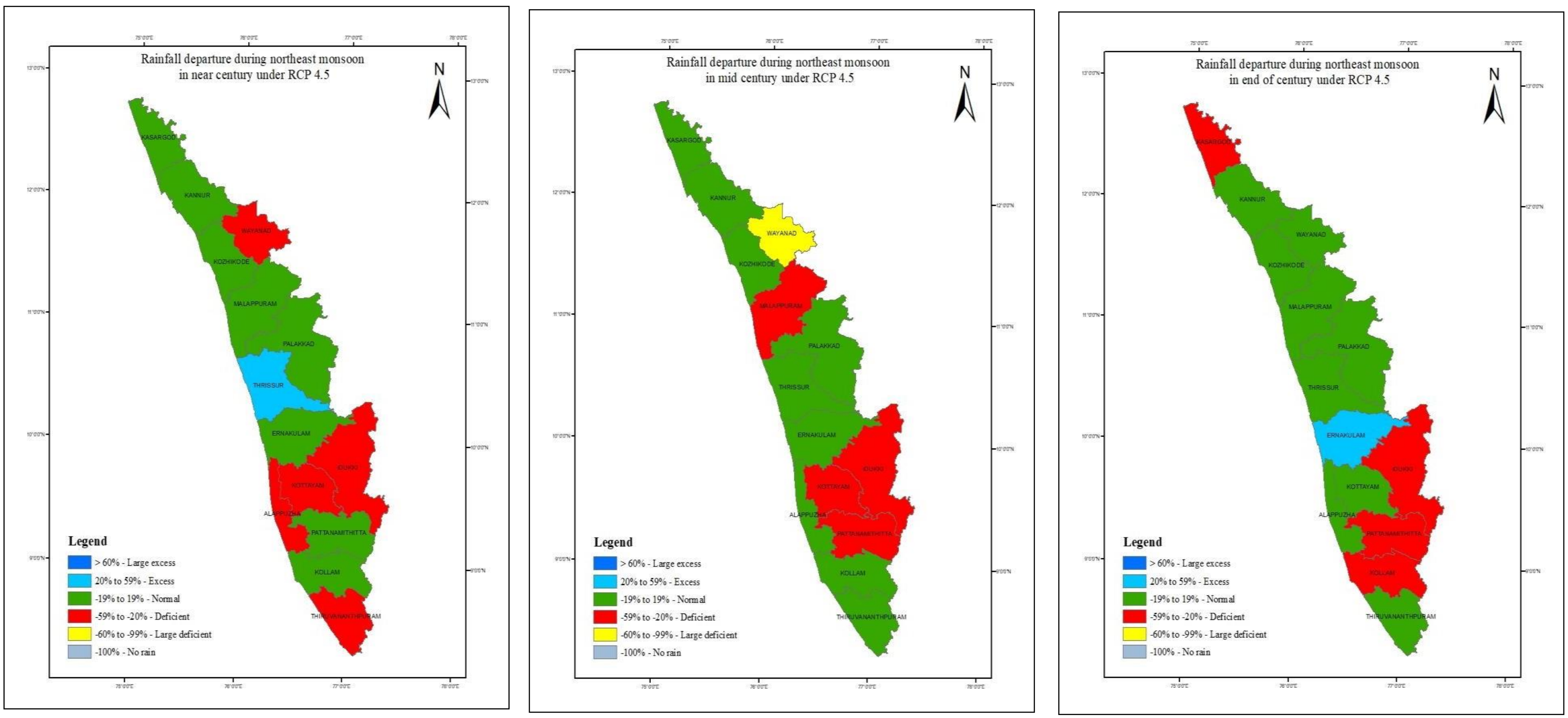


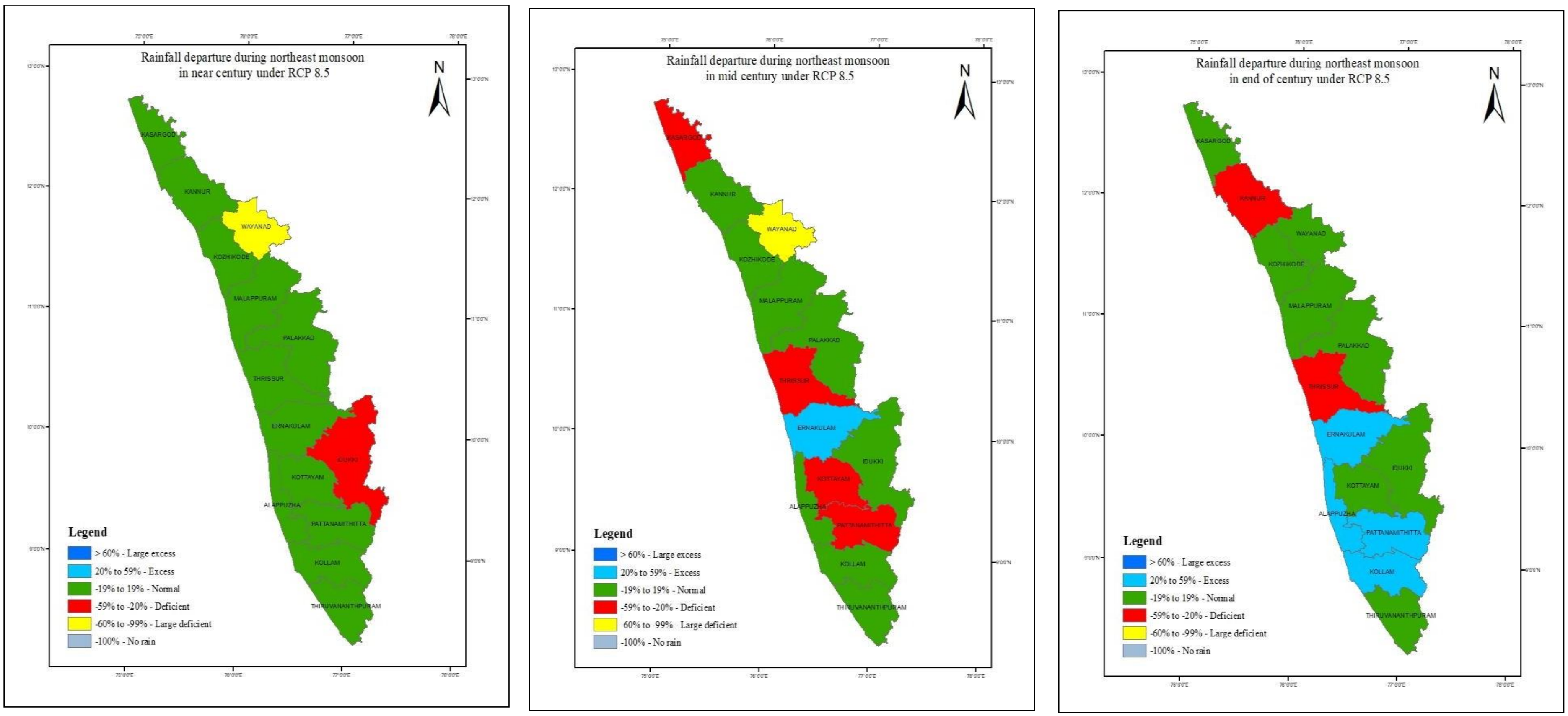
(c)

Fig. 5.48. Departure of rainfall from normal during southwest monsoon season under RCP 8.5 (a) near century (b) mid century (c) end of century



(a) (b) (c)

Fig. 5.49. Departure of rainfall from normal during northeast monsoon season under RCP 4.5 (a) near century (b) mid century (c) end of century



(a) (b) (c)

Fig. 5.50. Departure of rainfall from normal during northeast monsoon season under RCP 8.5 (a) near century (b) mid century (c) end of century

Thirssur a deficient rainfall is expected. In all the remaining districts northeast monsoon is expected to be normal (Fig. 5.50).

5.5.4.4. Winter season

Winter rainfall was predicted to decrease from normal in almost all parts of Kerala. Under RCP 4.5 in northern zone of Kerala winter rainfall decreased. In end of century an increase in winter rainfall was expected except in Malappuaram where it was found to be anormal. In central zone of Kerala a reduction in winter rainfall has been predicted in all the future simulations except in Ernakulam where the rainfall is expected show normalderparture. In Ernakulam by late century an increase in winter rainfall is predicted. In high range zone a deficient winter rainfall has been predicted in mid century. In near and end century Wayanad showed an deficient rainfall while in Idukki a normal departure is expected. In problematic zone a normal departure is expected in near century while a deficient rain is expected in Kottyam by mid an end of century has been predicted. In late century in Alappuzha an excess rainfall is expected. In southern zone of Kerala the winter rain has been predicted to decrease in all the future simulations. The departure is expected to be normal in Thiruvananthapuram (Fig. 5.51)

Under RCP 8.5 in near century a deficient and large deficient rainfall is expected in northern zone. In central zone, problematic zone and southern zone a deficient and normal rainfall is expected. In high range zone a normal departure is expected. In mid and end of century an excess rainfall is expected in northern zone except in Malappuram. In high range a deficient rain is expected in Wayanad and normal departure is expected in Idukki in mid and end of century In central zone a deficient rain is expected in central zone except in Ernakulamwher an excess rainfall is expected. In problematic zone in Alappuzha an excess rainfall and in Kottyamadeficient and normal rainfall is expected in mid and end of century. In southern zone a deficient rain is expected except in Thiruvananthapuram (Fig. 5.52).

5.5.4.5. Summer season

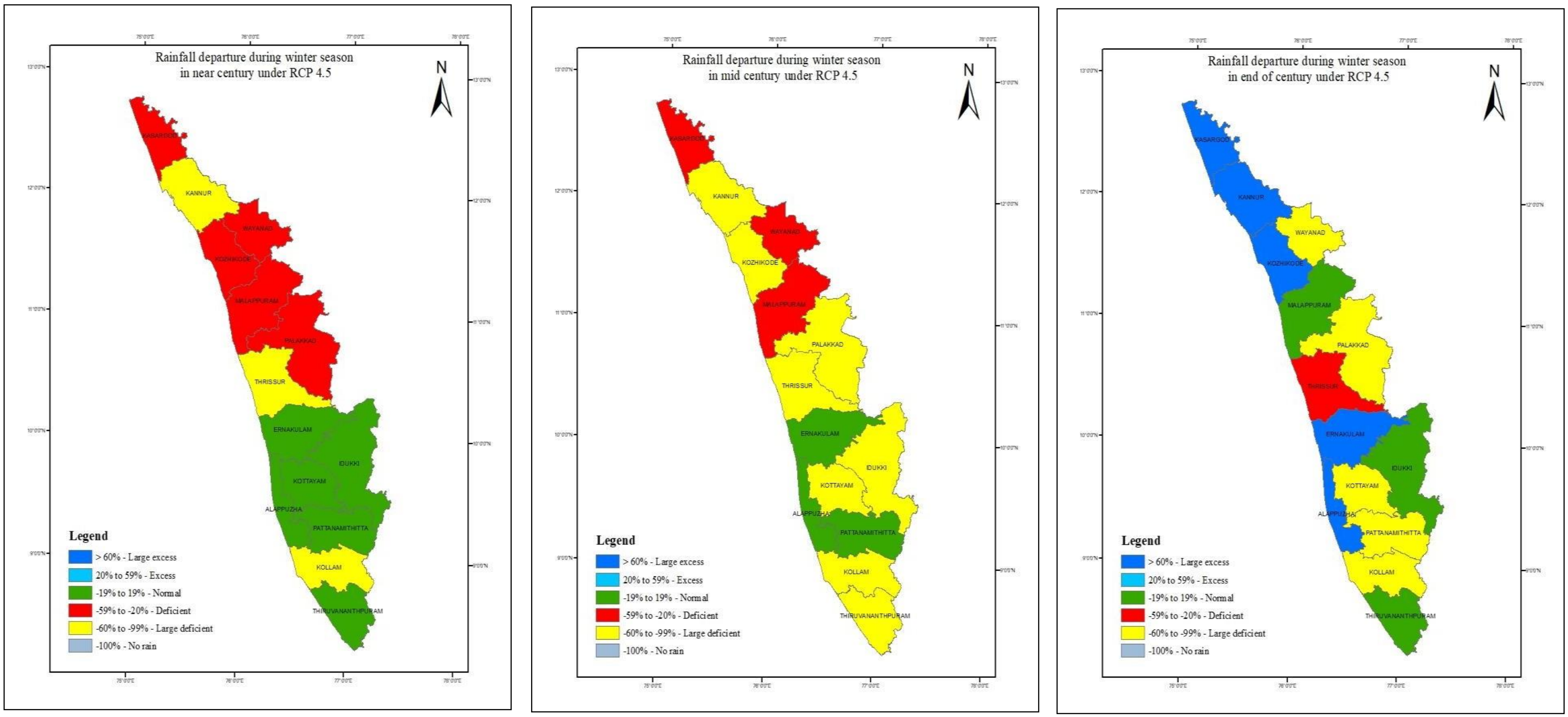
Departure of rainfall from normal during summer season under RCP 4.5 and 8.5 is shown in Figure 5.53 and 5.54. Under RCP 4.5 large excess and excess rainfall was expected in northern zone and central zone Kerala during summer season. In high range zone, a reduction rainfall is expected in Idukki while it showed an increase in Wayanad during all future simulations. In problematic zone normal summer showers are expected. In southern zone there was An excess rainfall is expected in near century except in Thiruvanathpuram. By mid and end of century normal deparute is expected except in Thiruvananthpuram where a deficient rainfall is expected.

A similar condition was observed under the RCP 8.5 scenario. In northern zone and central an increase in summer rainfall has been expected and in southern zone a reduction in summer rainfall has been predicted.

5.6. IMPACT OF CLIMATE CHANGE ON DURATION OF RICE VARIETIES

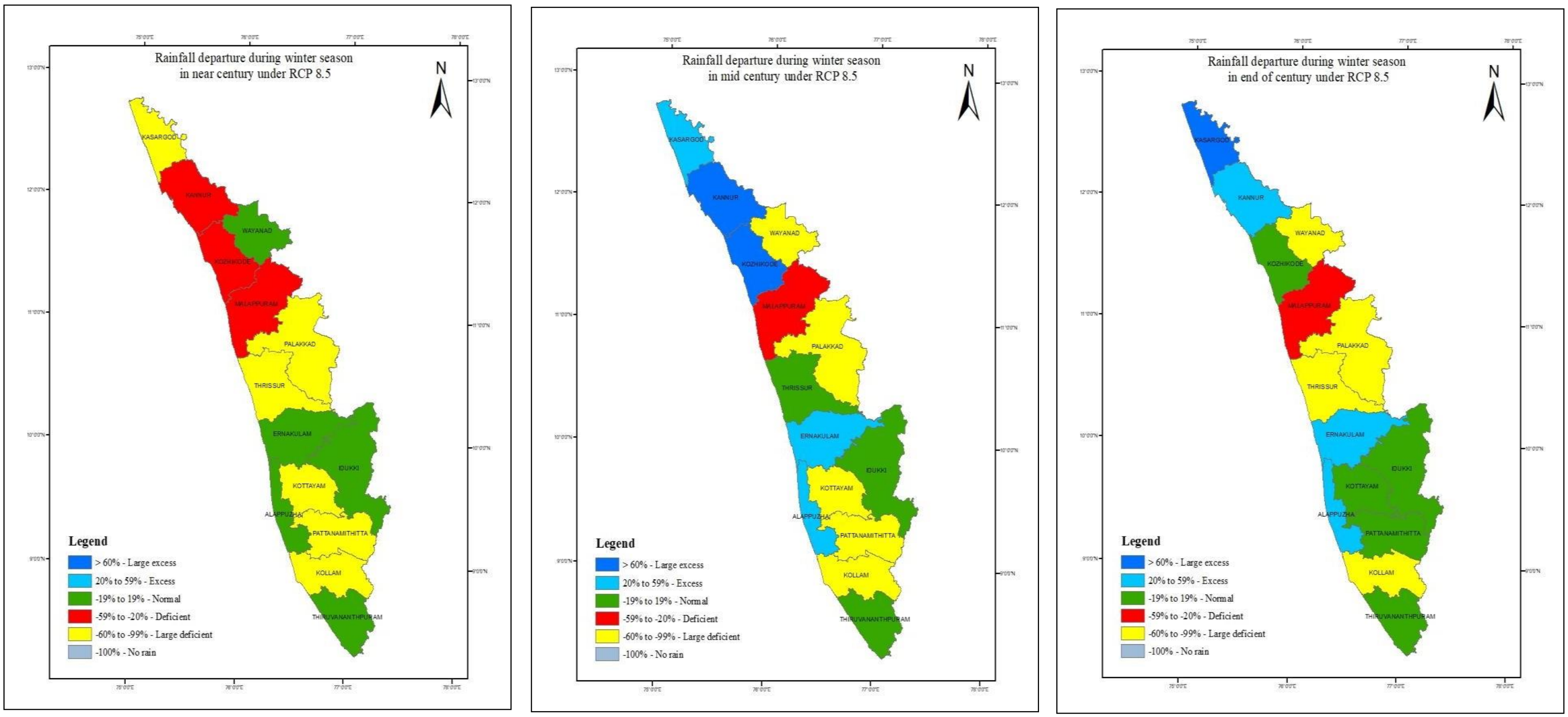
Short duration and medium duration variety showed a variation in their duration from base period in all the future simulation under both the RCPs. The duration of rice varieties showed a negative correlation with temperature. Figure 5.55 and 5.56 showed the impact of increase in temperature on the duration of crop under RCP 4.5 and RCP 8.5 in both varieties.

According to the findings of Lalitha *et al*. (1999) an increase in temperature above 26°C reduced the duration of transplanting to active tillering. In the study of Ziska *et al.* (1997) an early maturation of rice crop had been observed with an increase in temperature by 4°C. In dry season the maturity of crop is enhanced by six days and in wet season the crop is expected mature early by five days. Hence this must the reason of decrease in crop duration. In both the varieties, Jaya and Jyothi a decrease in crop duration is expected in all the future simulations in most parts of Kerala. In northern zone, central zone and problematic zone an early maturity of rice crop from base has been observed in all the future simulation under both the RCPs. The duration of rice is expected to increase with the increase in temperature. The deviation of temperature from normal is expected to be less in southern zone hence the duration of crop is also showing less deviation. In high range zone like Idukki the temperature is expected to decrease and that may the reason for increasing the duration of crop in future simulations. Both the varieties showed a similar trend in the duration of the crop.



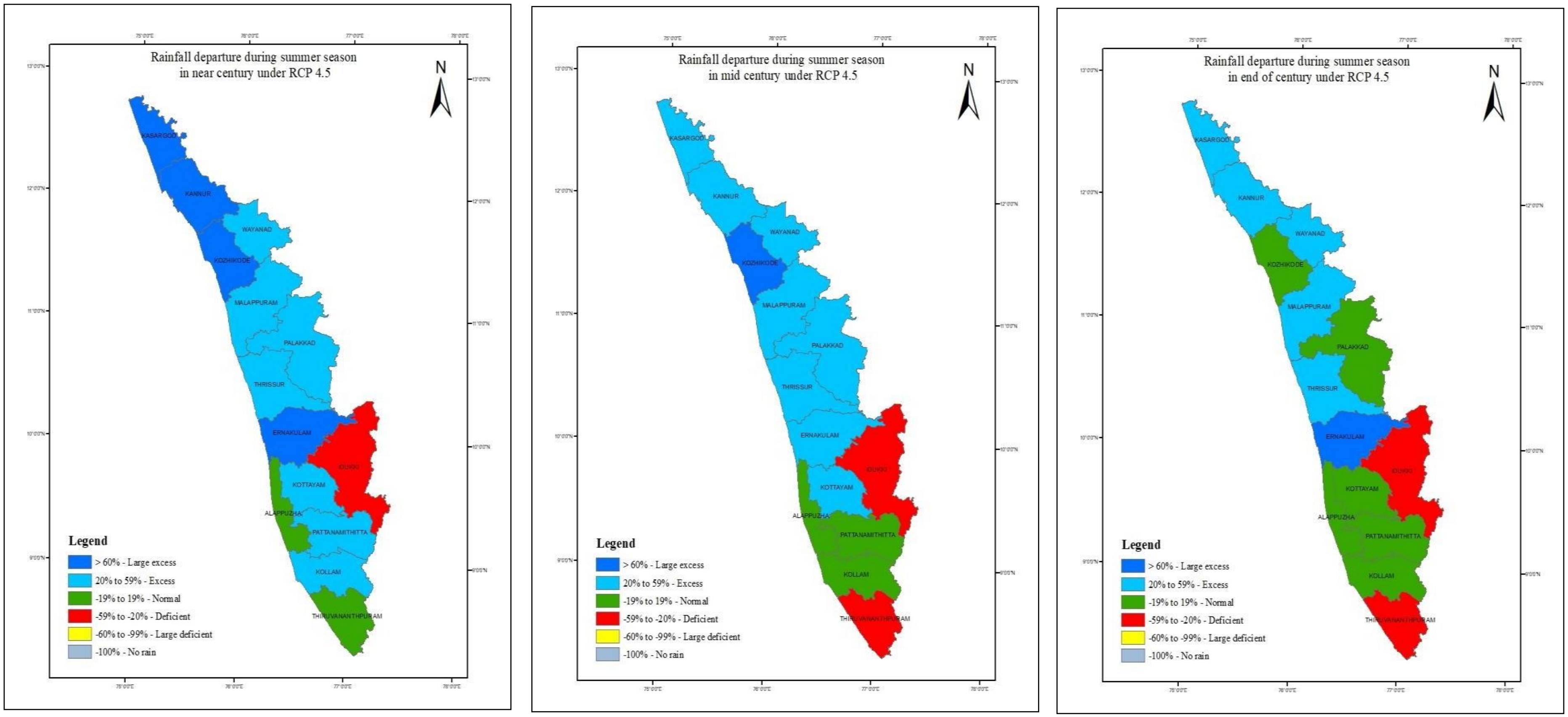
(a) (b) (c)

Fig. 5.51. Departure of rainfall from normal during winter season under RCP 8.5 (a) near century (b) mid century (c) end of century



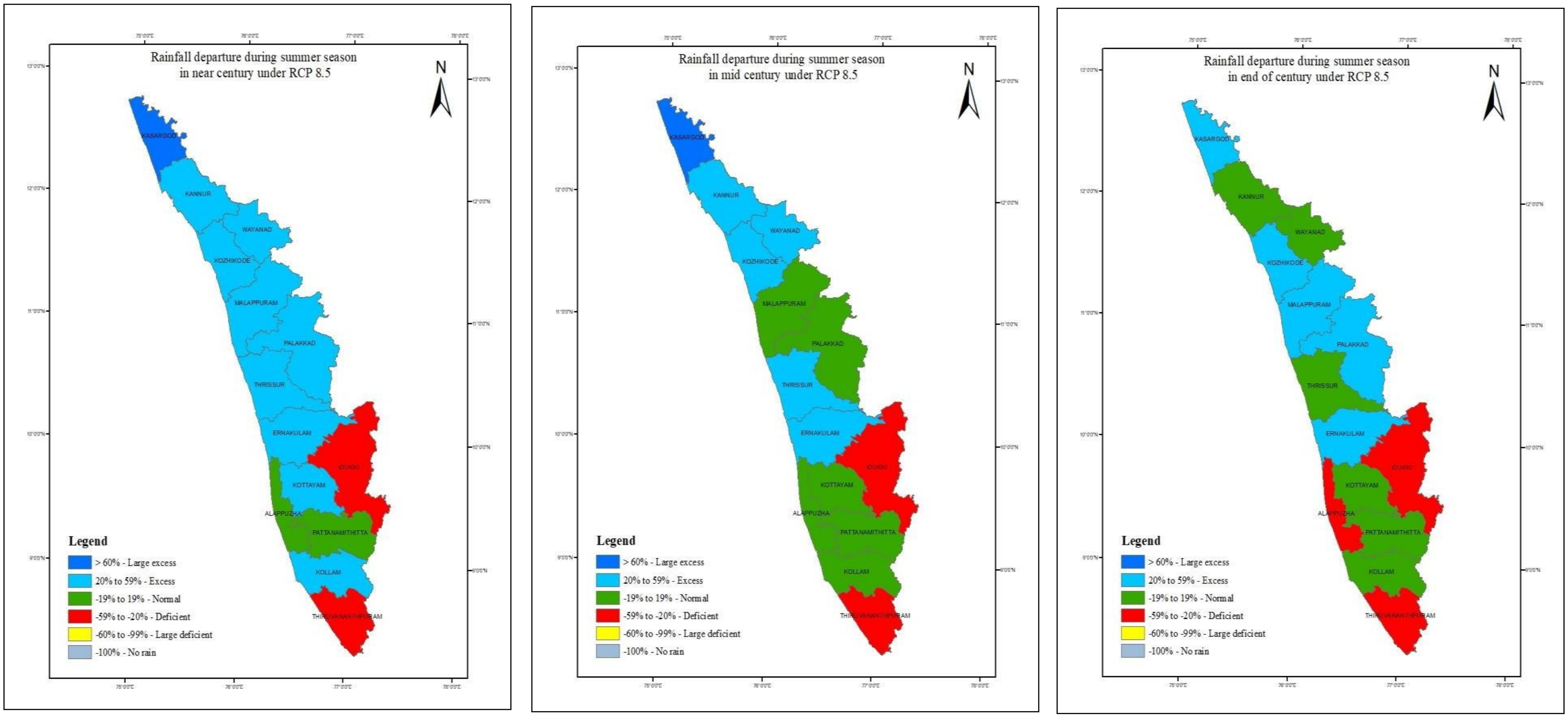
(a) (b) (c)

Fig. 5.52. Departure of rainfall from normal during winter season under RCP 8.5 (a) near century (b) mid century (c) end of century



(a) (b) (c)

Fig. 5.53. Departure of rainfall from normal during summer season under RCP 4.5 (a) near century (b) mid century (c) end of century



(a) (b) (c)

Fig. 5.54. Departure of rainfall from normal during summer season under RCP 4.5 (a) near century (b) mid century (c) end of century

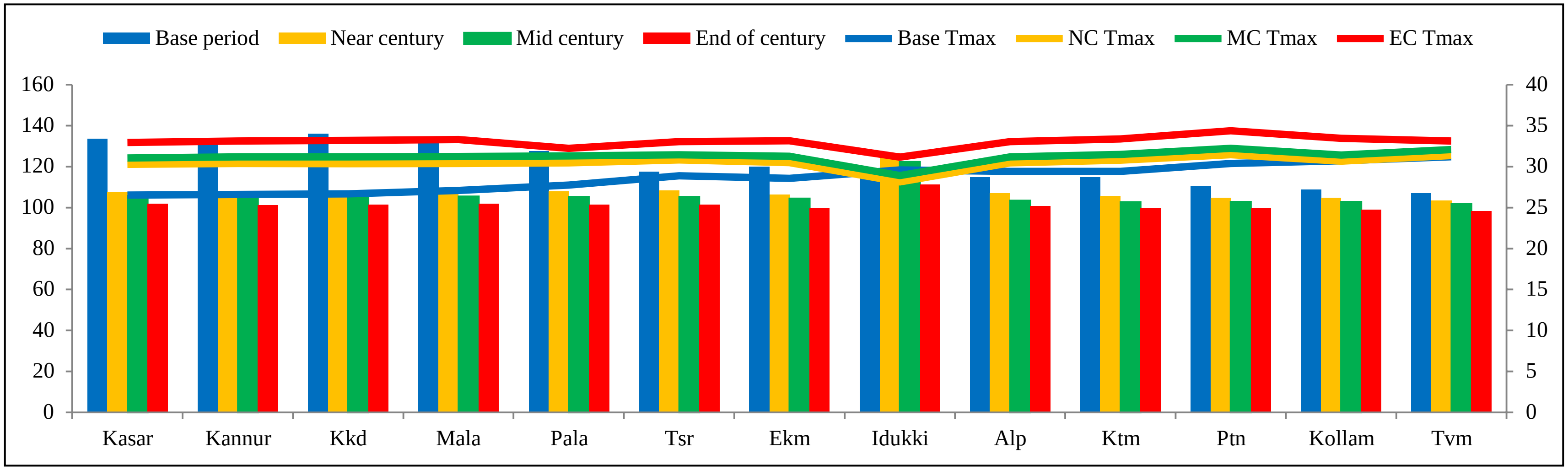


Fig. 5.55. (a) Impact of increase in temperature on the duration of Jaya under RCP 4.5

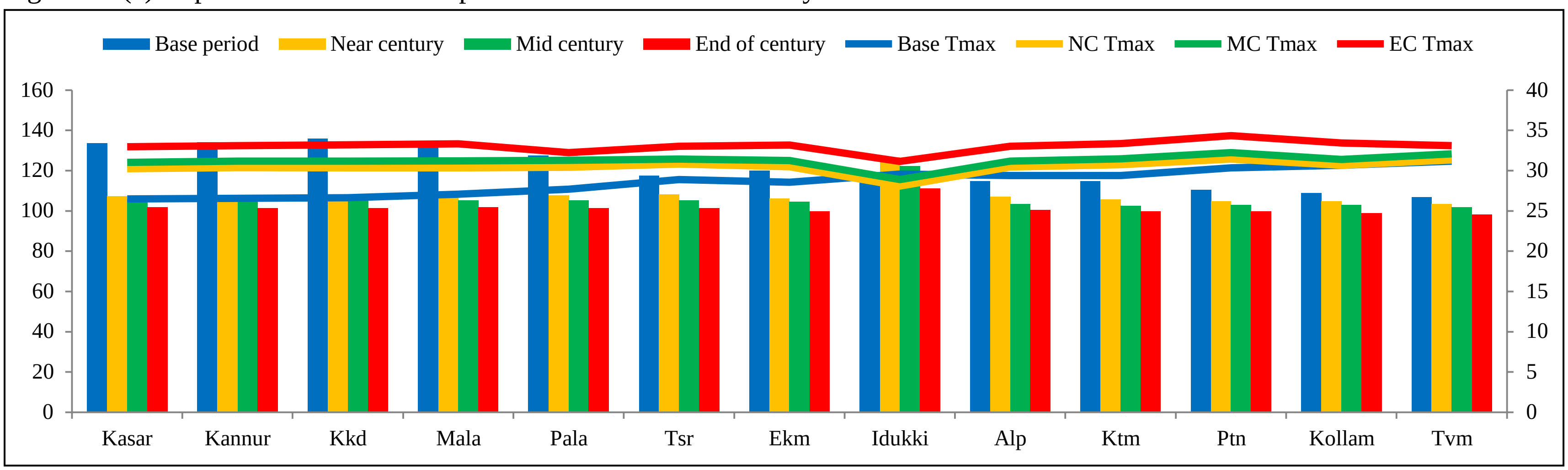


Fig. 5.55. (b) Impact of increase in temperature on the duration of Jaya under RCP 8.5

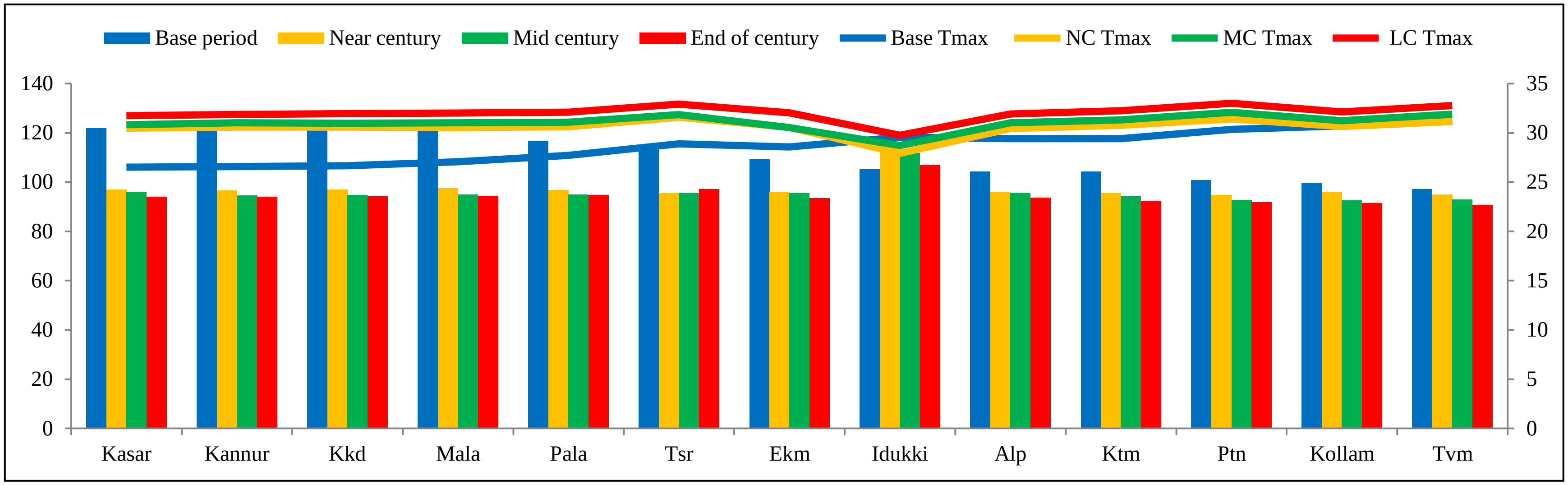


Fig. 5.56. (a) Impact of increase in temperature on the duration of Jyothi under RCP 4.5

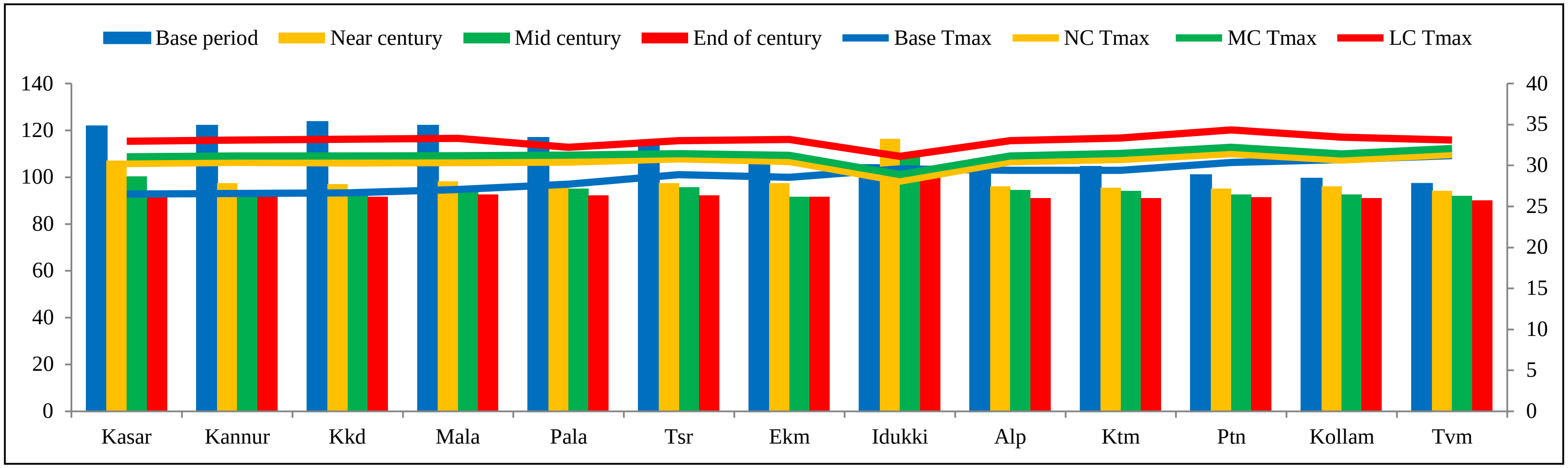


Fig. 5.56. (b) Impact of increase in temperature on the duration of Jyothi under RCP 8.5

5.7. IMPACT OF CLIMATE CHANGE ON YIELD OF RICE VARIETIES

The effect of climate change on the yield of rice on different dates of planting has been discussed in detail. The growth of rice has been classified into three phenophases which are:

1. Transplanting to panicle initiation
2. Panicle initiation to anthesis
3. Anthesis to physiological maturity

The yield of rice varieties has been predicted for 13 districts of Kerala where the rice cultivation is carried out during the *Kharif* season.

5.7.1 Rice production in the northern zone of Kerala

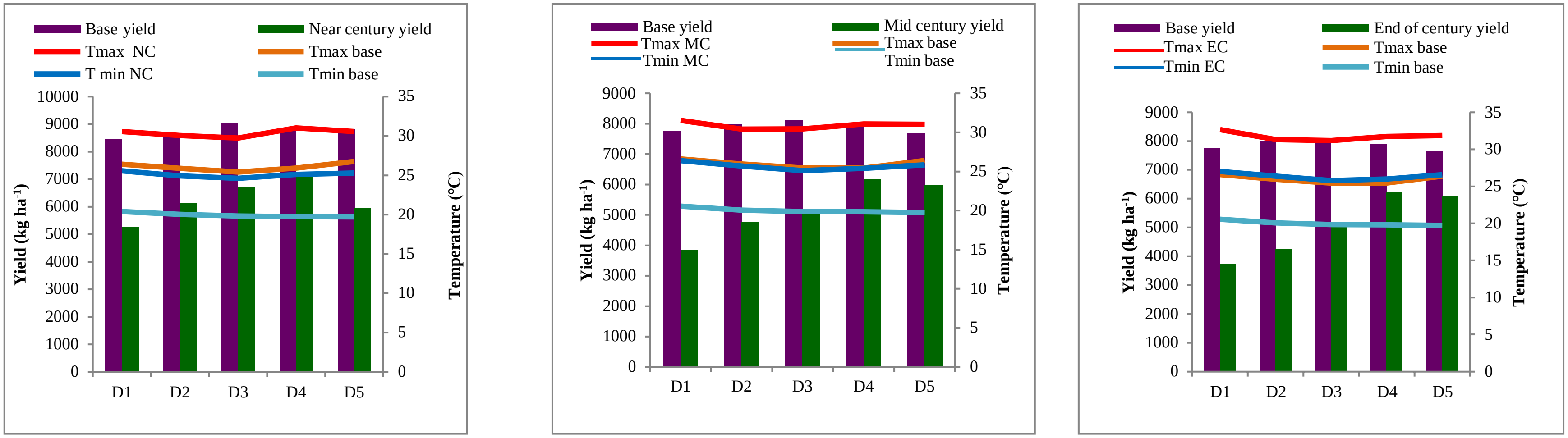
In the northern zone of Kerala during the base period,the highest potential yield of Jaya has been recorded during June 5th planting except in Kasargod where the potential yield was recorded during July 5th planting. In Jyothi highest potential yield during the base period was observed during July 5th in Kasargod, June 5th in Kozhikode and June 20th in Malappuram and Kannur. In both varieties, a reduction in rice yield has been observed in near-century, mid-century and by the end of the century under both the RCPs.In all future simulations, the potential yield is higher during July 20th planting under both the RCPs.

Variation in temperature and precipitation patterns may be the reason for the reduced yield. Figure 5.58 to 5.88 (a) shows the comparison of yield and temperature (maximum and minimum) experienced during each date of planting in the base period and different future simulations under both the RCPs. Similarly, Figure 5.58 to 5.88 (b) shows the comparison of yield an rainfall experienced during each date of planting in the base period and different future simulations under both the RCPs in different districts of the Northern zone. Gao *et al.* (1992) and Abbas and Mayo, 2021 reported that an increased temperature during the vegetative phase had a positive effect on rice production. A similar finding has been found in this study also. In future simulations when compared to other dates of planting during July 5th planting an increase in temperature was observed (Fig 5.58.a). This increase in temperature may be the reason for increased yield in July 5th planting.

Increased rainfall during vegetative phase results in reduced solar radiation. This negatively influences the number of tillers and thereby yield (Sridevi and Chellamuthu, 2015). Also, Kamalan *et al.*(1988) reported that reduced rain during vegetative growth negatively affects the tillering rate which results in yield reduction. Hence it is necessary to receive an optimum amount of rainfall for increased production.

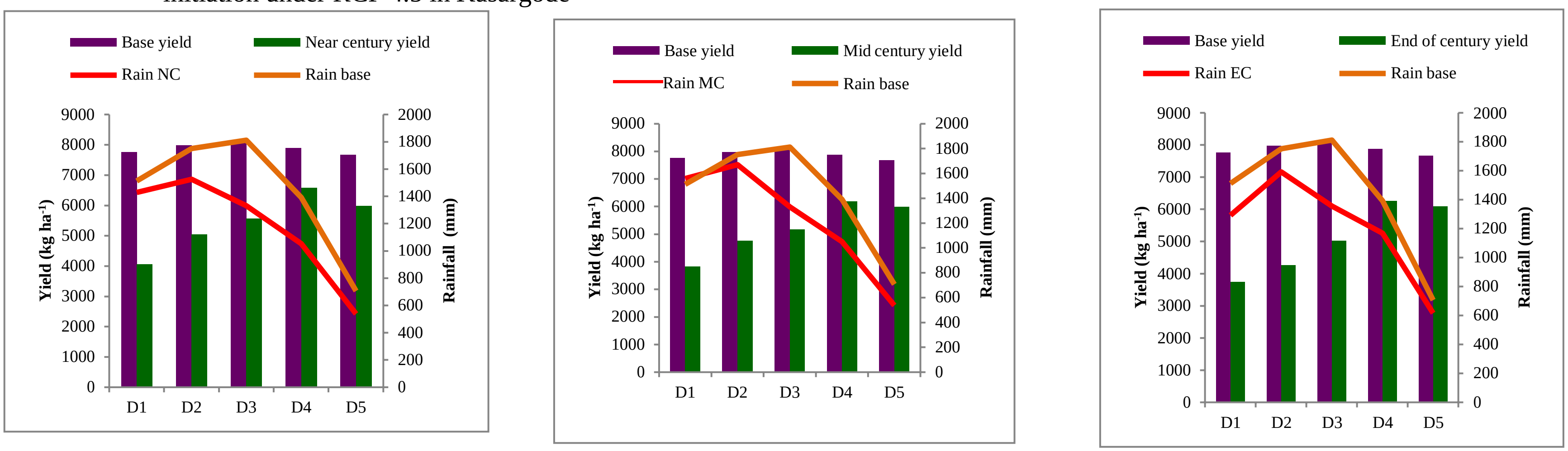
During panicle initiation to anthesis, temperature showed a significant negative impact. In the reports of Abbas and Mayo, 2021 it was stated that a significant reduction in yield occurs when there is an increase in minimum and maximum temperature during the panicle initiation to anthesis. Jagadish *et al.* (2010) also reported that flowering is the most sensitive stage of rice which is sensitive to both heat stress and cold stress. Matsui *et al*. (2001) and Zhao *et al.* (2010) conclude that an increased maximum temperature hinders pollen germination and dehiscence. The results of Prasad *et al.* (2006) also concluded that an increased maximum temperature decreased the production of pollen.

Mohammed and Tarpley, (2009) reported that an increased minimum temperature reduced the pollen grains germination. Hence an increase in temperature in the future duringpanicle initiation to anthesis may be the reason for the yield reduction in the future.Vijayakumar, 1996 reported that continuous rainfall for three days during flowering significantly affected rice production.



i ii iii

Fig. 5.57. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Kasargode



i ii iii

Fig. 5.57. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Kasargode

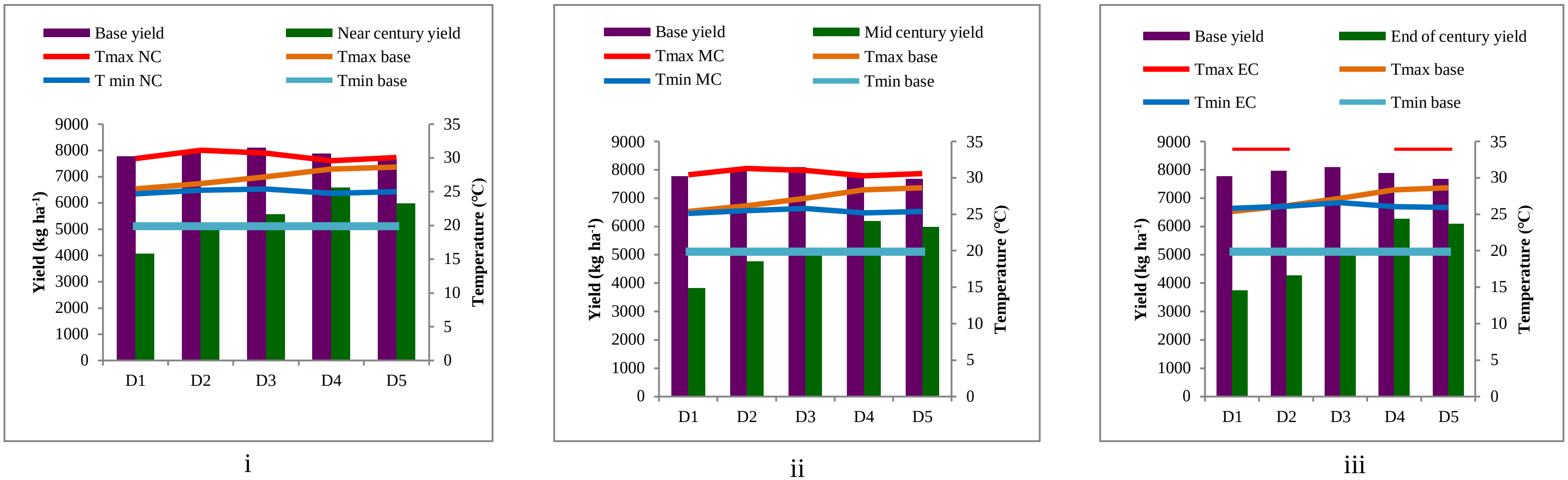


Fig. 5.58. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Kasargode

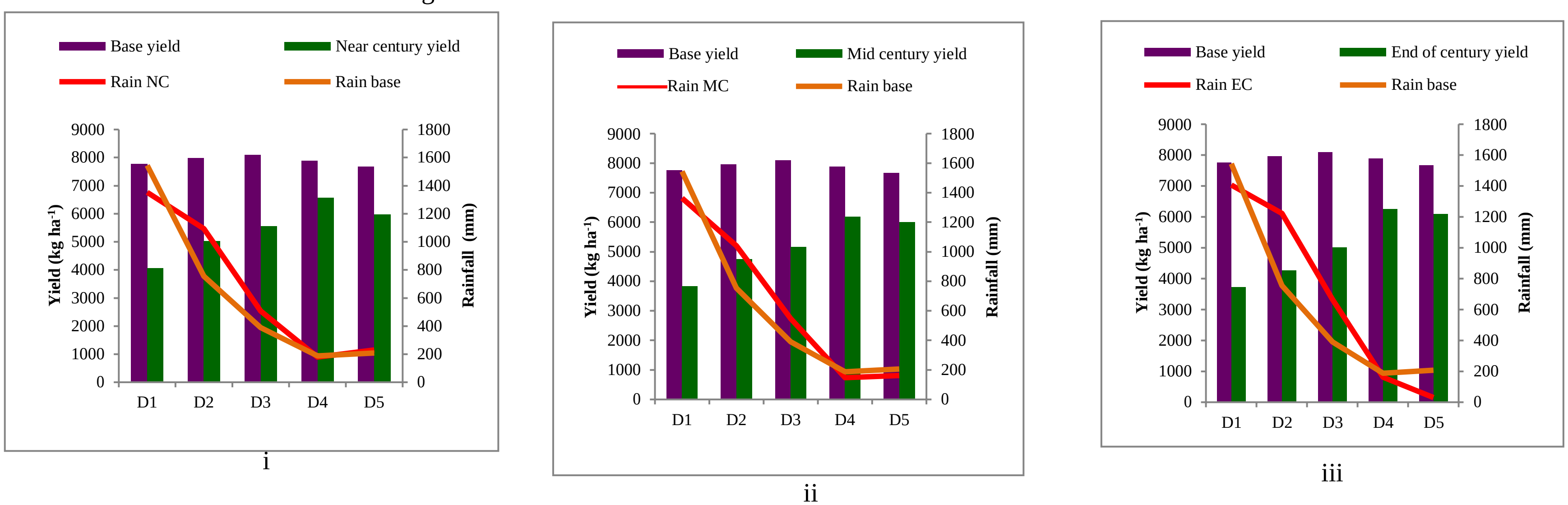


Fig. 5.58. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Kasargode

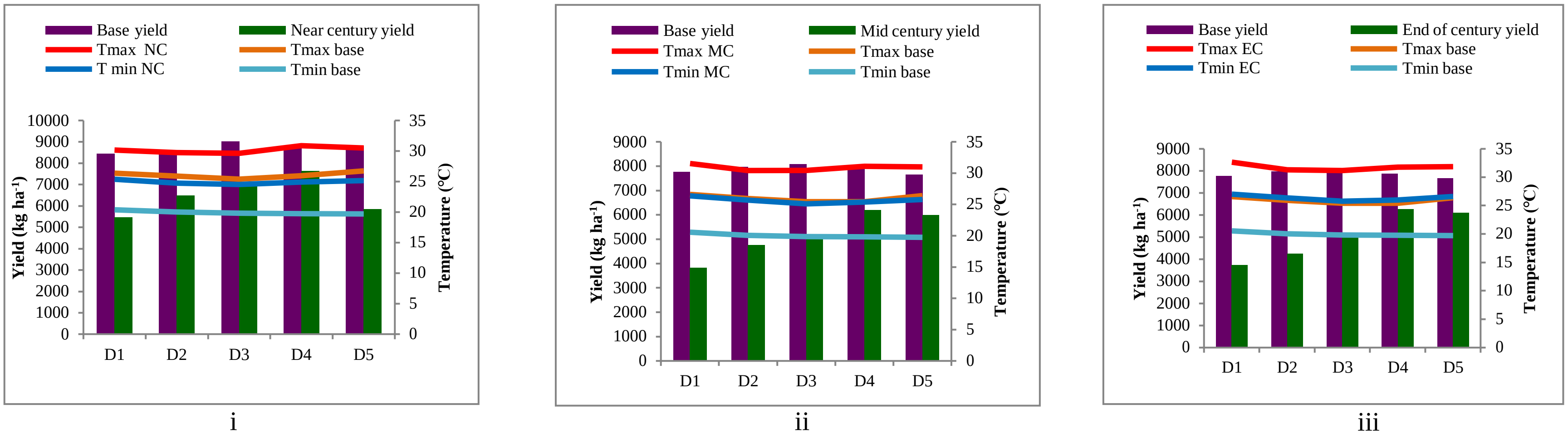


Fig. 5.59. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Kasargode

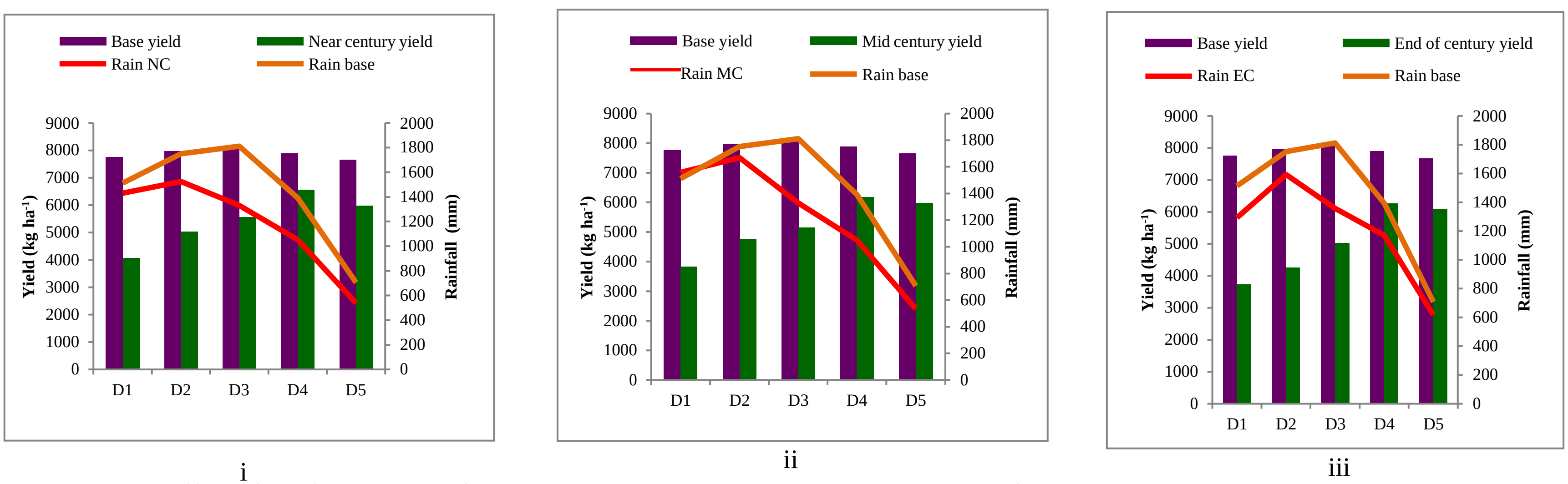
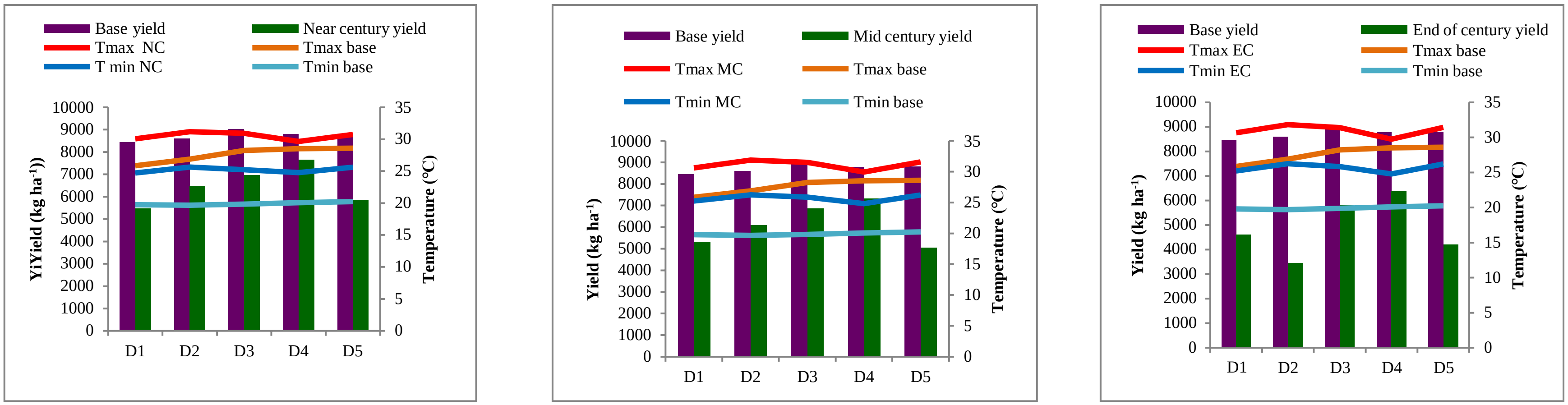
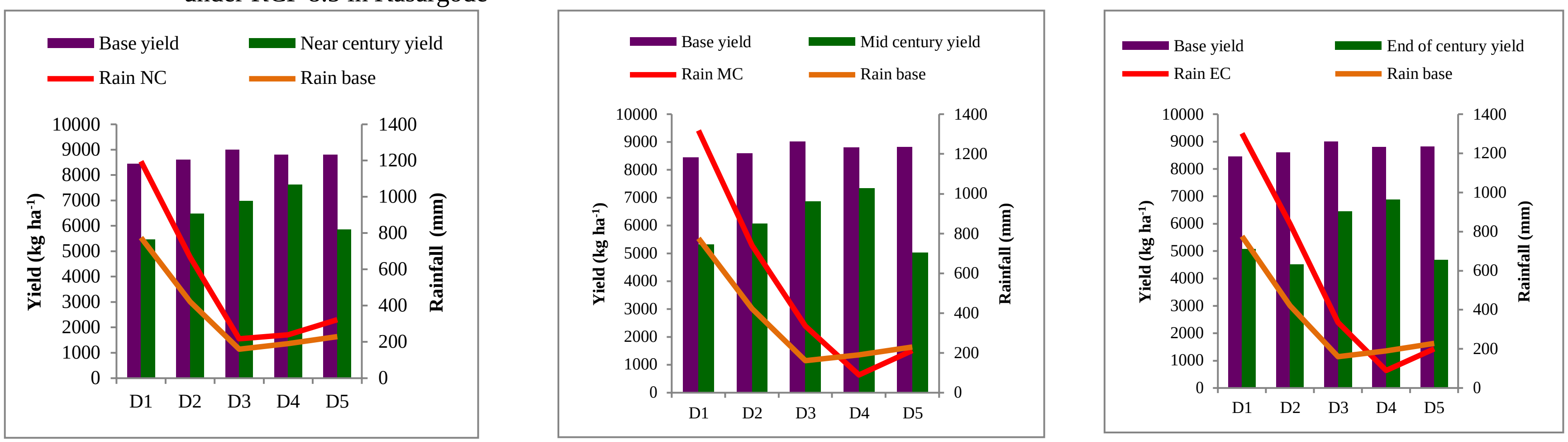


Fig. 5.59. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Kasargode



i ii iii

Fig. 5.60. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Kasargode



i ii iii

Fig. 5.60. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Kasargode

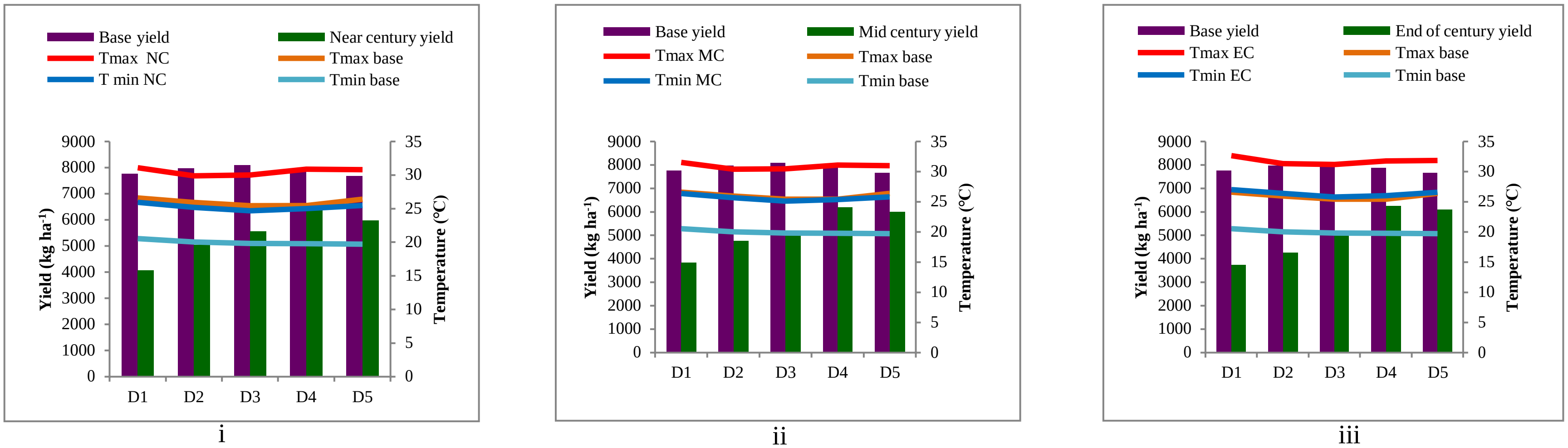


Fig. 5.61. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Kasargode

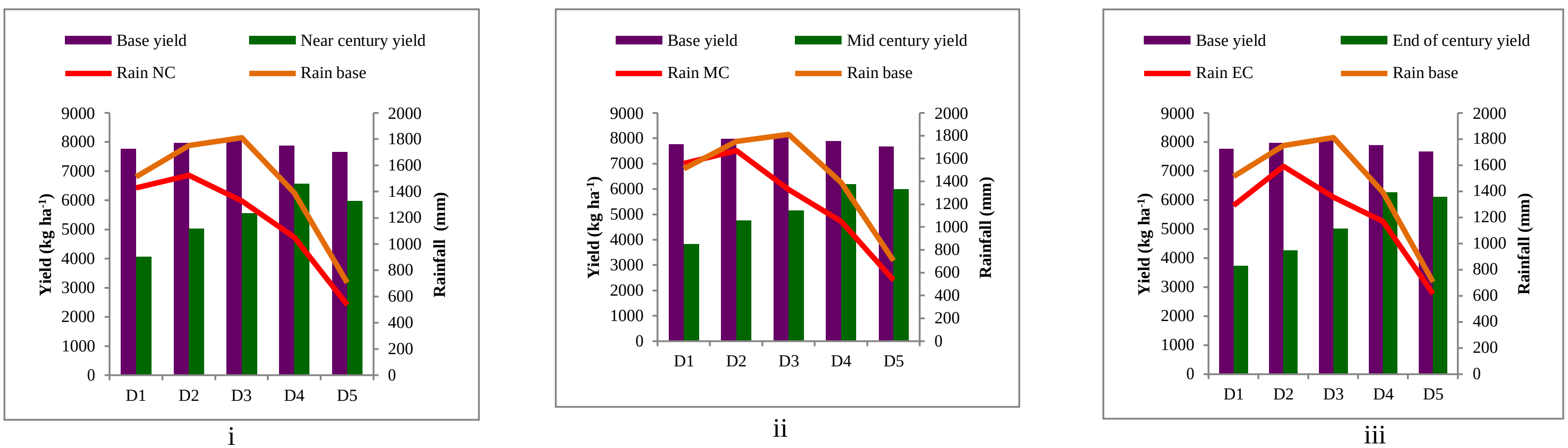
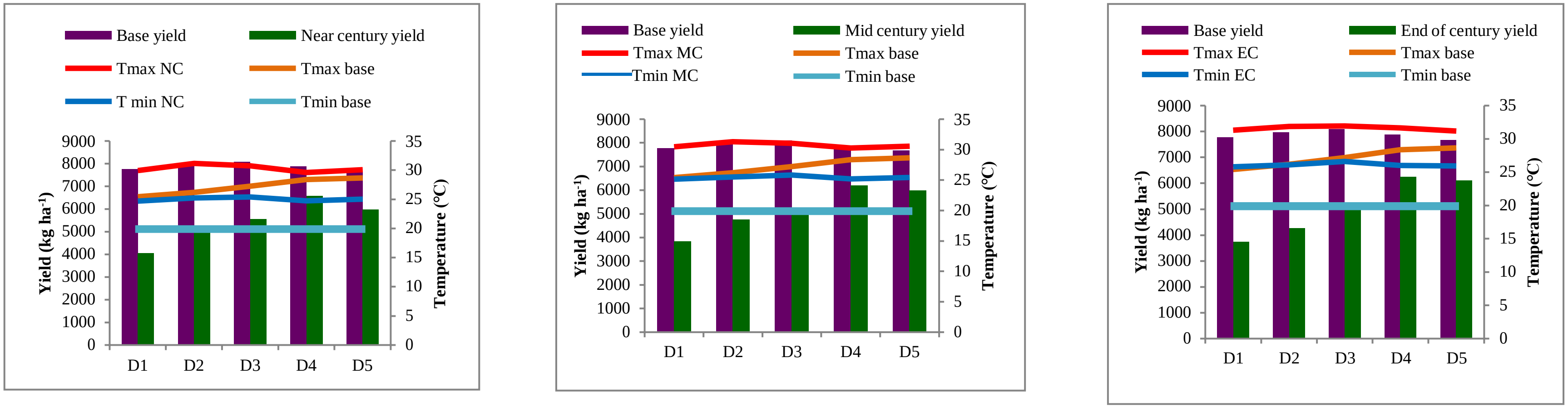
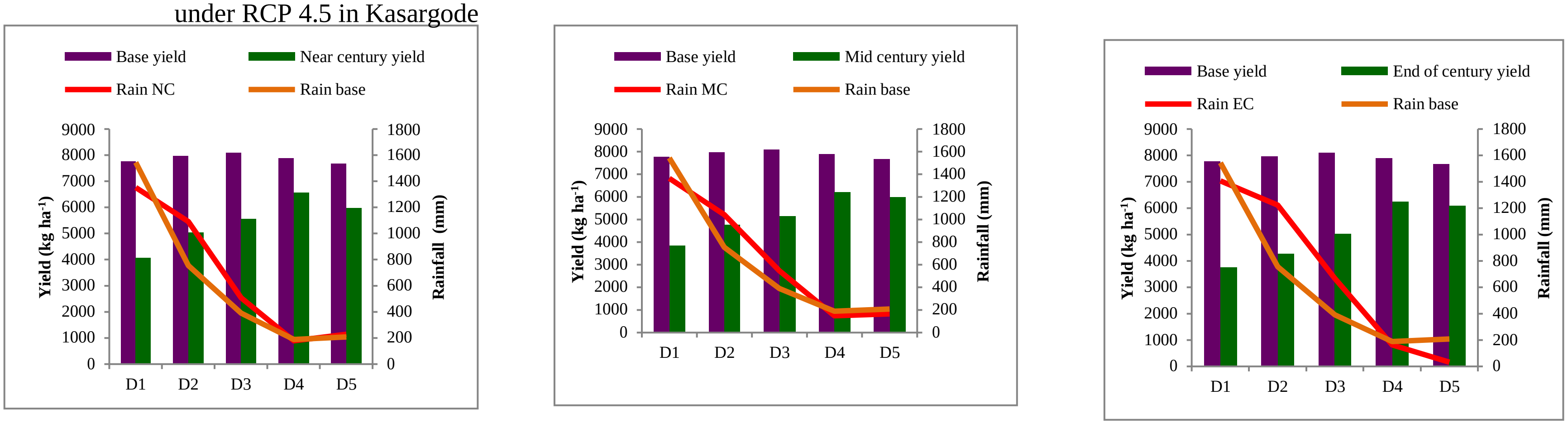


Fig. 5.61. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Kasargode



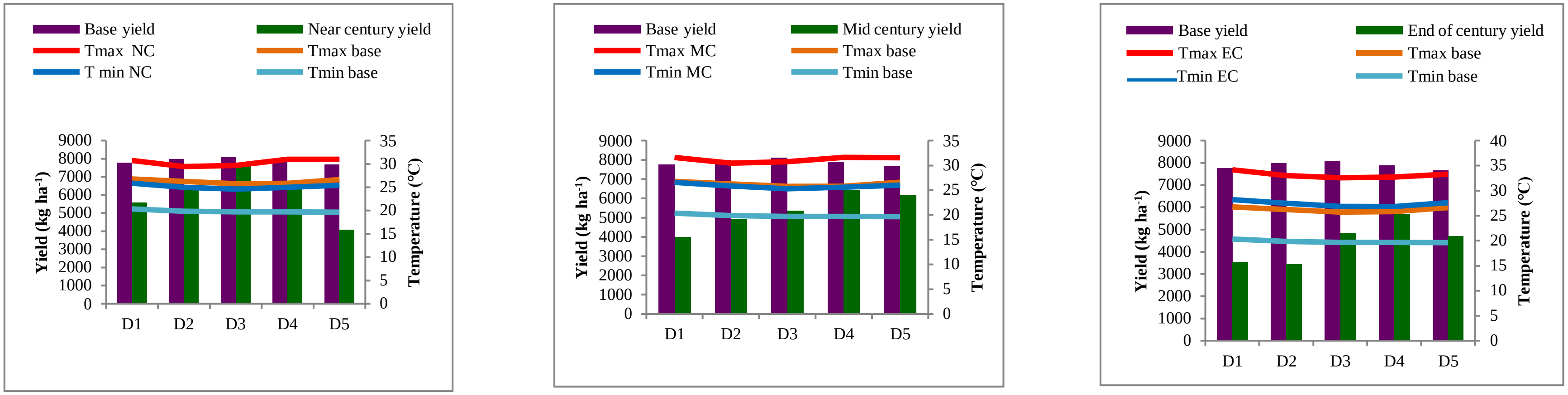
i ii iii

Fig. 5.62. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Kasargode



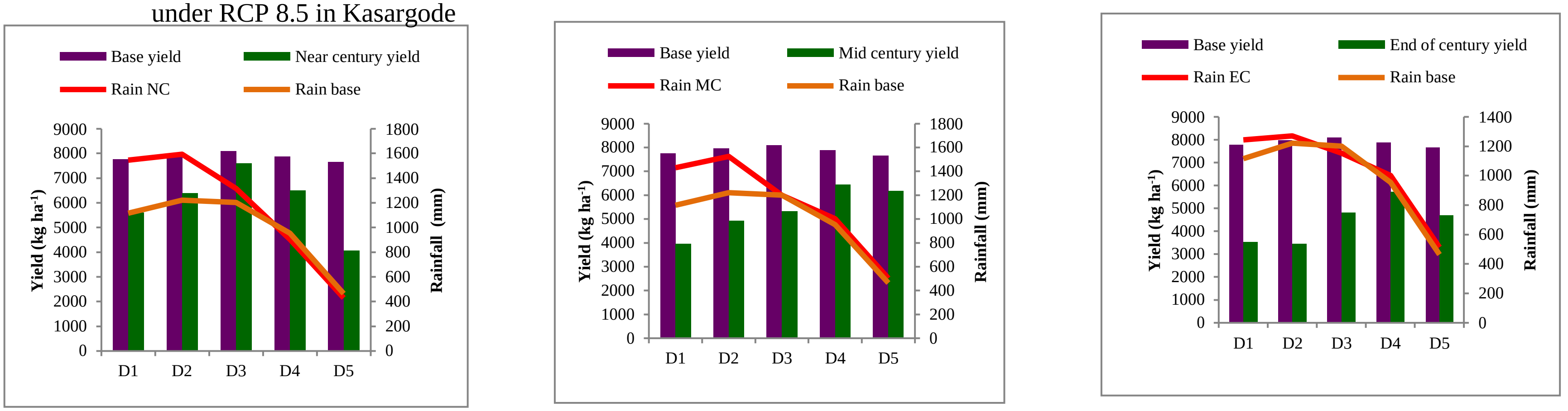
i ii iii

Fig. 5.62. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Kasargode



i ii iii

Fig. 5.63. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Kasargode



i ii iii

Fig. 5.63. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5in Kasargode

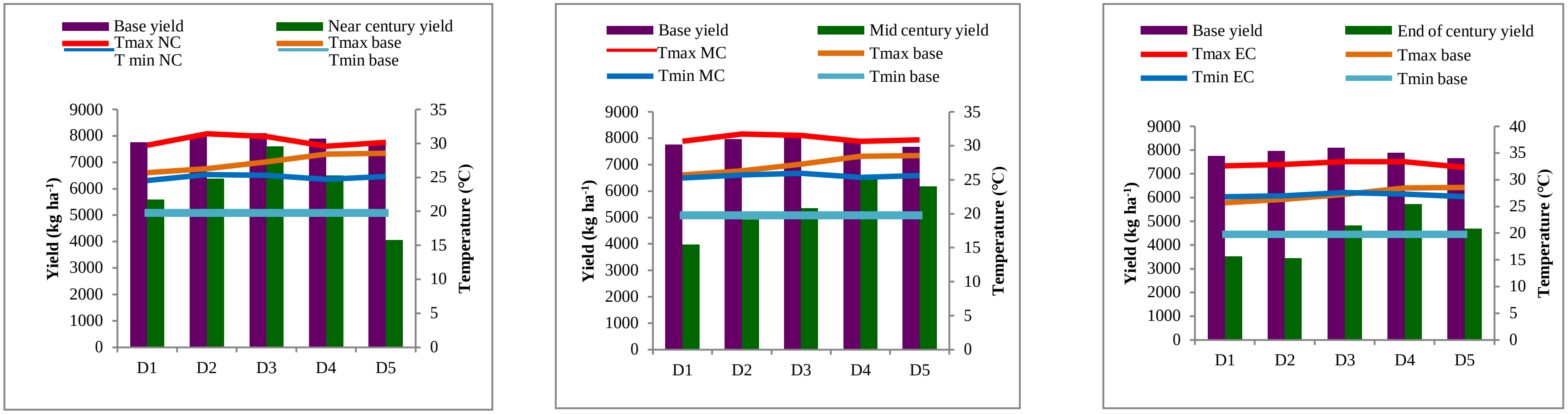


Fig. 5.64. (a). Effect of temperature on yieldof Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Kasargode

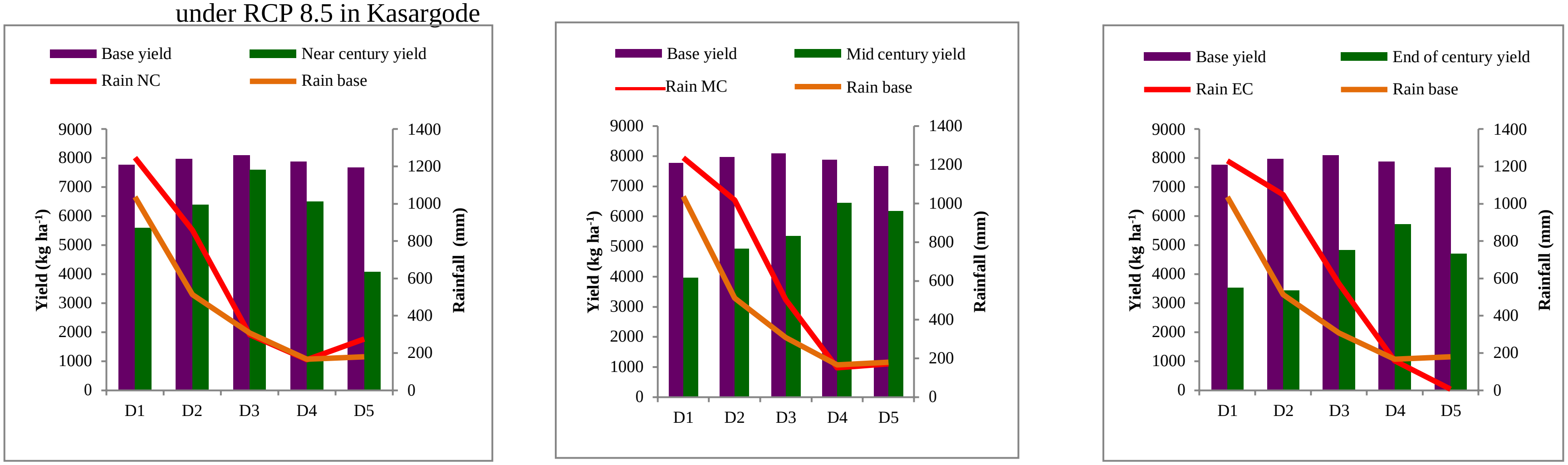
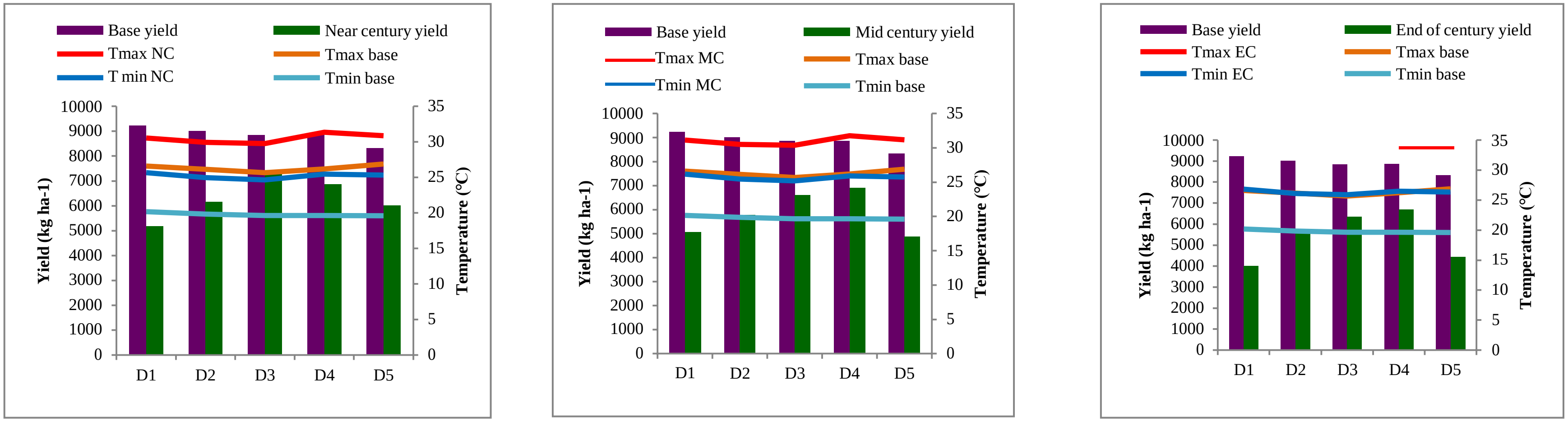


Fig. 5.64. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Kasargode



i ii iii

Fig. 5.65. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Kannur

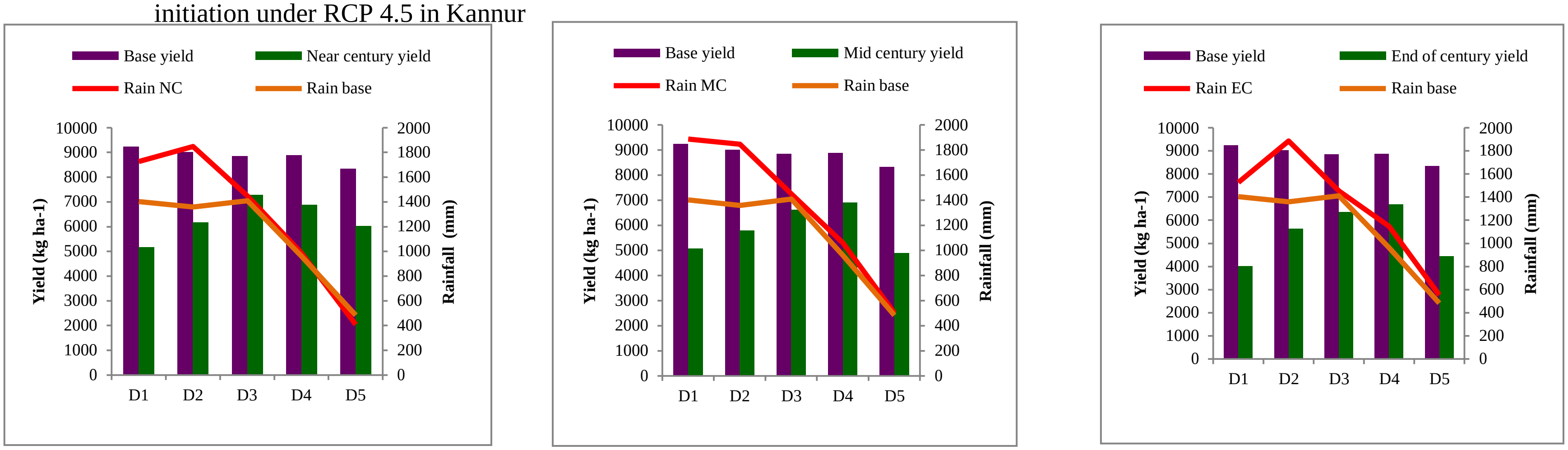


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Fig. 5.65. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Kannur

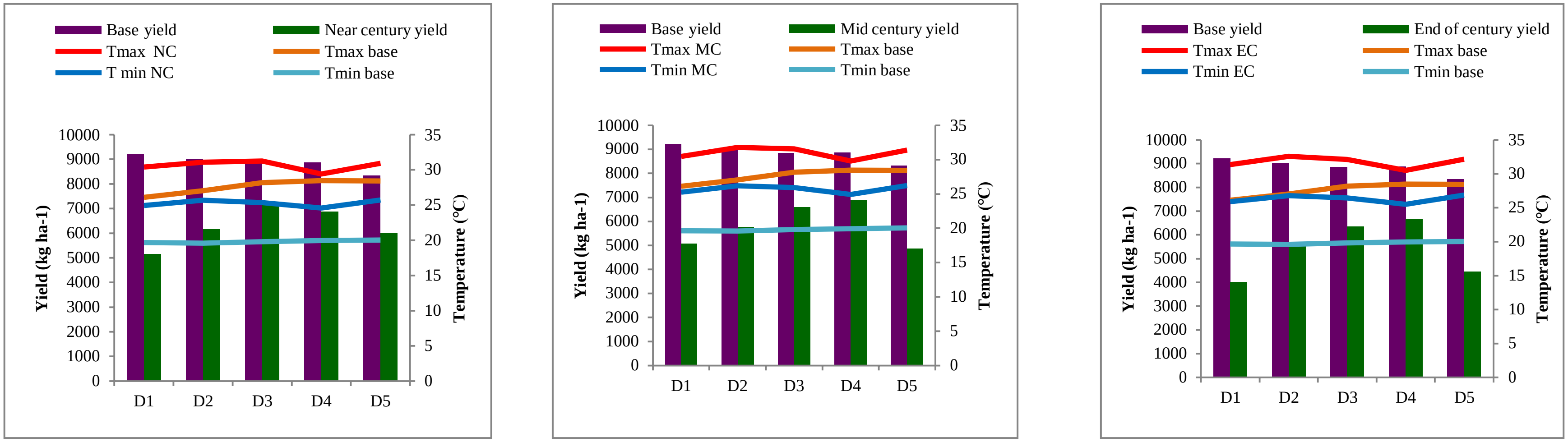

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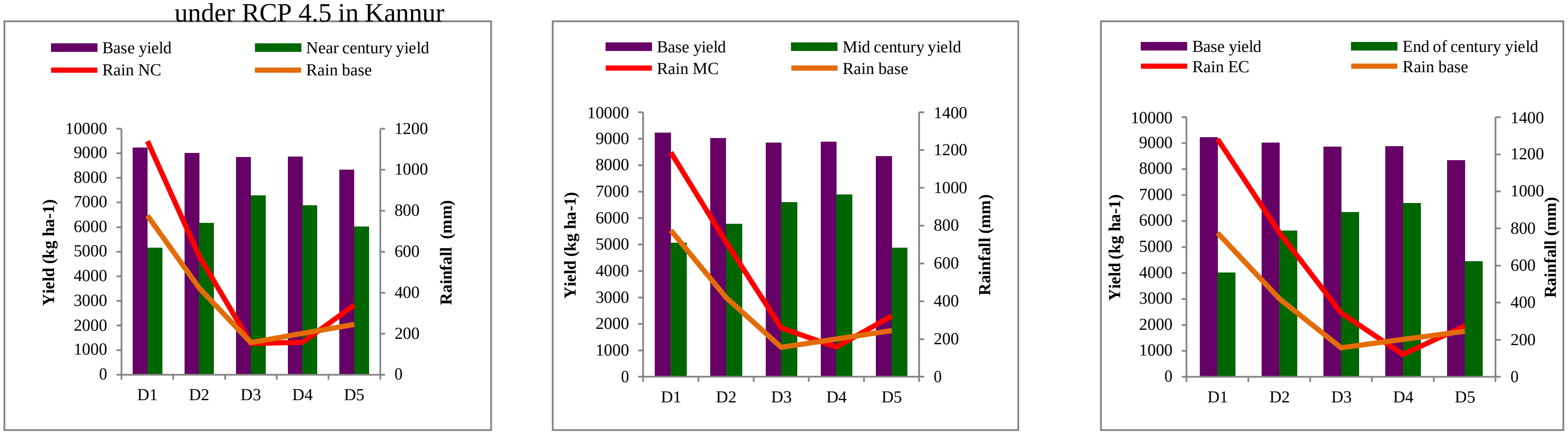
Fig. 5.66. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Kannur



i ii iii

Fig. 5.66. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Kannur

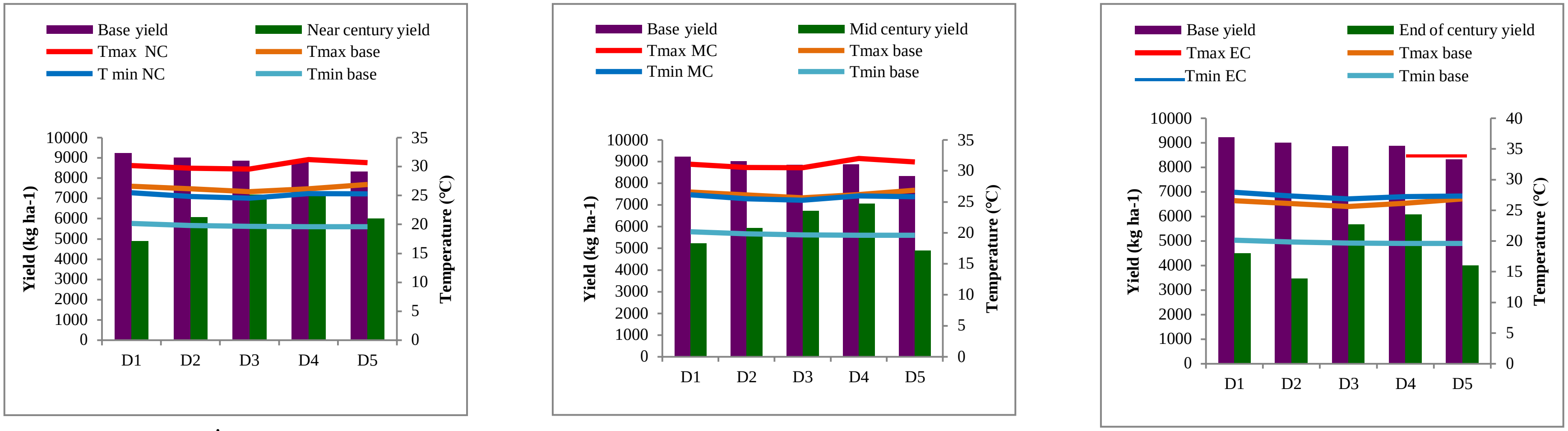


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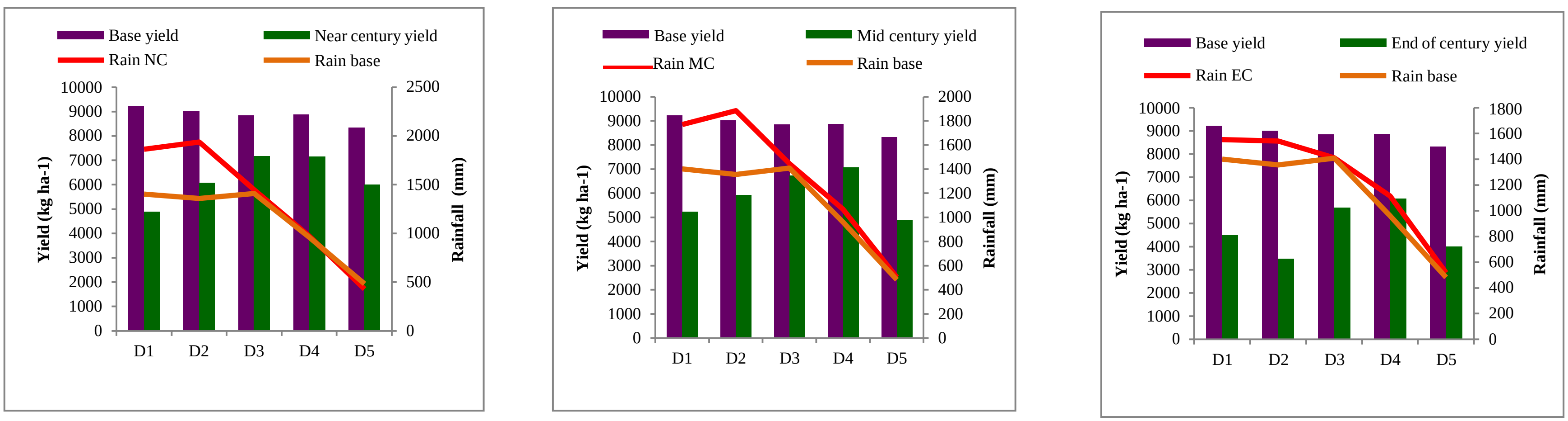
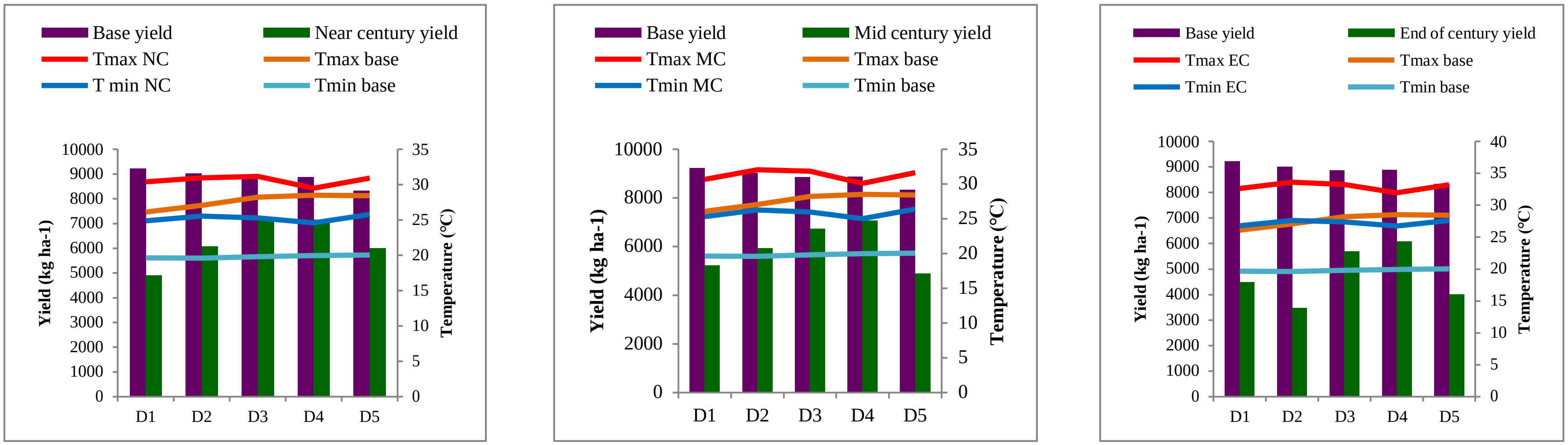
Fig. 5.67. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Kannur



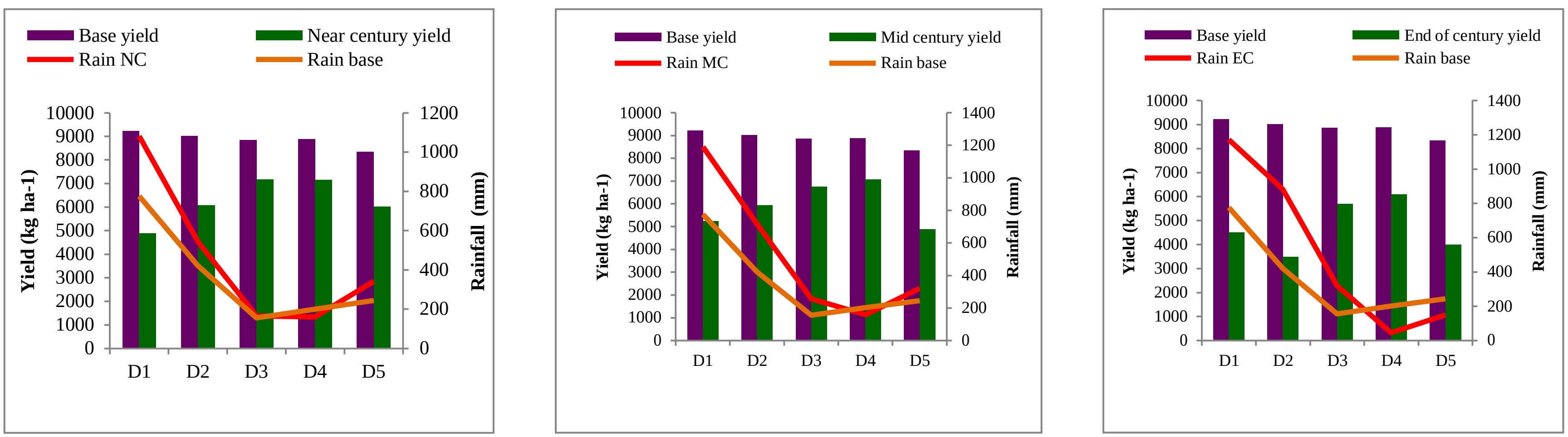
i ii iii

Fig. 5.67. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Kannur



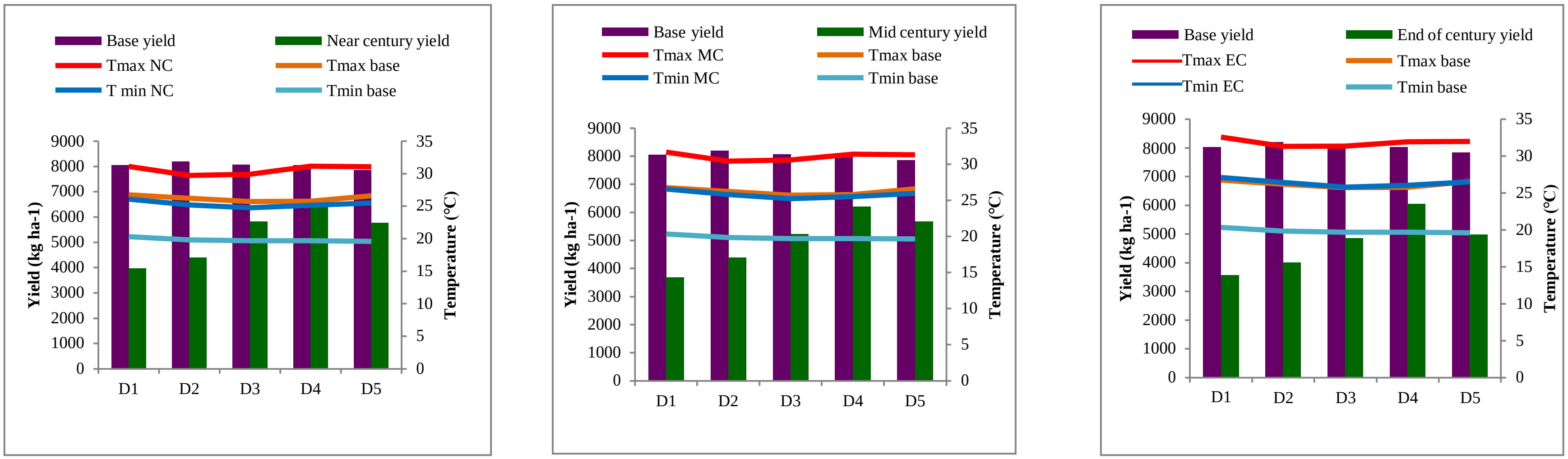
i ii iii

Fig. 5.68. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Kannur



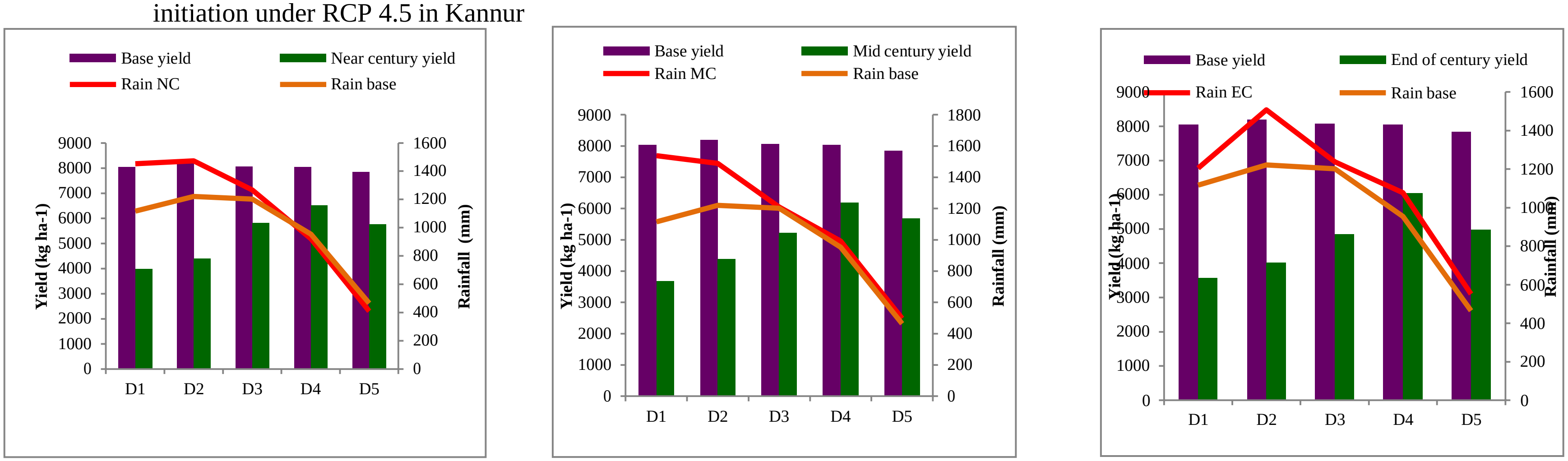
i ii iii

Fig. 5.68 (b). Effect of rainfall on yieldof Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5in Kannur



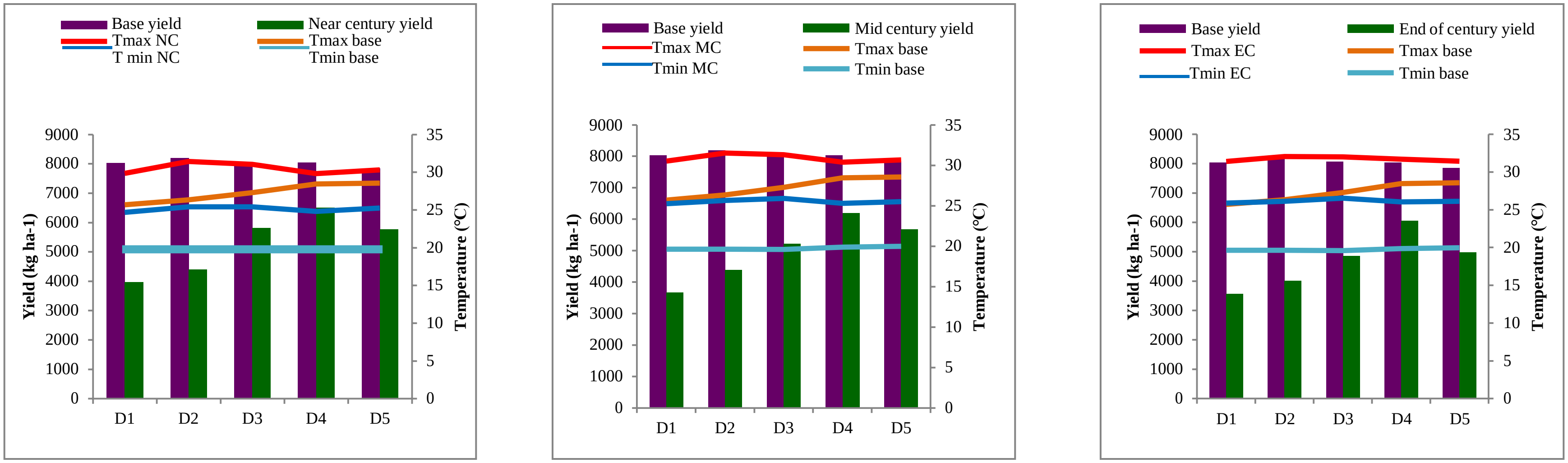
i ii iii

Fig. 5.69. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Kannur



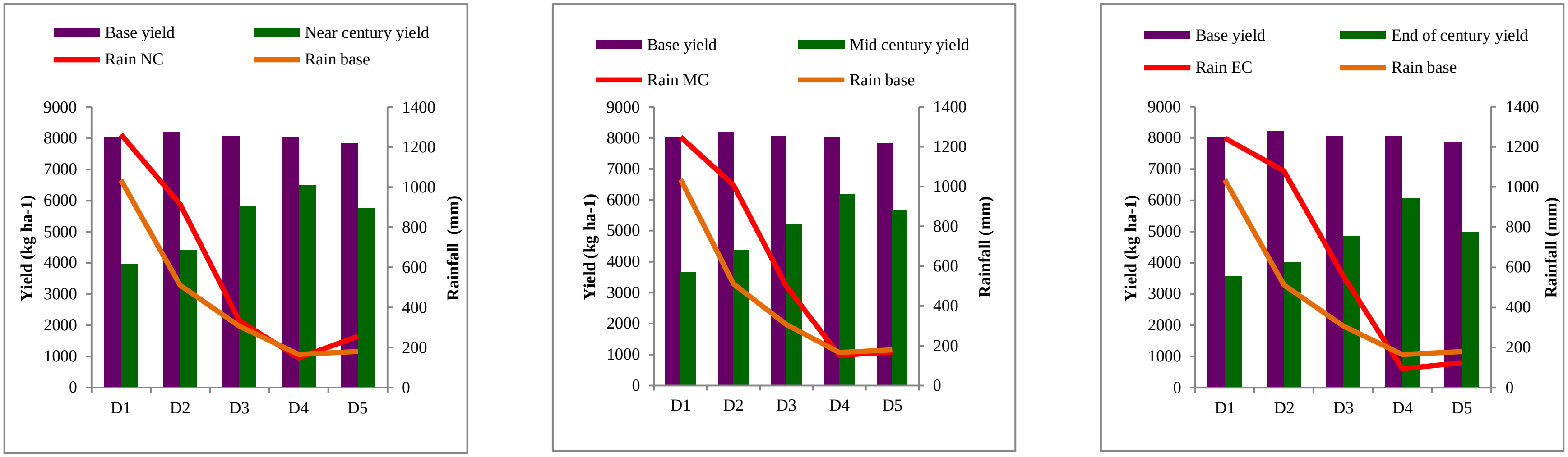
i ii iii

Fig. 5.69. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Kannur



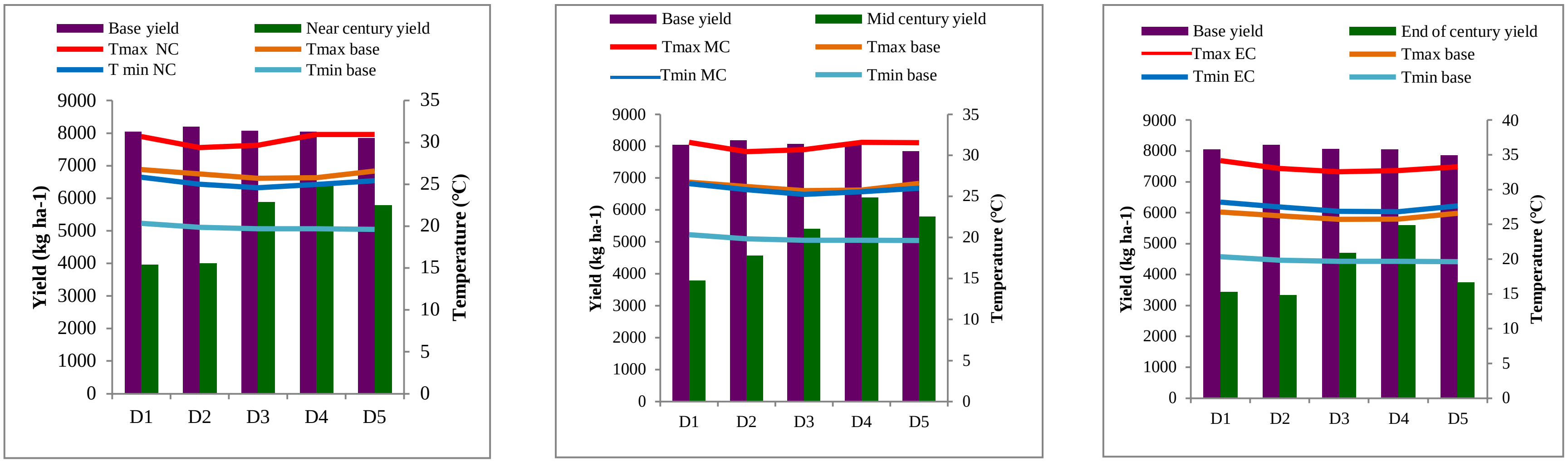
i ii iii

Fig. 5.70. (a). Effect oftemperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Kannur



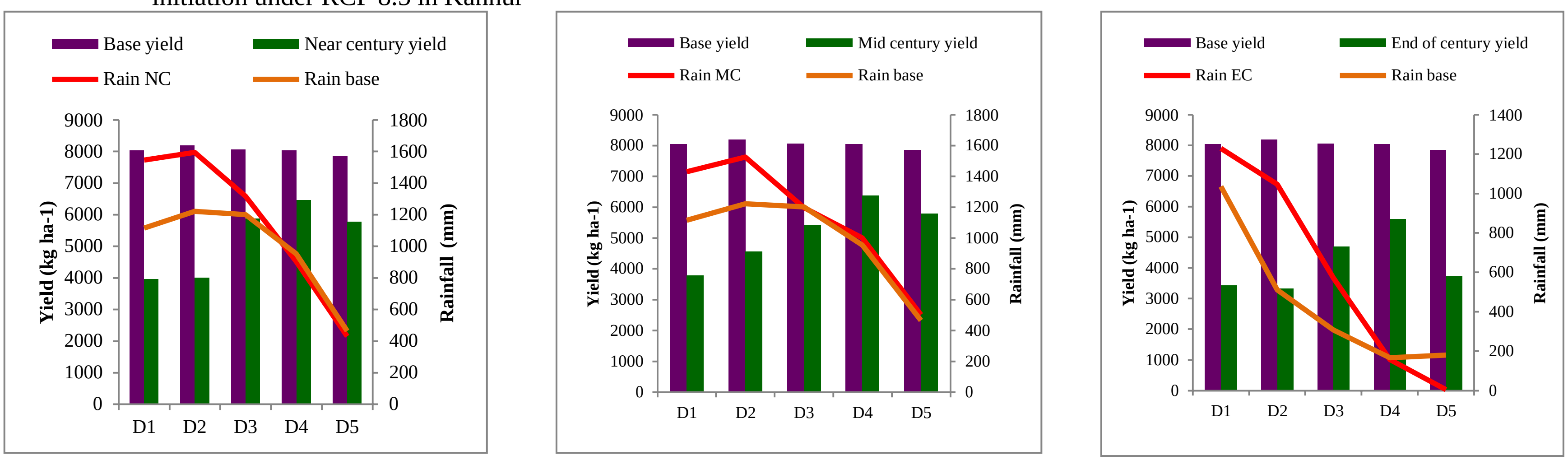
i ii iii

Fig. 5.70. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Kannur



i ii iii

Fig. 5.71. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Kannur



i ii iii

Fig. 5.71. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Kannur

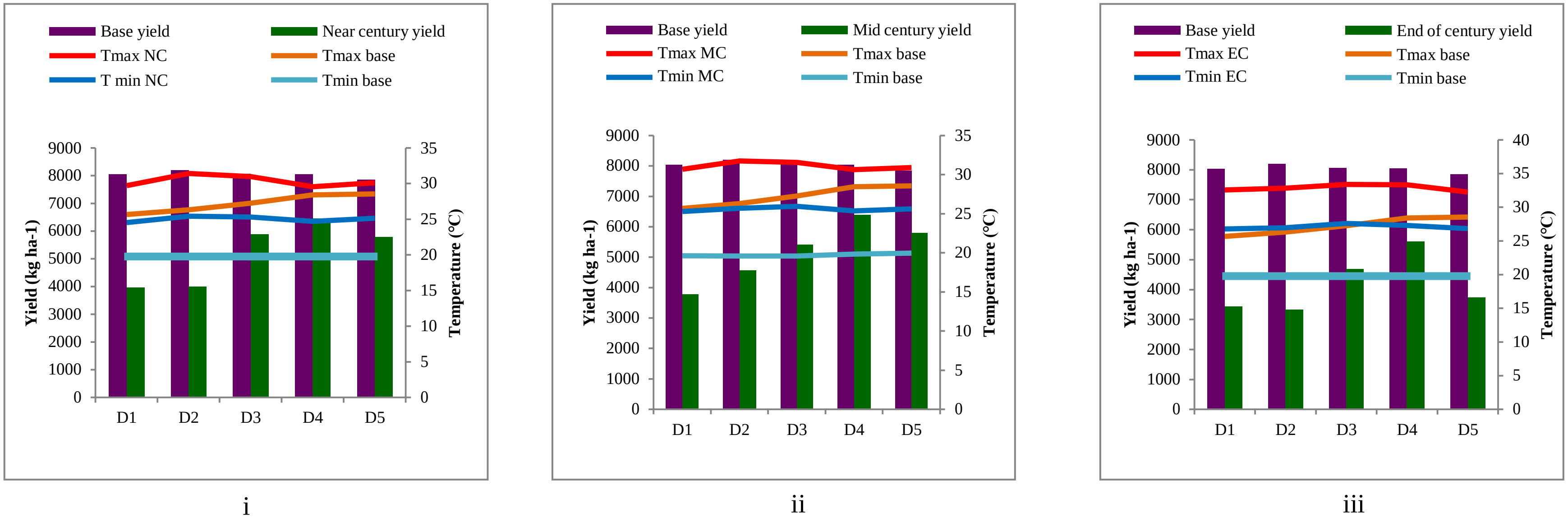


Fig. 5.72. (a). Effecttemperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Kannur

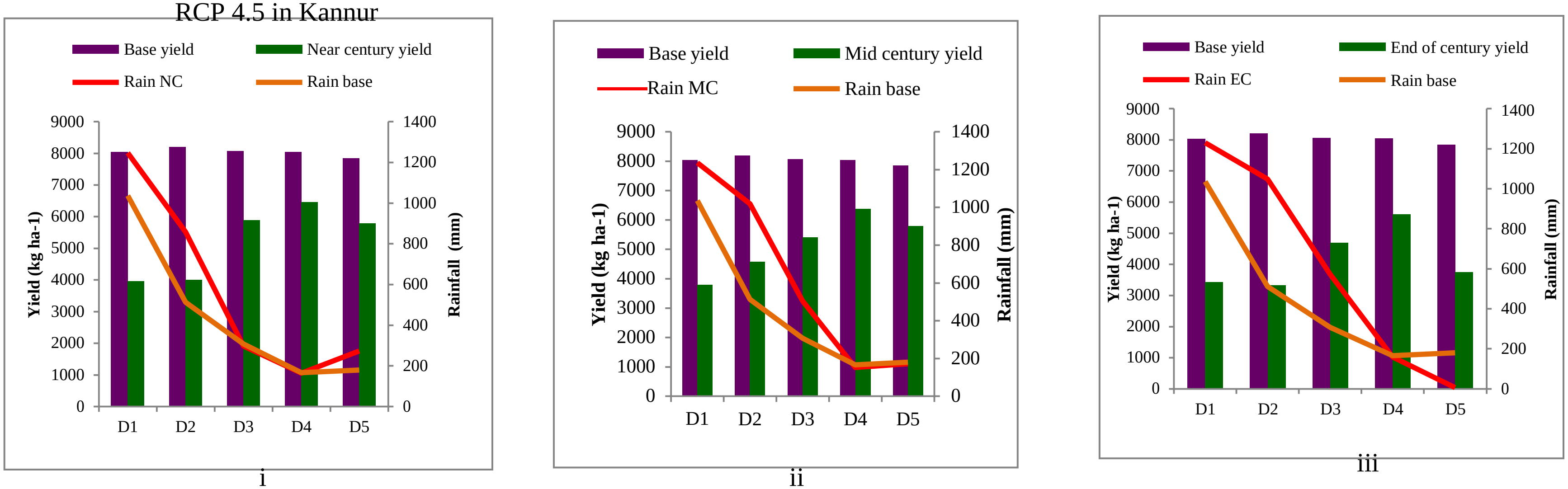
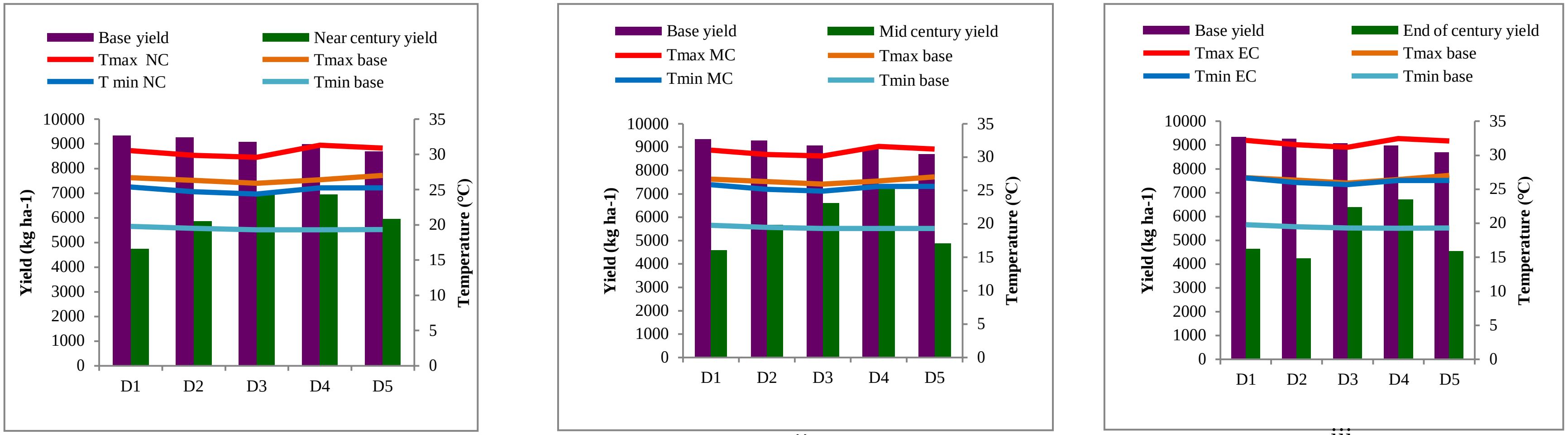
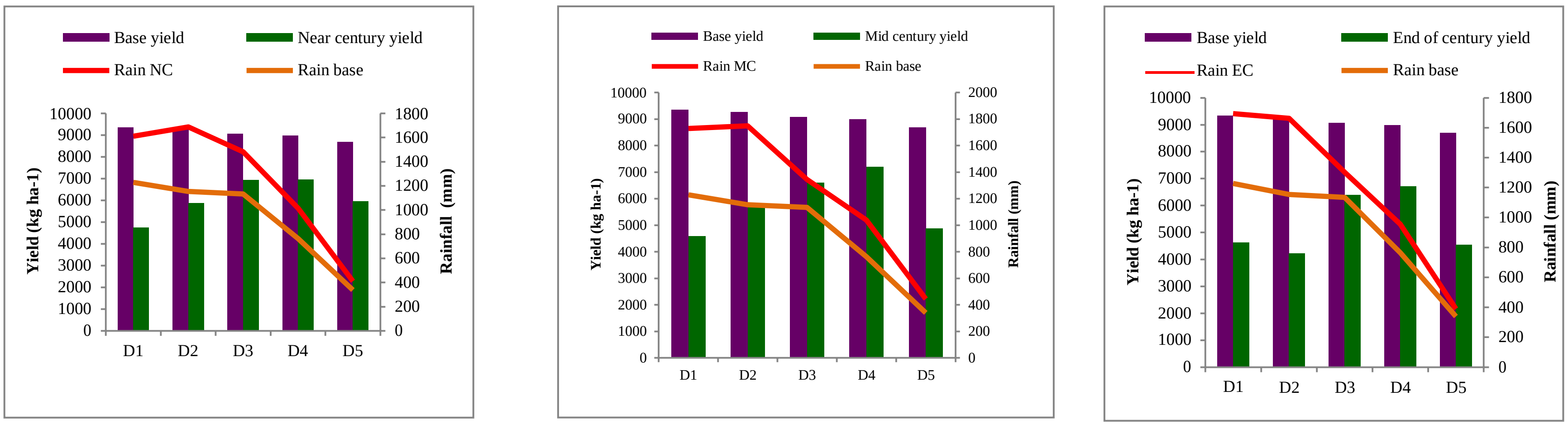


Fig. 5.72. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Kannur



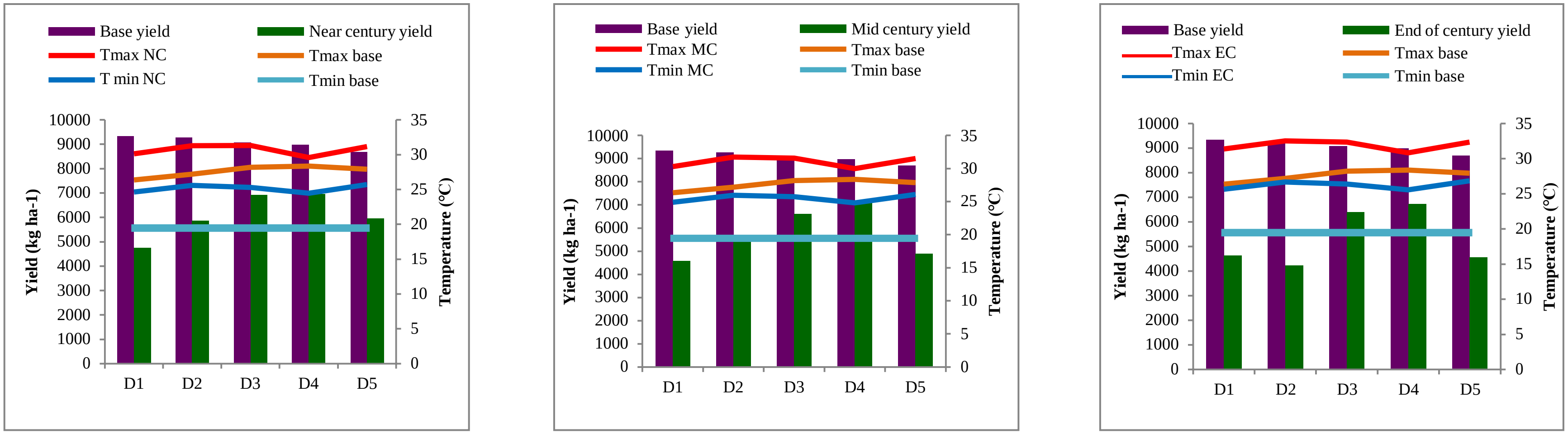
i ii iii

Fig. 5.73. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Kozhikode



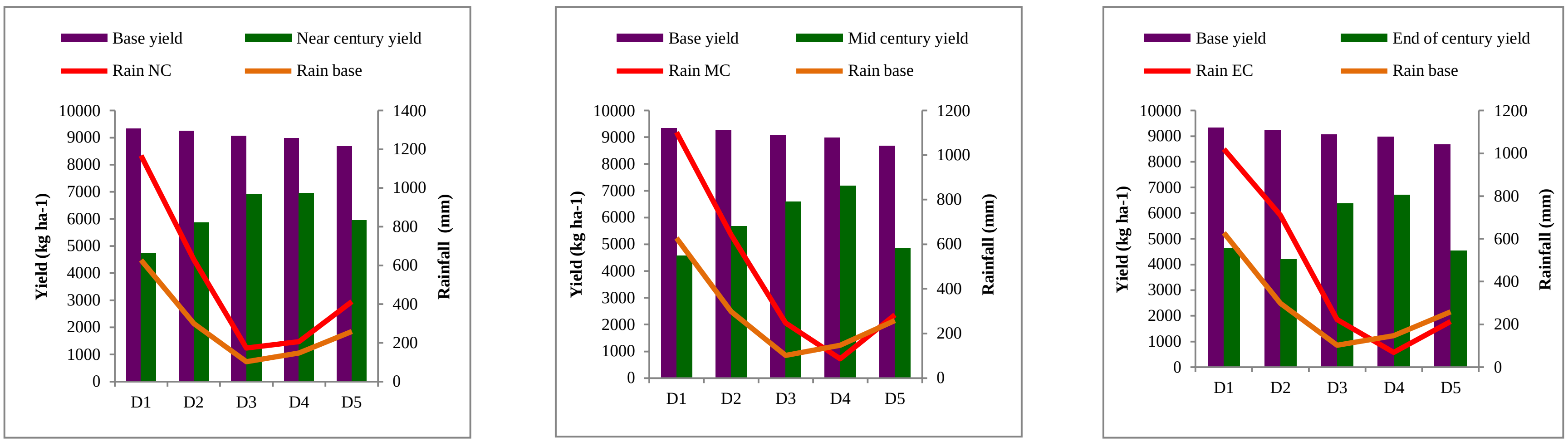
i ii iii

Fig. 5.73. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Kozhikode



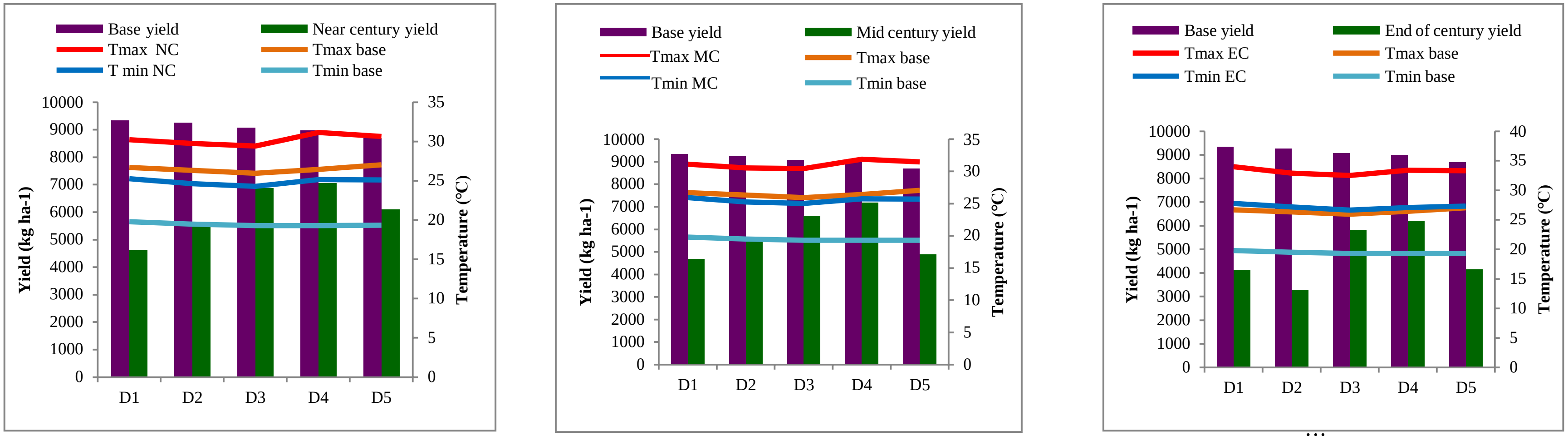
i ii iii

Fig. 5.74 (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Kozhikode



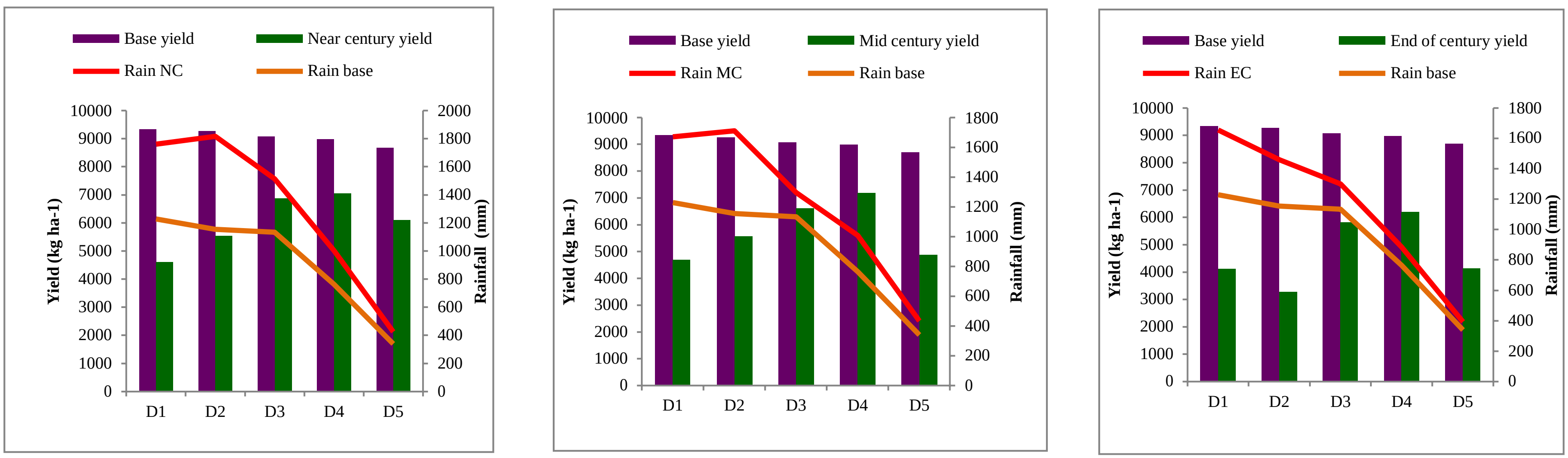
i ii iii

Fig. 5.74. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Kozhikode



i ii iii

Fig. 5.75. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Kozhikode



i ii iii

Fig. 5.75. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Kozhikode

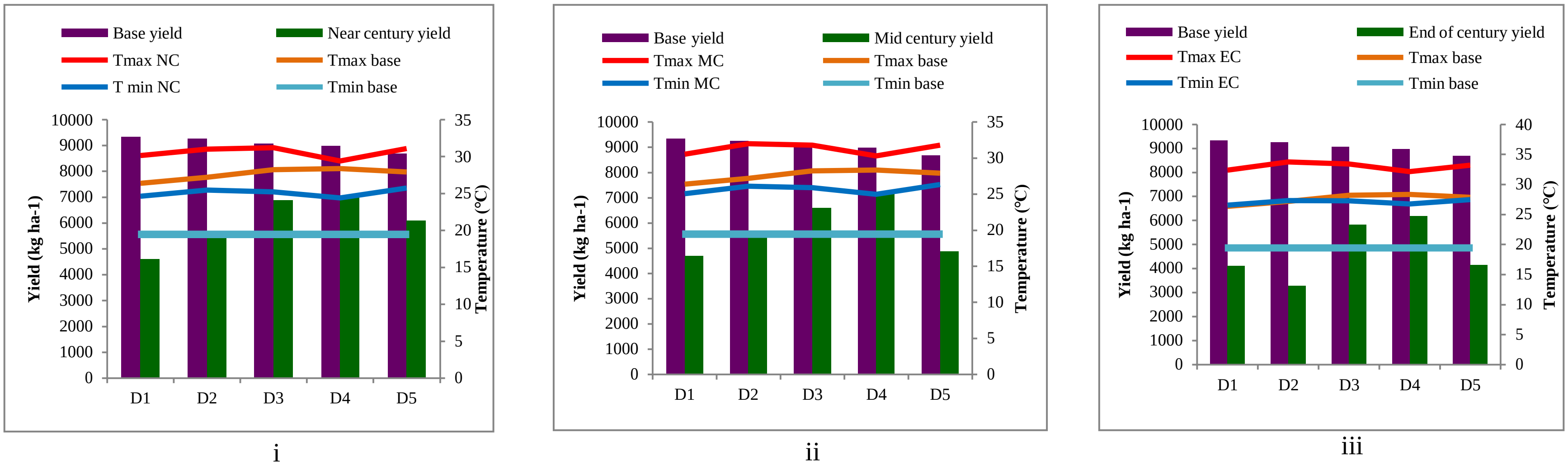


Fig. 5.76 (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Kozhikode

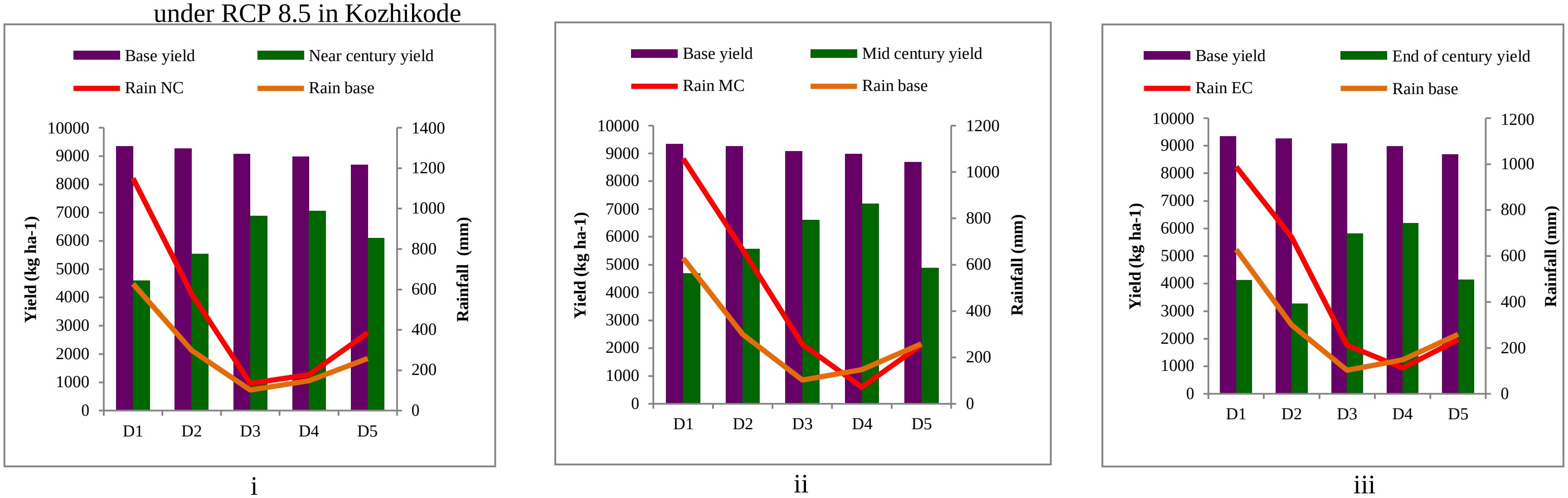
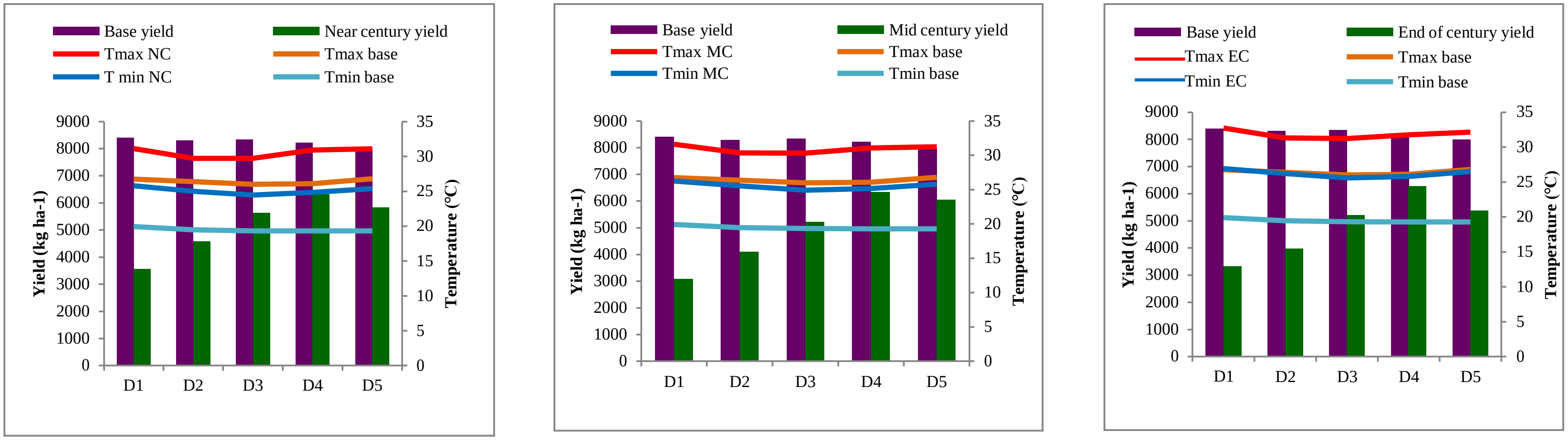
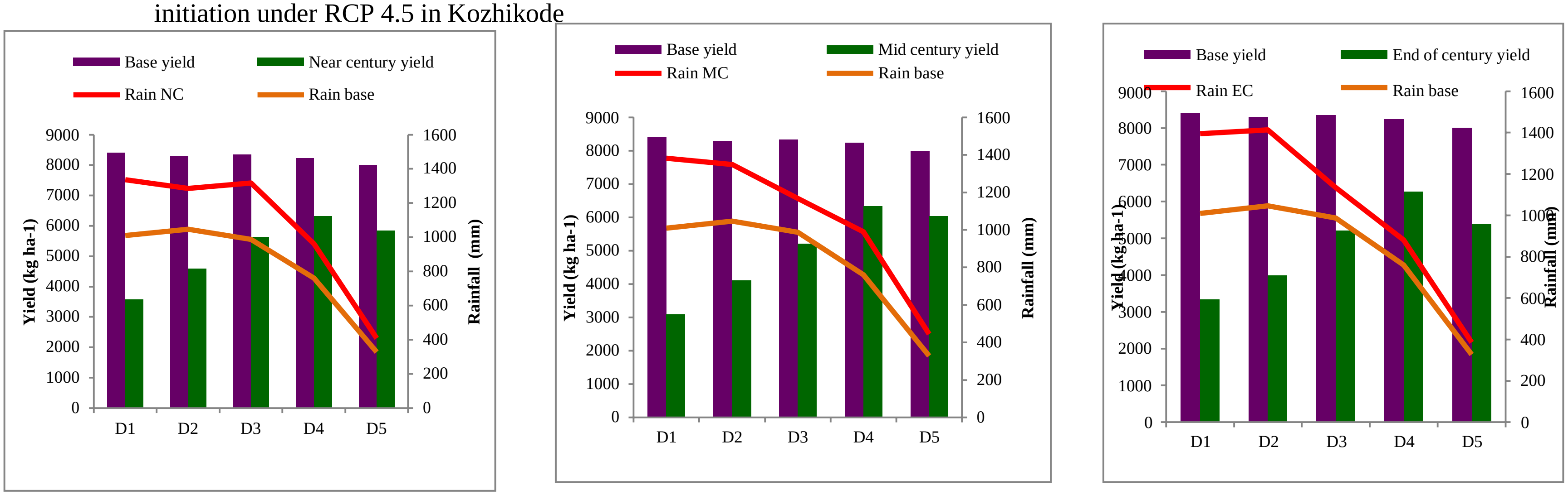


Fig. 5.76 (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Kozhikode



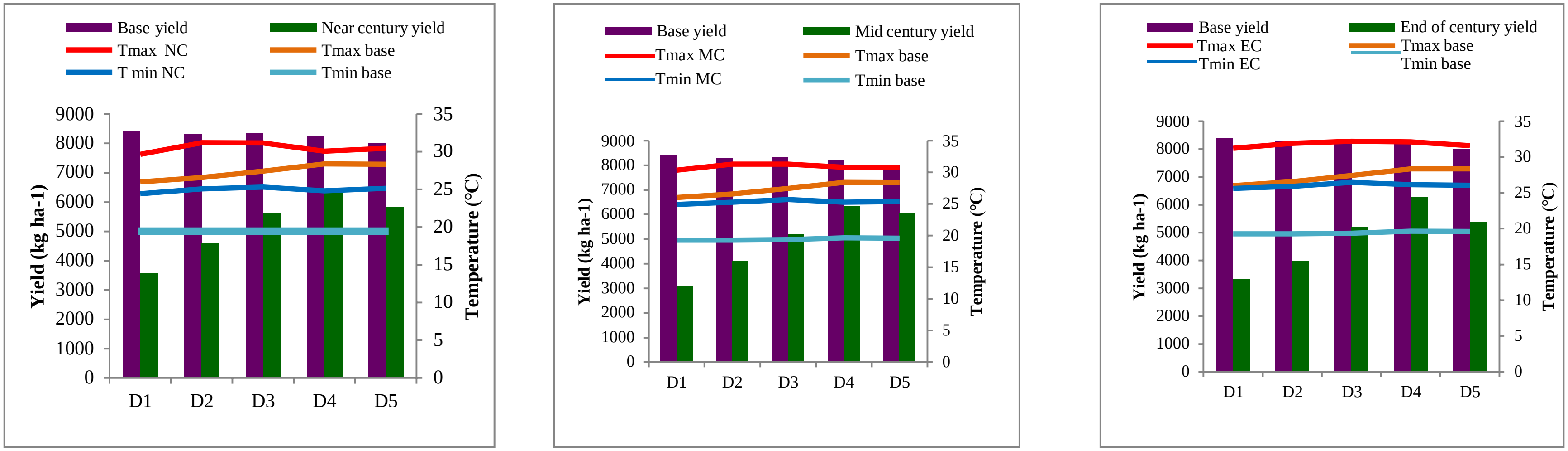
i ii iii

Fig. 5.77. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Kozhikode



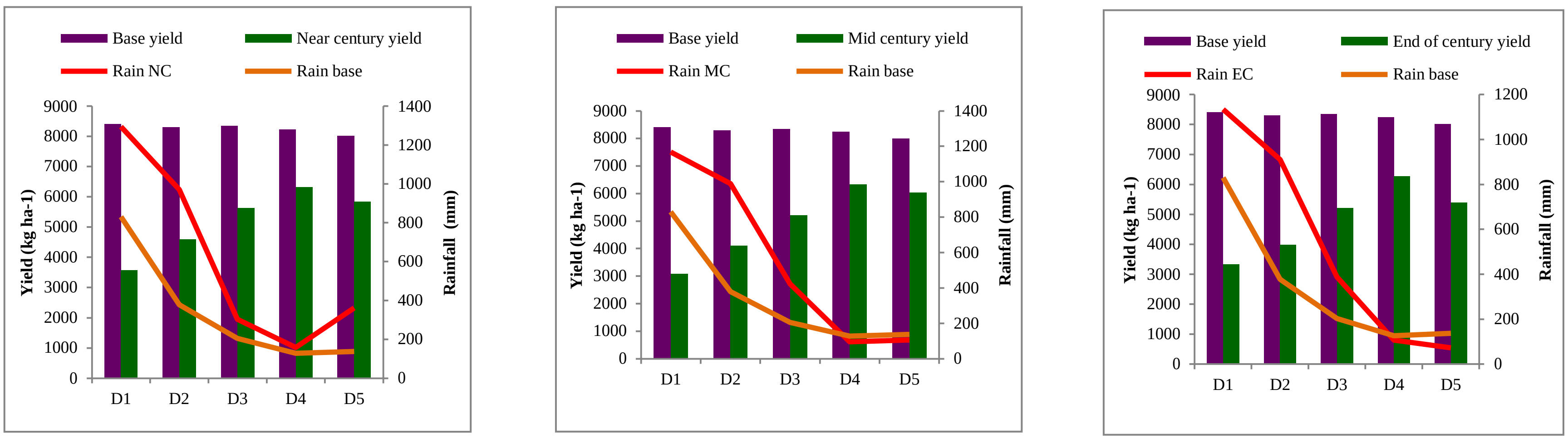
i ii iii

Fig. 5.77. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Kozhikode



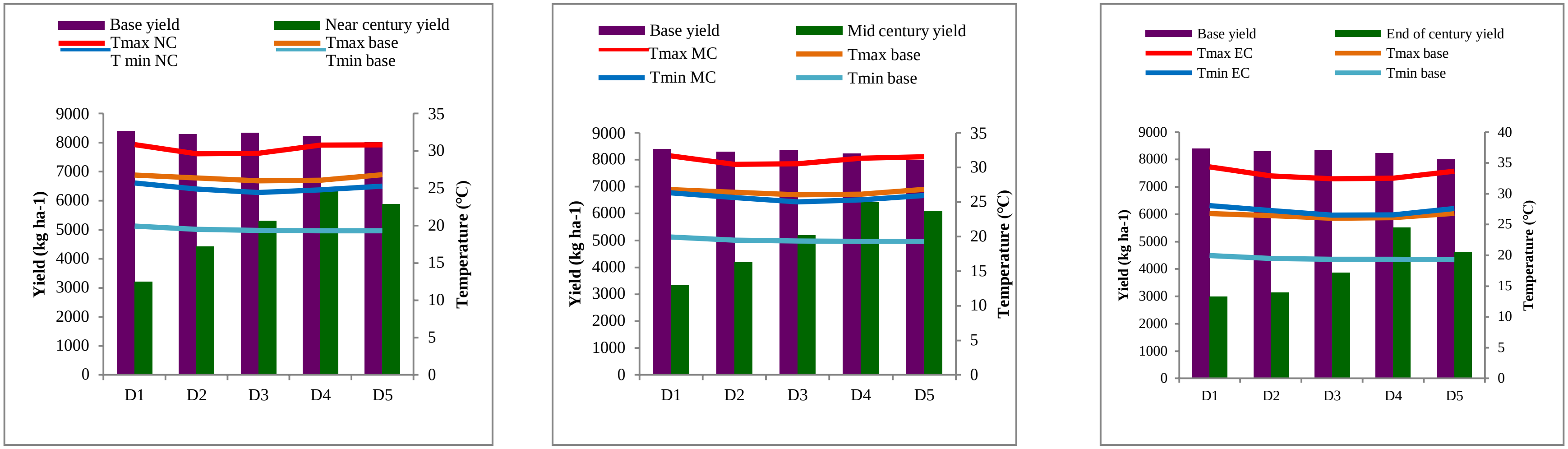
i ii iii

Fig. 5.78. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Kozhikode



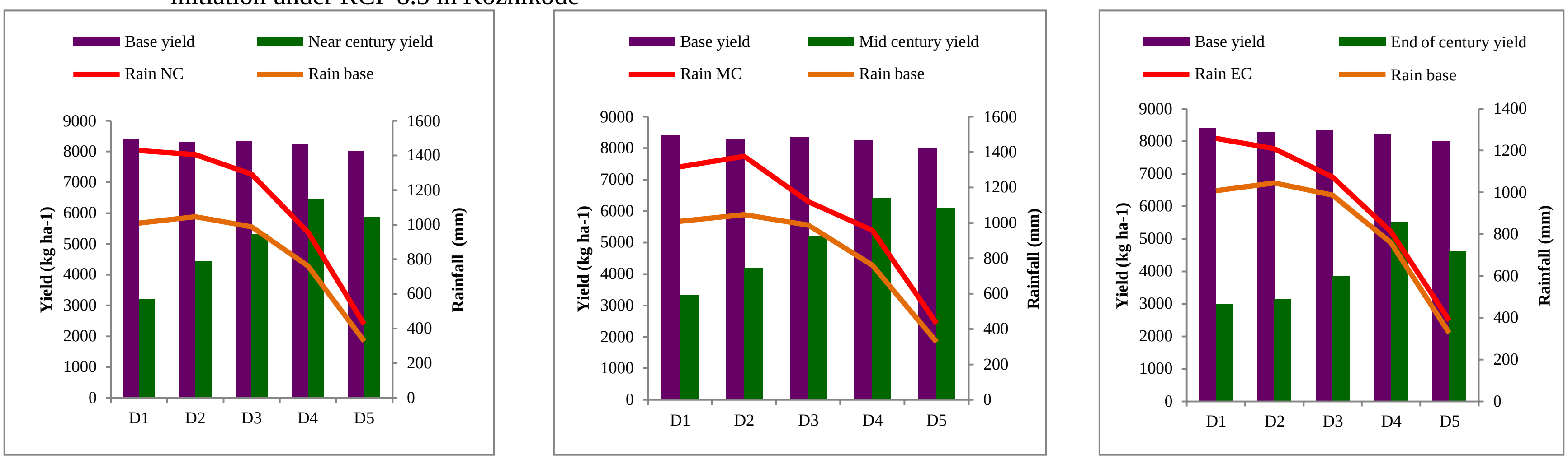
i ii iii

Fig. 5.78 (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Kozhikode



i ii iii

Fig. 5.79 (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Kozhikode



i ii iii

Fig. 5.79. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Kozhikode

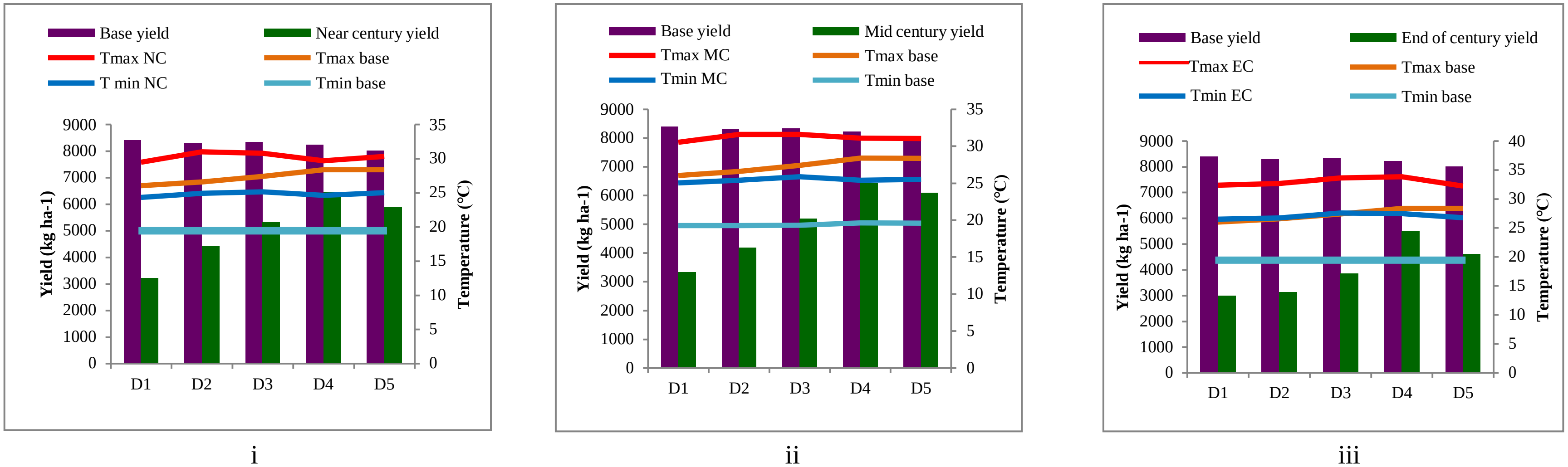


Fig. 5.80. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Kozhikode

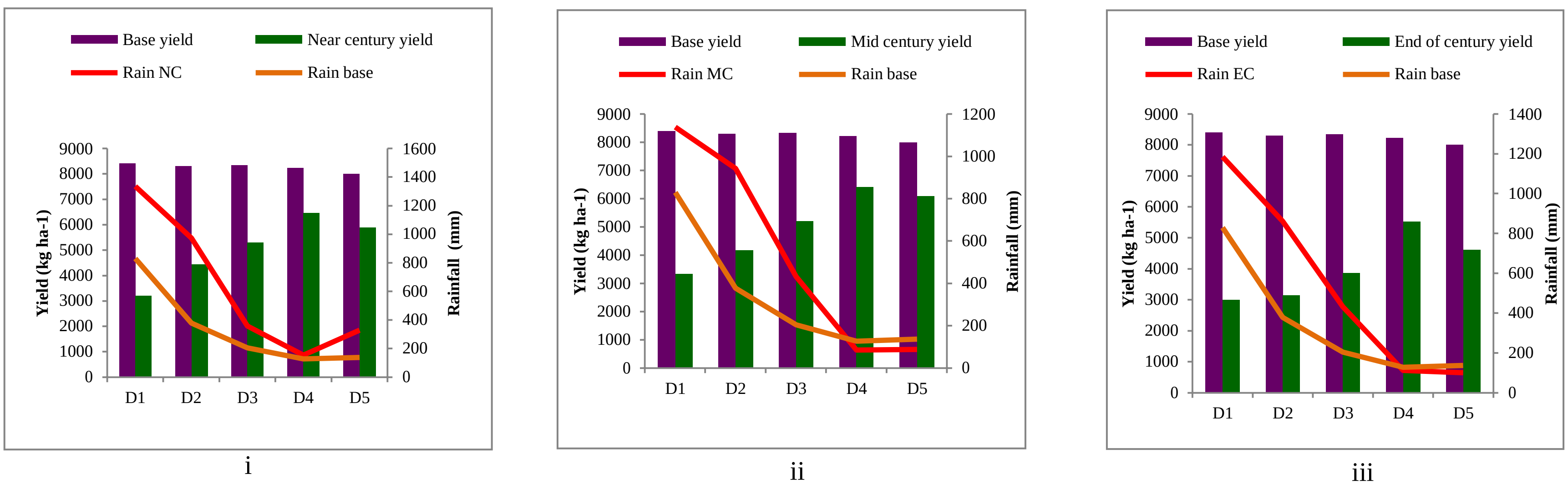
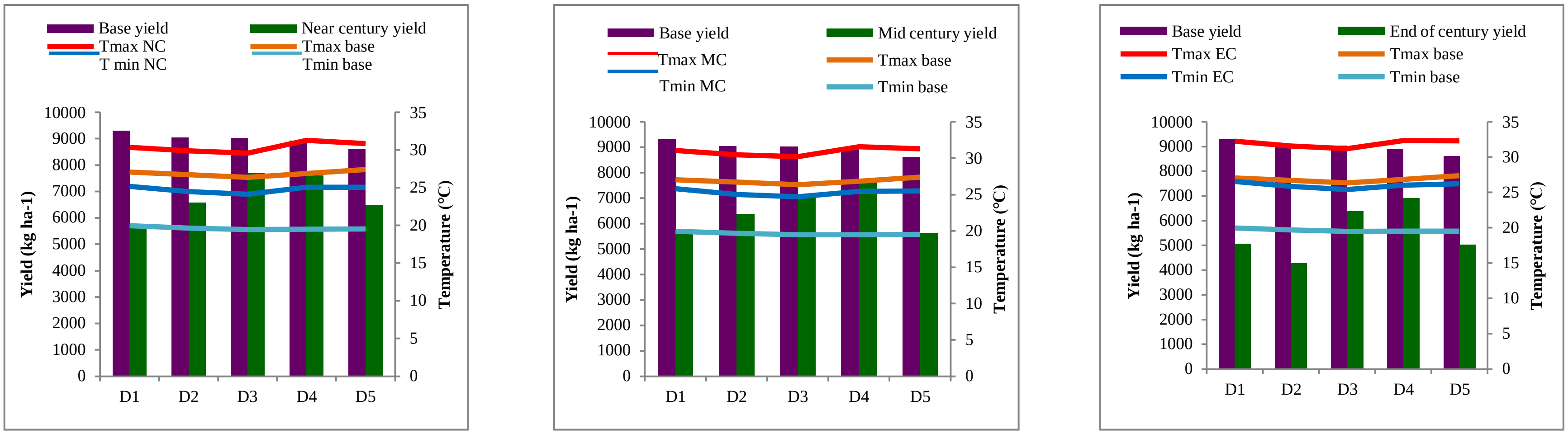
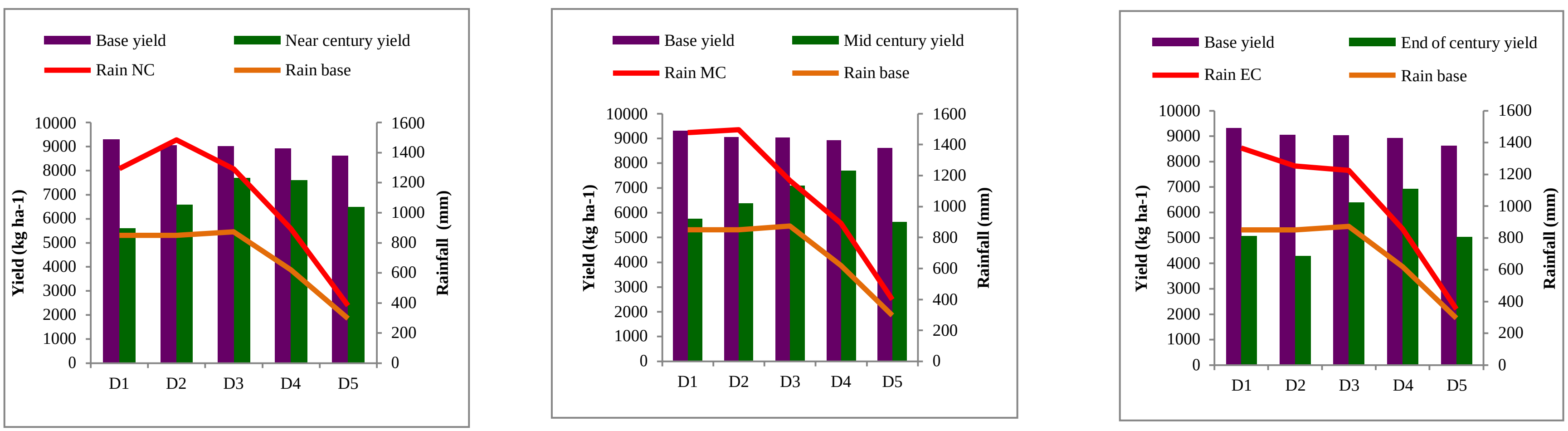


Fig. 5.80. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Kozhikode



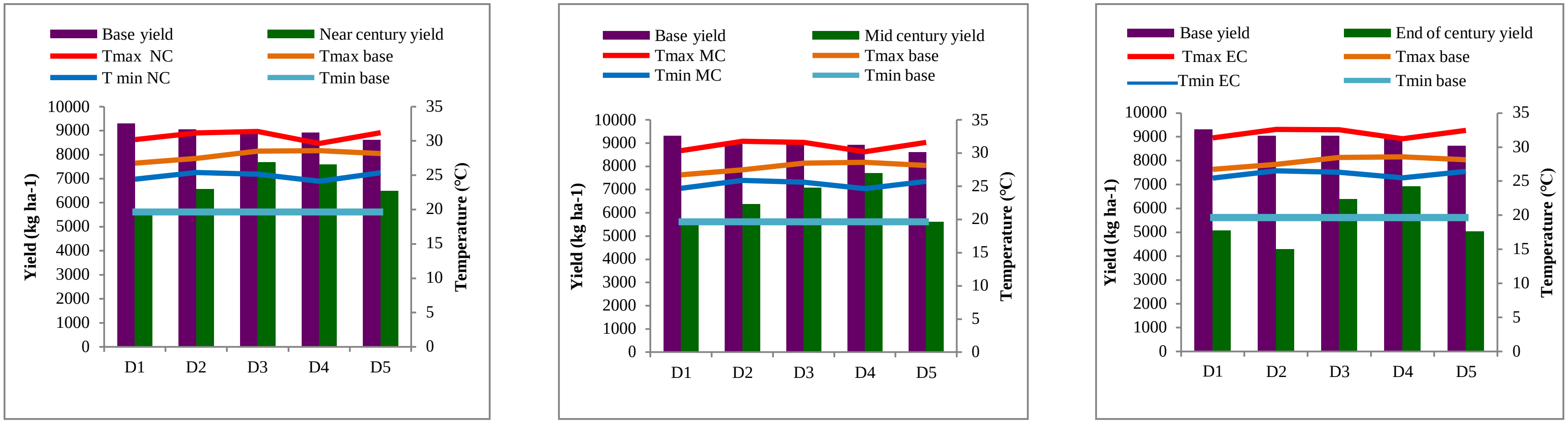
i ii iii

Fig. 5.81. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Malappuarm



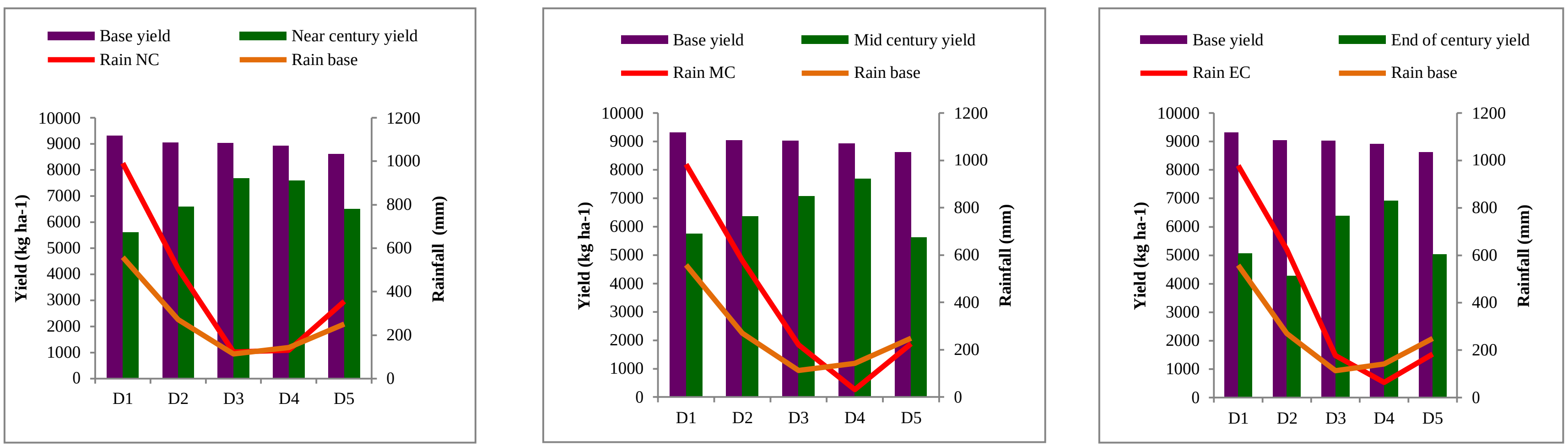
i ii iii

Fig. 5.81. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Malappuarm



i ii iii

Fig. 5.82 (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Malappuarm



i ii iii

Fig. 5.82. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Malappuarm

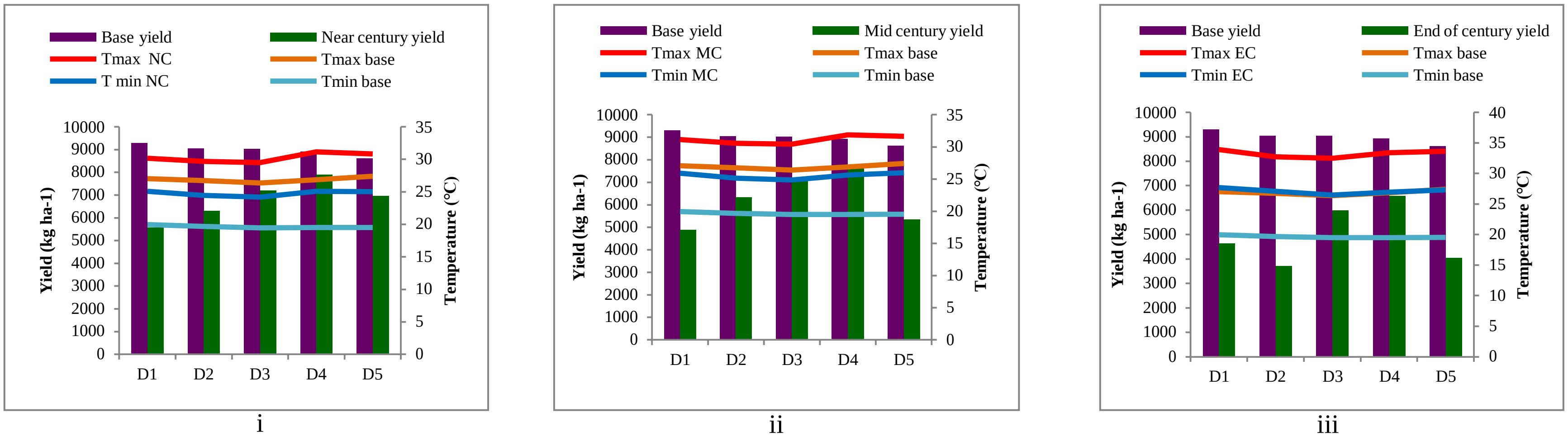


Fig. 5.83 (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Malappuarm

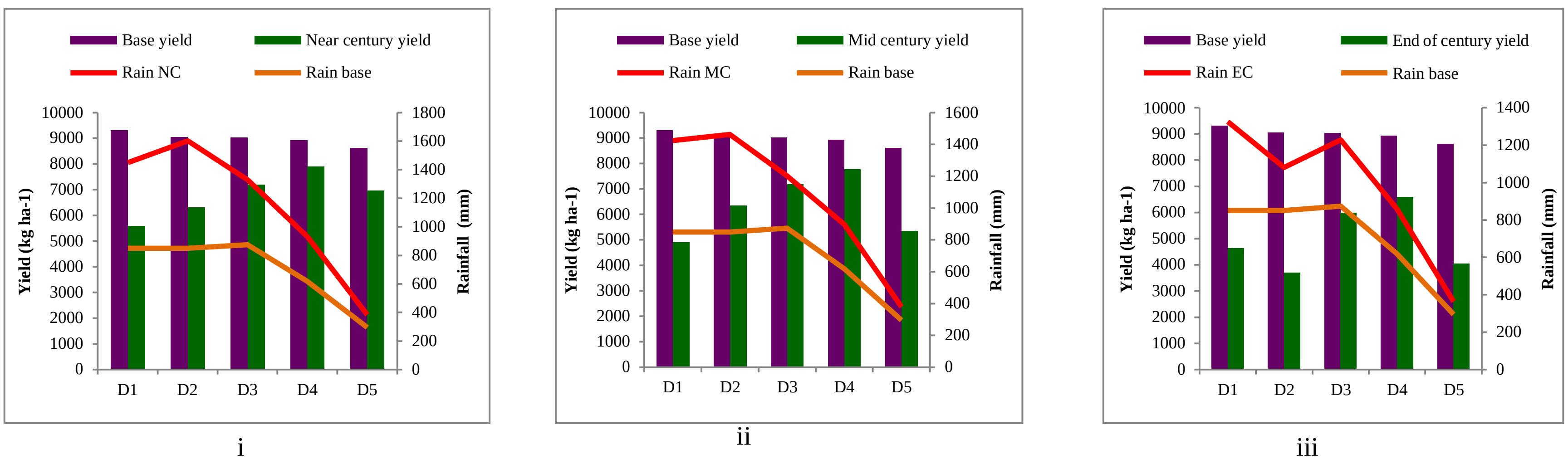


Fig. 5.83 (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Malappuarm

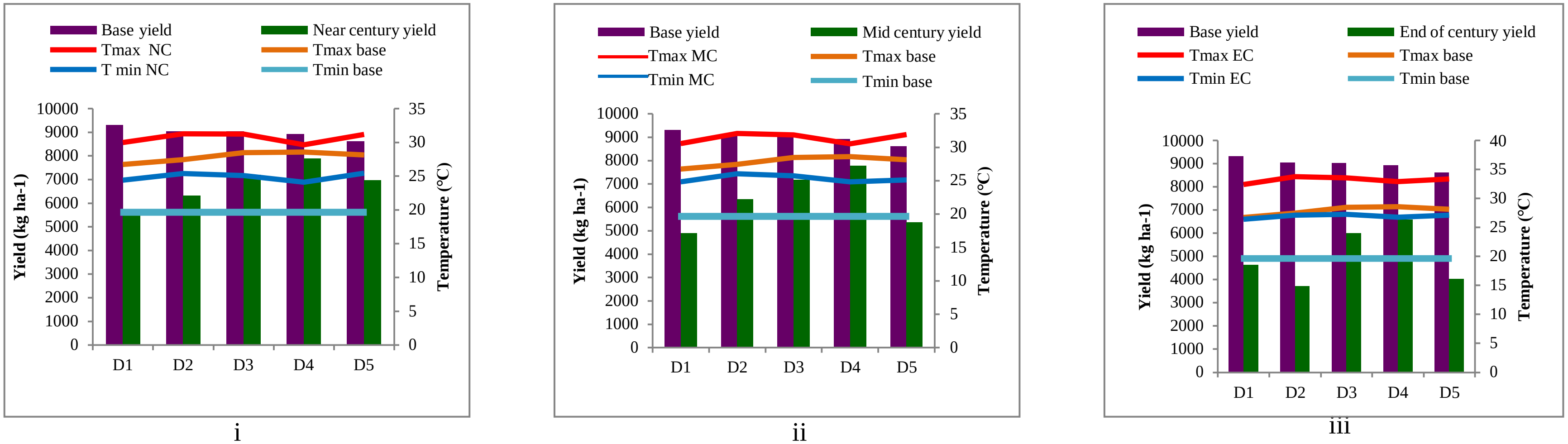


Fig. 5.84 (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Malappuarm

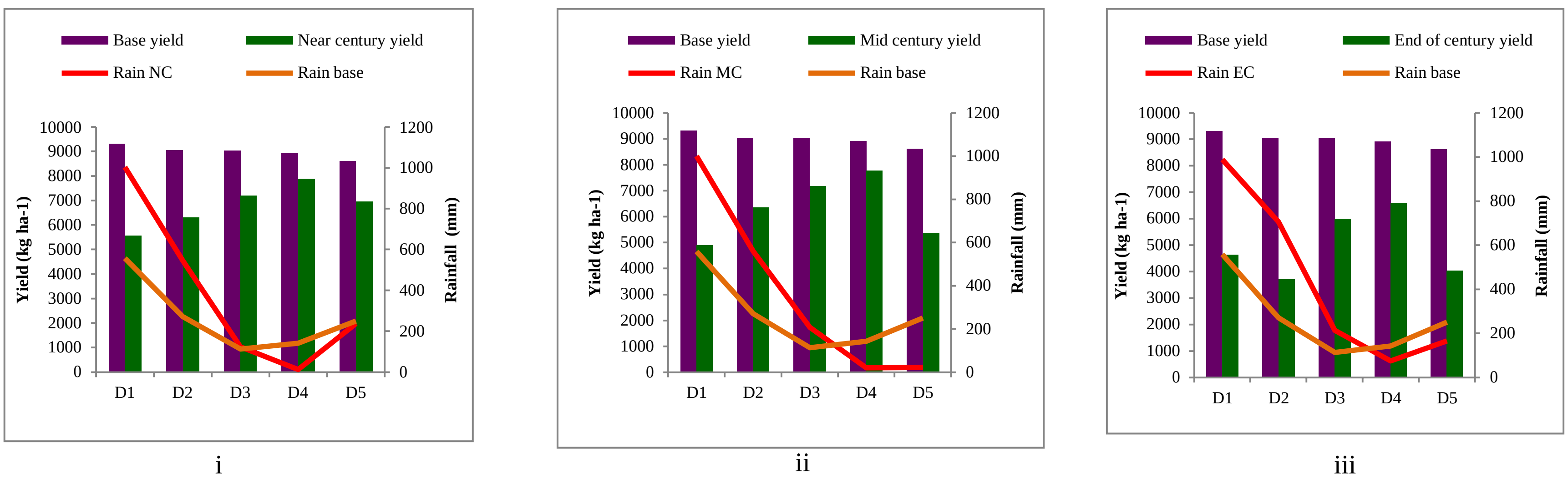
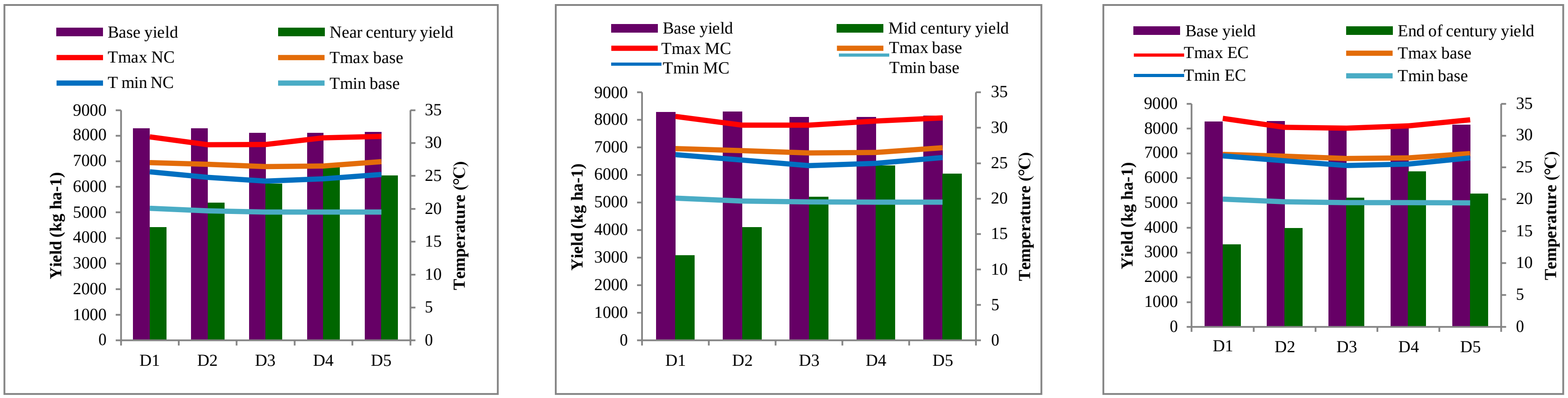
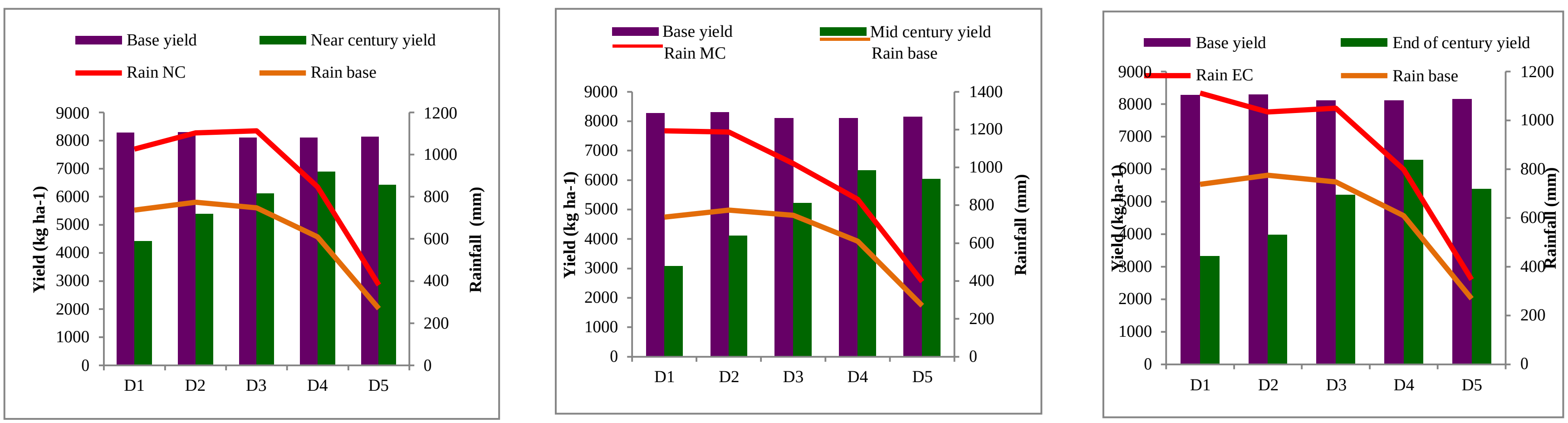


Fig.5.84. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Malappuarm



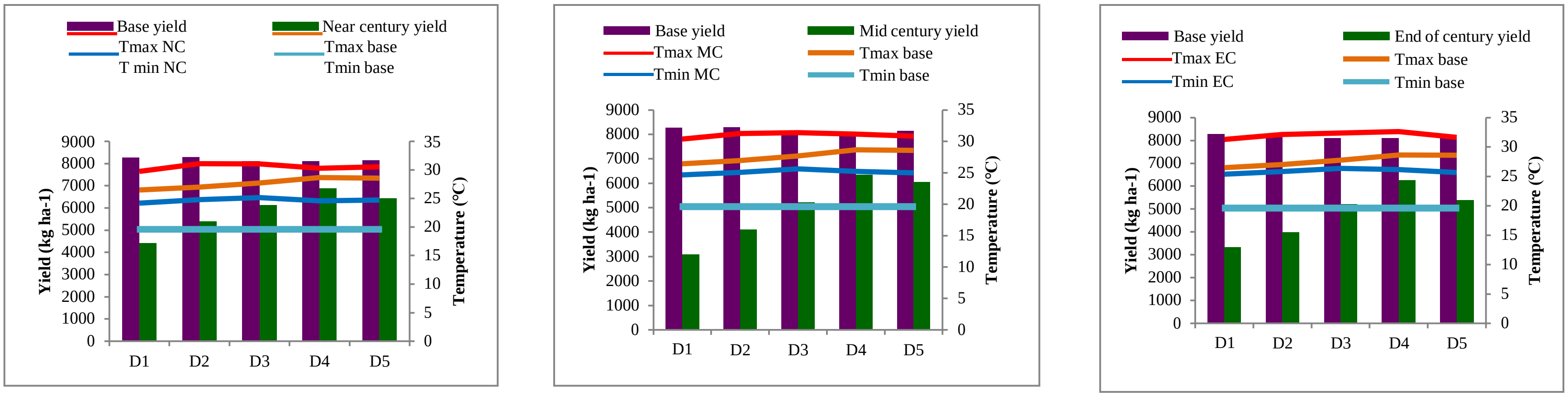
i ii iii

Fig. 5.85. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Malappuarm



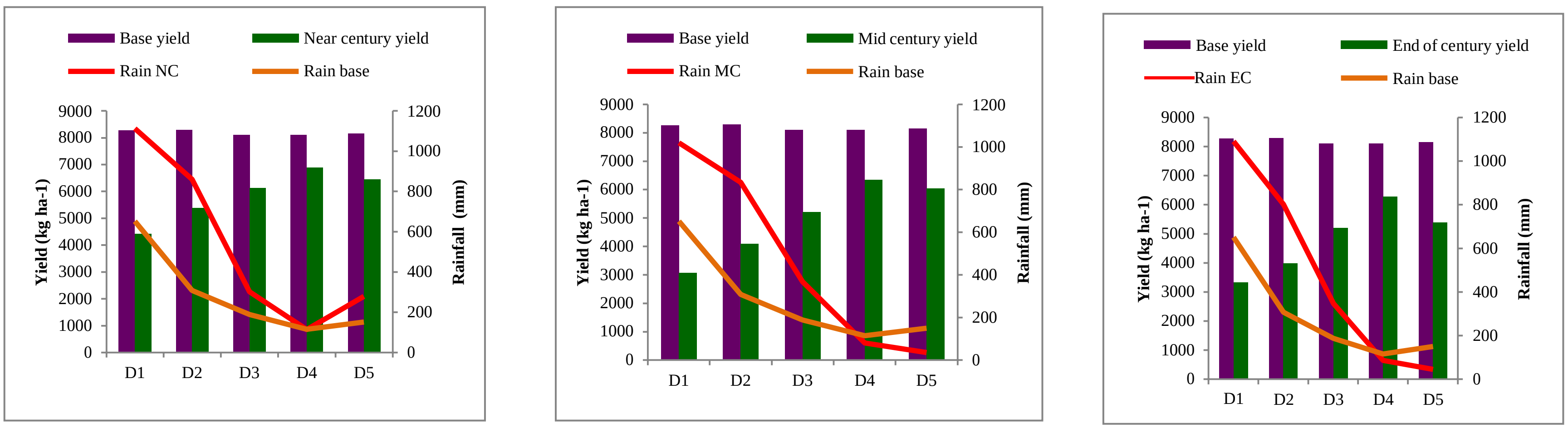
i ii iii

Fig. 5.85. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Malappuarm



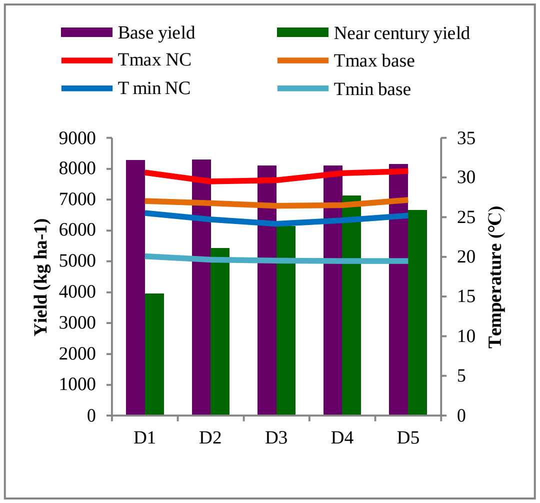
i ii iii

Fig. 5.86 (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Malappuarm

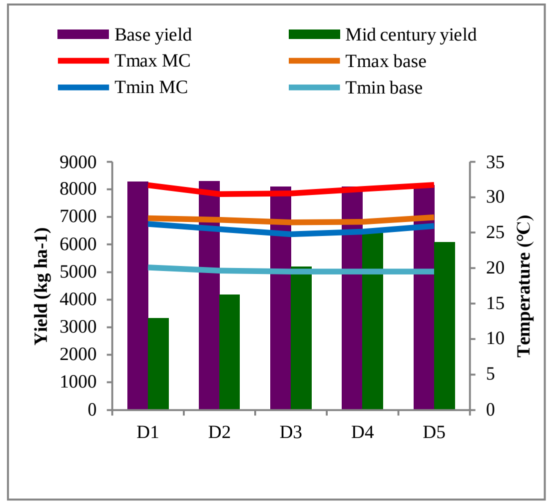


i ii iii

Fig. 5.86 (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Malappuarm



i



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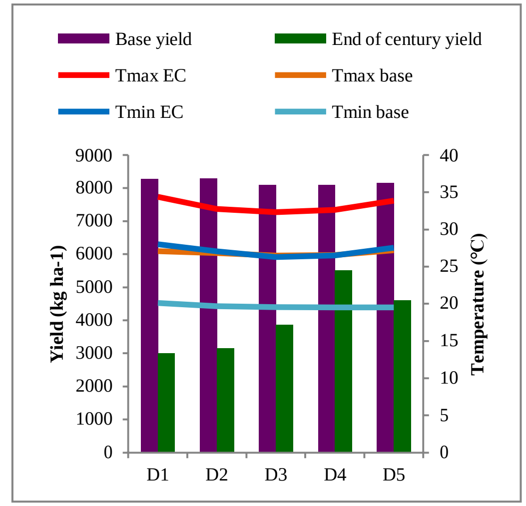
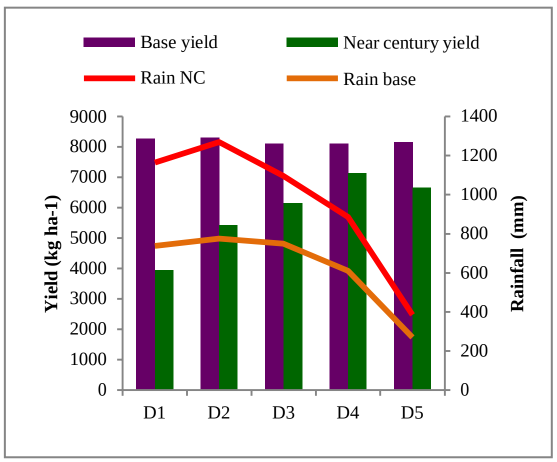
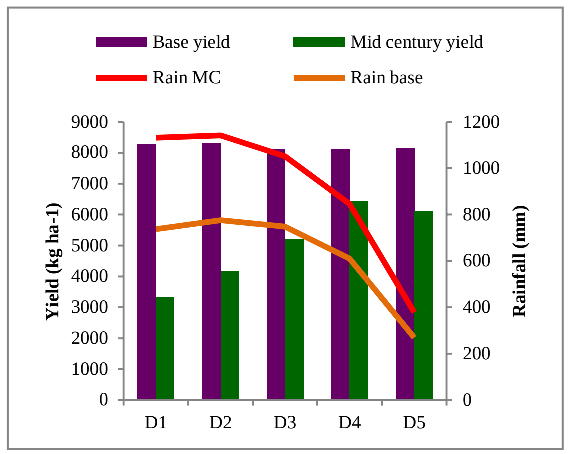


iii

Fig. 5.87 (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Malappuarm



i



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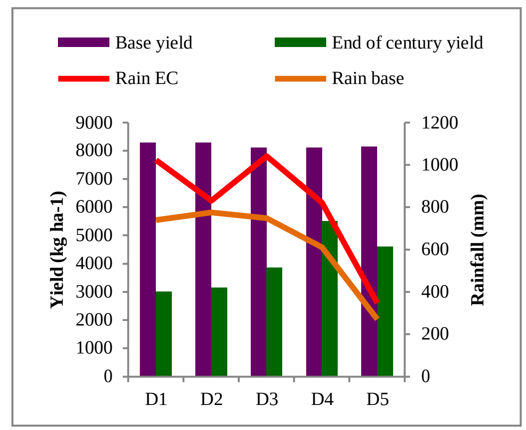


iii

Fig. 5.87 (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Malappuarm

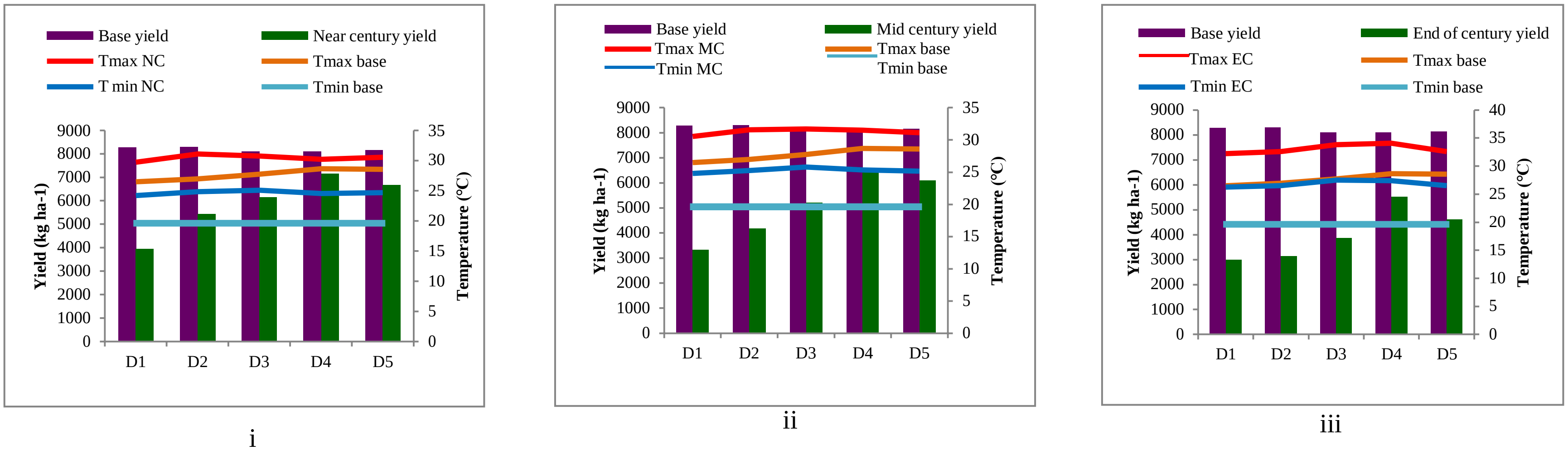


Fig. 5.88 (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5in Malappuarm

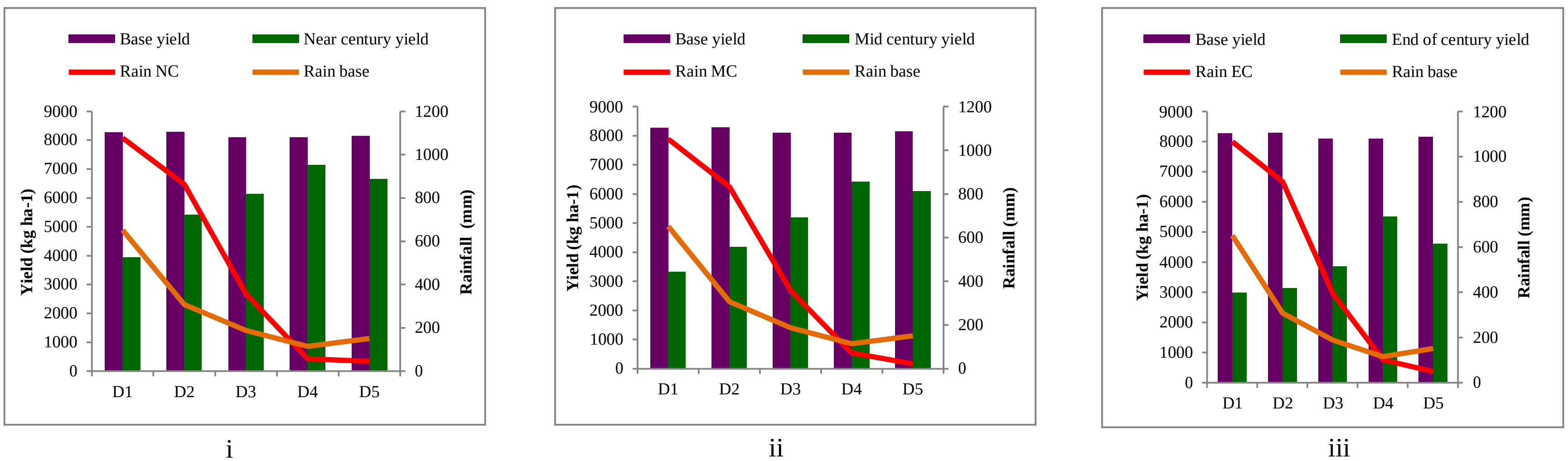


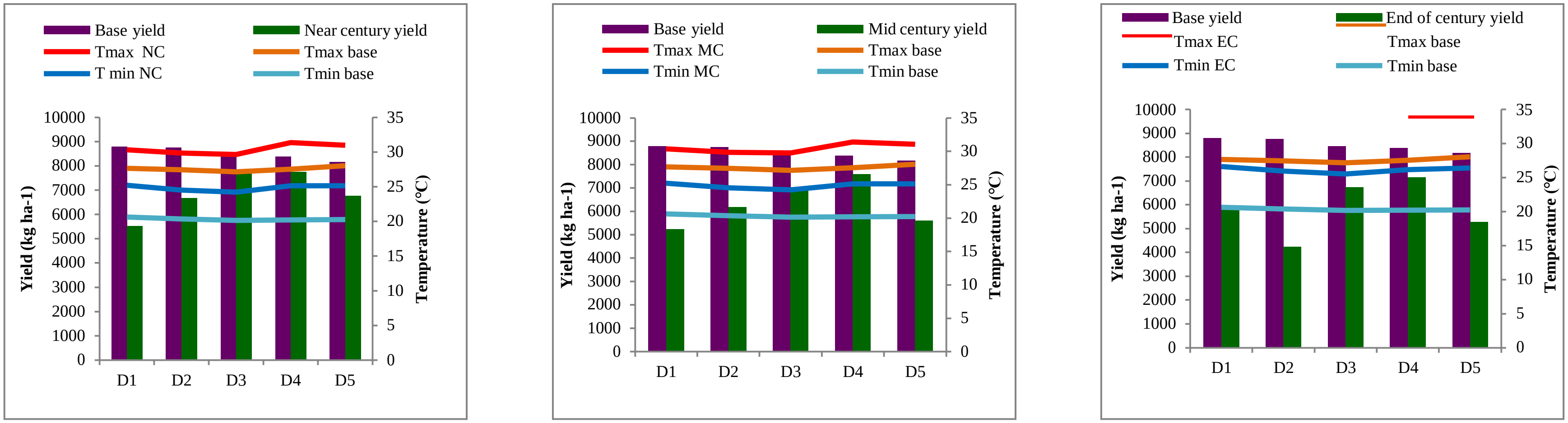
Fig. 5.88 (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5in Malappuarm

5.7.2. Rice production in the central zone of Kerala

Rice production is expected to decrease in all the future simulations under both the RCPs in Jaya and Jyothi. An expectation is found in the near-century in the yield of Jaya where the yield is expected to increase by 1% and 2 % under RCP 4.5.The deviation of yield from the base period is found to be less on July 20th planting for both the varieties in all future simulations. The departure of temperature from normal during panicle initiation to anthesis is found less in July 20th planting.According to Oh-e et al. (2007), a maximum temperature of 31.8°C during the entire crop period of rice hastens senescence of leaf, decreases photosynthetic rate which leads to the yield reduction in rice. That may the reason for the yield reduction in future simulations. An increase in temperature by 1℃ may lead to the reduction of rice production by 7.2 % as per the report of Krishnan *et al*. (2011). An increase in rainfall during panicle initiation to anthesis is expected in all the future simulations during June 5th and 20th planting which may the reason for the maximum deviation of yield from the base period. In the study of Vijayakumar *et al.* (1996) he reported that increased morning rainfall during the flowering period reduces the pollination thereby reduces the yield. A similar result was also observed by Haritharaj (2019). Figure 5.89 to 5.112 depicts the yield and weather (temperature and rainfall) experienced during transplanting to panicle initiation and panicle initiation to anthesis in all the districts of the central zone.

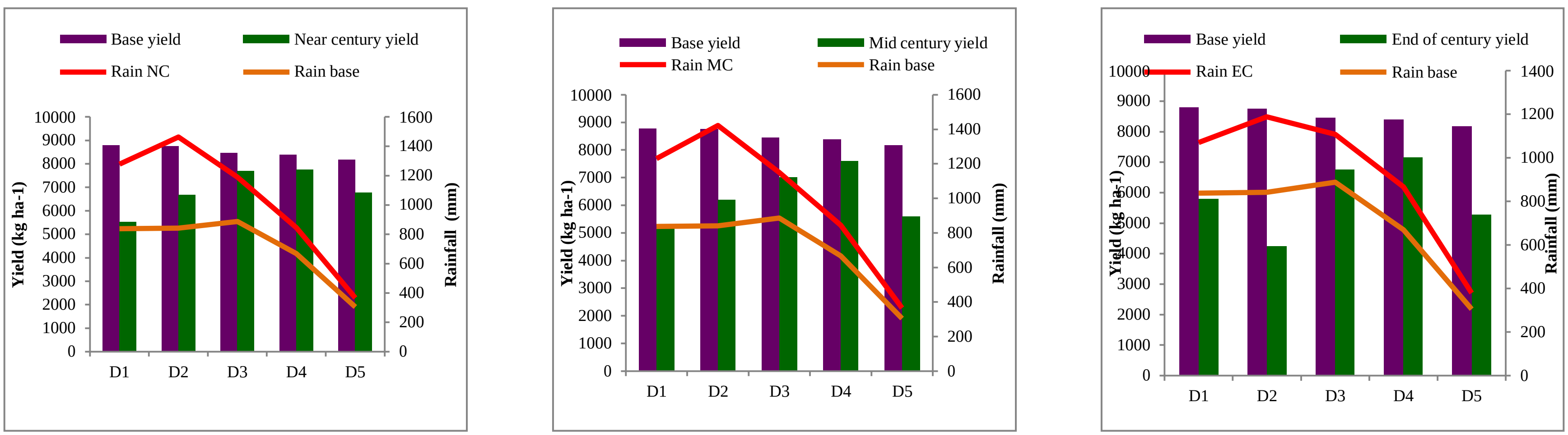
5.7.3. Rice production in the problematic zone of Kerala

In problematic zone Kerala in all the future simulations highest yield has been recorded in July 20th planting under both the RCPs in Jaya. While in case of Jyothi highest potential was observed during July 20th in near century . In mid and end of century highest potential yield wasobsereved in August 5th planting.In Kottayam an increase in yield by 1% in near and mid century under RCP 4.5 in August 5th planting is expected. During this period in the temperature during panicle initoiation to anthesis is decreased by 0.1℃ from base. The rainfall during this stage is less than 100 mm which may favour the increased production in rice. In the intial dates of plantings the increase in temperature and increased rainfall during flowering may lead to the decreased yield of rice. Peng *et al.*(2004) reported that an increase in the minimum temperature at the time anthisis enhances the repiration and that may lead to the reduction in grain yield (Fig.5.113 to 5.128)



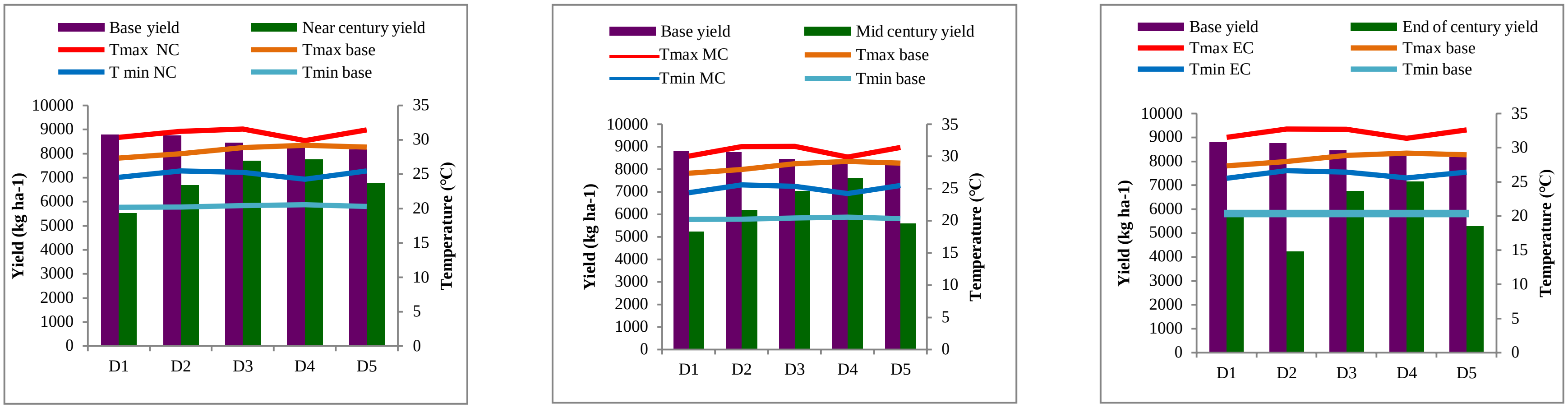
i ii iii

Fig. 5.89. a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Palakkad



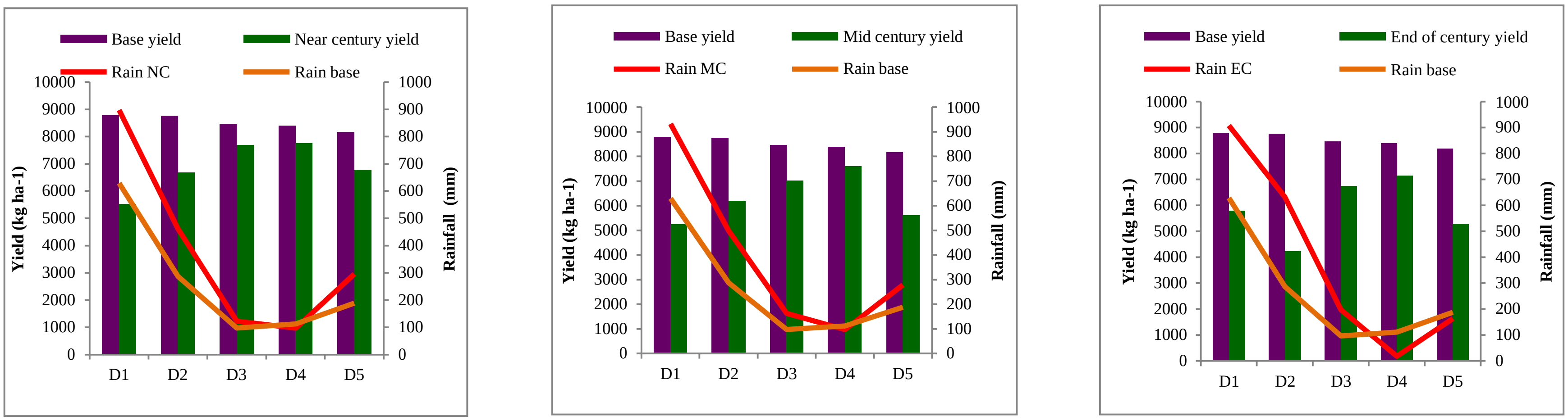
i ii iii

Fig. 5.89 (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Palakkad



i ii iii

Fig. 5.90. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Palakkad



i ii iii

Fig. 5.90. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Palakkad

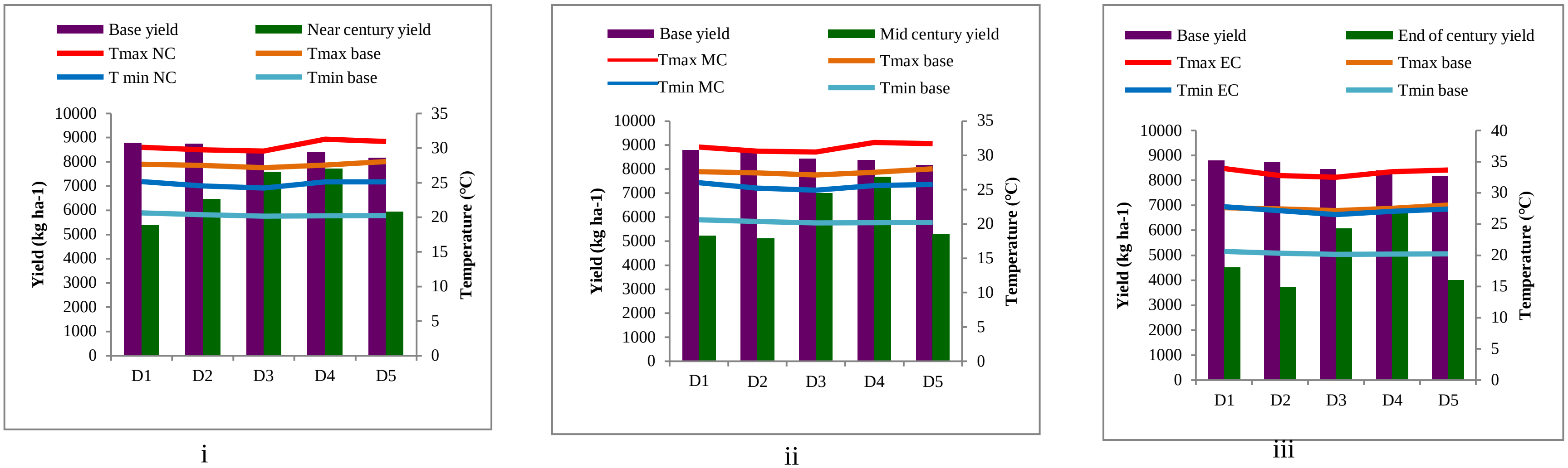


Fig. 5.91.(a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Palakkad

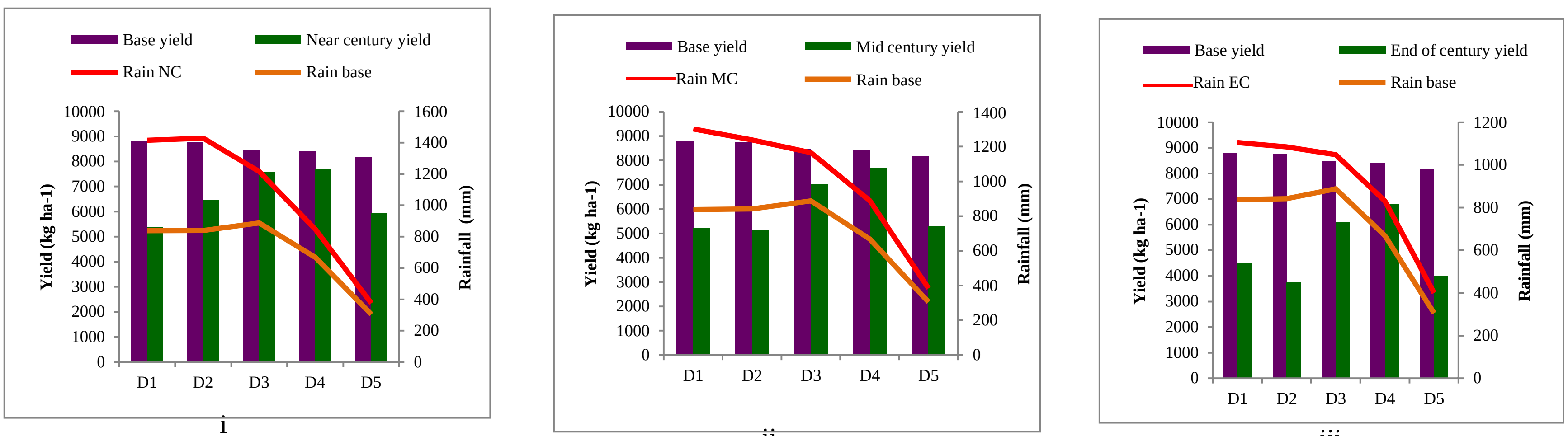


Fig. 5.91. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Palakkad

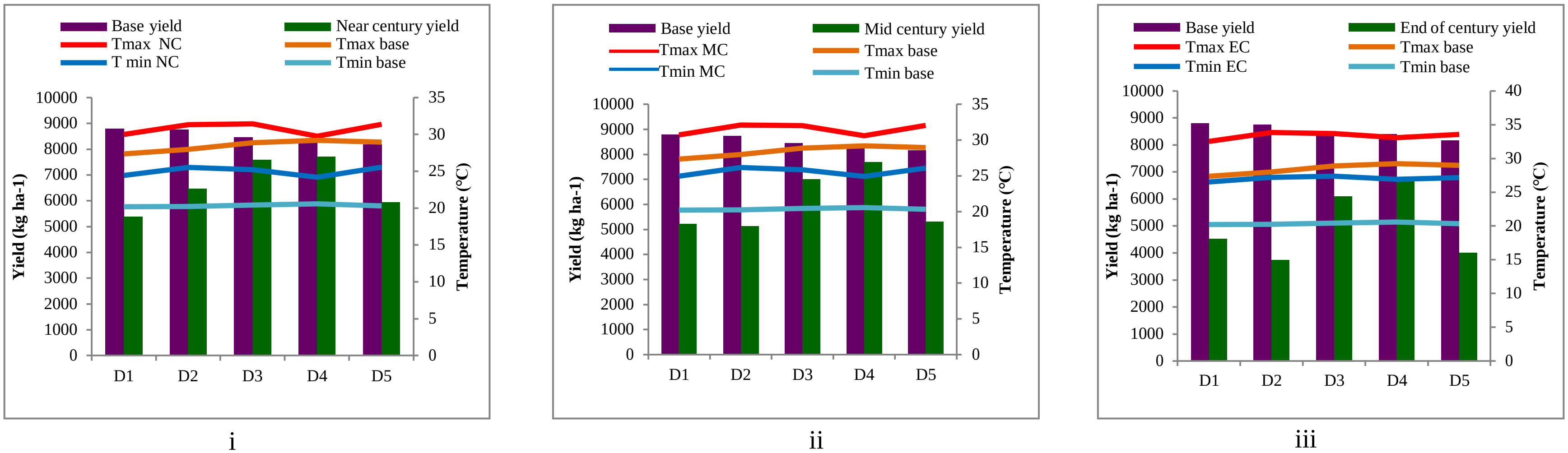


Fig. 5.92. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Palakkad

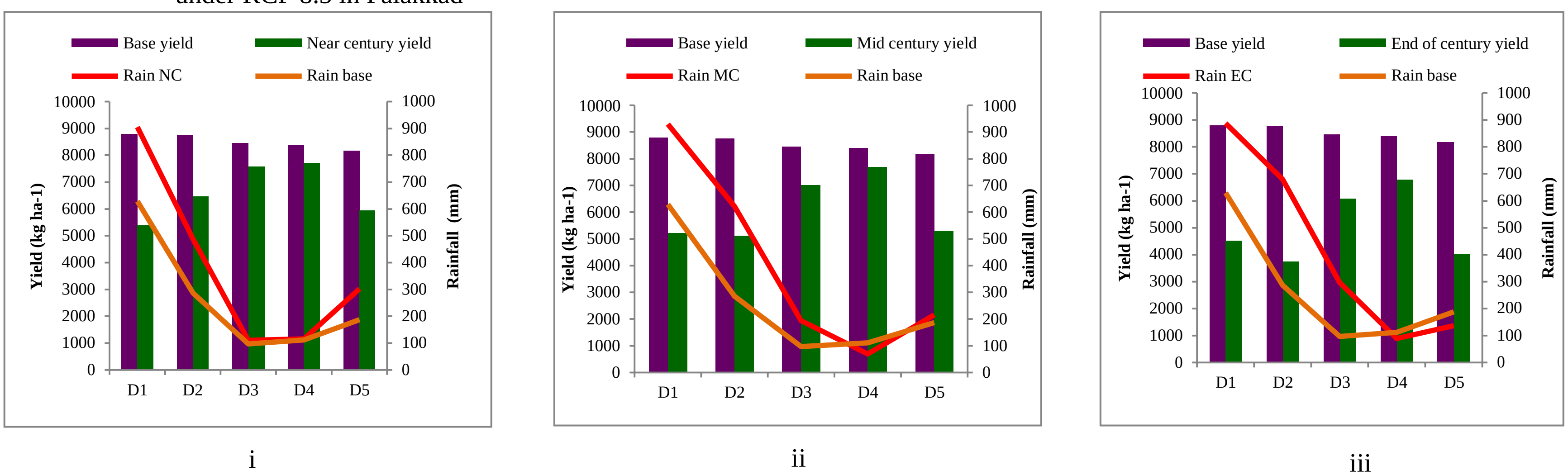
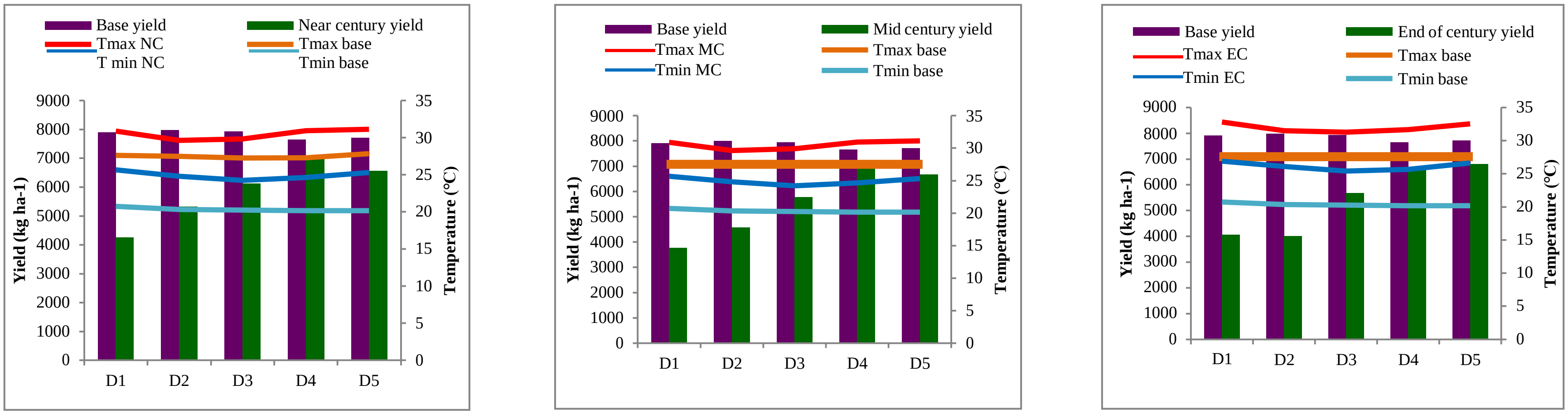
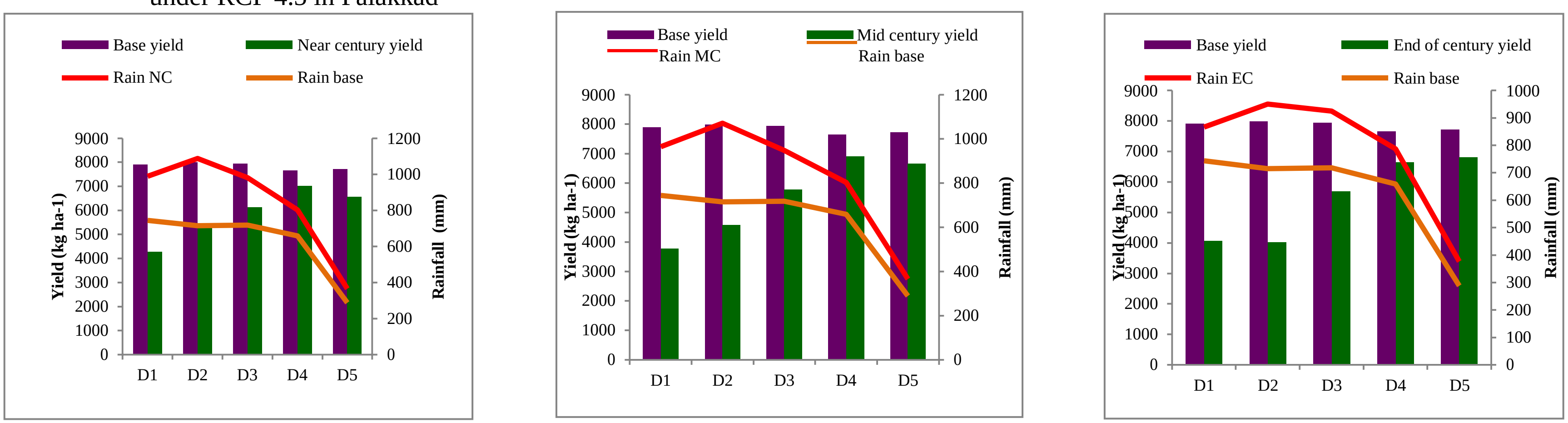


Fig. 5. 92. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Palakkad



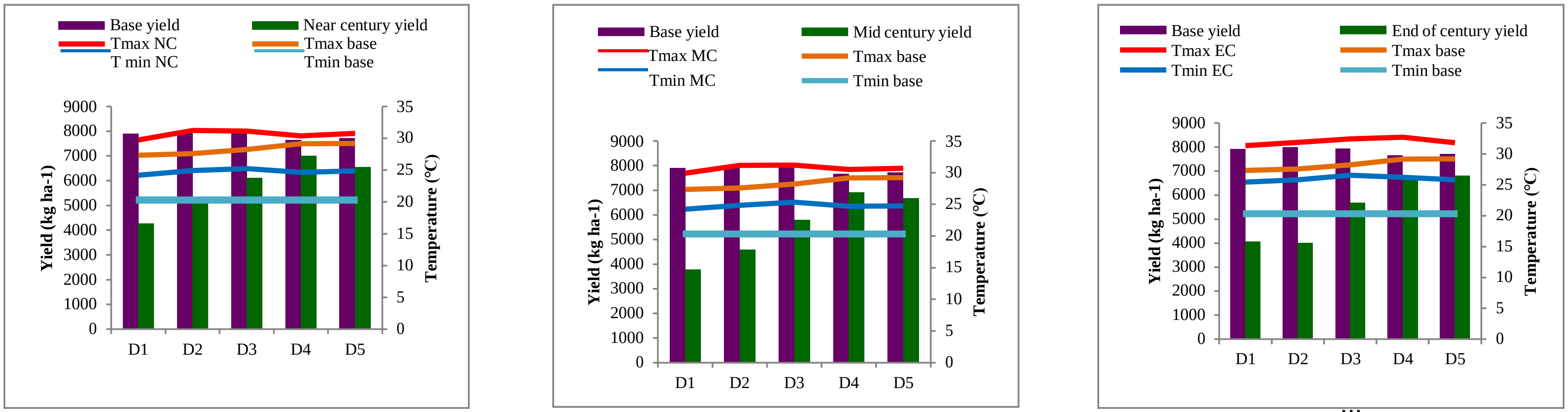
i ii iii

Fig. 5.93. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Palakkad



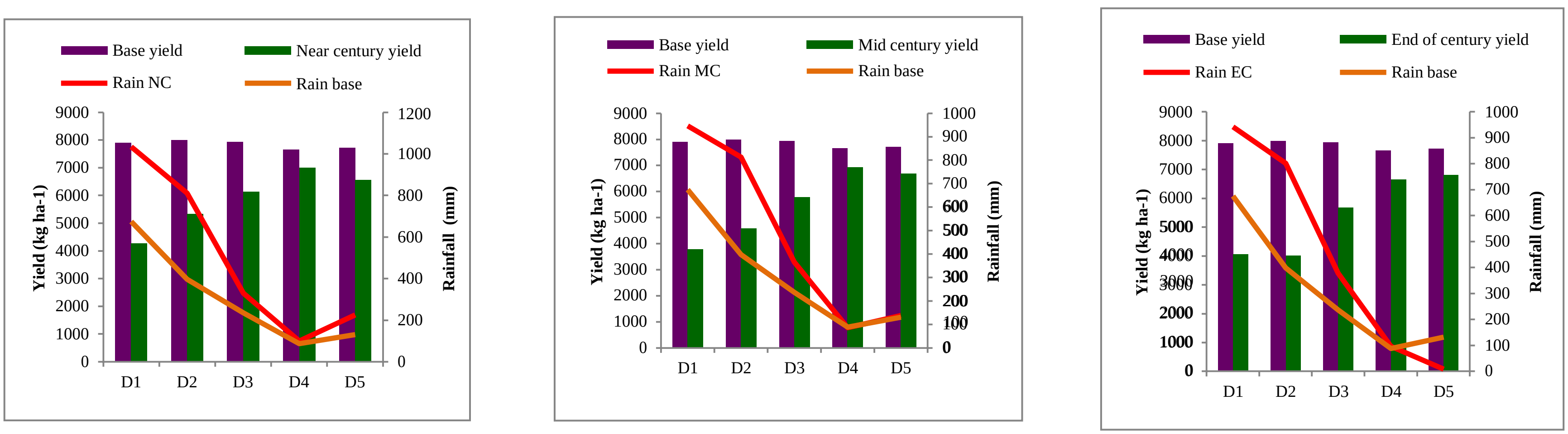
i ii iii

Fig. 5.93. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Palakkad



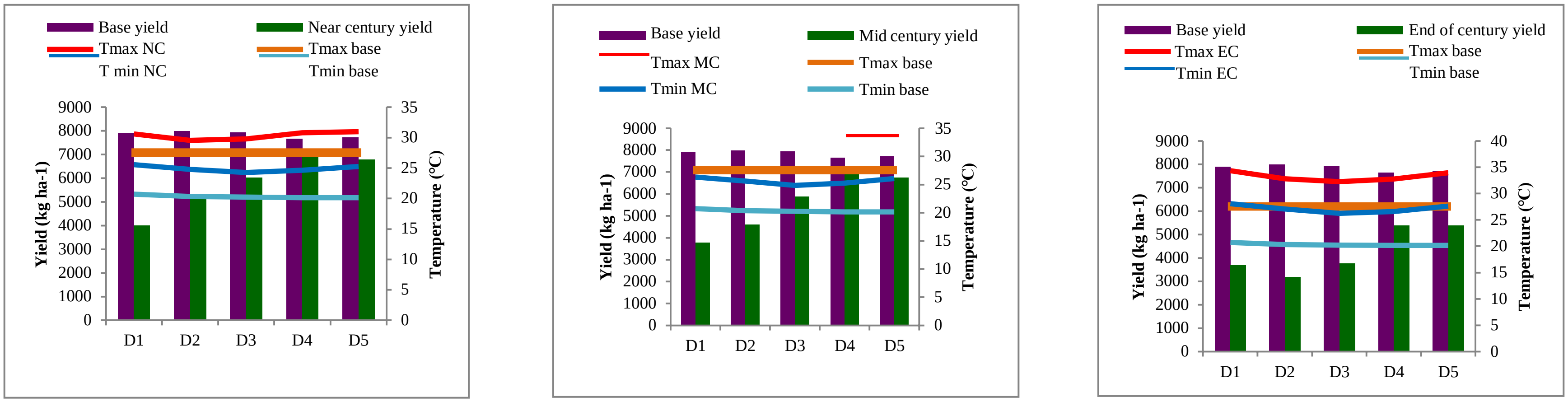
i ii iii

Fig. 5.94. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Palakkad



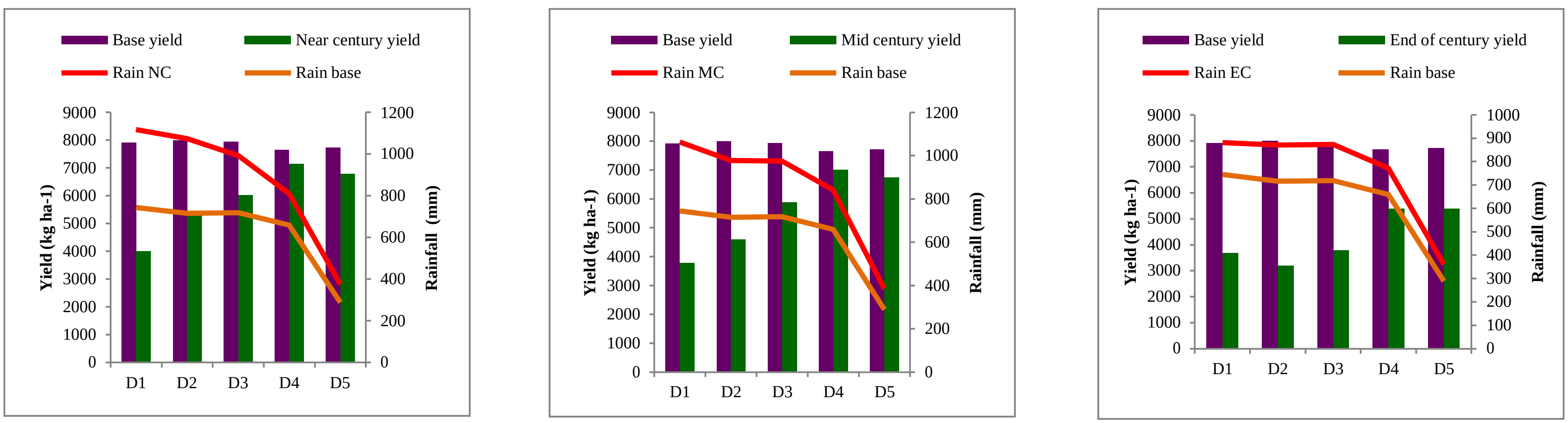
i ii iii

Fig. 5.94. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4. 5 in Palakkad



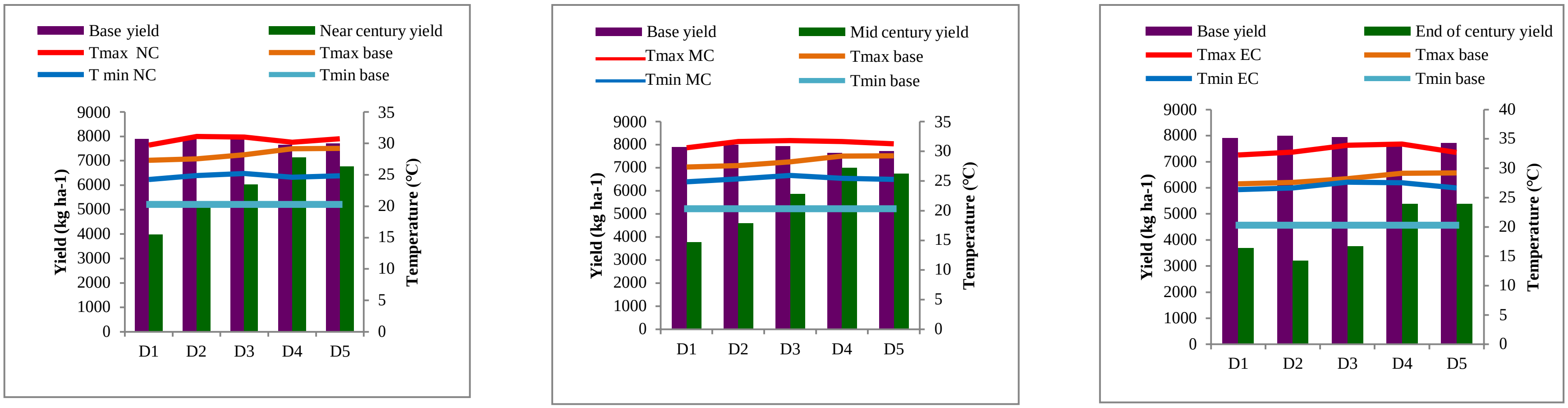
i ii iii

Fig. 5.95 (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Palakkad



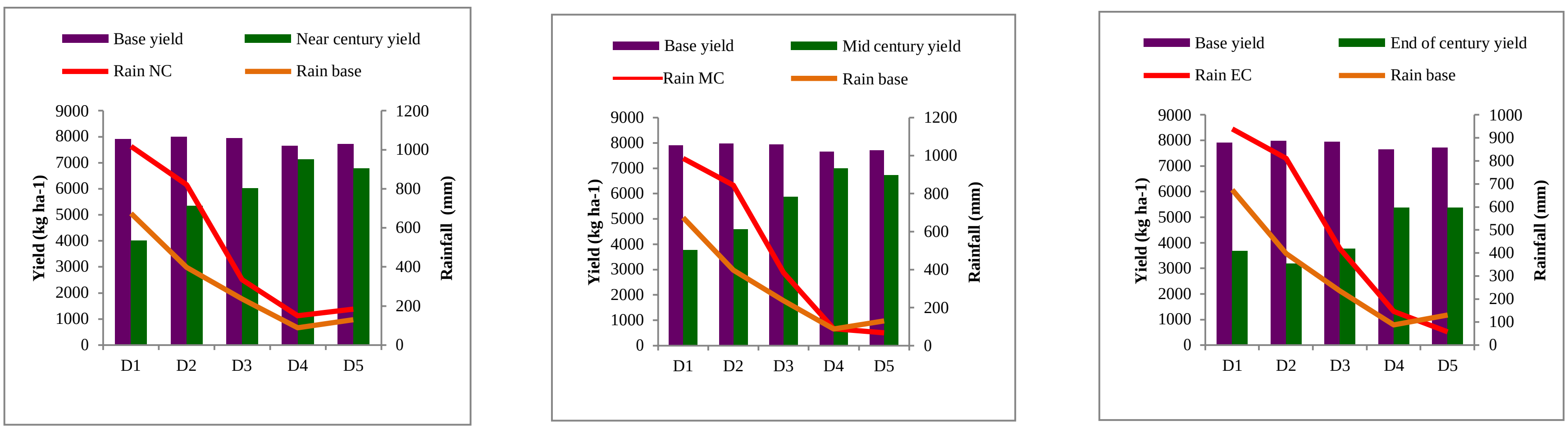
i ii iii

Fig. 5.95 (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Palakkad



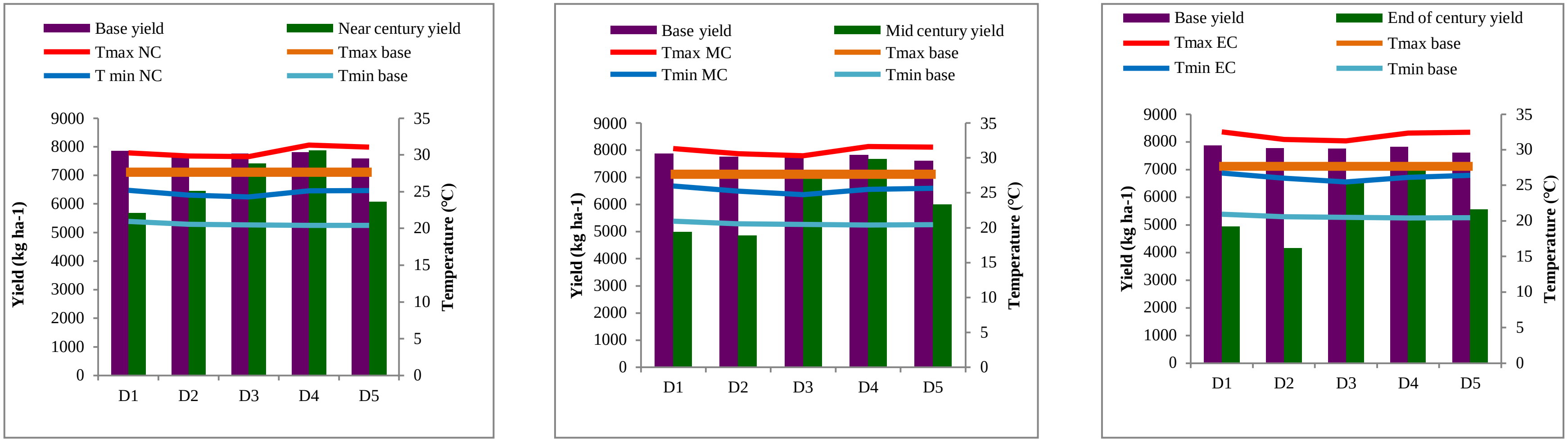
i ii iii

Fig. 5.96 (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Palakkad



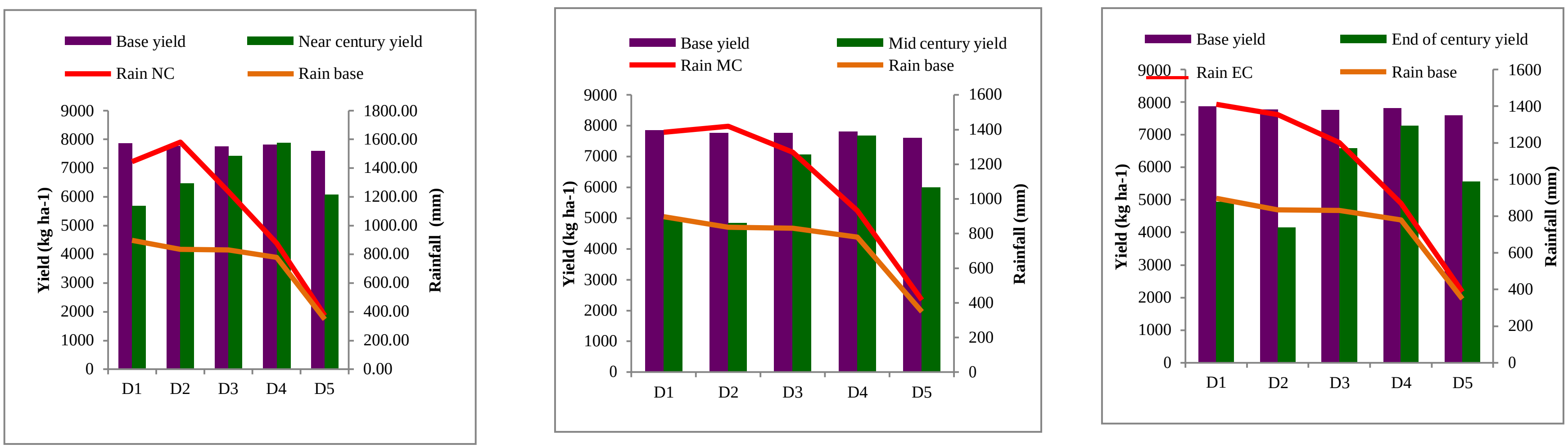
i ii iii

Fig. 5.96 (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Palakkad



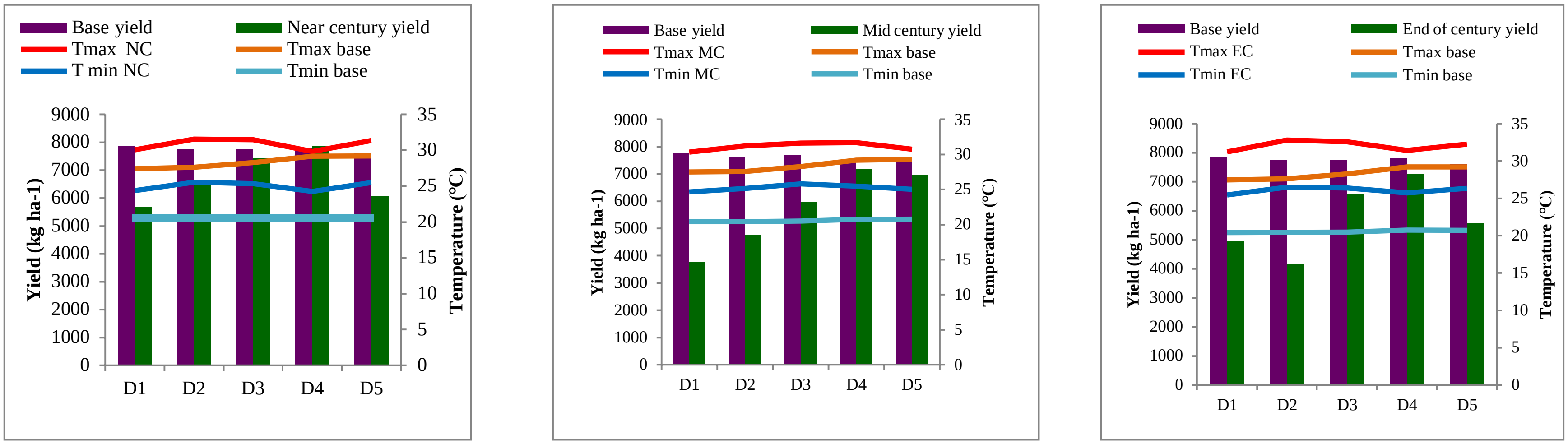
i ii iii

Fig. 5.97 (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Thrissur



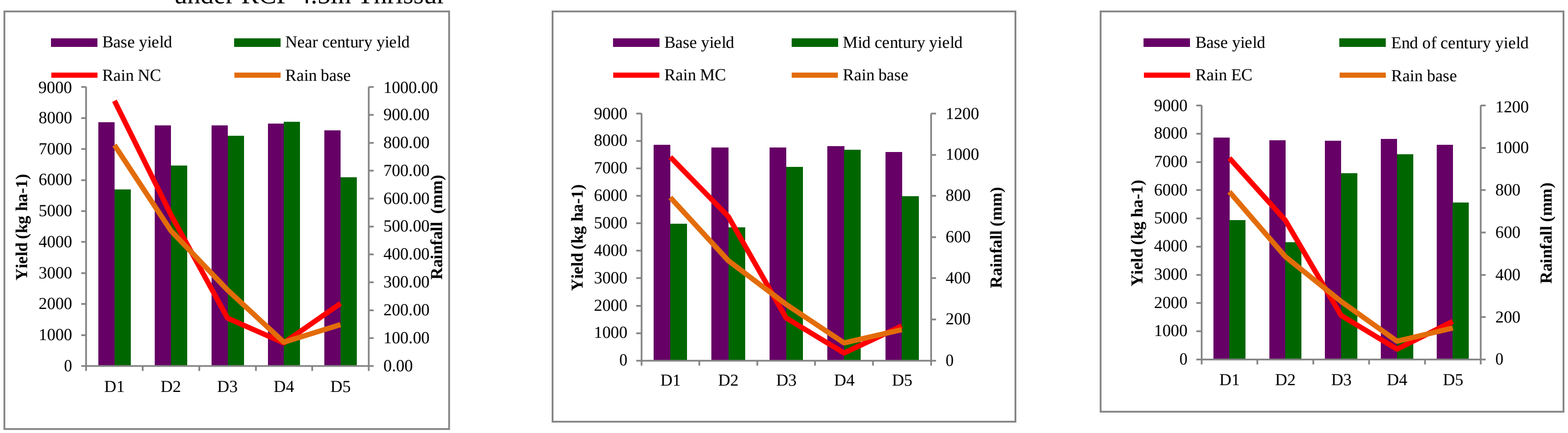
i ii iii

Fig. 5.97. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Thrissur



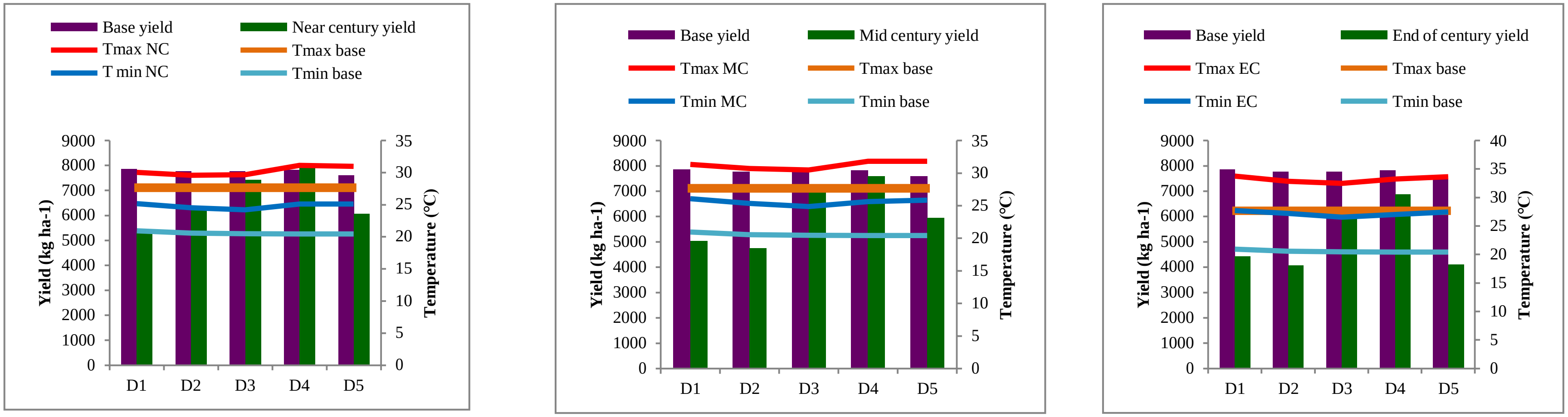
i ii iii

Fig. 5.98 (a). Effect of temperature on yieldof Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5in Thrissur



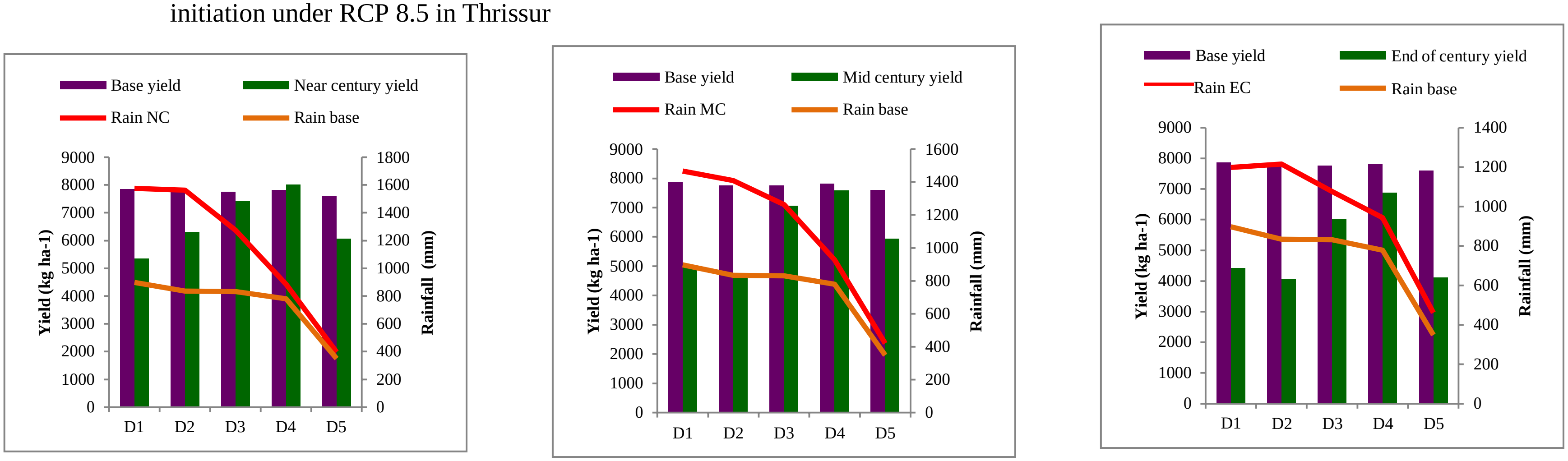
i ii iii

Fig. 5.98. (b). Effect of rainfall on yieldof Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5in Thrissur



i ii iii

Fig. 5.99. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Thrissur



i ii iii

Fig. 5.99. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Thrissur

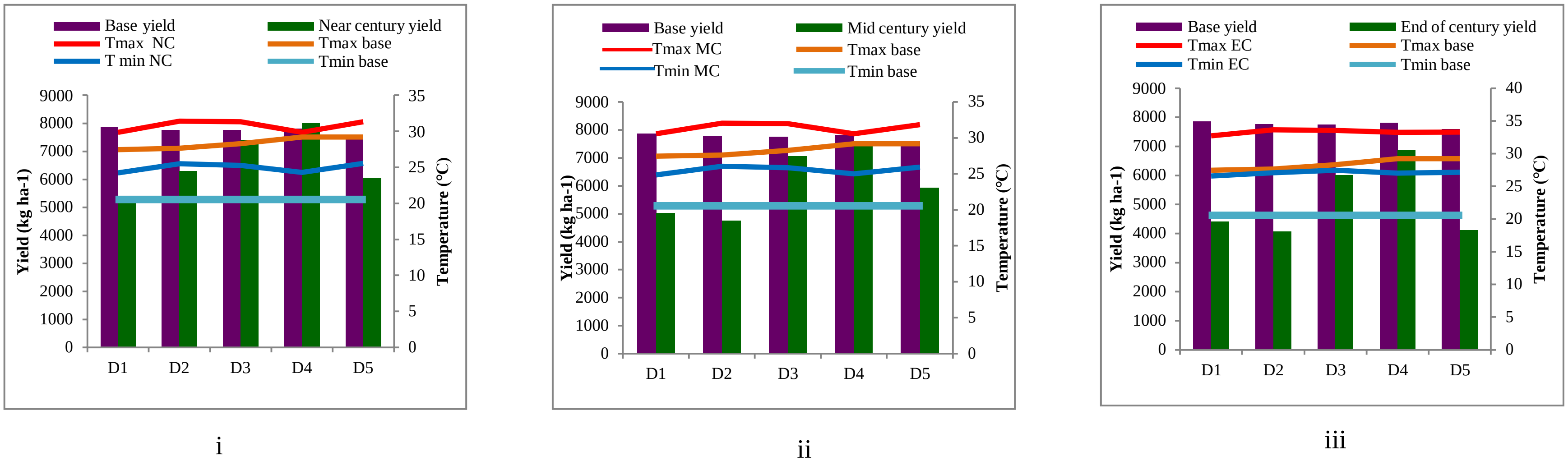


Fig. 5.100.(a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Thrissur

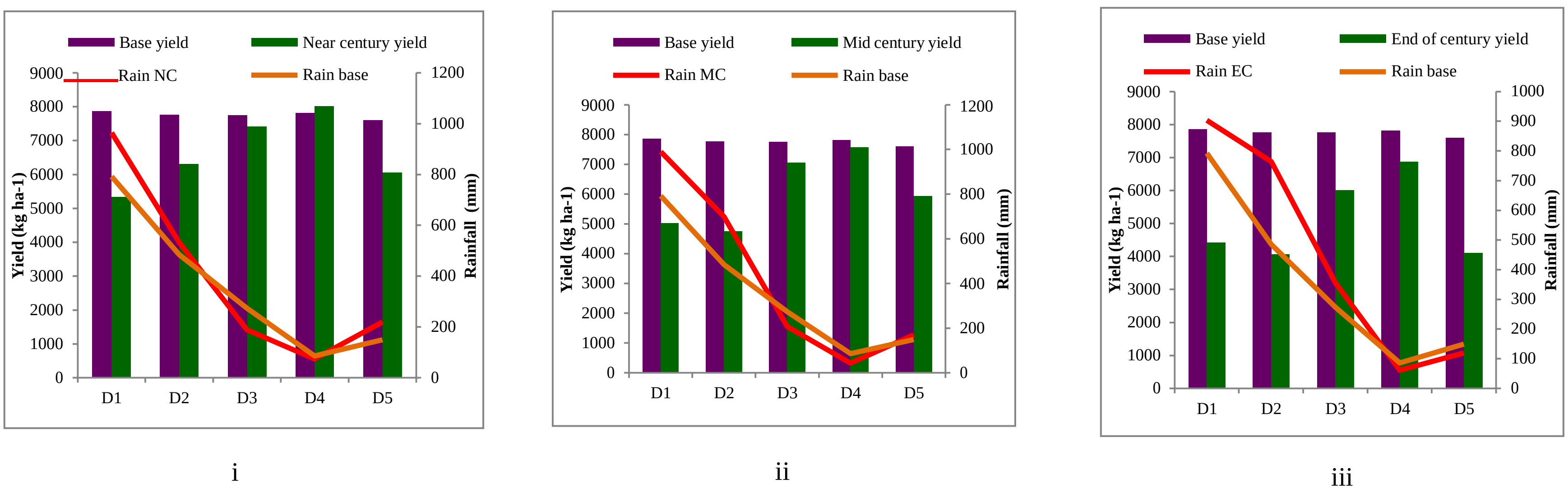
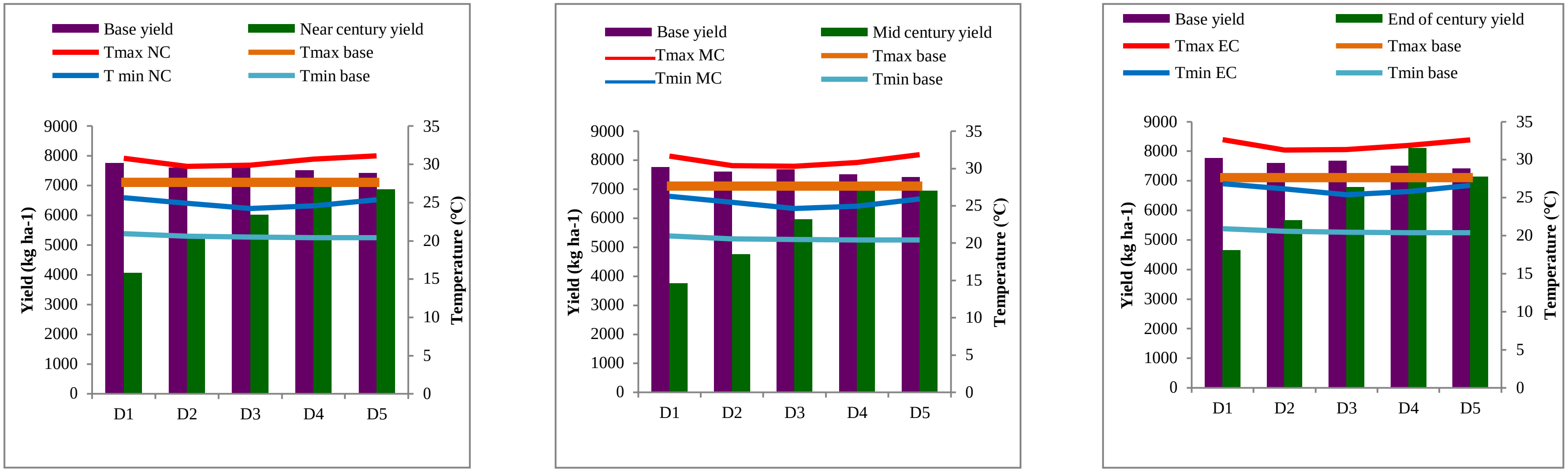
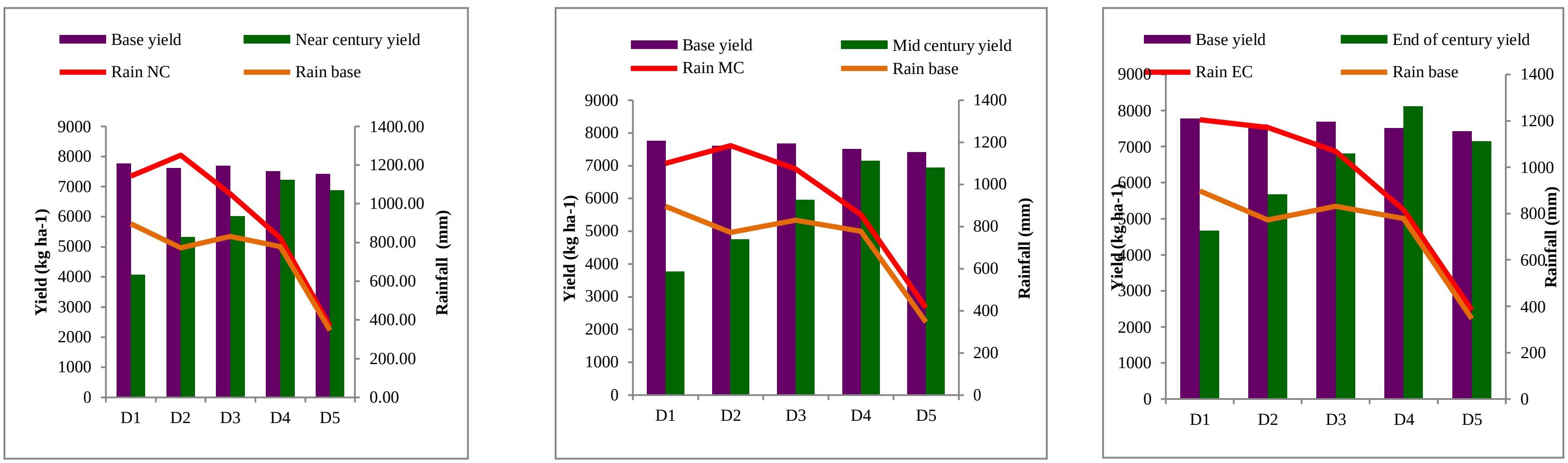


Fig. 5.100 (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Thrissur



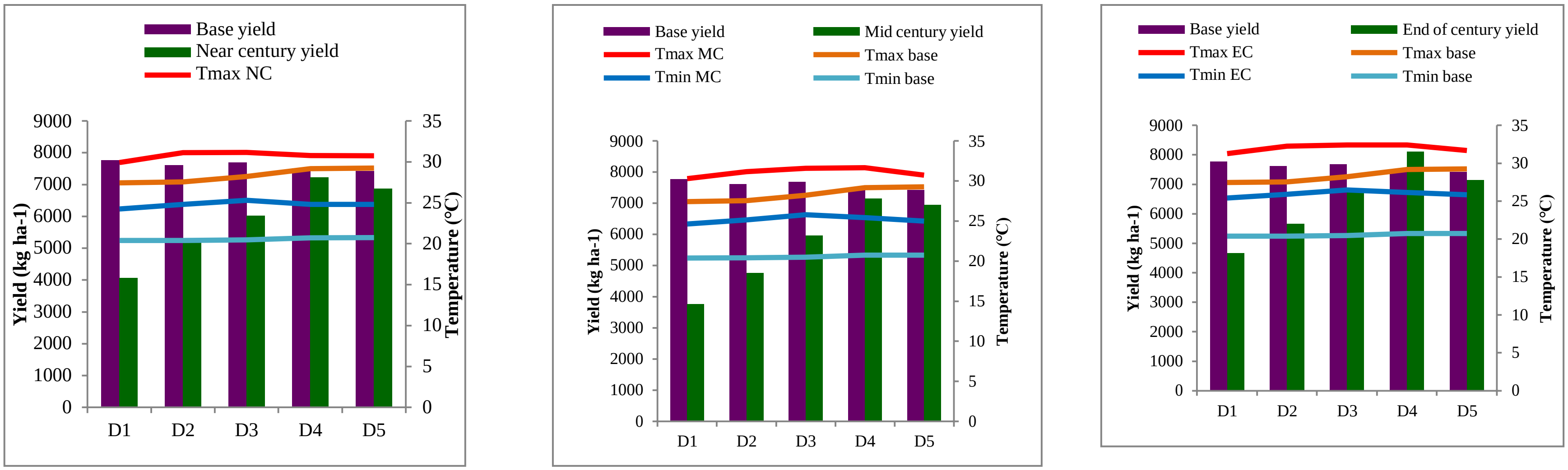
i ii iii

Fig. 5.101 (a). Effect of temperature on yieldof Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5in Thrissur



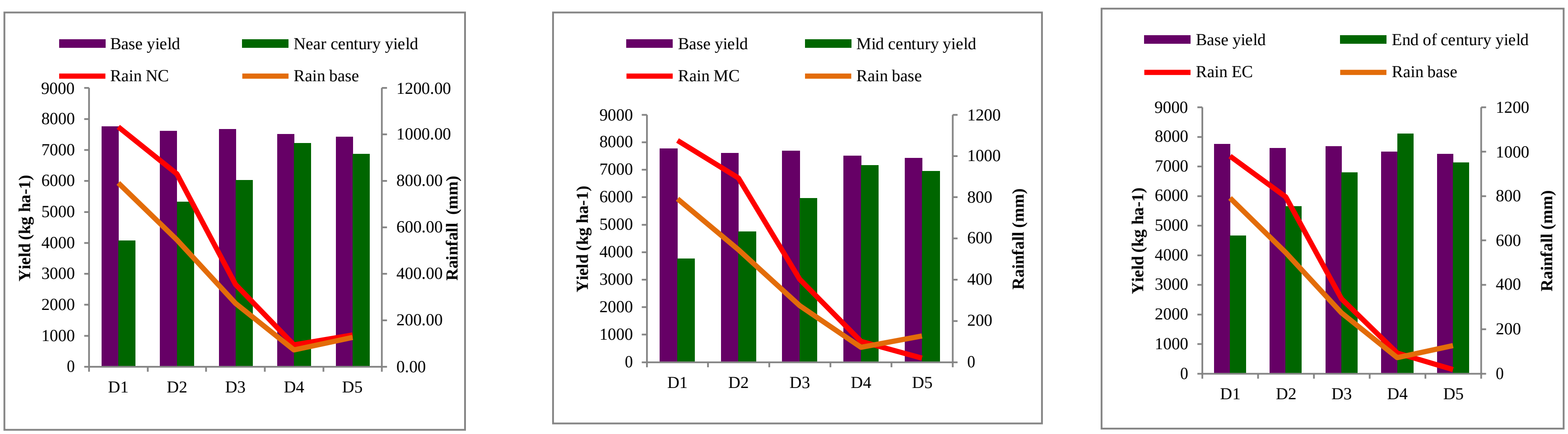
i ii iii

Fig. 5.101. (b). Effect of rainfall on yieldof Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5in Thrissur



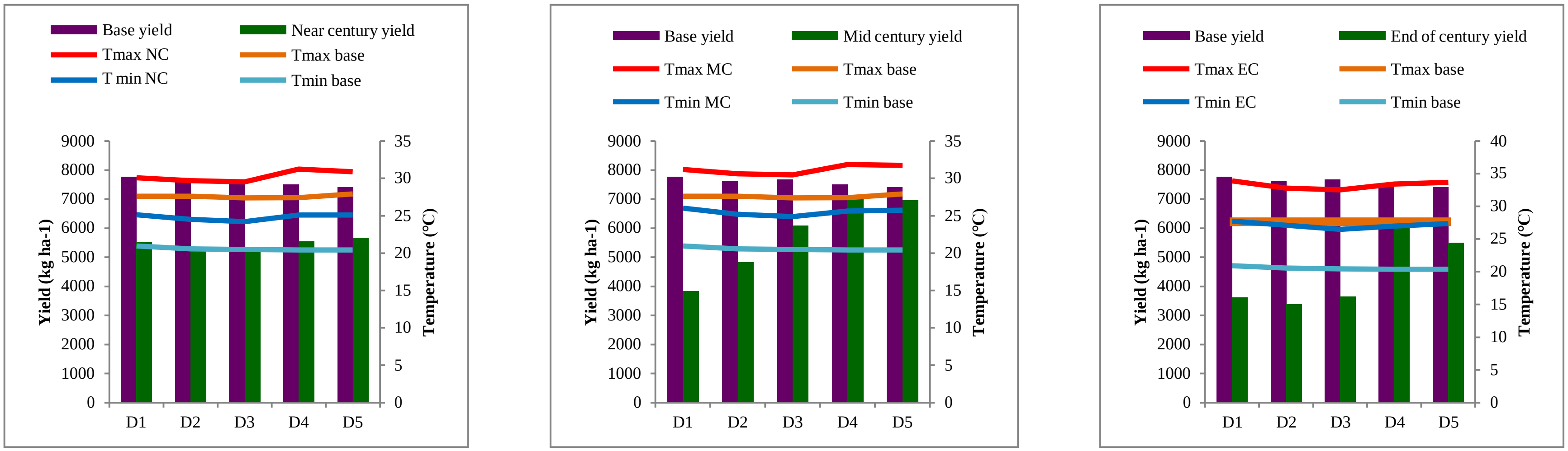
i ii iii

Fig. 5.102. (a). Effect of temperature on yieldof Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5in Thrissur



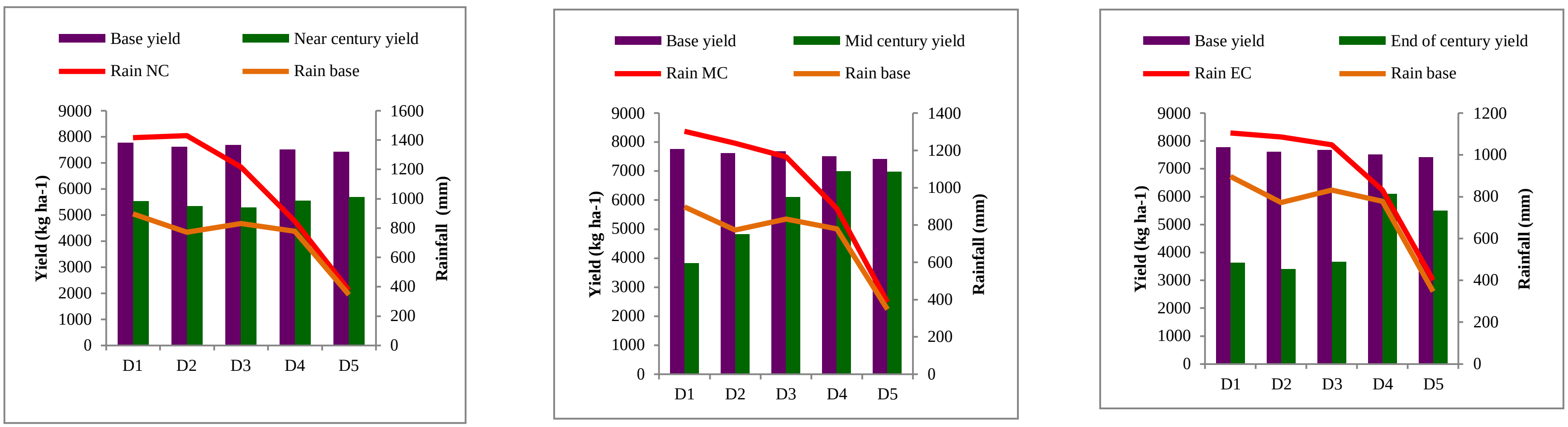
i ii iii

Fig. 5.102. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Thrissur



i ii iii

Fig. 5.103. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Thrissur



i ii iii

Fig. 5.103. (b). Effect of rainfall on yieldof Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Thrissur

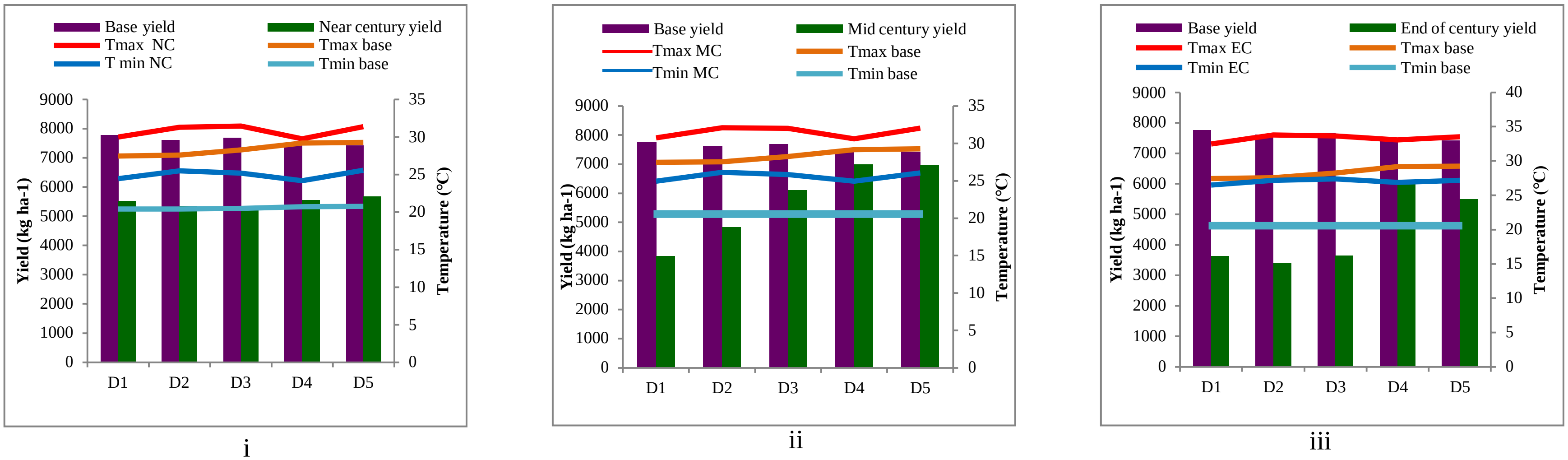


Fig. 5.104. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Thrissur

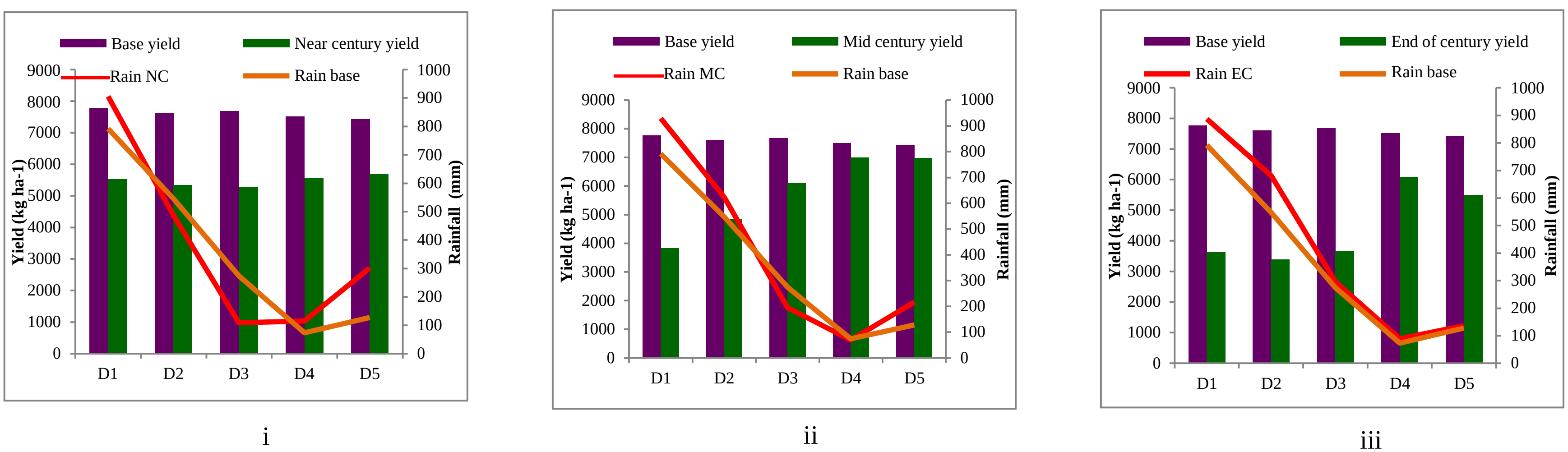


Fig. 5.104. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Thrissur

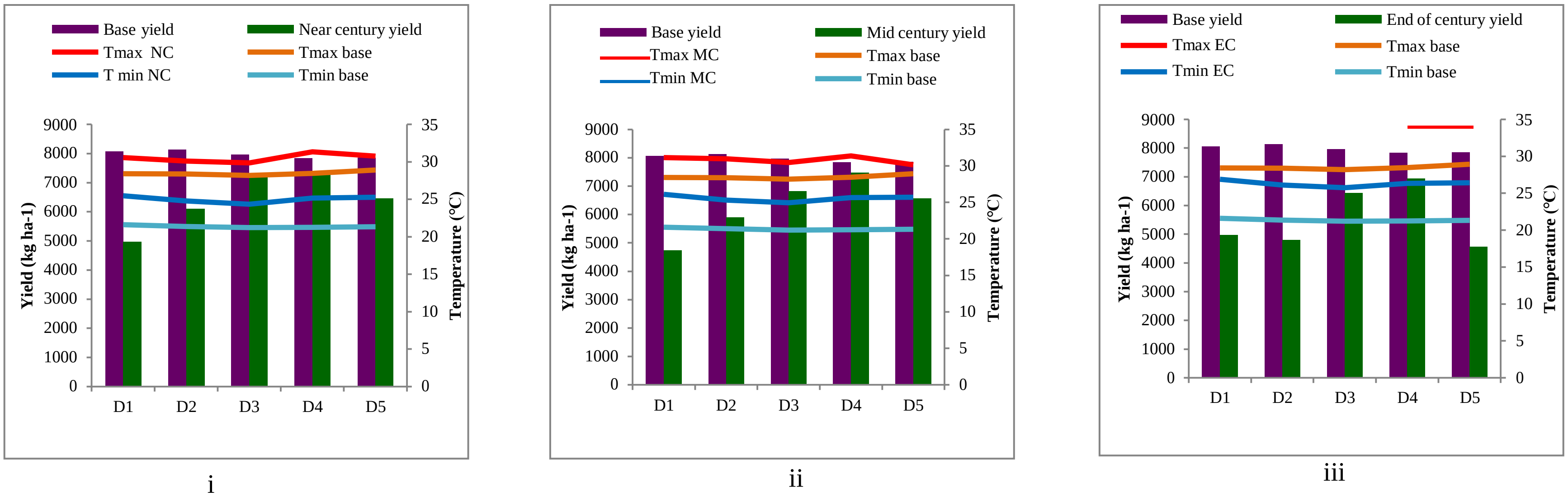


Fig. 5.105. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Ernakulam

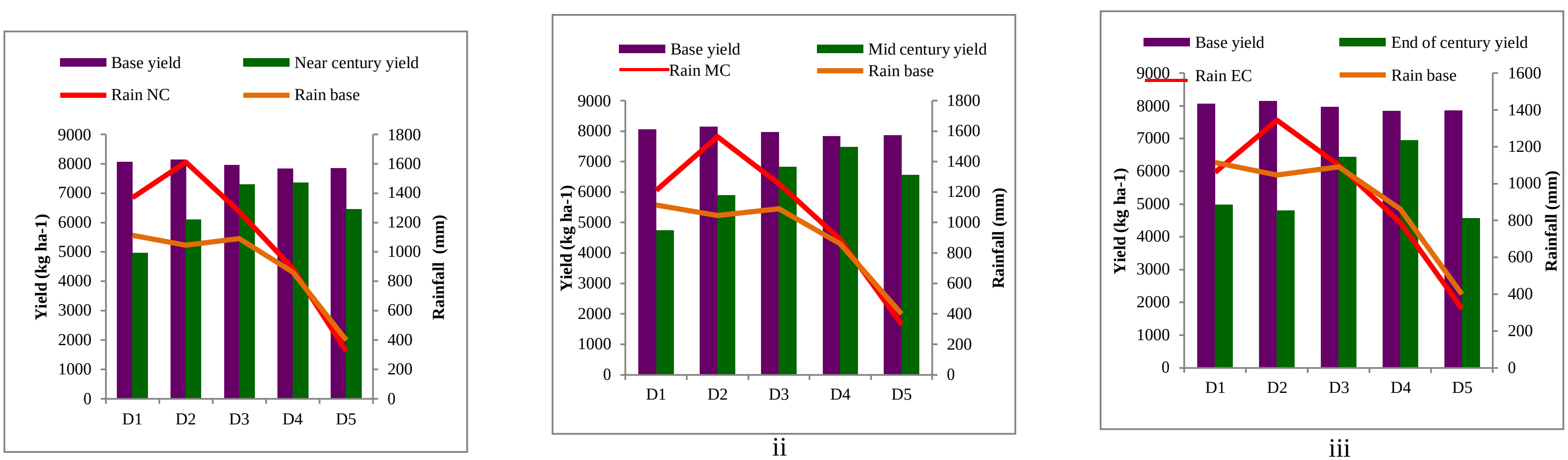
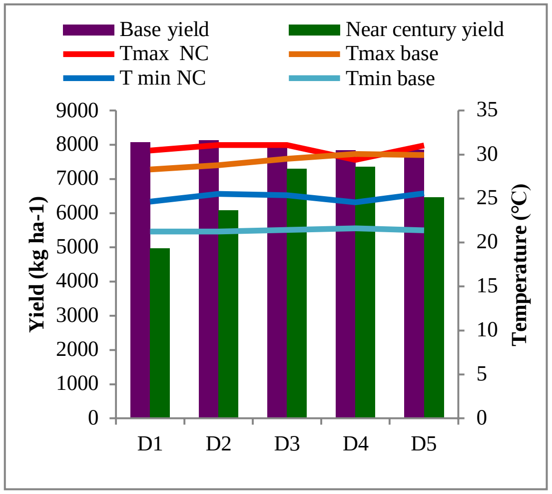
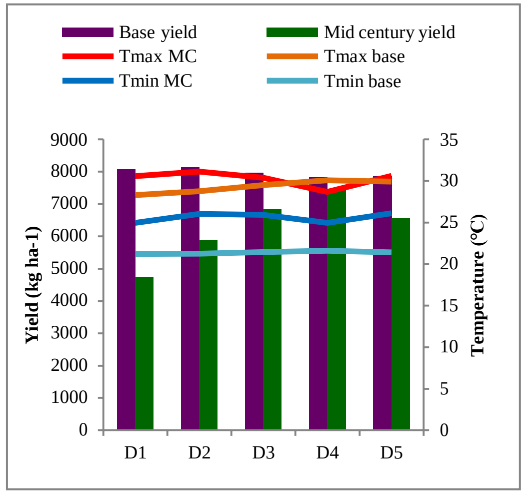
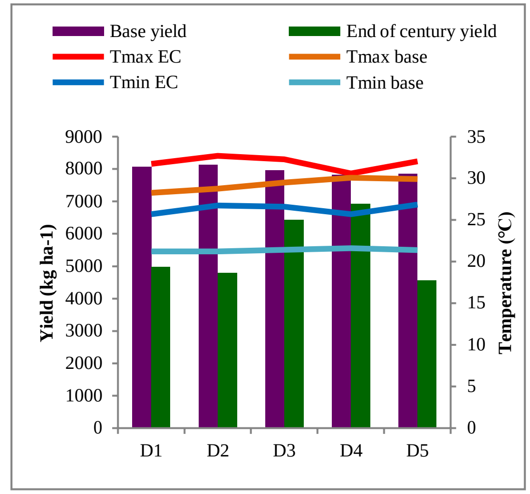


Fig. 5.105. (b). Effect of rainfall on yieldof Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Ernakulam

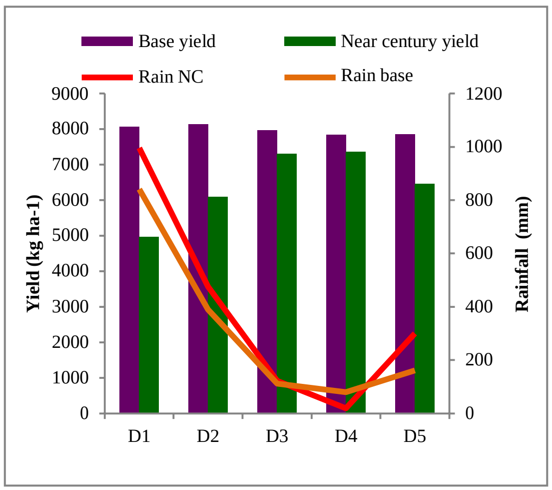


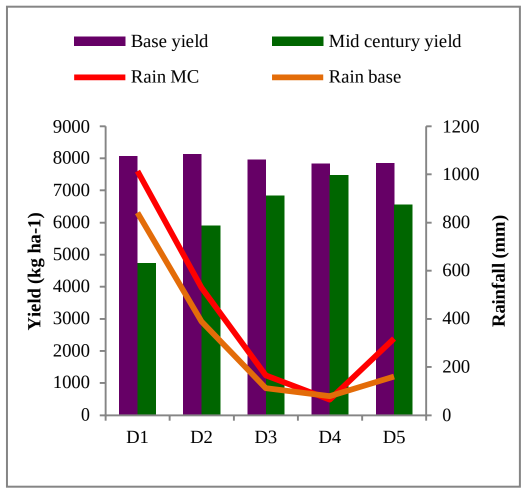


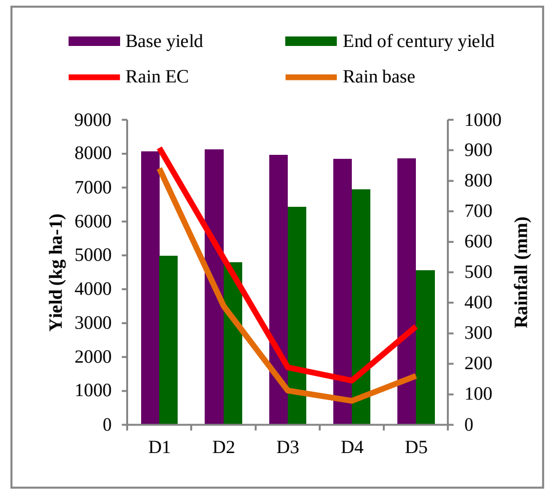


i ii iii

Fig. 5.106. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Ernakulam

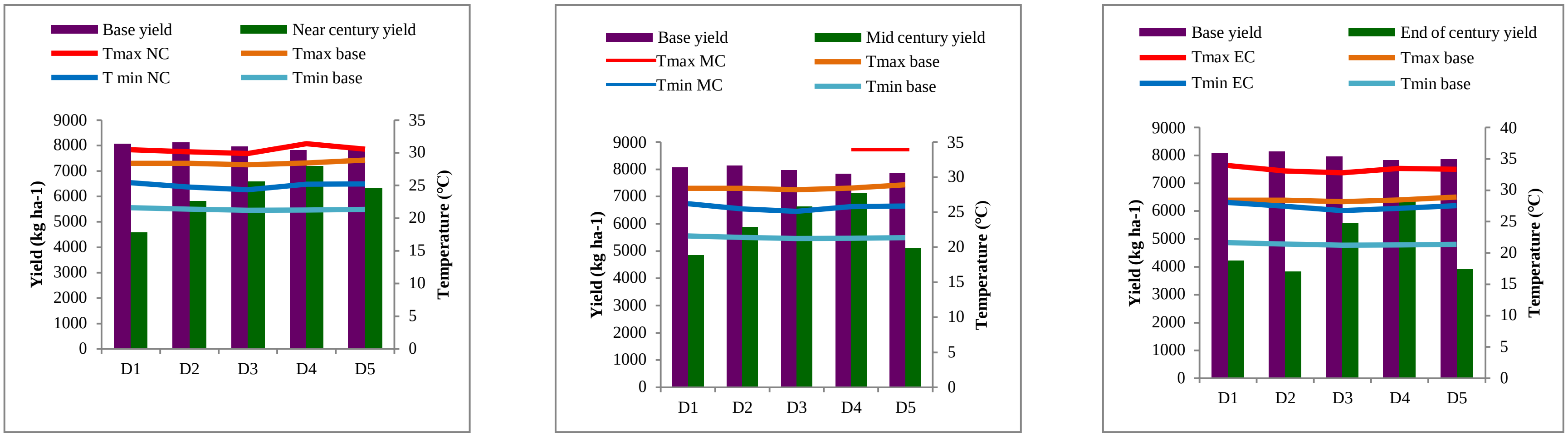






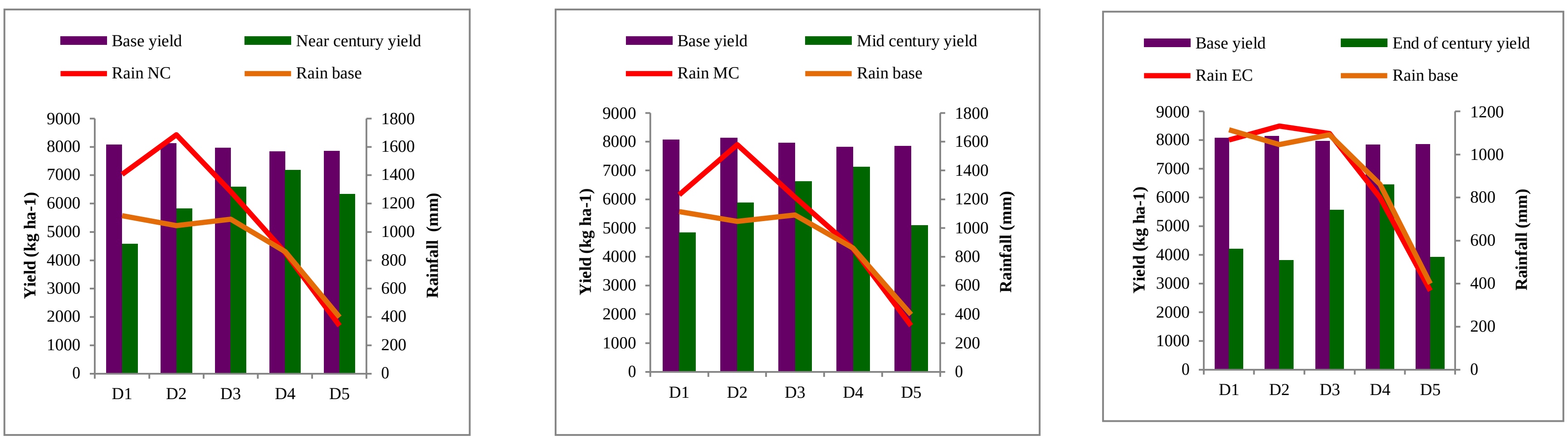
i ii iii

Fig. 5.106. (b). Effect of rainfall on yieldof Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Ernakulam



i ii iii

Fig. 5.107. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Ernakulam



i ii iii

Fig. 5.107. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Ernakulam

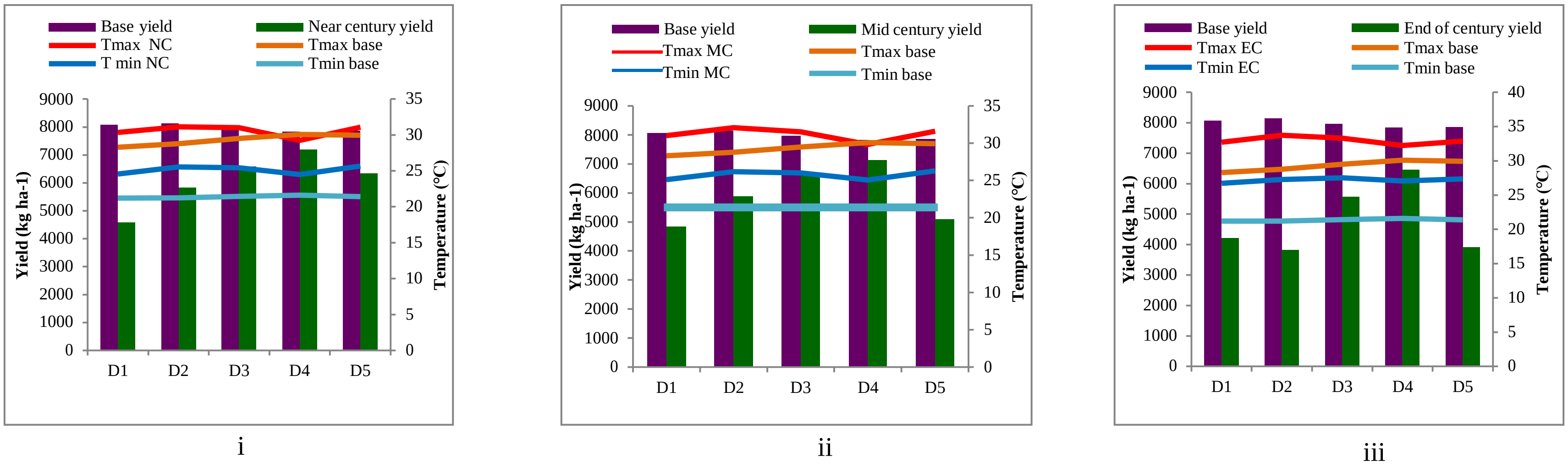


Fig. 5.108. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Ernakulam

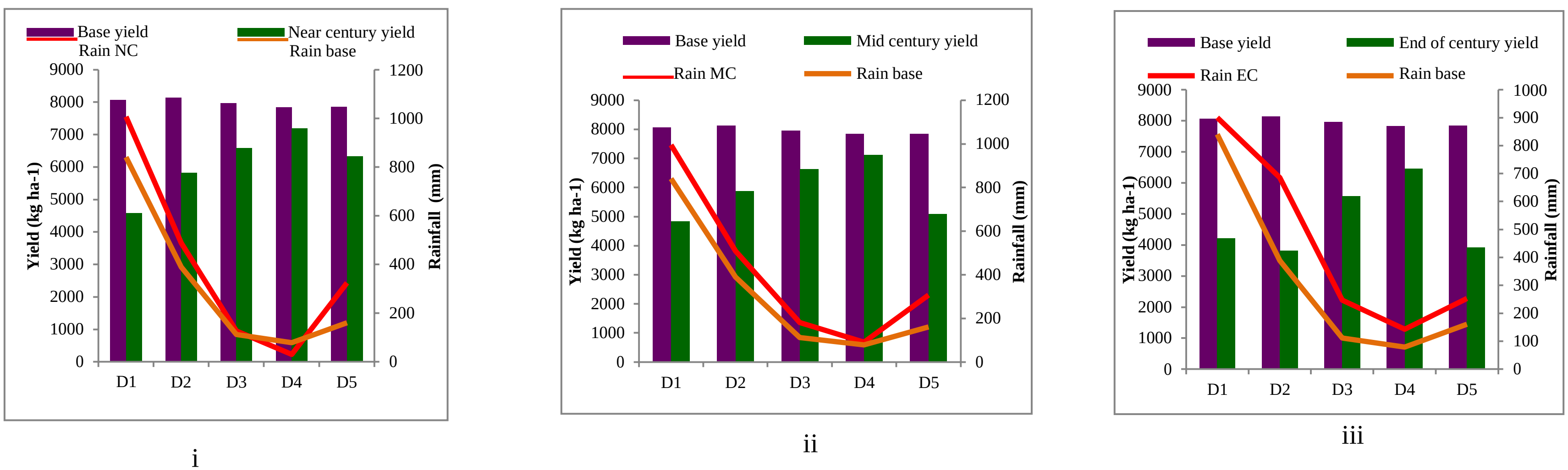
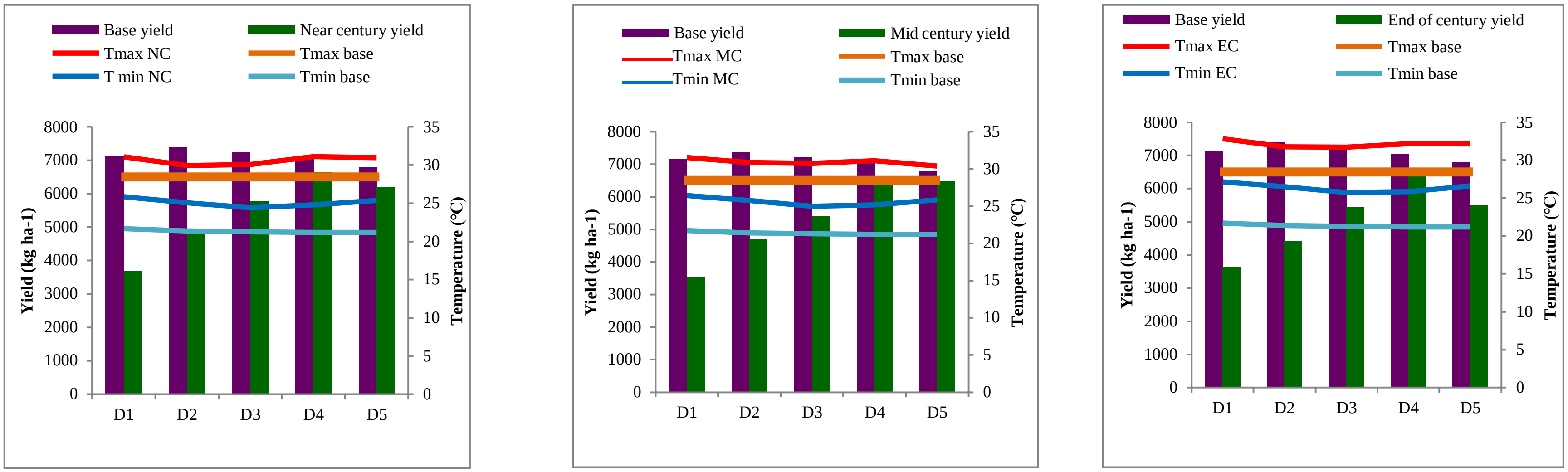
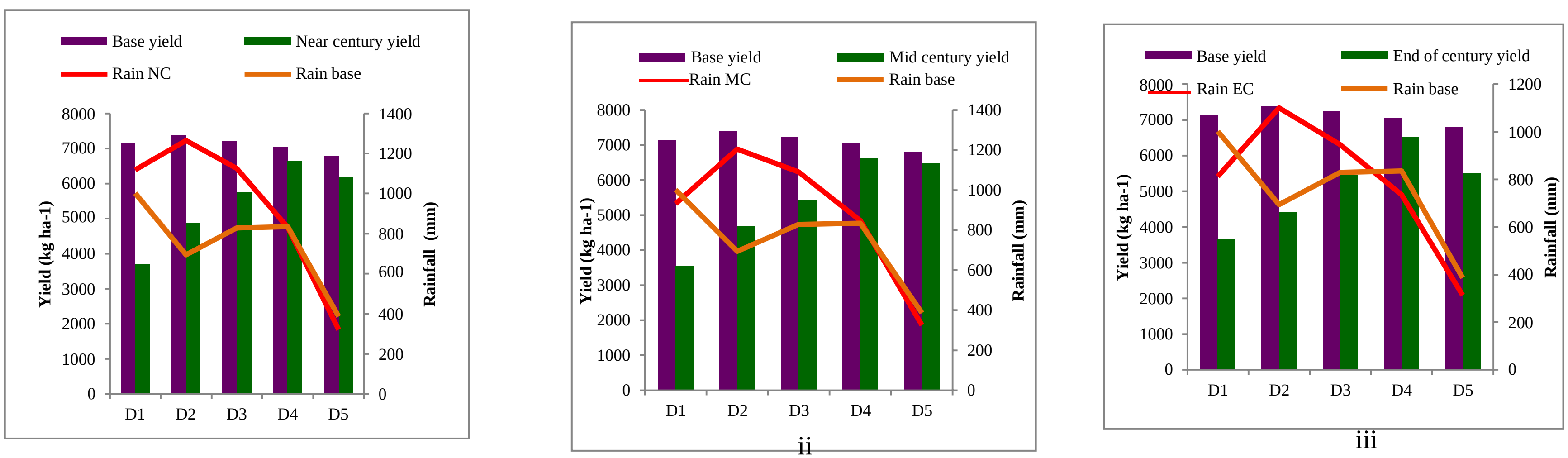


Fig. 5.108. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Ernakulam



i ii iii

Fig. 5.109. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Ernakulam



i ii iii

Fig. 5.109. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Ernakulam

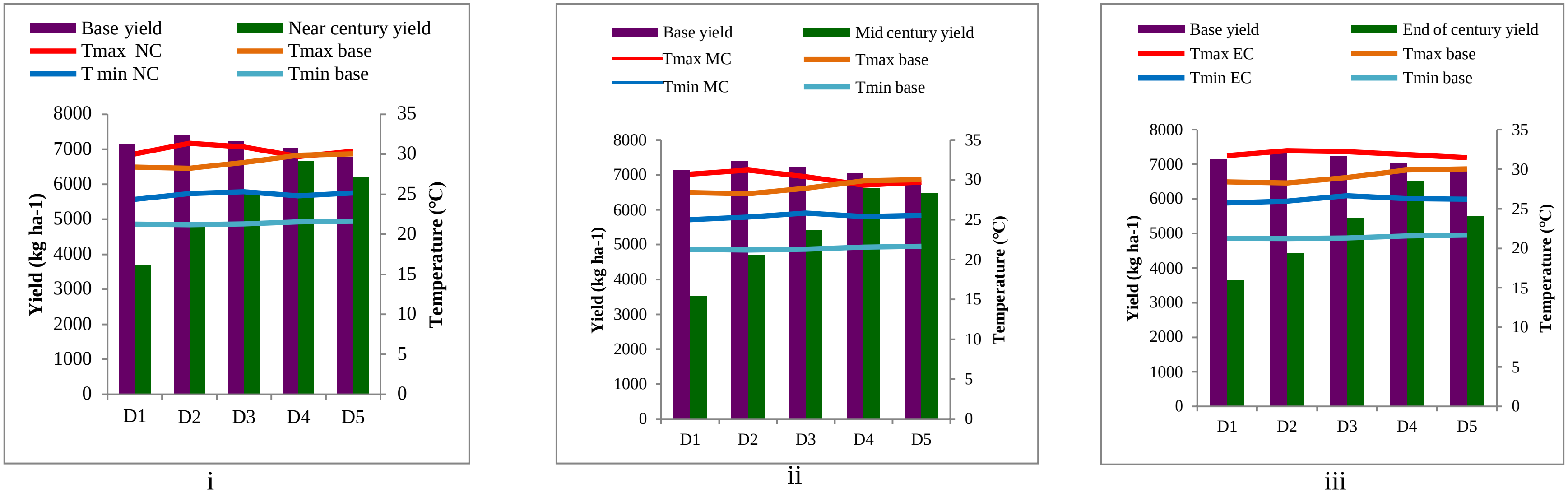


Fig. 5.110. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Ernakulam

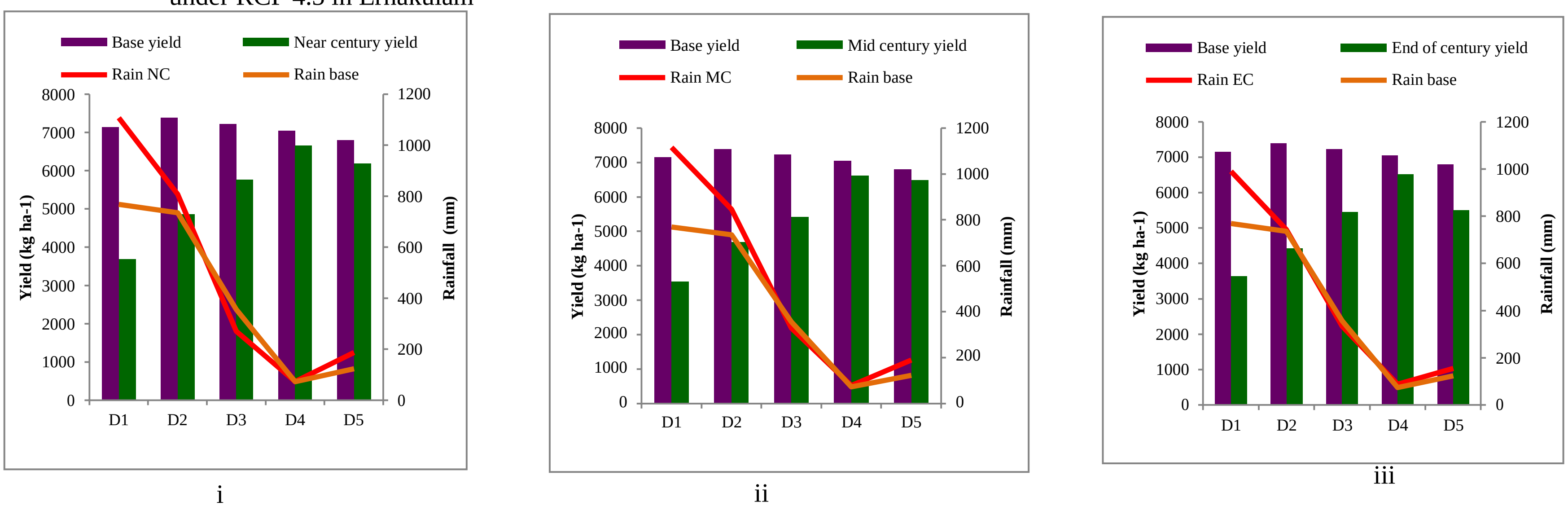
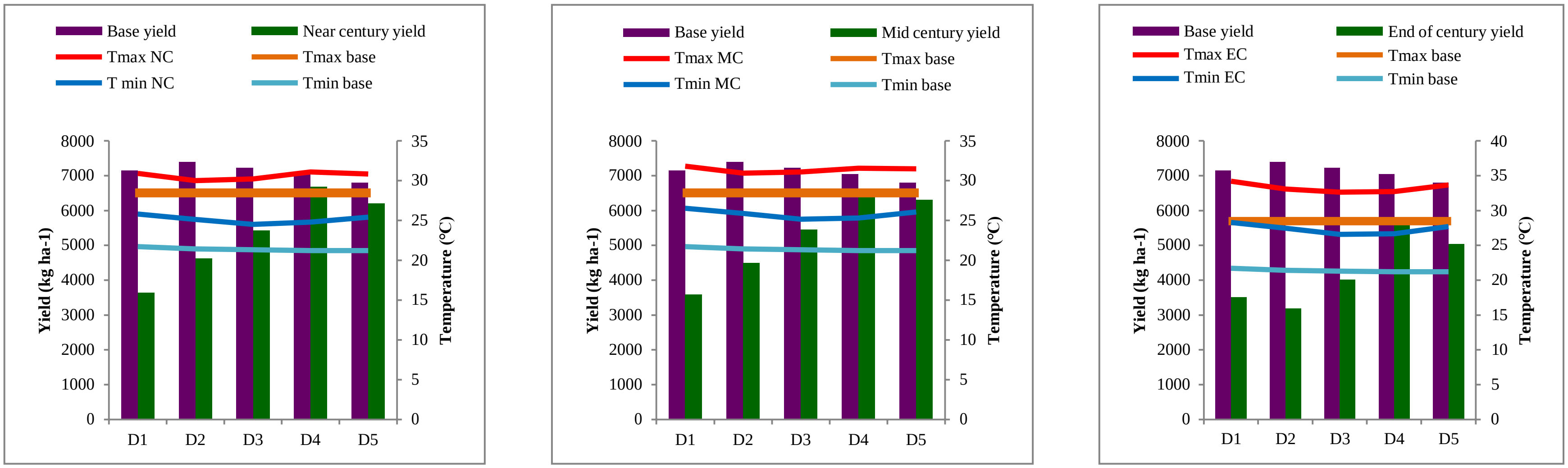
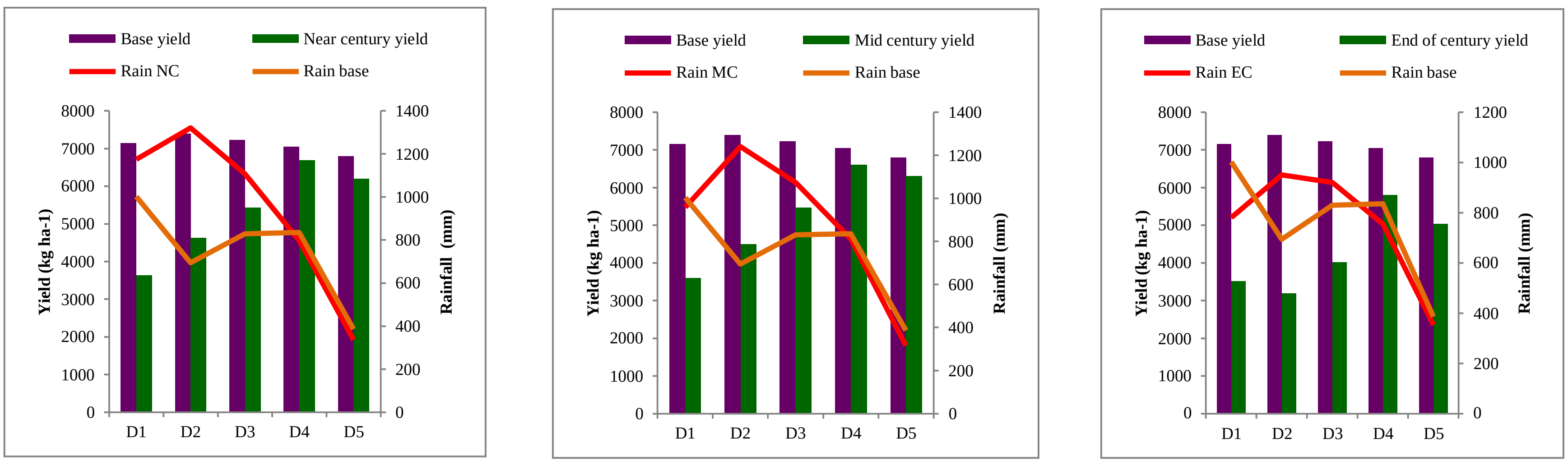


Fig. 5.110. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Ernakulam



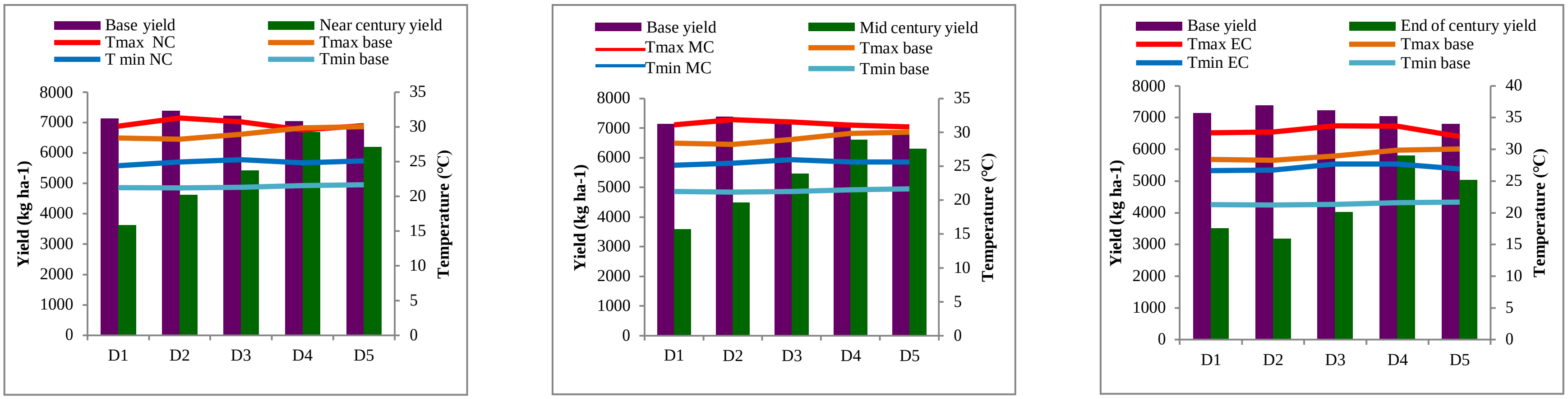
i ii iii

Fig. 5.111 (a). Effect of temperature on yieldof Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Ernakulam



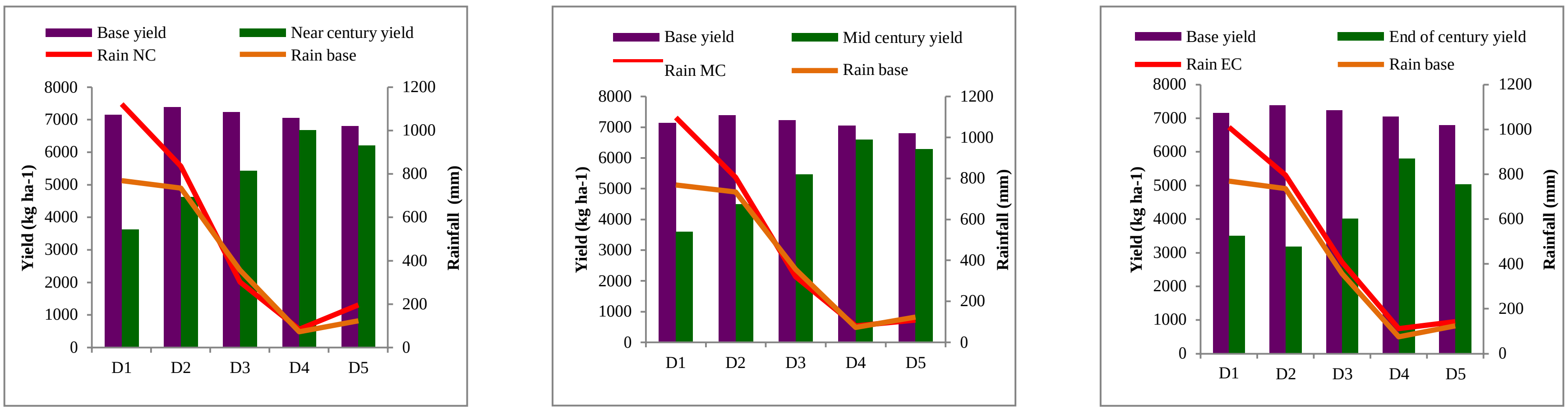
i ii iii

Fig. 5.111. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Ernakulam



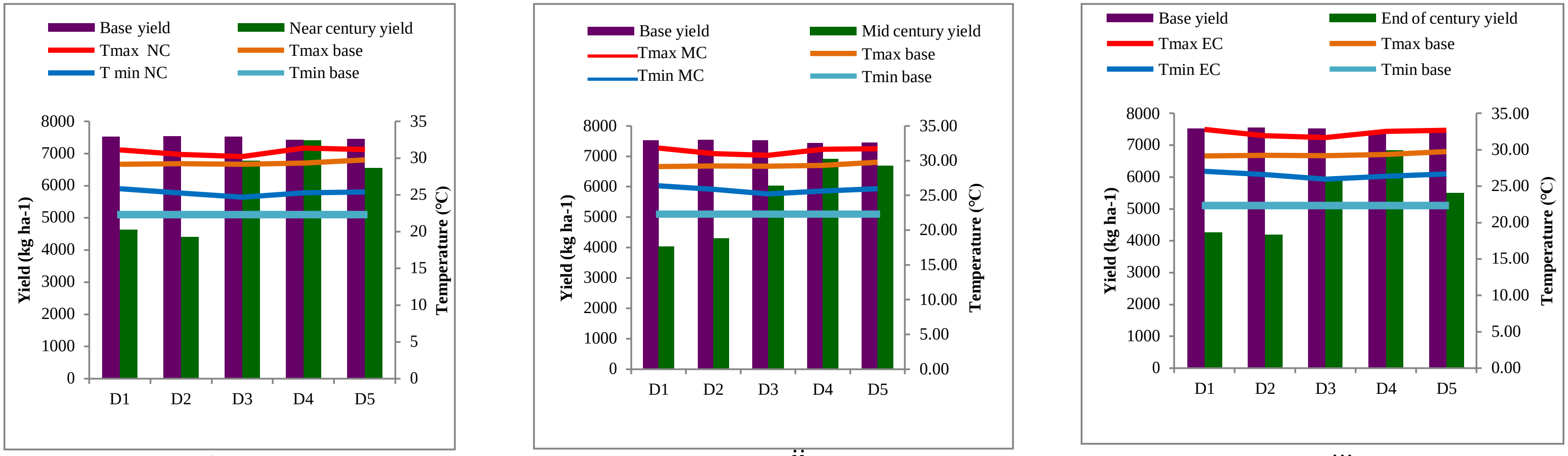
i ii iii

Fig. 5.112. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Ernakulam



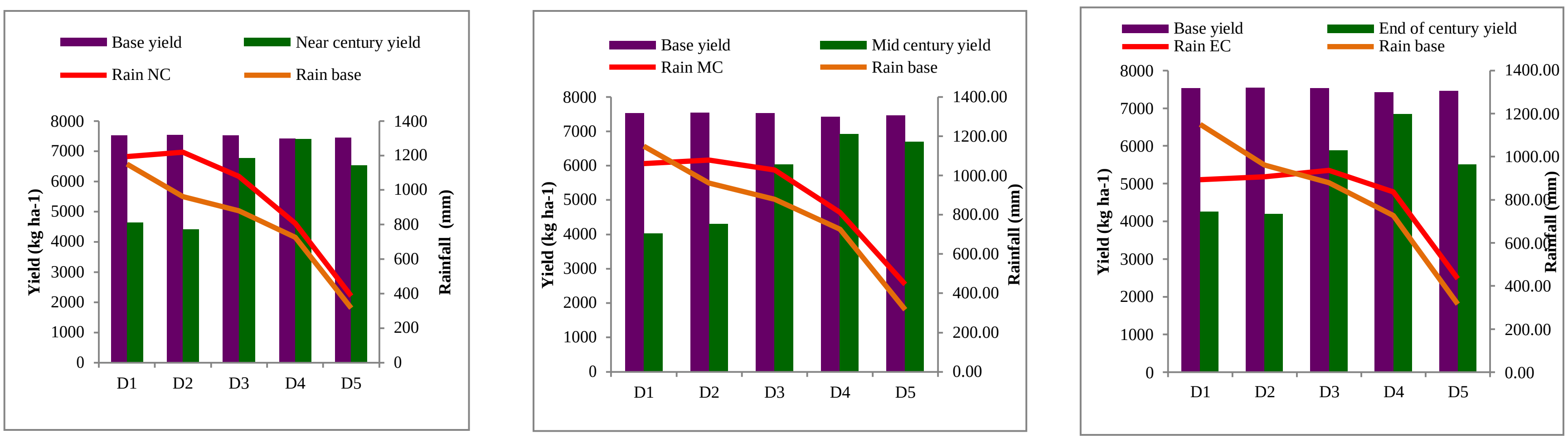
i ii iii

Fig. 5.112. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5in Ernakulam



i ii iii

Fig. 5.113. (a). Effect of temperature on yieldof Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Kottayam



i ii iii

Fig. 5.113. (b). Effect of rainfall on yieldof Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5in Kottayam

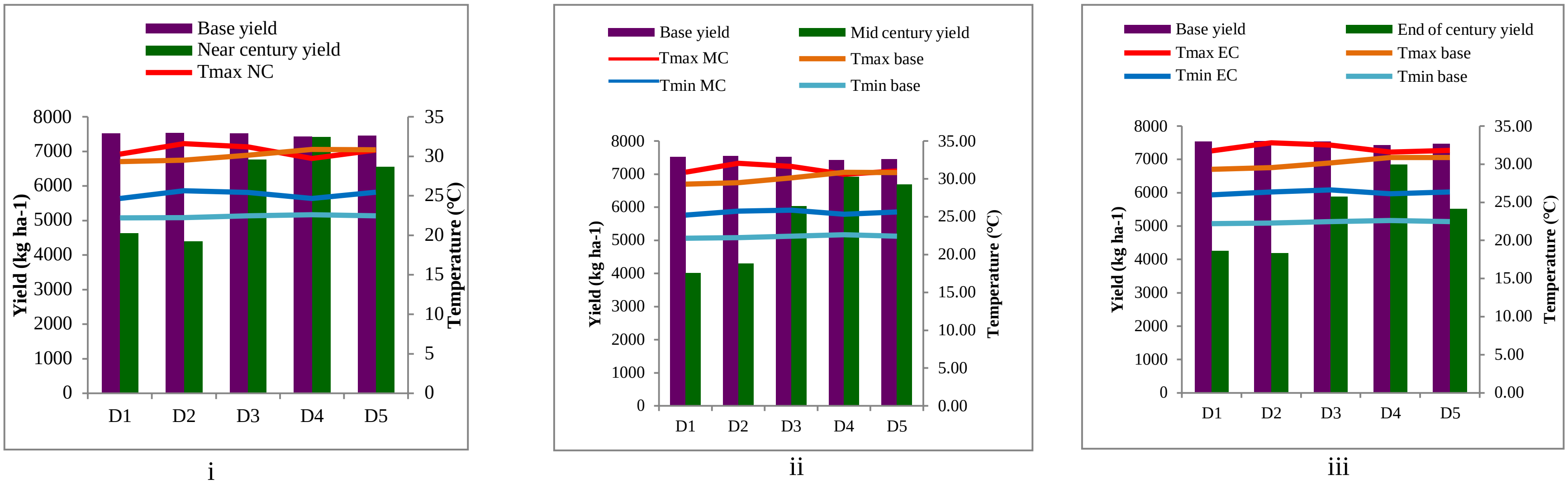


Fig. 5.114. (a). Effect of temperature on yieldof Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5in Kottayam

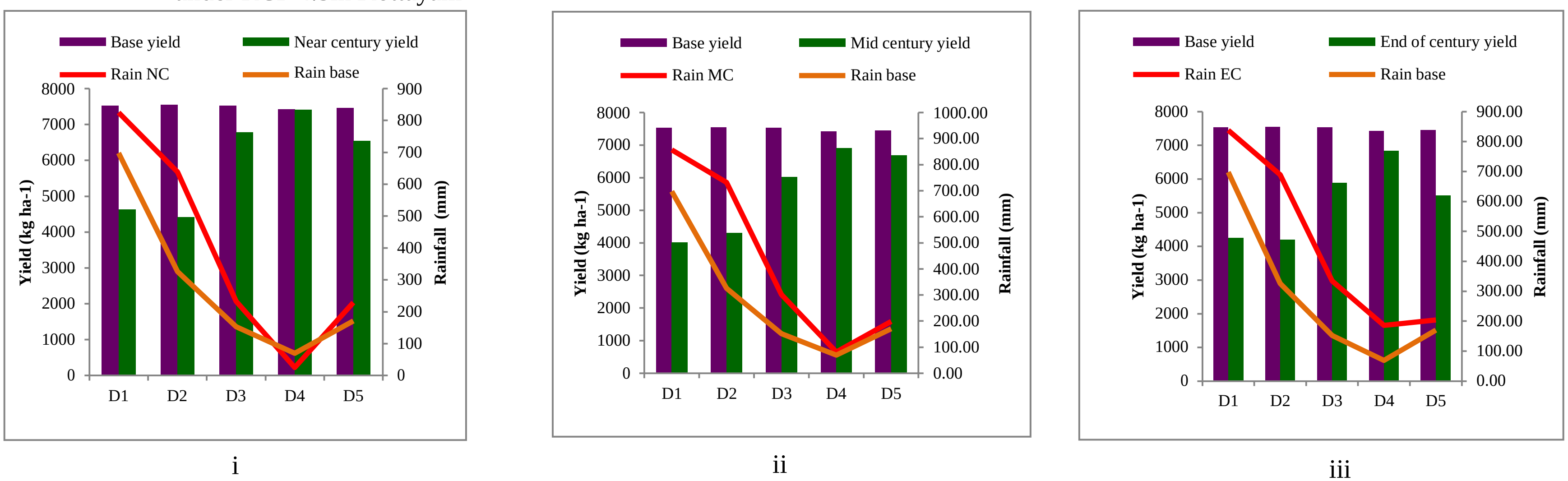
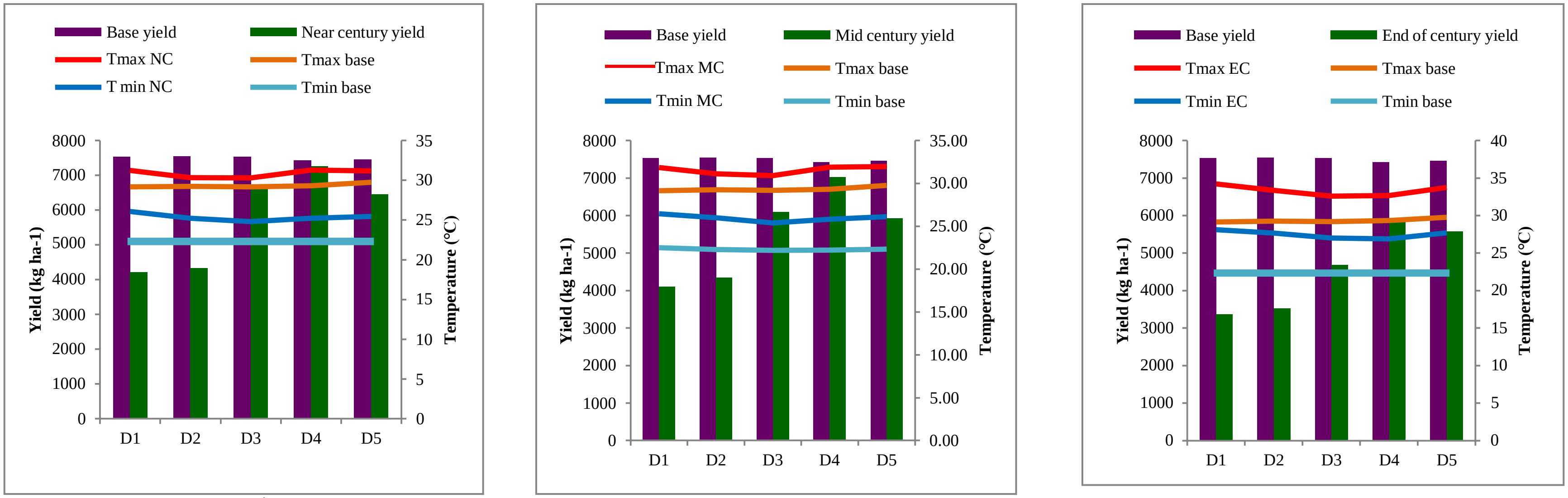
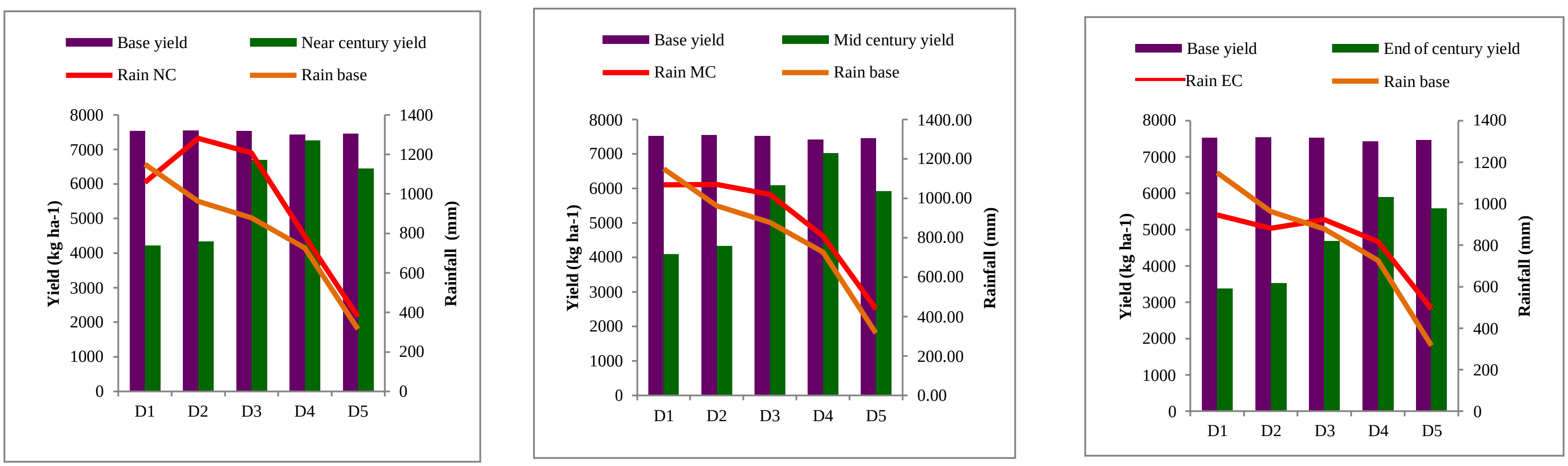


Fig. 5.114. (b). Effect of rainfall on yieldof Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5in Kottayam



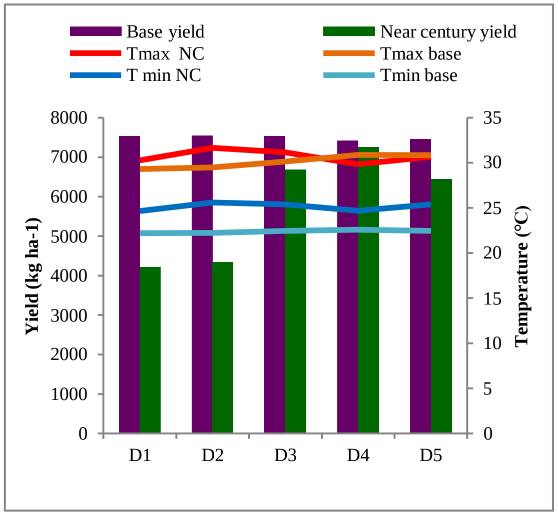
i ii iii

Fig. 5.115 (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Kottayam



i ii iii

Fig. 5.115. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5in Kottayam



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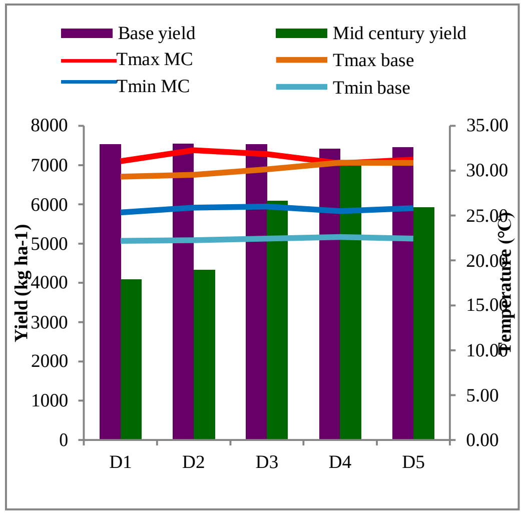

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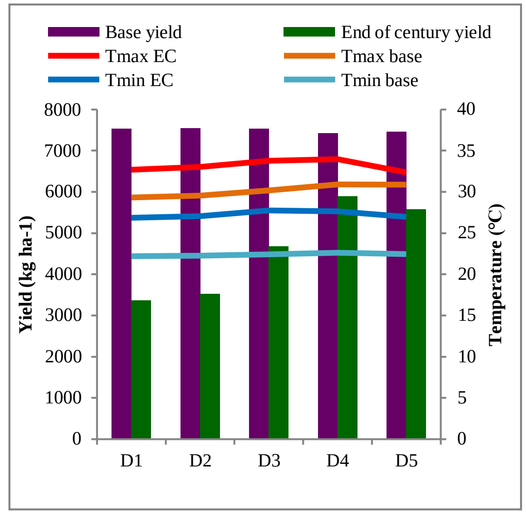
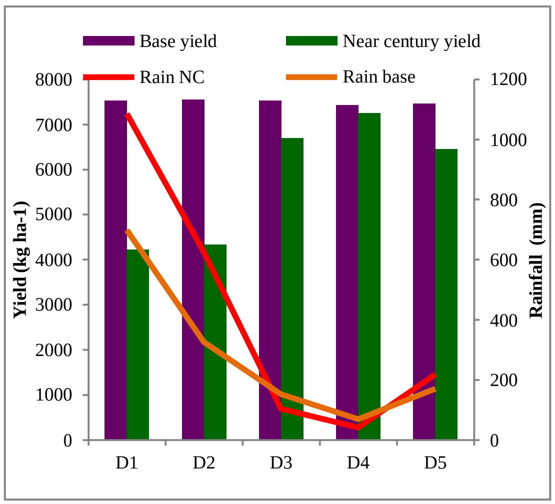


iii

Fig. 5.116 (a). Effect of temperature on yieldof Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Kottayam



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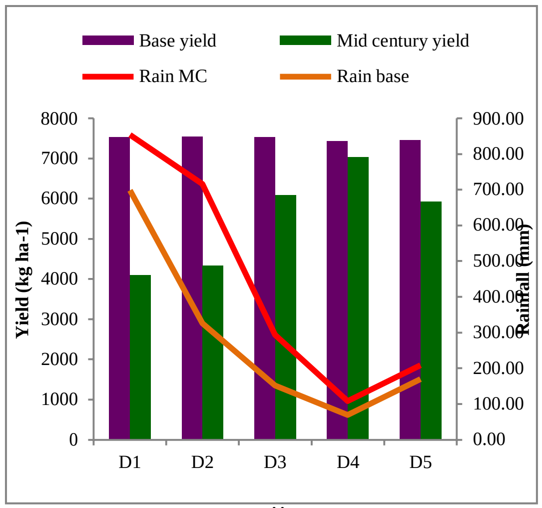

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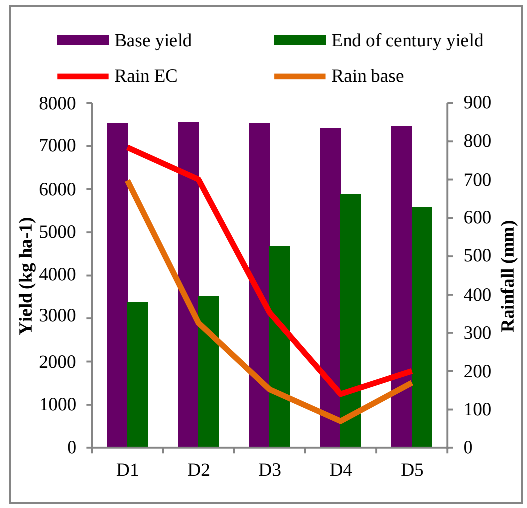
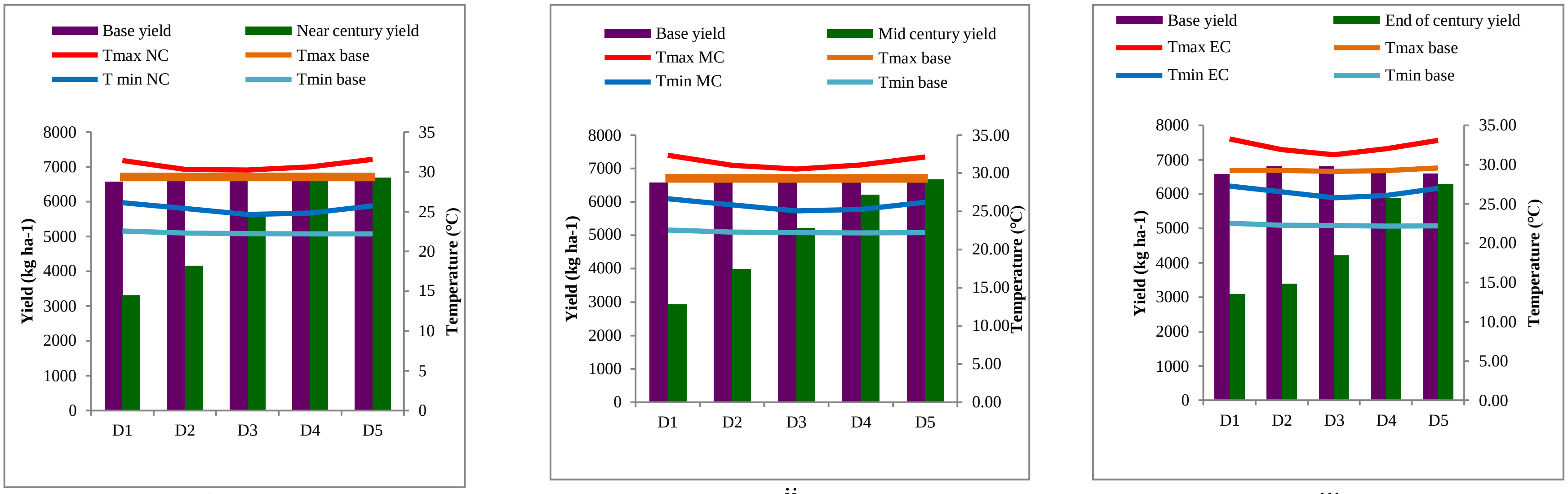


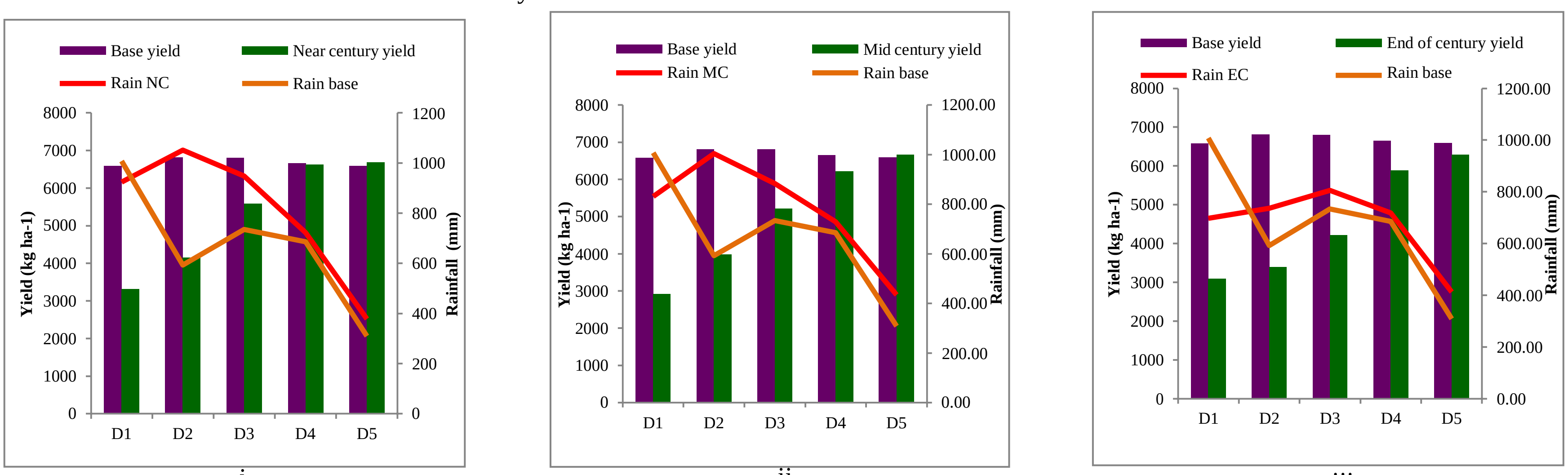
iii

Fig. 5.116. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Kottayam



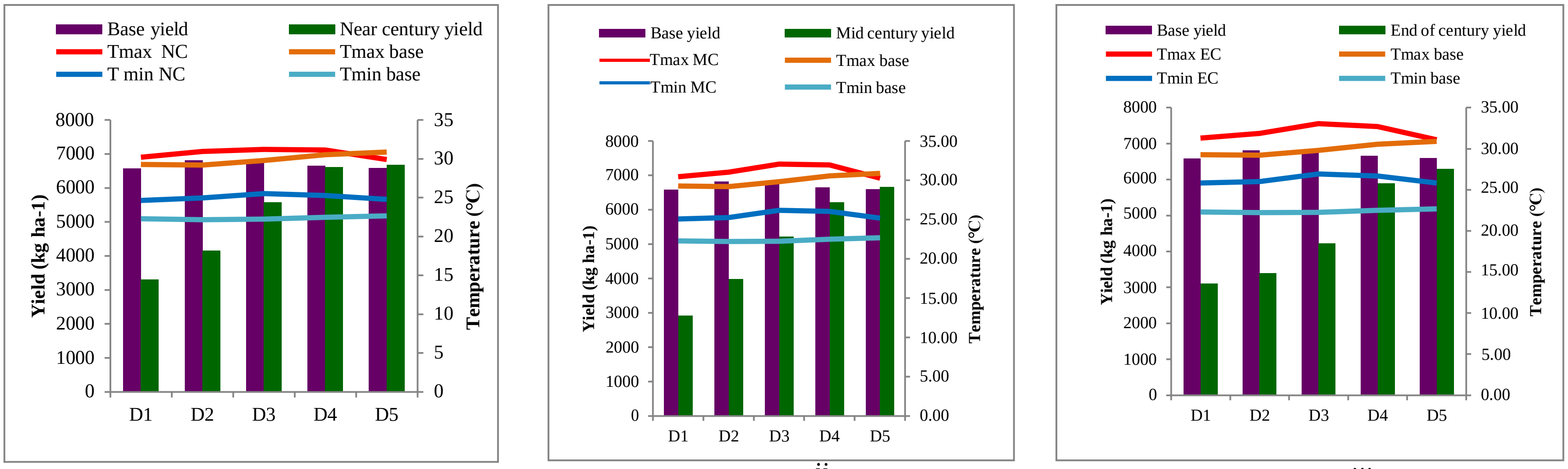
i ii iii

Fig. 5.117 (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Kottayam



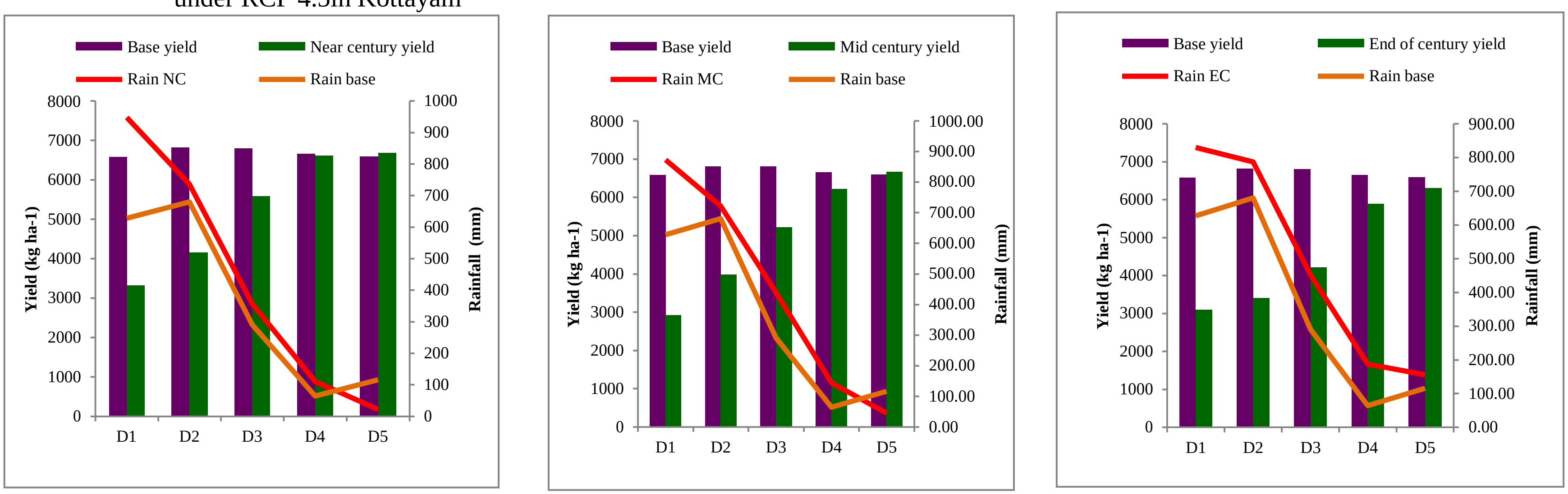
i ii iii

Fig. 5.117. (b). Effect of rainfall on yieldof Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5in Kottayam



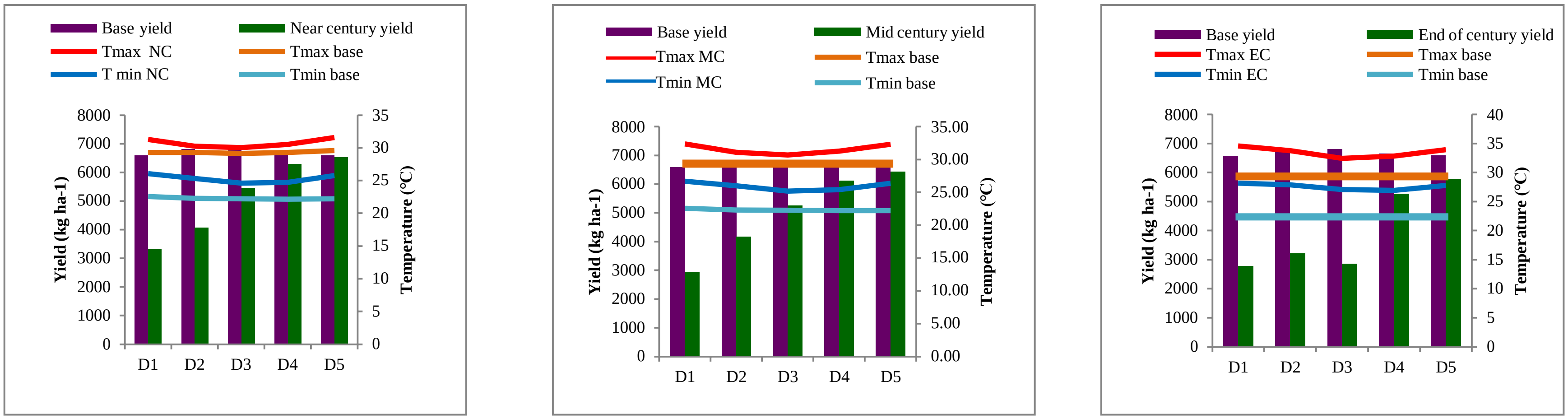
i ii iii

Fig. 5.118. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5in Kottayam



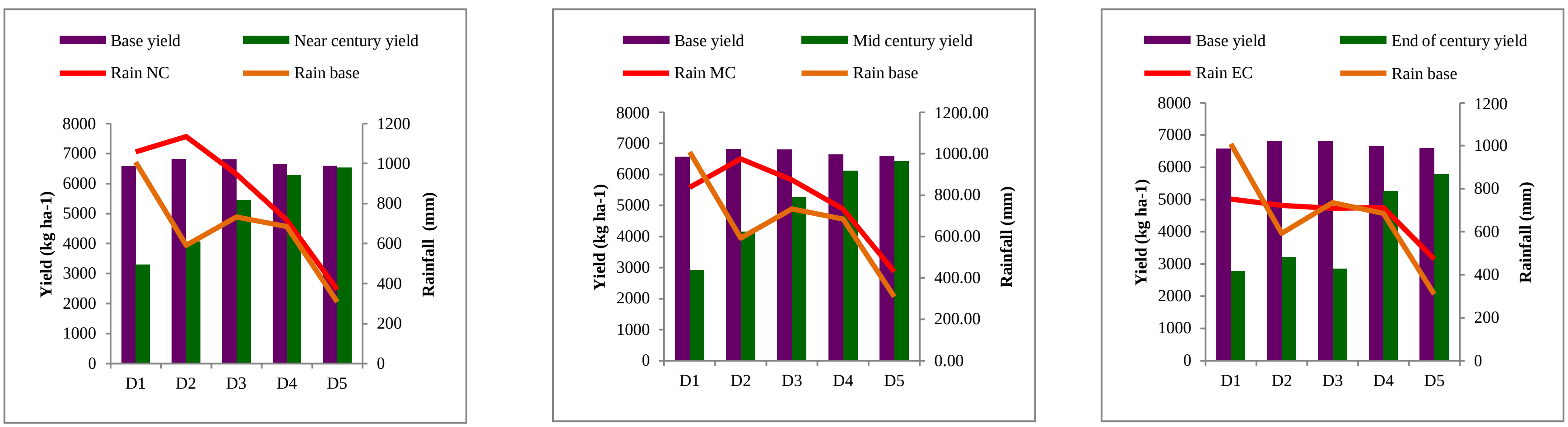
i ii iii

Fig. 5.118. (b). Effect of rainfall on yieldof Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Kottayam



i ii iii

Fig. 5.119 (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end o.f century during transplanting to panicle initiation under RCP 8.5 Kottayam



i ii iii

Fig. 5.119. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Kottayam

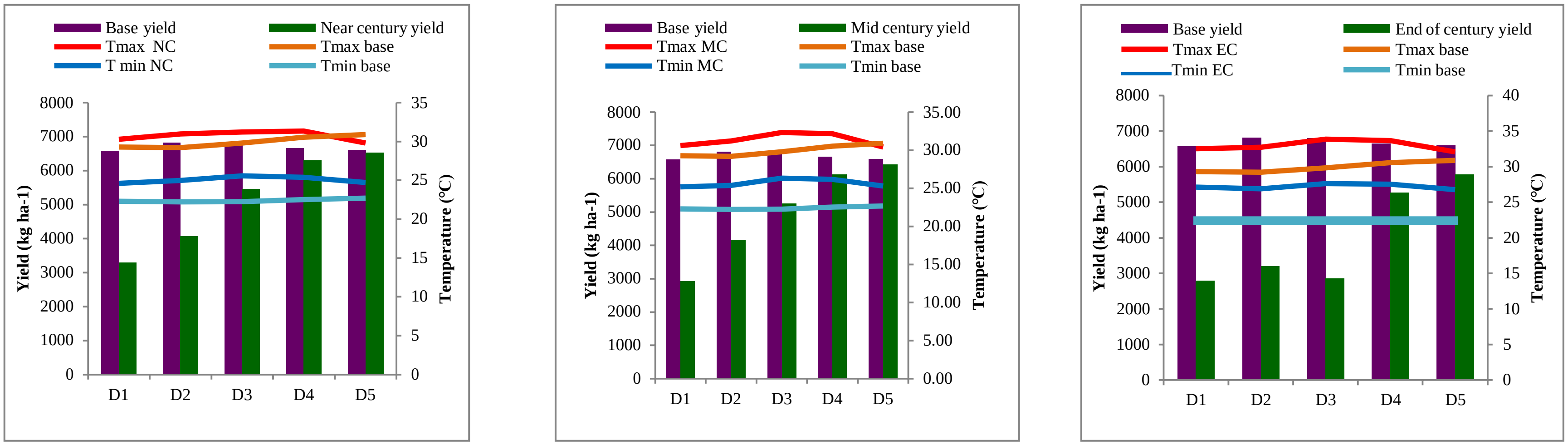


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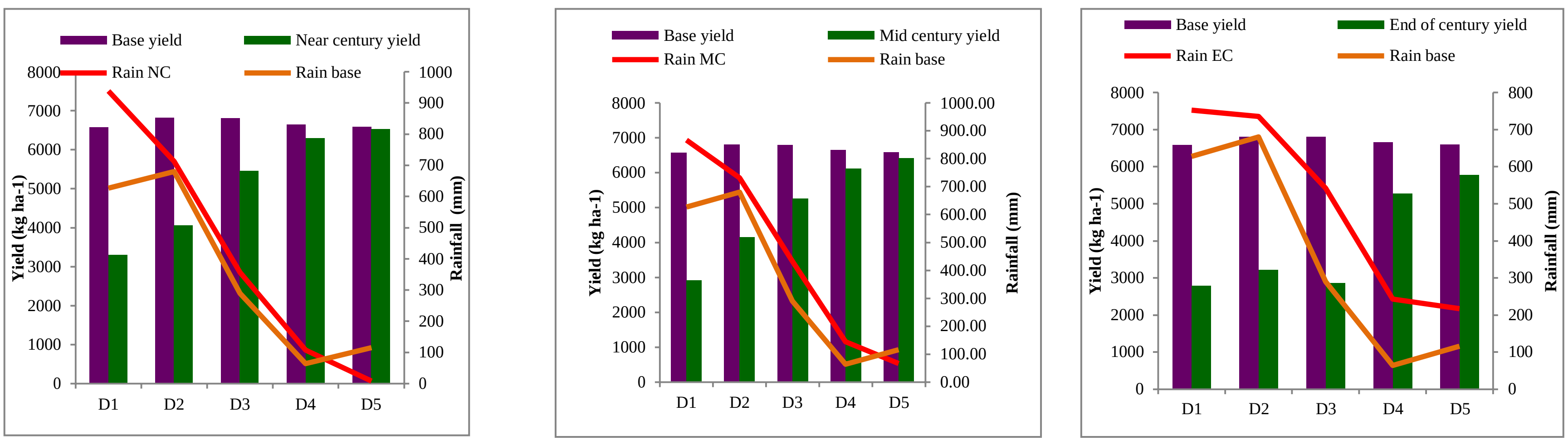
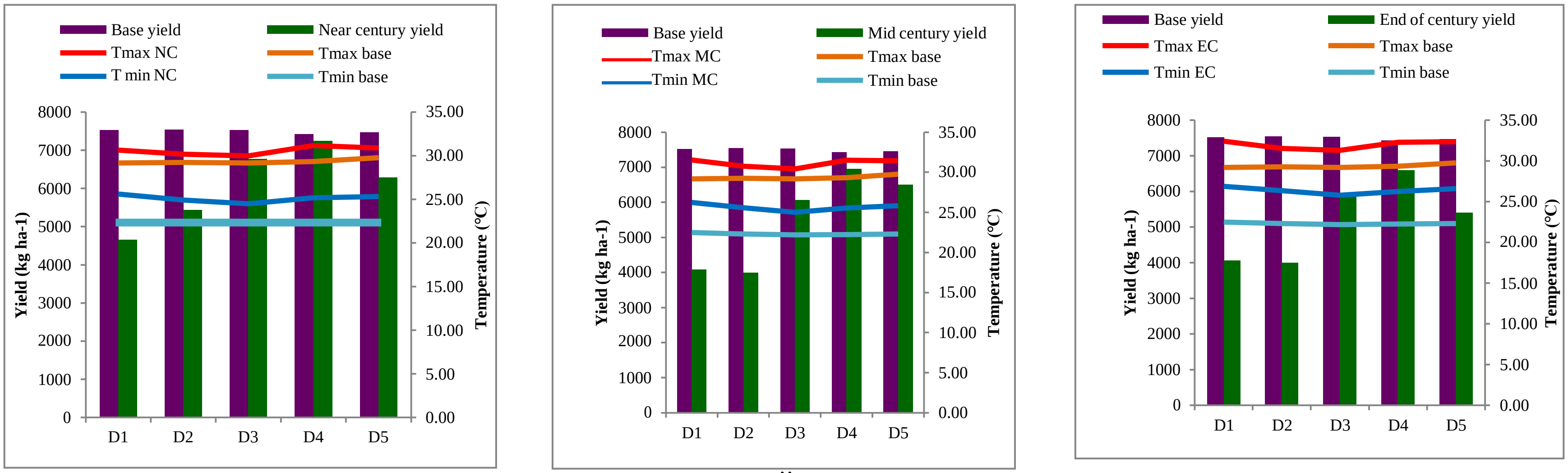
Fig. 5.120. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Kottayam



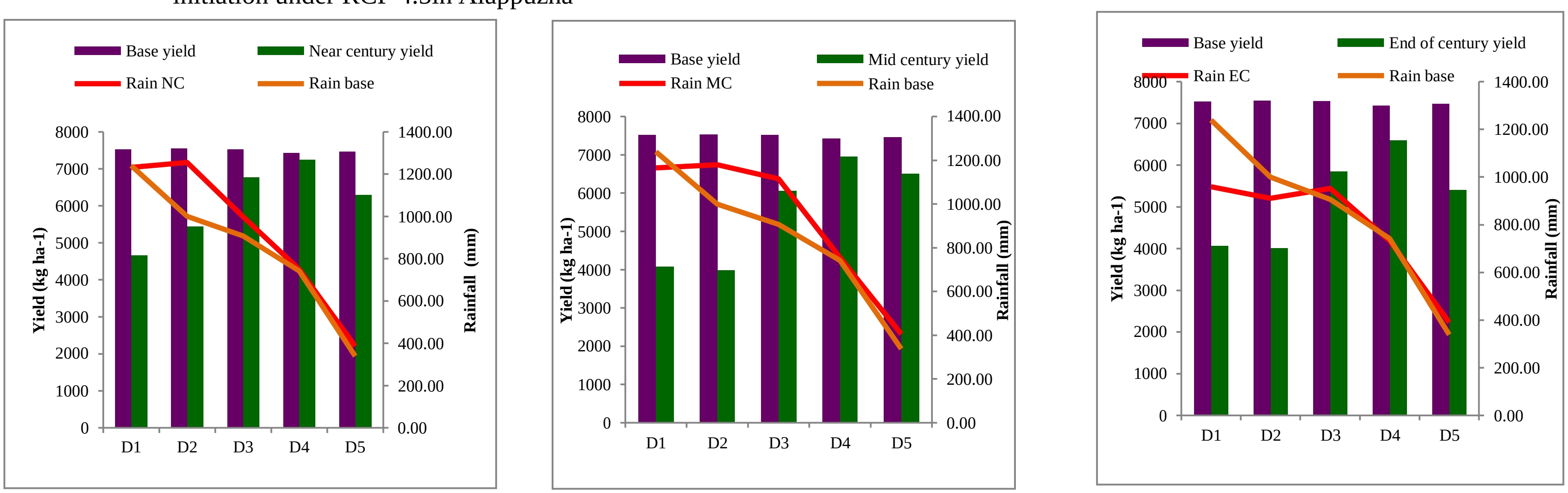
i ii iii

Fig. 5.120..(b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Kottayam



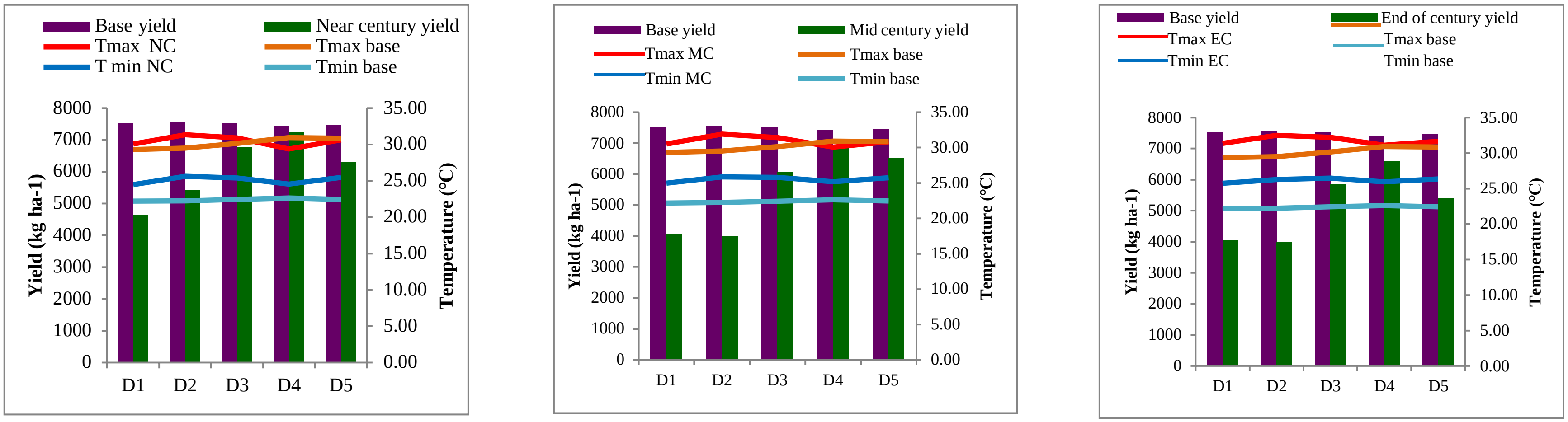
i ii iii

Fig. 5.121. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5in Alappuzha



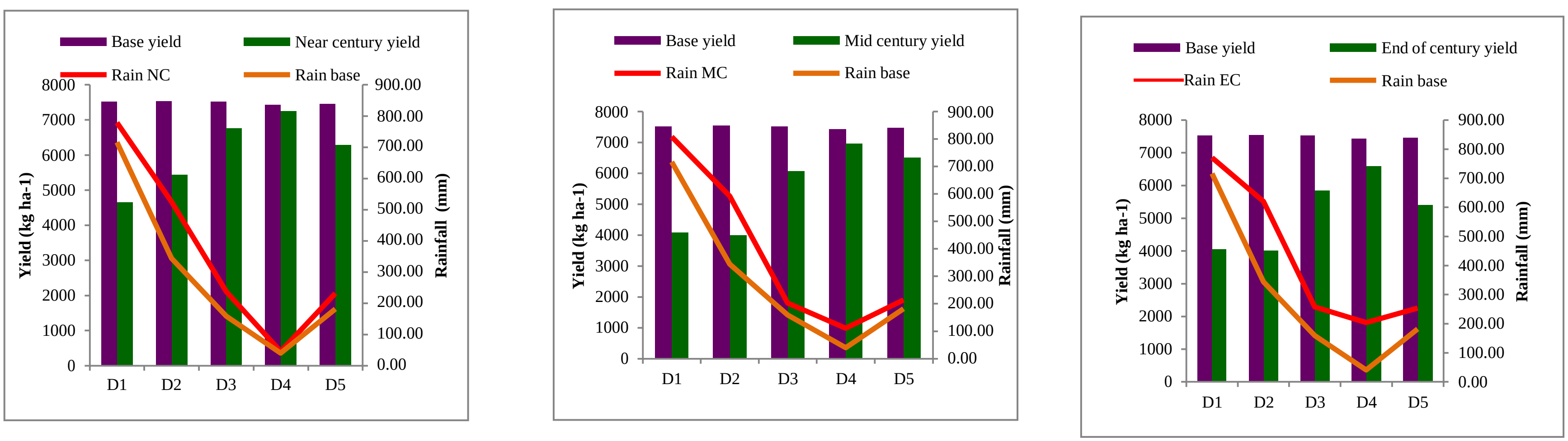
i ii iii

Fig. 5.121. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Alappuzha



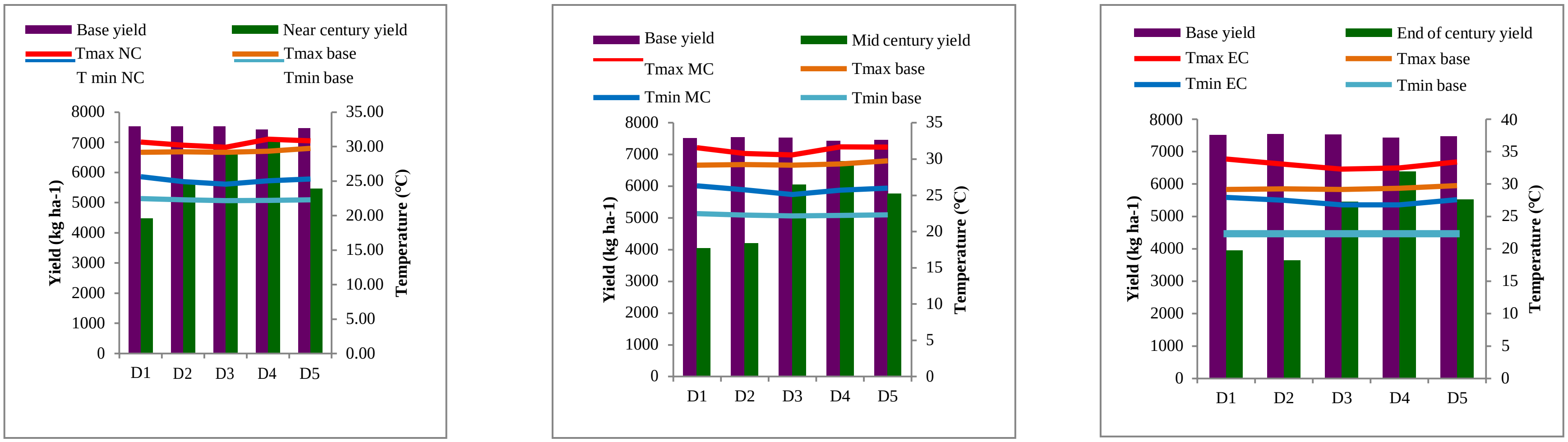
i ii iii

Fig. 5.122. (b). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Alappuzha



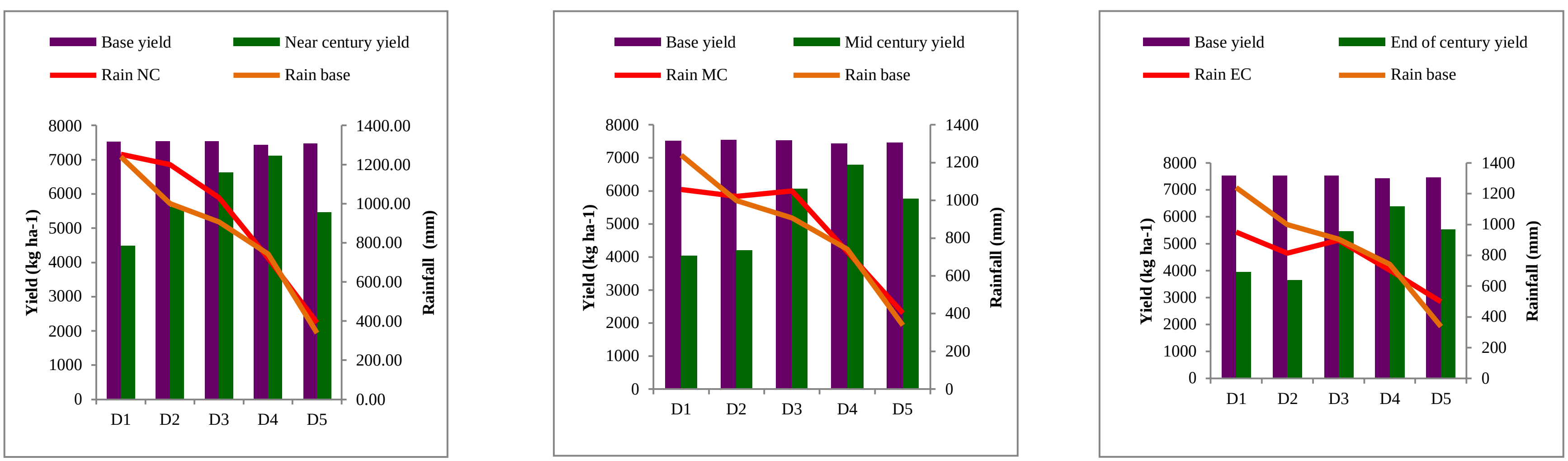
i ii iii

Fig. 5.122. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Alappuzha



i ii iii

Fig. 5.123. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Alappuzha



i ii iii

Fig. 5.123. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Alappuzha

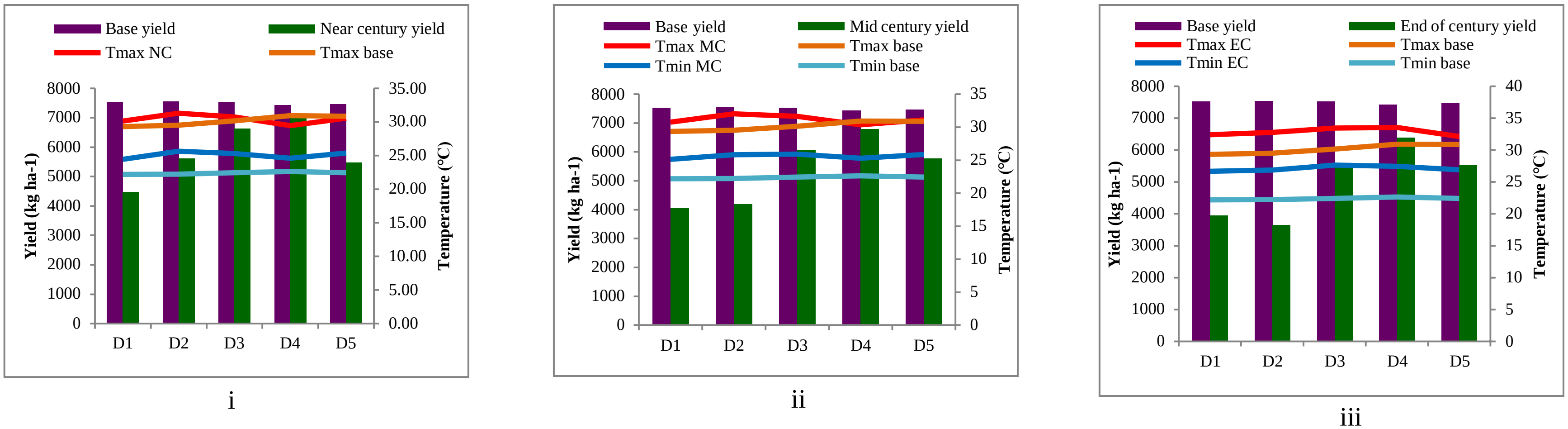


Fig. 5.124. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Alappuzha

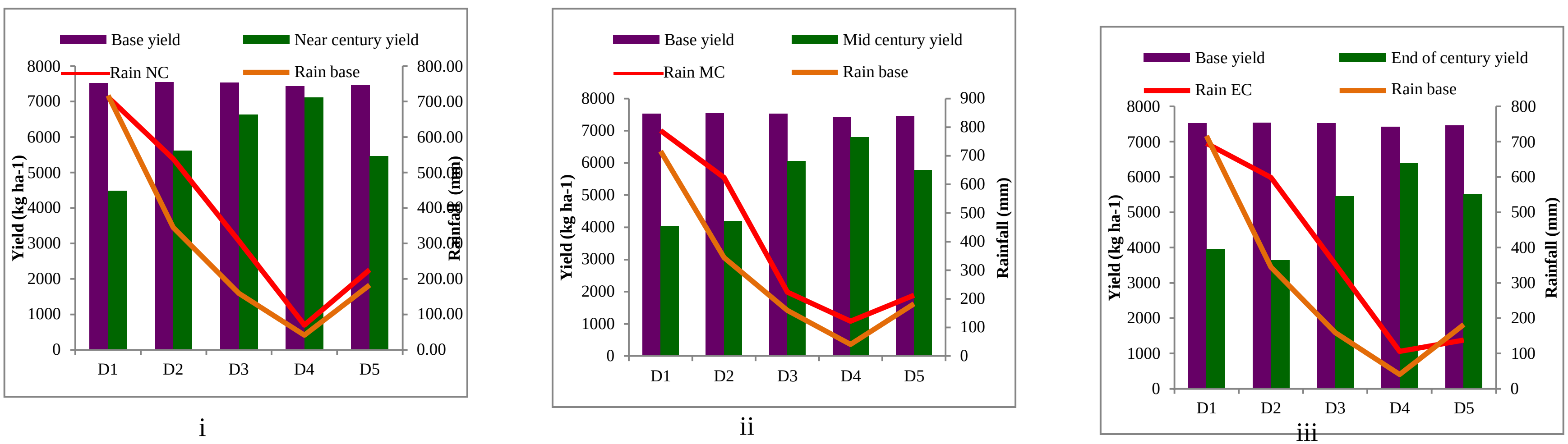


Fig. 5.124. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Alappuzha

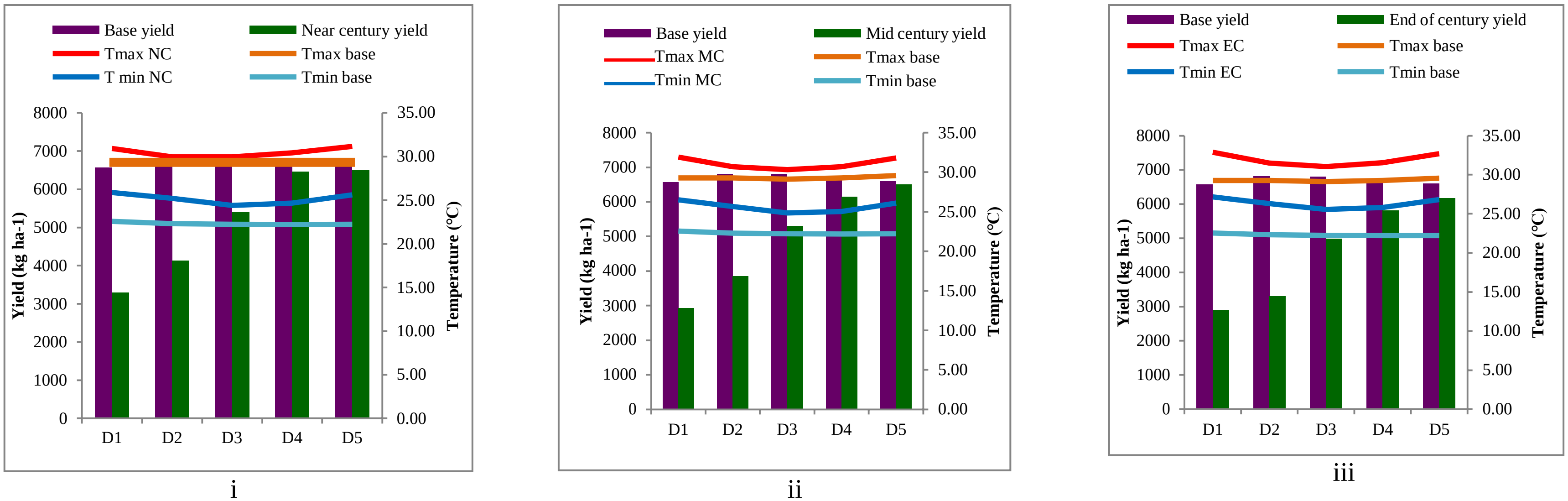


Fig. 5.125. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Alappuzha

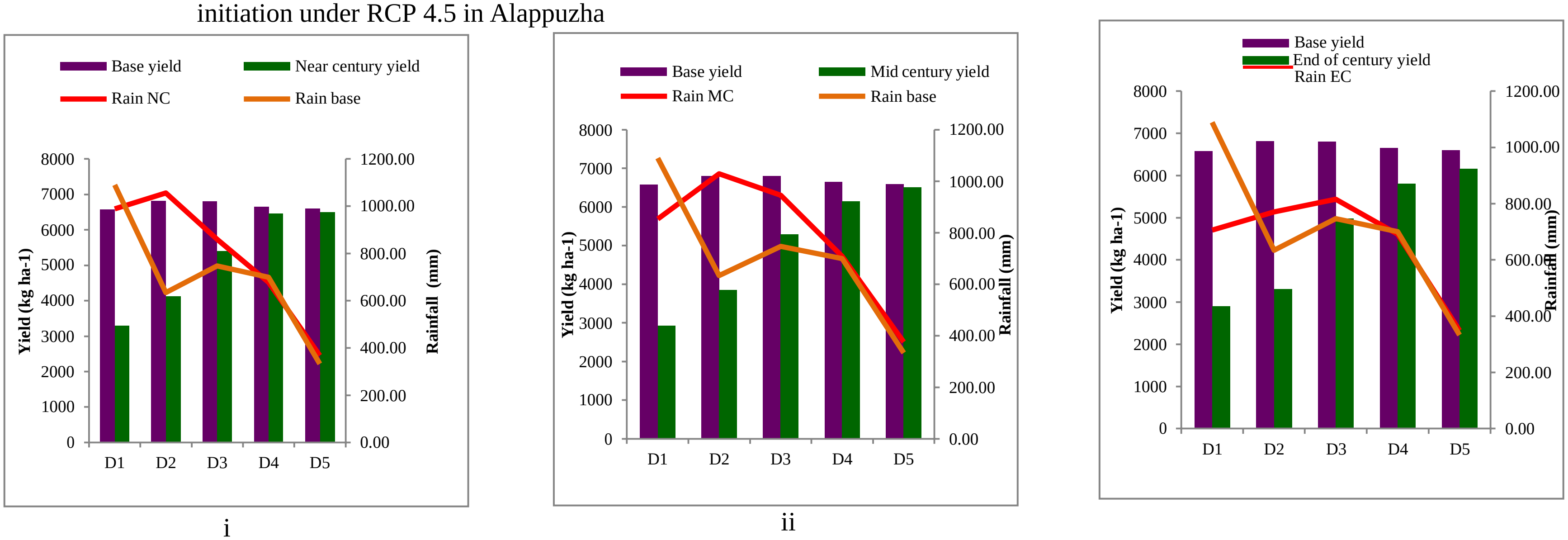
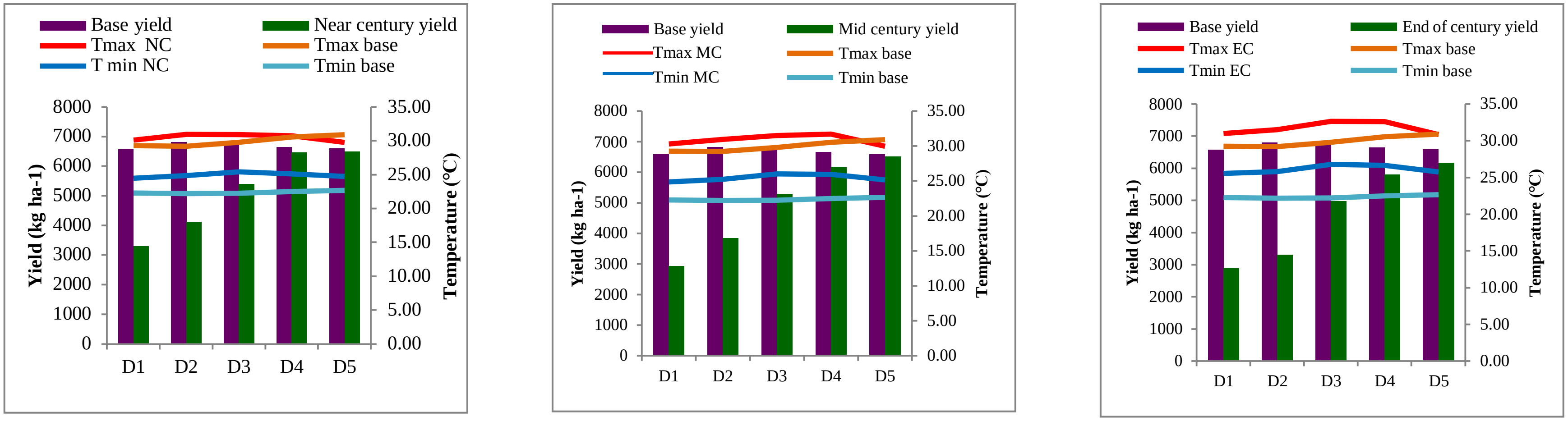


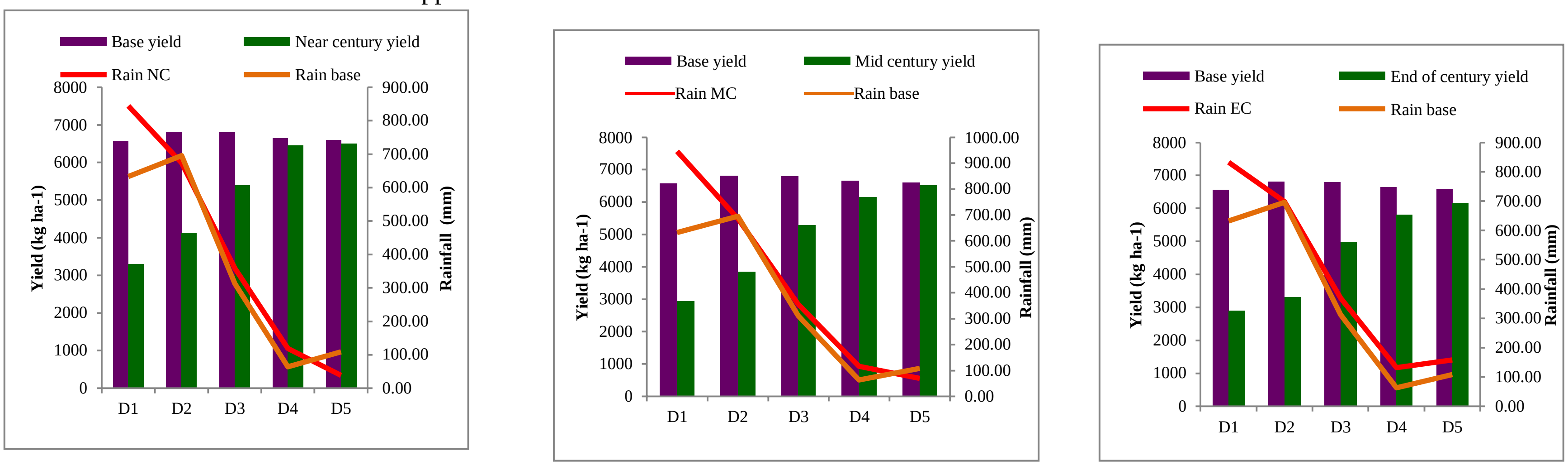
Fig. 5.125. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Alappuzha

iii



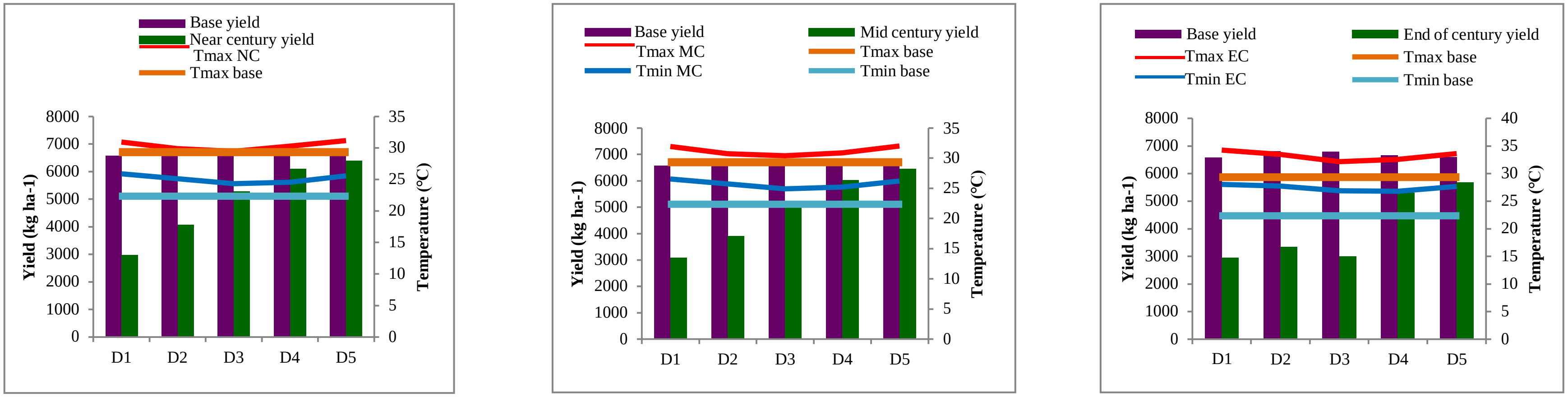
i ii iii

Fig. 5.126 (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Alappuzha



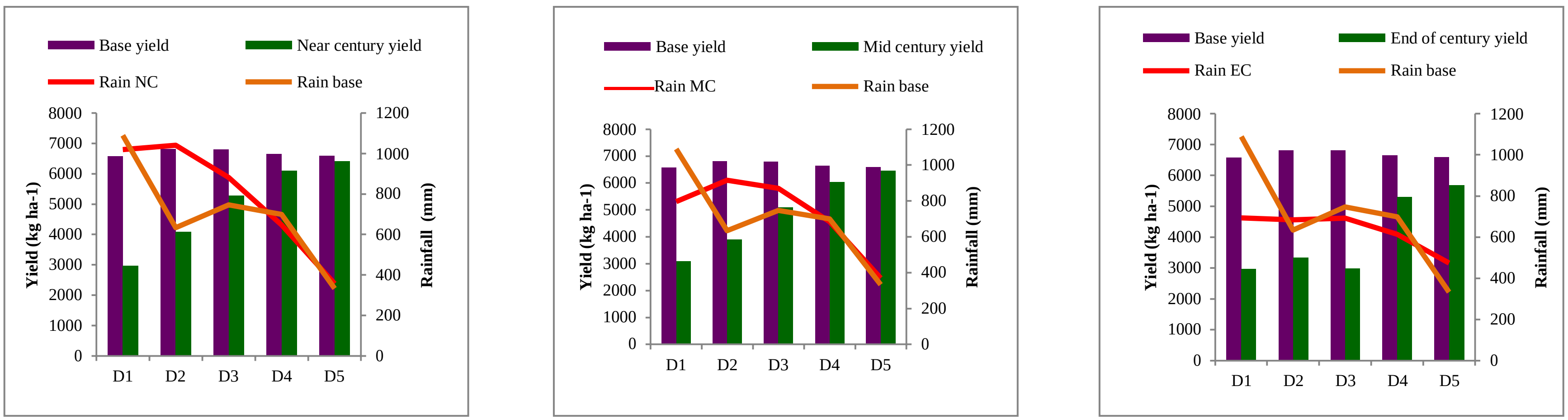
i ii iii

Fig. 5.126. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Alappuzha



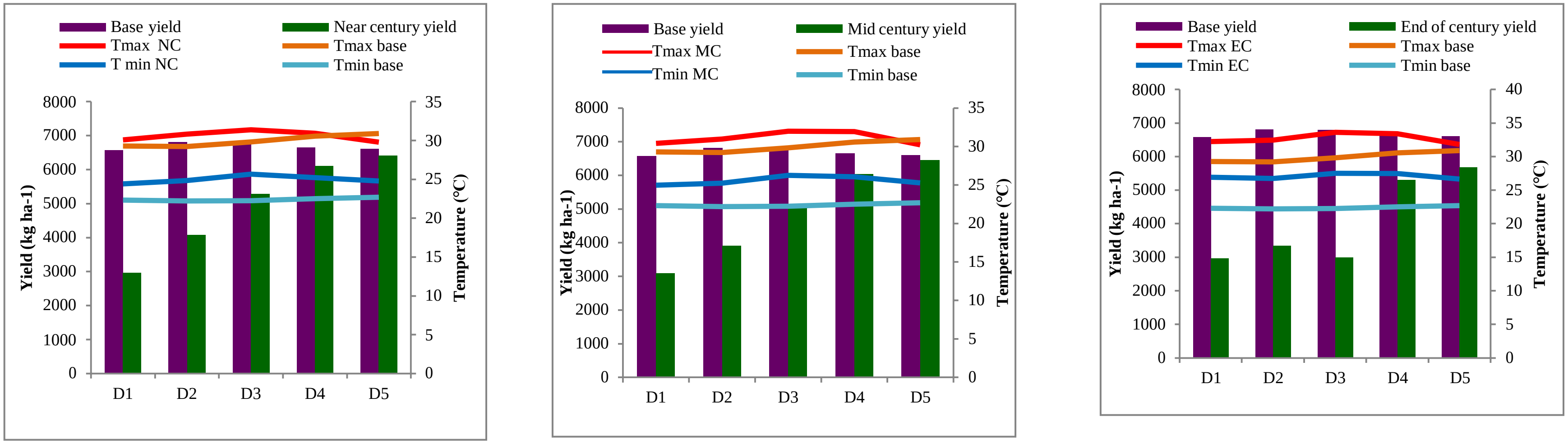
i ii iii

Fig. 5.127 (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5in Alappuzha



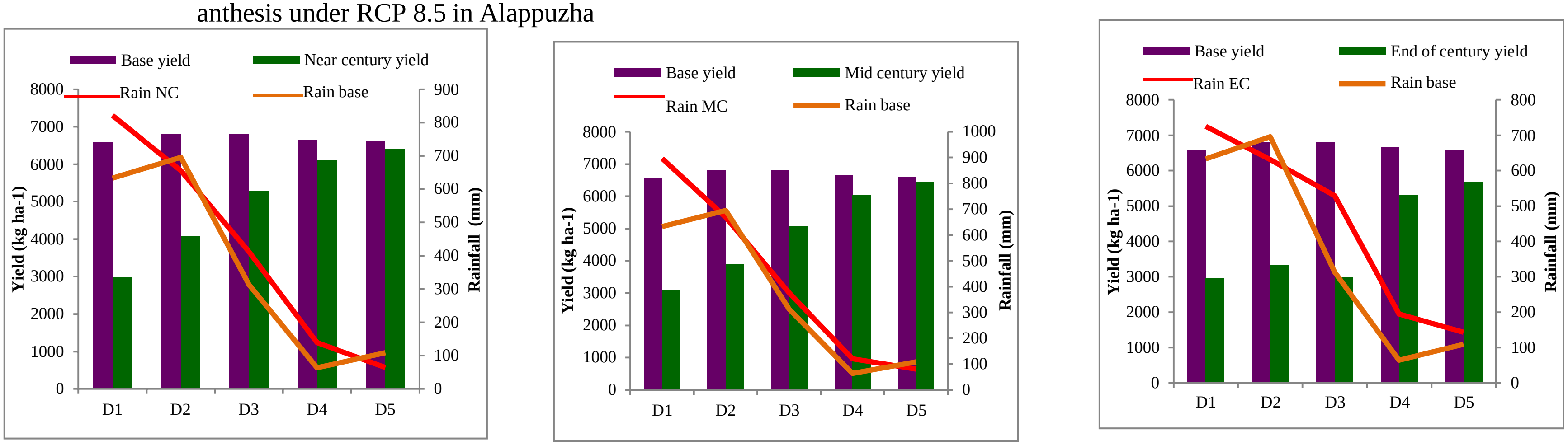
i ii iii

Fig. 5.127. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Alappuzha



i ii iii

Fig. 5.128. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Alappuzha



i ii iii

Fig. 5.128. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Alappuzha

5.7.4. Rice production in high range zone of Kerala

In high range zone *Kharif* cultivation is practiced only in Idukki. In Wayanad instead of conventional cropping seasons like *Kharif* and *Rabi*, *Nanja and Punja* has been practiced. In Idukki an increase in yield from base period has been expected in last three dates of planting and also when compares with other districts the least deviation is shown in Idukki.

Under RCP 4.5 maximum positive deviation was observed during July 20th planting (27%) in near and mid century and by the end of century a deviation of 20% was observed. June 5th and 20th planting showed a negative deviation under both RCPs. Under RCP 8.5 maximum deviation is observed during the end of century where June 5th planting showed a negative deviation of -31%. In July 20th planting higher yield has been observed and shows a positive deviation of 27%, 24% and 10% in near, mid and end of century. In Jyothi under RCP 4.5 maximum positive deviation was observed during July 20th planting *i.e.* 34% in near, 28% in mid century and by the end of century a deviation of 23% was observed. June 5th and 20th planting showed a negative deviation under both RCPs.

Under RCP 8.5 maximum deviation is observed during the end of century where June 5th planting showed a negative deviation of -31%. In July 20th planting higher yield has been observed and shows a positive deviation of 38%, 28% in near and mid century respectively. By the end of century yield is expected to decrease except in August 5th planting which showed a positive deviation of 12%.

In Idukki a decrease in temperature is expected during all the phenophase in Jaya and Jyothi in the last three dates of planting. Also the deviation is less in first two dates of plantings. An increase in rainfall is expected during transplanting to panicle initiation period from the base period. Bhattacharya and Panda (2013) reported that rice yield may increase in the conditions of reduced temperature and increased rainfall. Hence this may the reason for an increased yield in rice in high range zone.

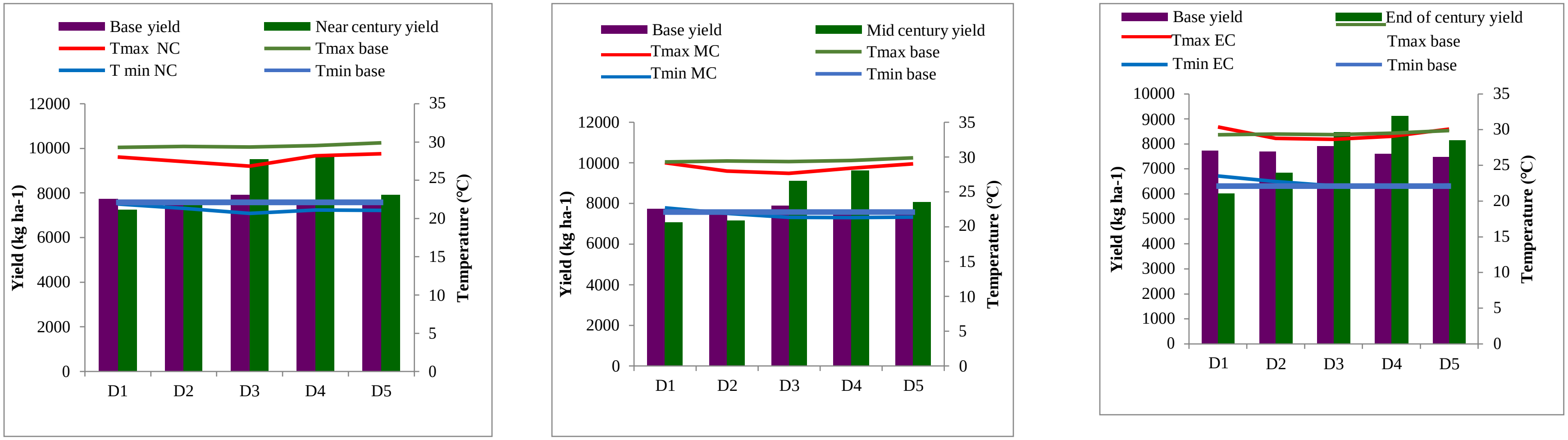
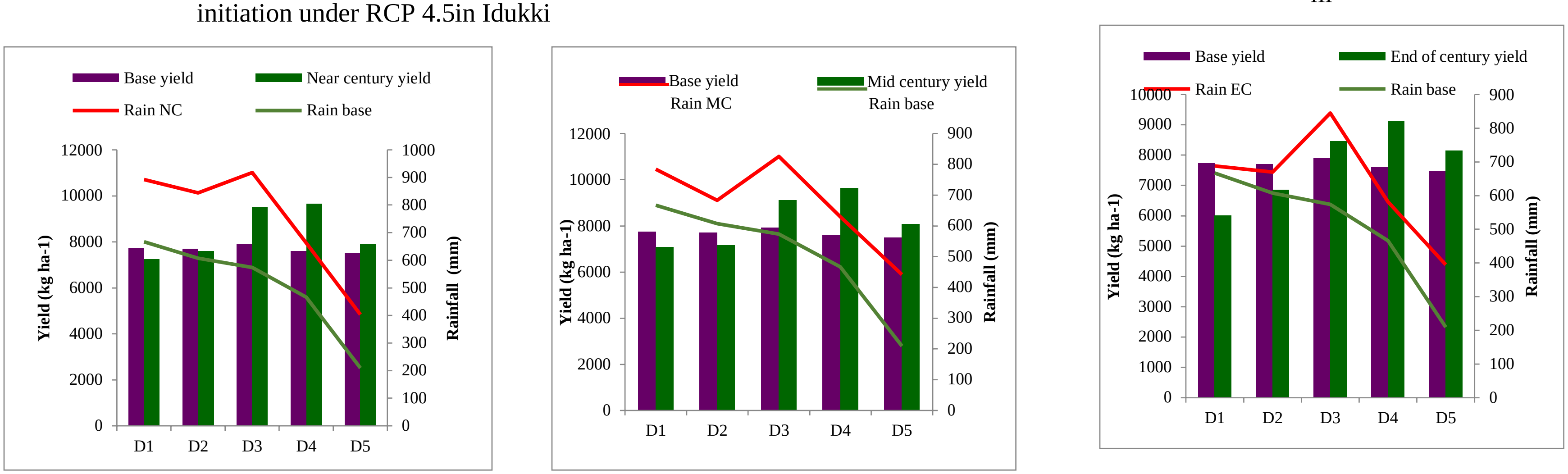


Fig. 5.129 (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5in Idukki

i ii iii



i ii iii

Fig. 5.129. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Idukki

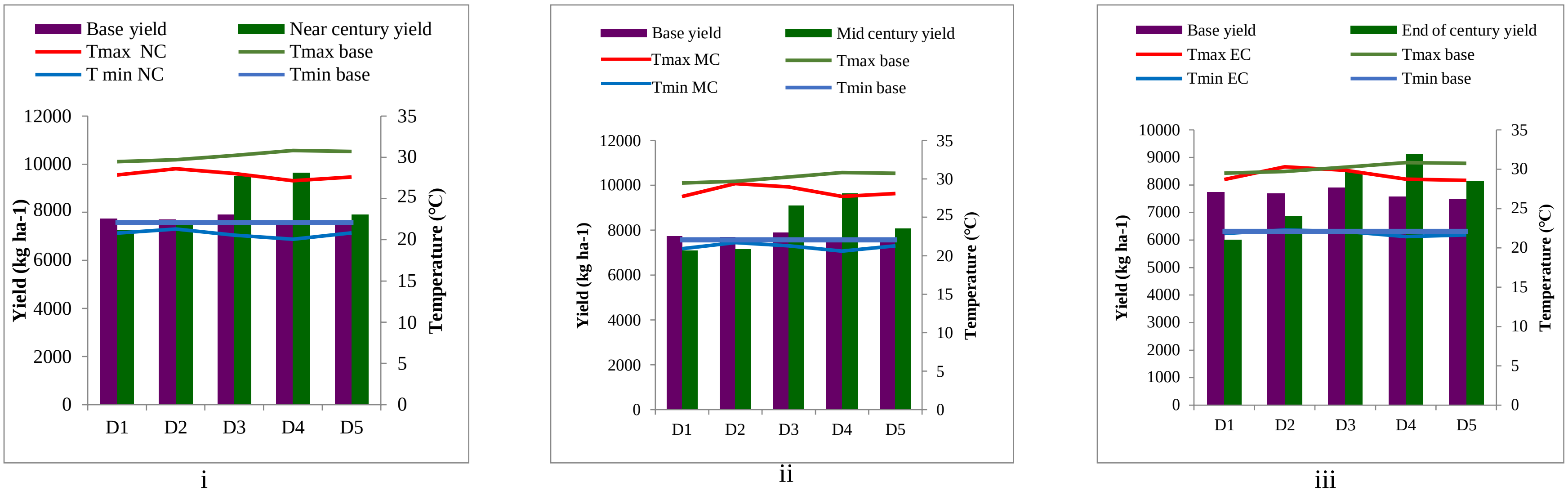


Fig. 5.130 (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Idukki

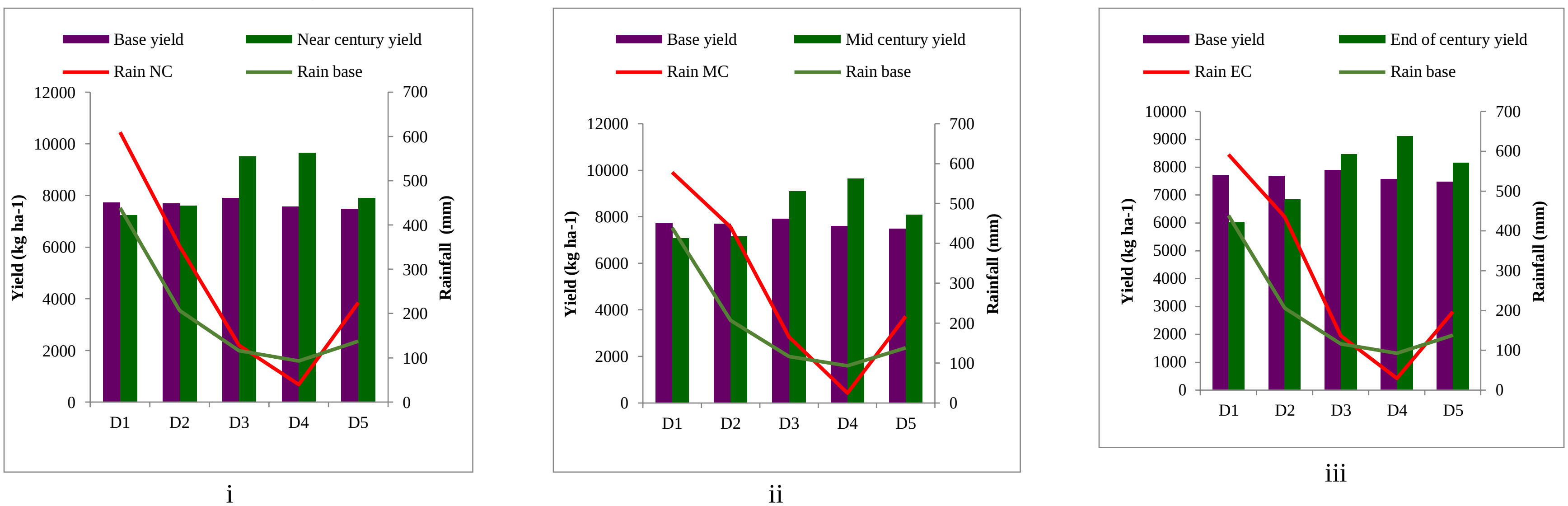
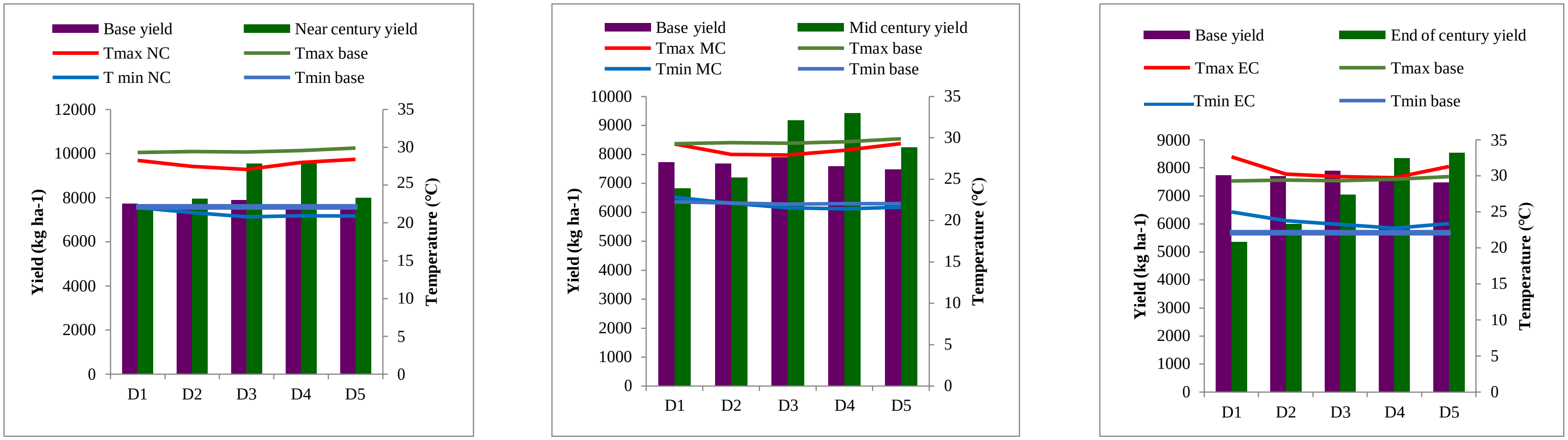
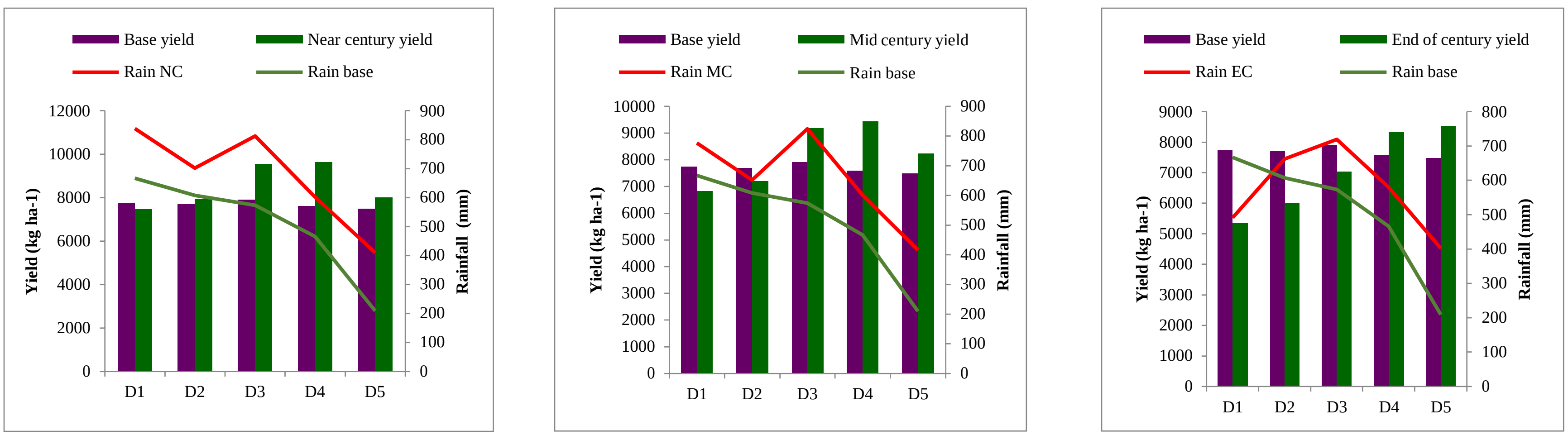


Fig. 5.130 . (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Idukki



i ii iii

Fig. 5.131 (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5in Idukki



i ii iii

Fig. 5.131. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Idukki

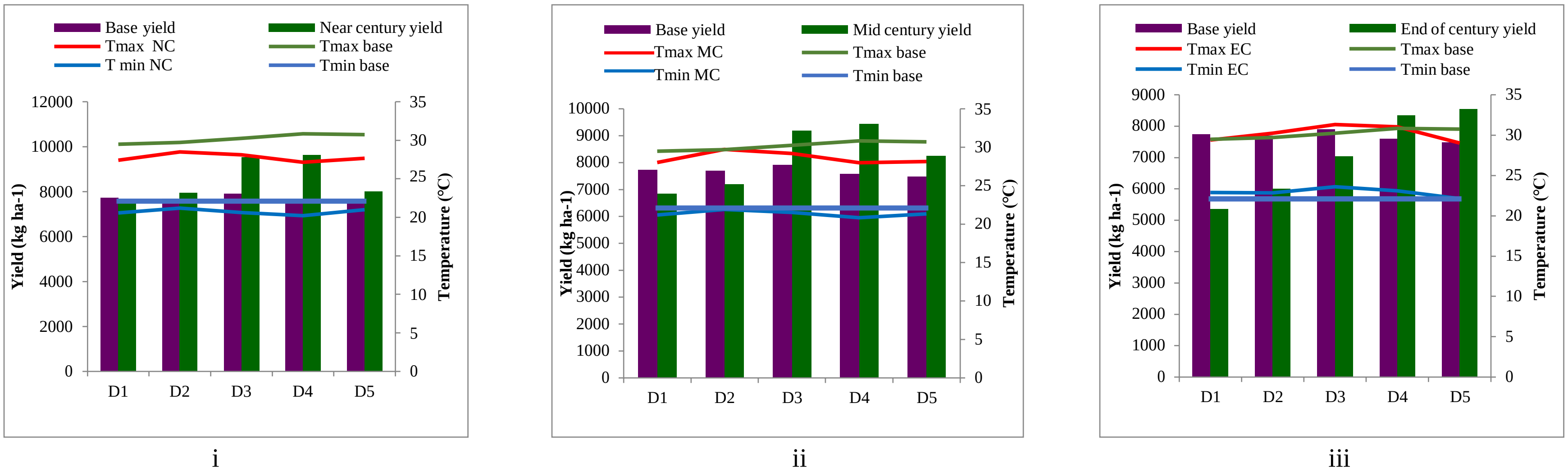


Fig. 5.132 (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Idukki

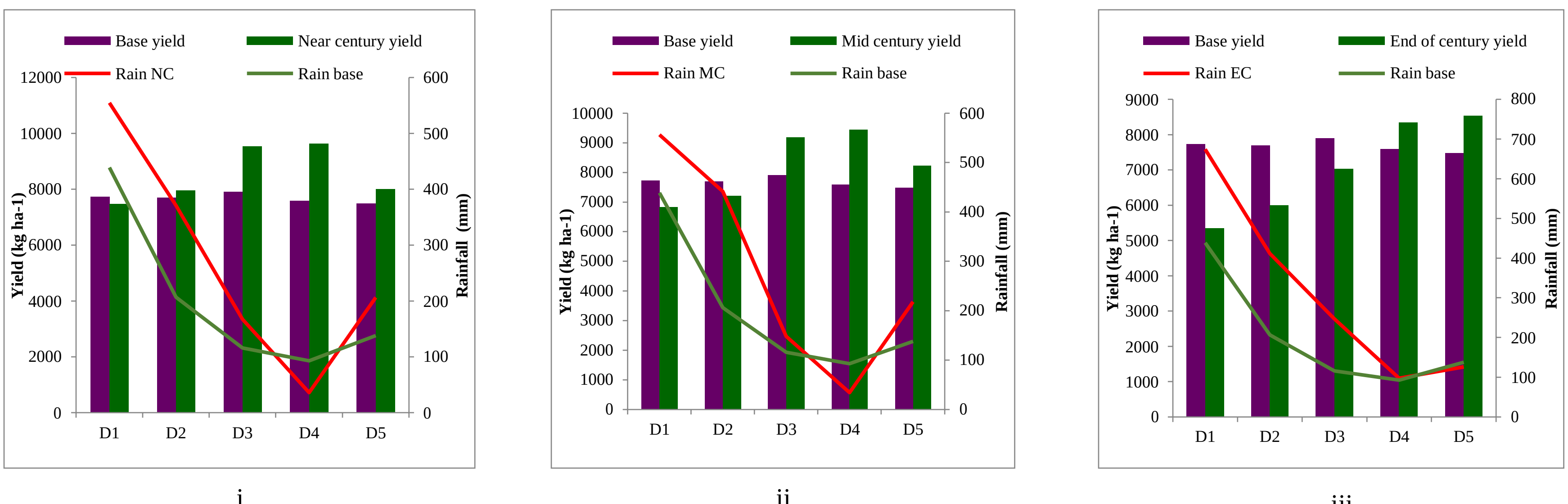
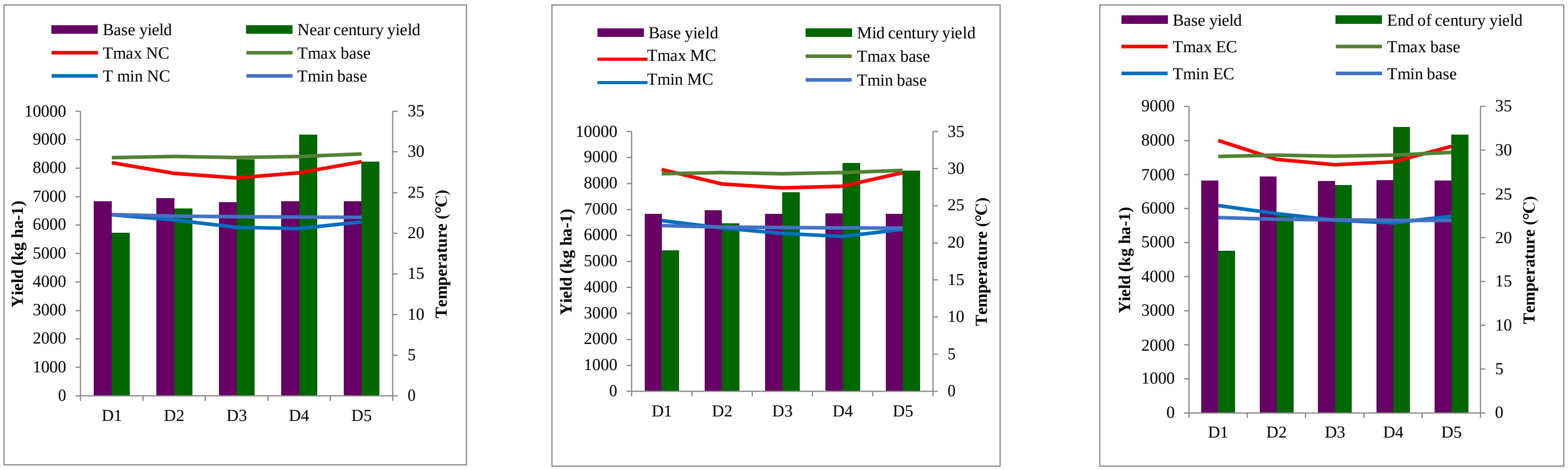
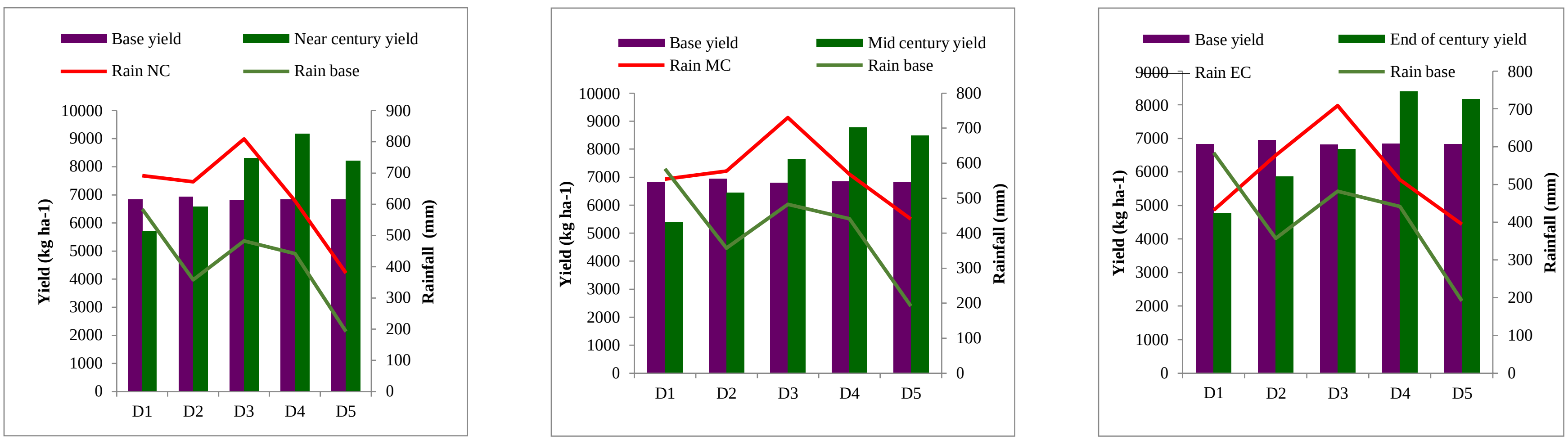


Fig. 5.132. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Idukki



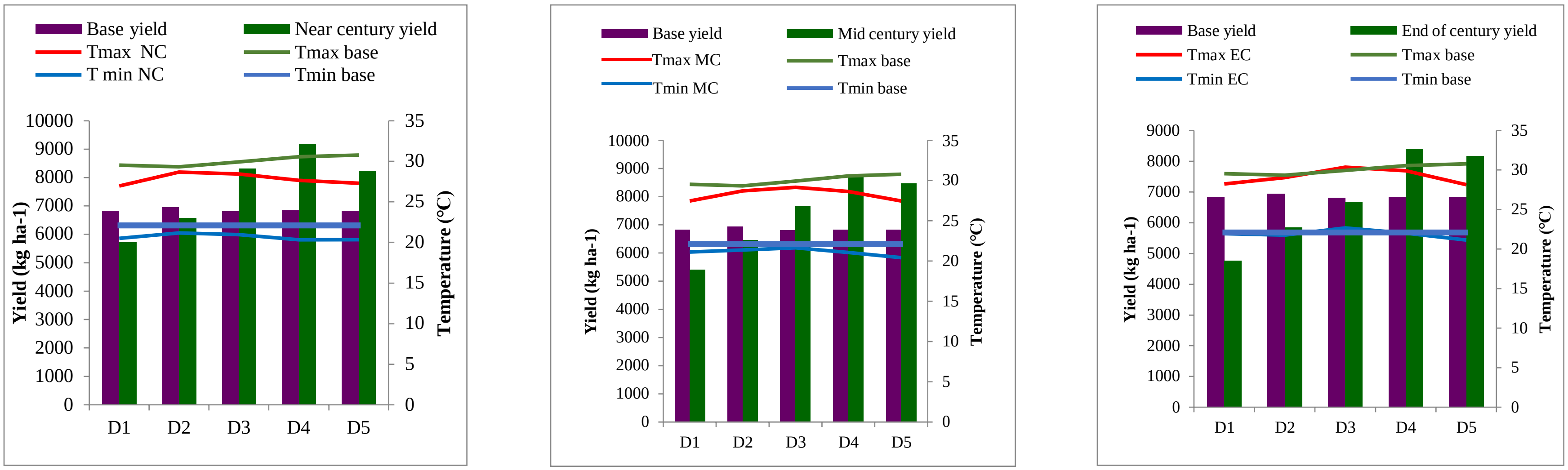
i ii iii

Fig. 5.133. (a). Effect of temperature on yieldof Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5in Idukki



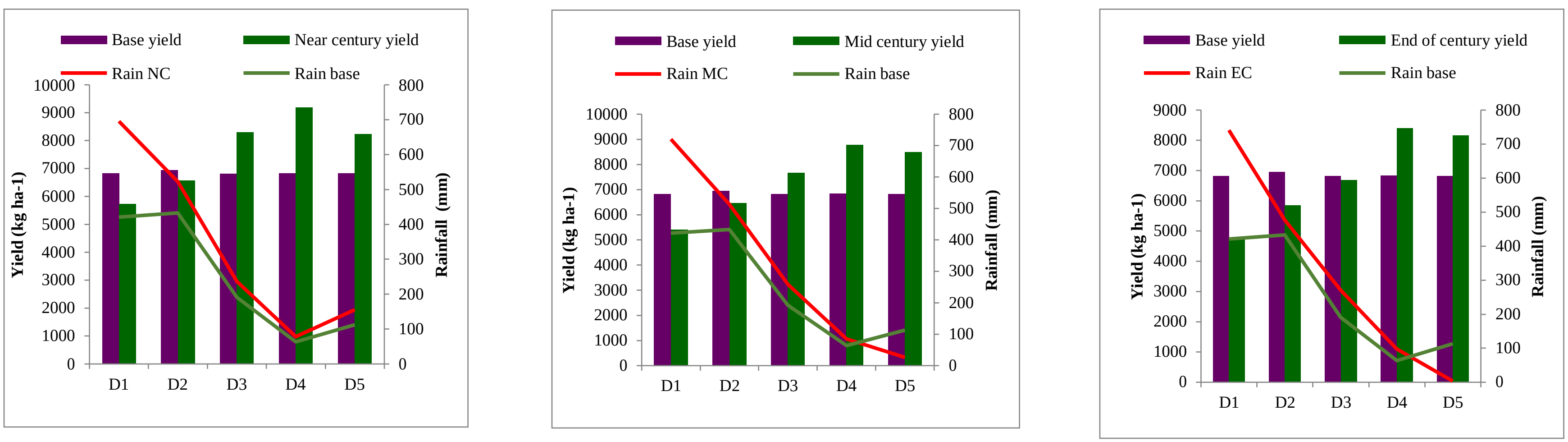
i ii iii

Fig. 5.133. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Idukki



i ii iii

Fig. 5.134. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Idukki



i ii iii

Fig. 5.134. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Idukki

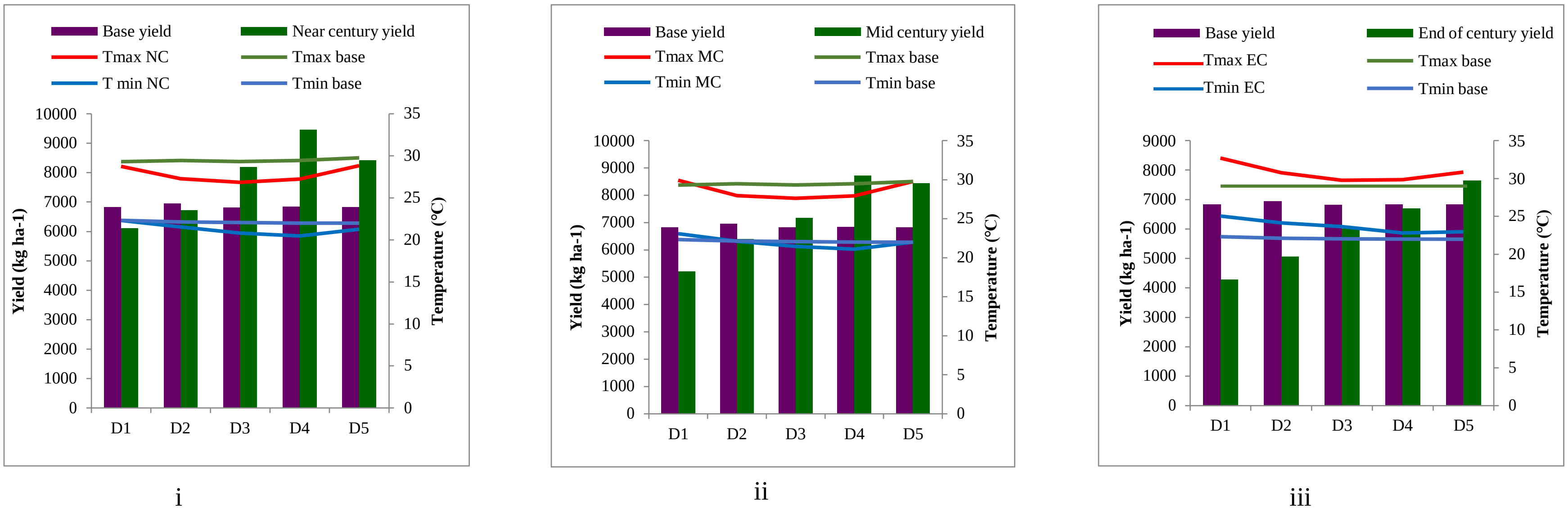


Fig. 5.135. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Idukki

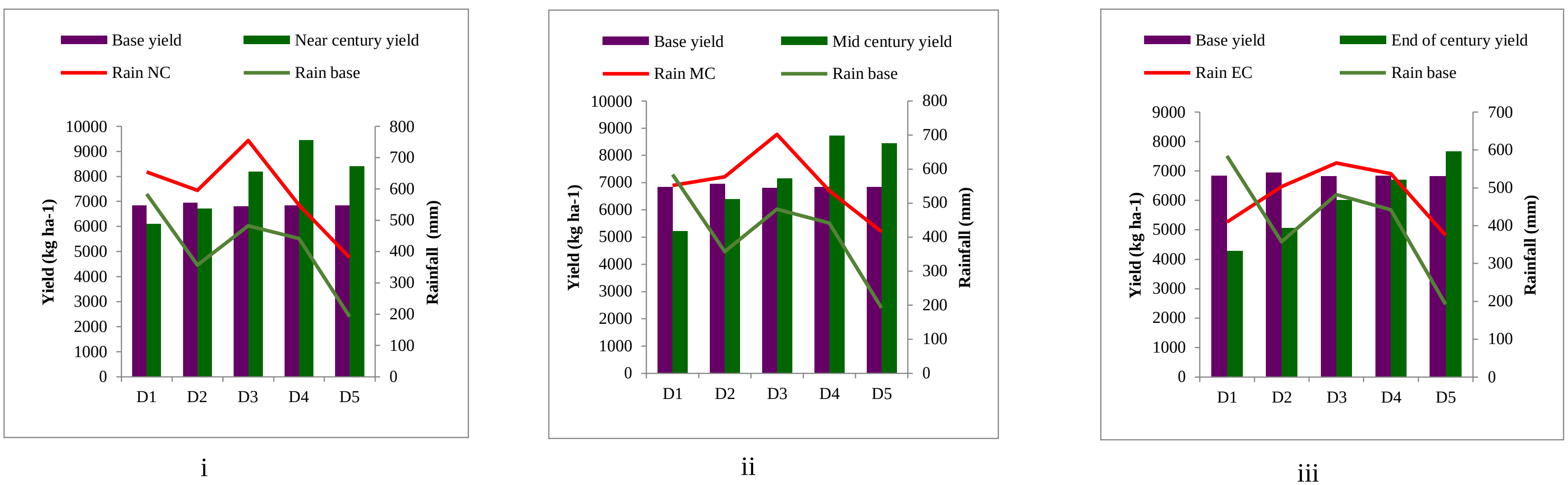


Fig. 5.135. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Idukki

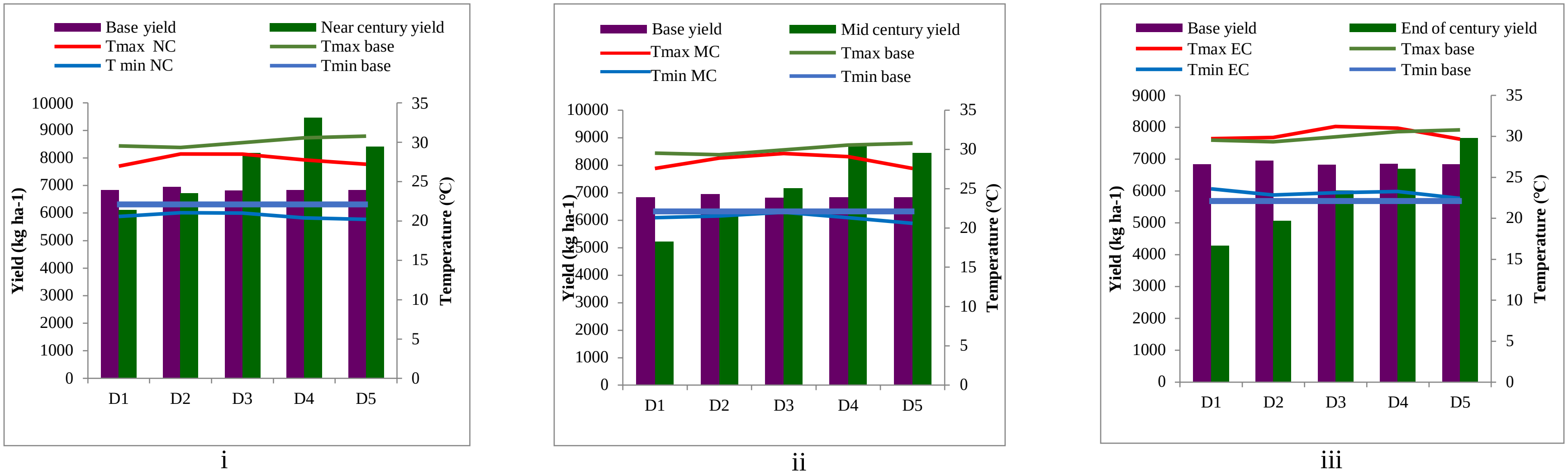


Fig. 5.136. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Idukki

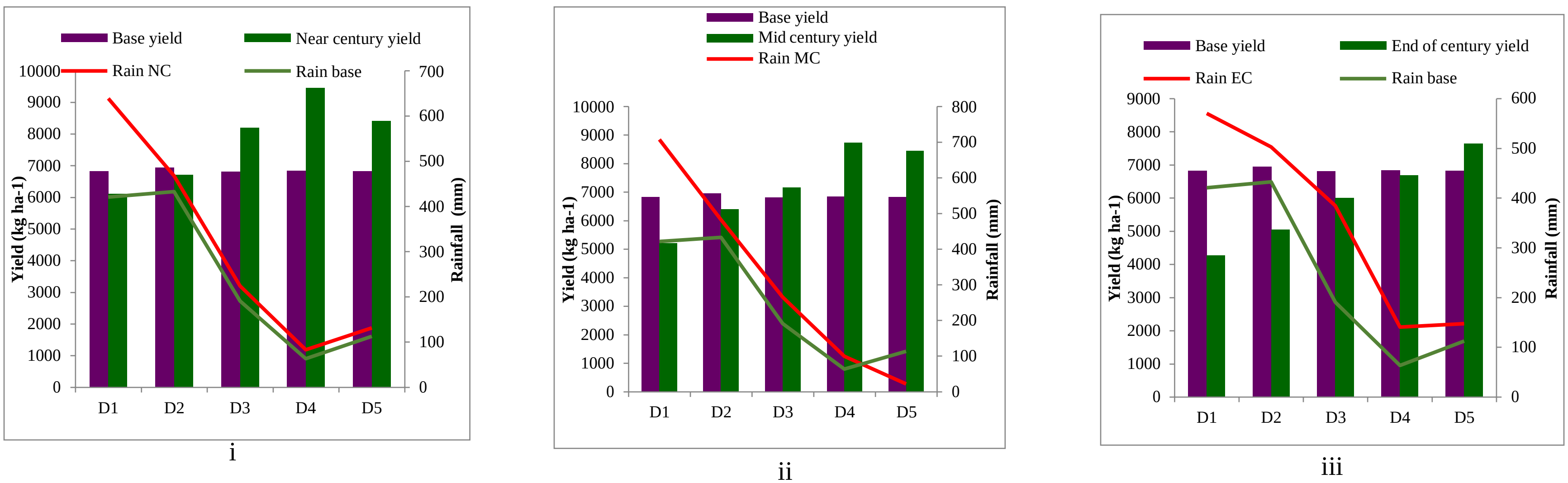


Fig. 5.136. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis RCP 8.5 in Idukki

5.7.5. Rice production in the southern zone of Kerala

In southern zone of Kerala highest potential yield of Jaya has been observed in July 20th planting in all the future simulations under both RCPs. In case of Jyothi the highest potential yield has been observed in August 5th planting.

The temperature was expected to decrease in near century, mid century and end of century during July 20th and August 5th planting. Also an increase rain rainfall is expected. Hence this may be the reason for an increase yield in last dates of plantings. Bhattacharya and Panda (2013) reported that rice yield may increase in the conditions of reduced temperature and increased rainfall. Hence this may be the reason for an increased yield during August 5th plantings.

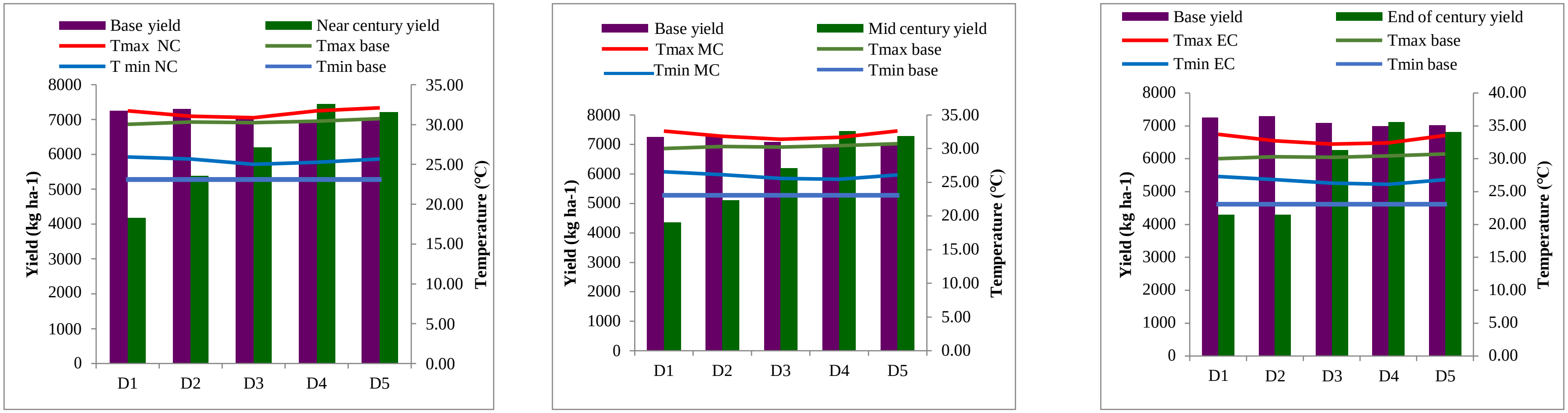
Figure 137 (a) to Figure 160 (a) indicates the impact of temperature and Figure 137 (b) to Figure 160 (b) indicates the impact of rainfall on yield of Jaya and Jyothi in districts of southern zone of Kerala.

5.8. SHIFT IN PLANTING DATES

In Kerala during the base period higher yield was observed during the early plantings *i.e.* June 5th and June 20th plantings in both the varieties. Under RCP 4.5 and 8.5 in near, mid and end of century the higher yield has been expected during the late plantings *i.e.* July 5th, July 20th and August 5th plantings.

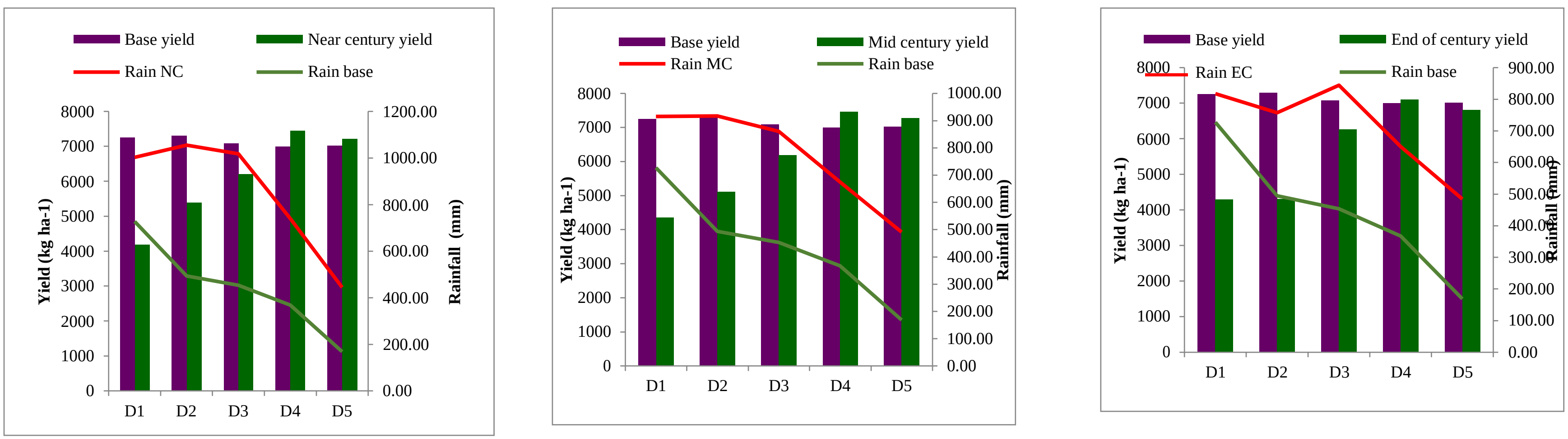
Ghildyal and Jana (1967) reported that the rainfall at different growth stages determines whether it is good or not for the yield of rice. Increased rainfall during the flowering period is having a negative effect on the yield of rice. From the assessment of climate change it was concluded that there will be an increase in rainfall in most parts of Kerala during the south west monsoon season. It was observed that high rainfall coincided with the flowering period of early planting varieties. As well as the temperature difference from base period was found to be higher in early plantings. While in late plantings when compared to early plantings the difference of maximum temperature from base period was found to be less during panicle initiation to anthesis. Also the rainfall during this stage was found to be less in late plantings of both varieties. These results suggest that there may be chance of shift in date of planting in future and late plantings are found to better in future.

Figure 161 to 176 shows the impact of temperature and rainfall during the panicle initiation to anthesis period on early and late plantings of rice yield in near, mid and end of century in Jyothi and Jaya.



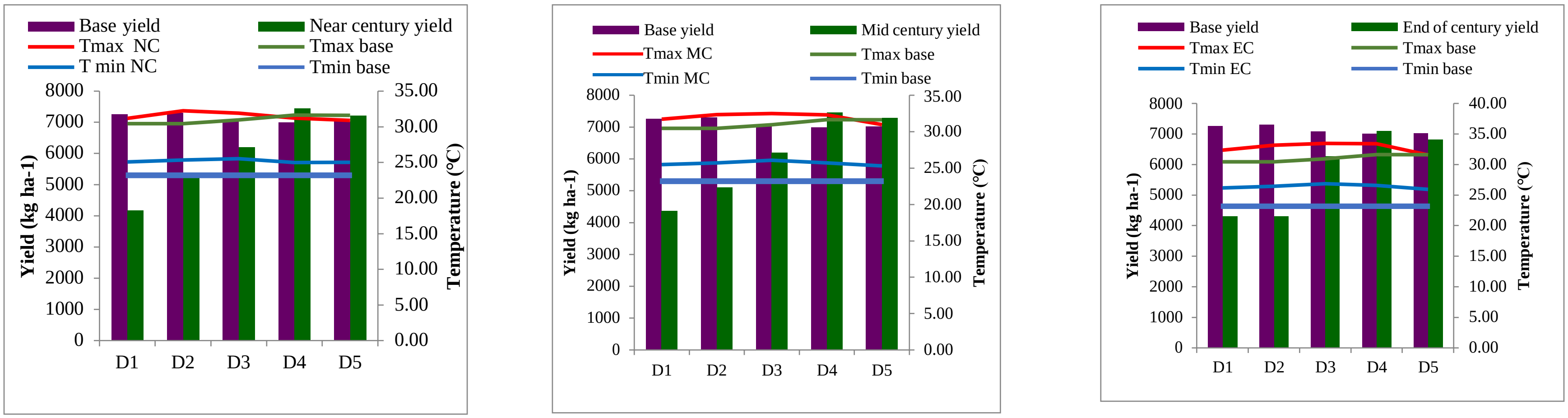
i ii iii

Fig. 5.137. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5in Pathanamthitta



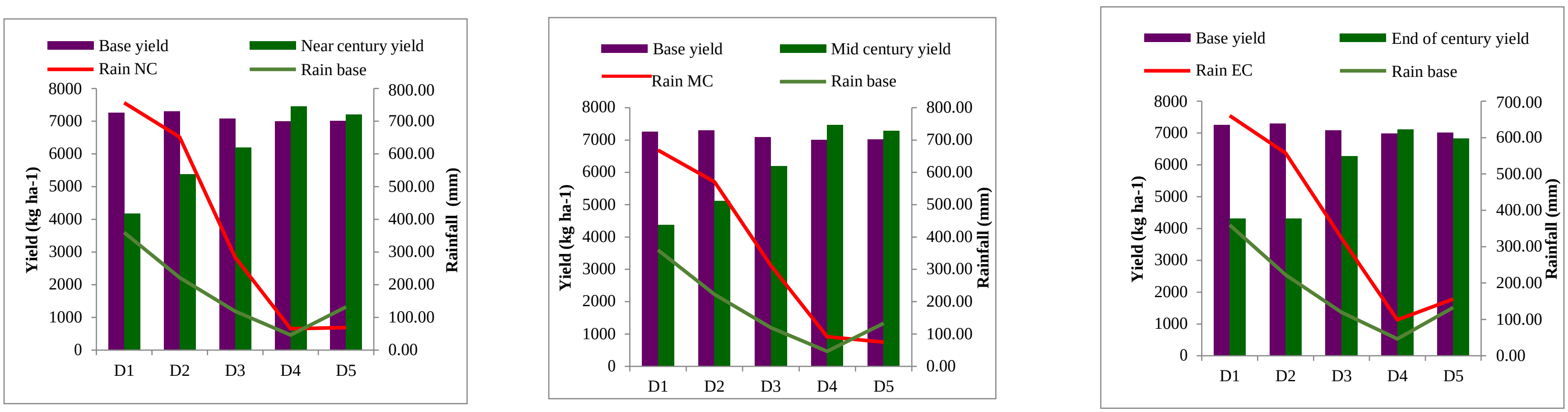
i ii iii

Fig. 5.137. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Pathanamthitta



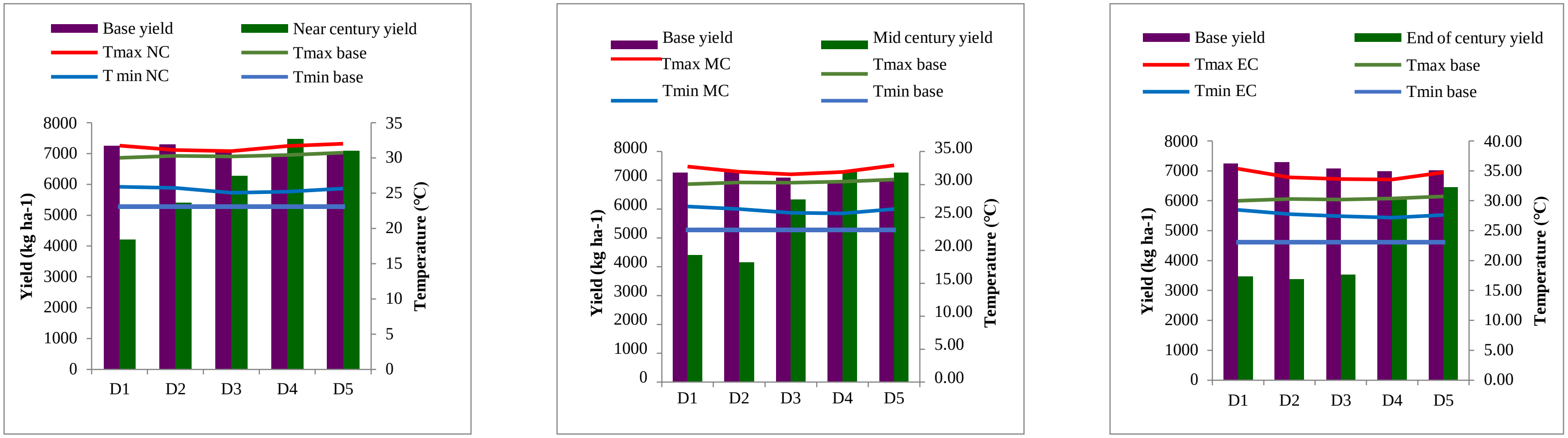
i ii iii

Fig. 5.138. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Pathanamthitta



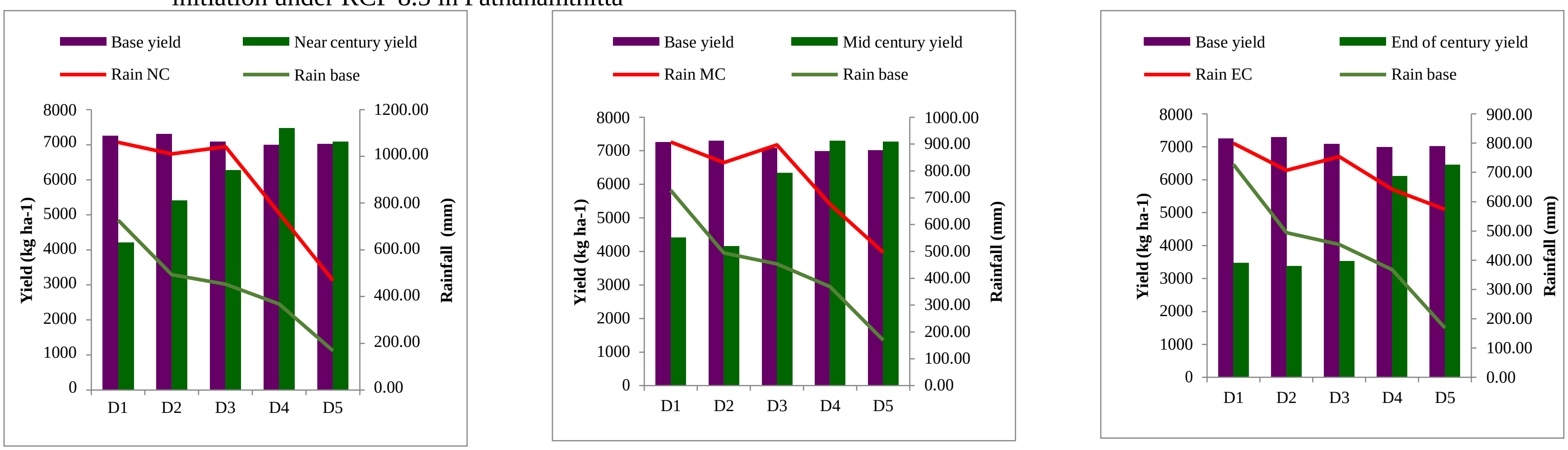
i ii iii

Fig. 5.138. (b). Effect of rainfall on yieldof Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5in Pathanamthitta



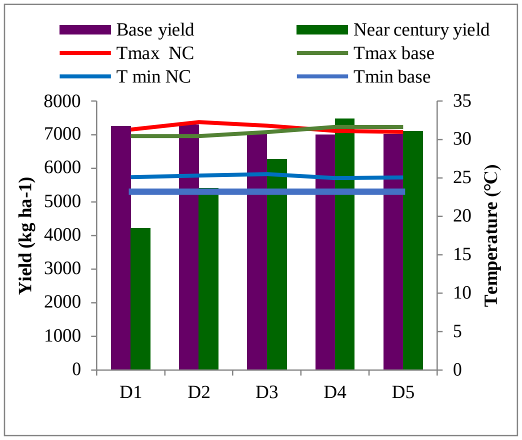
i ii iii

Fig. 5.139. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Pathanamthitta



i ii iii

Fig. 5.139. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Pathanamthitta



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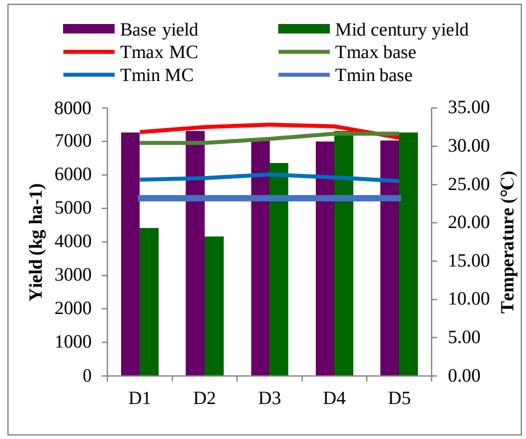
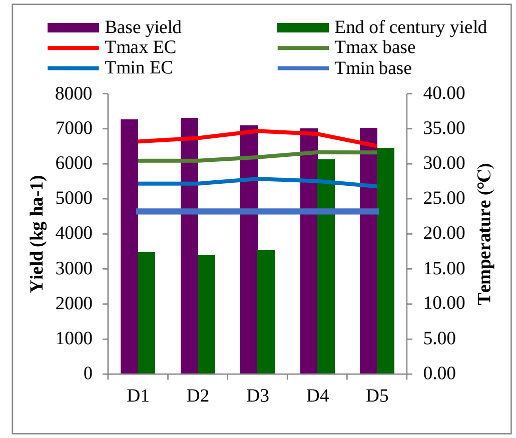
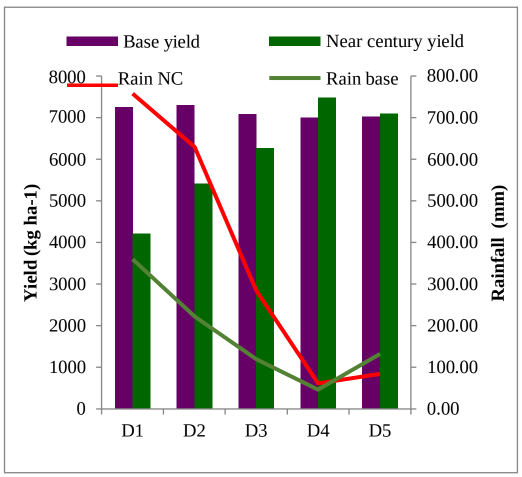


ii

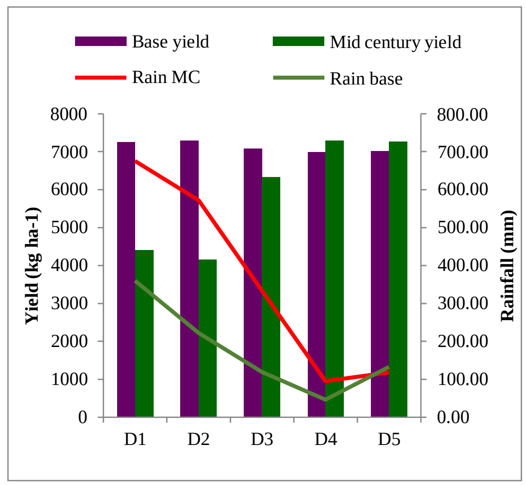


iii

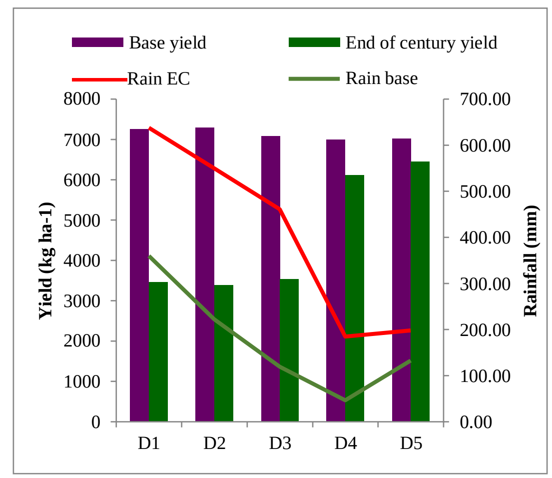
Fig. 5.140. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Pathanamthitta



i

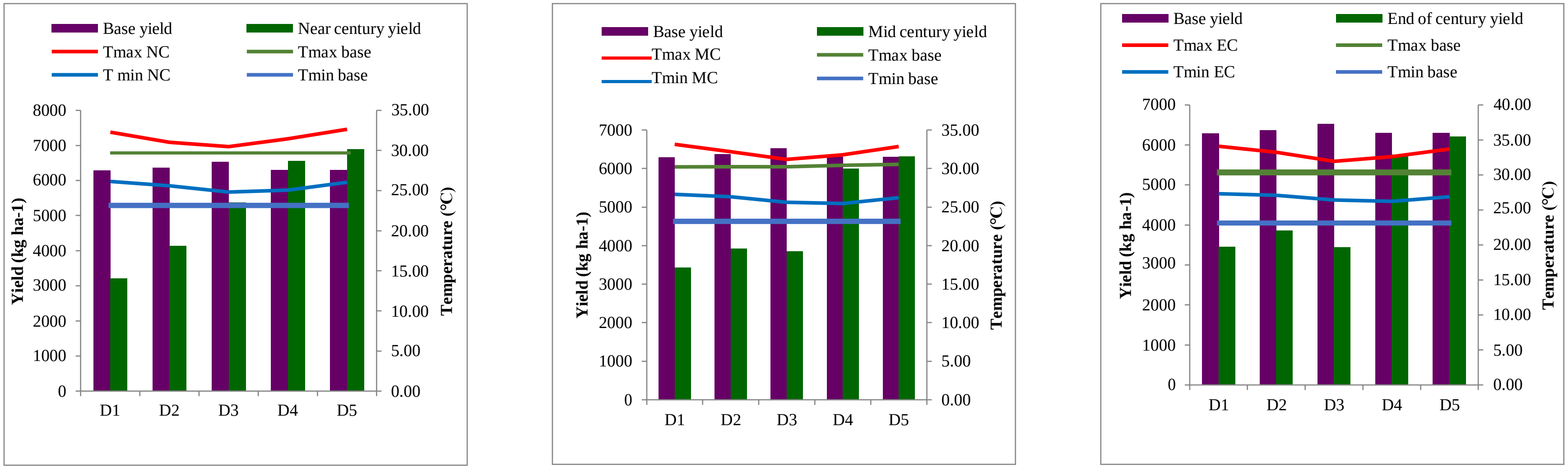


ii



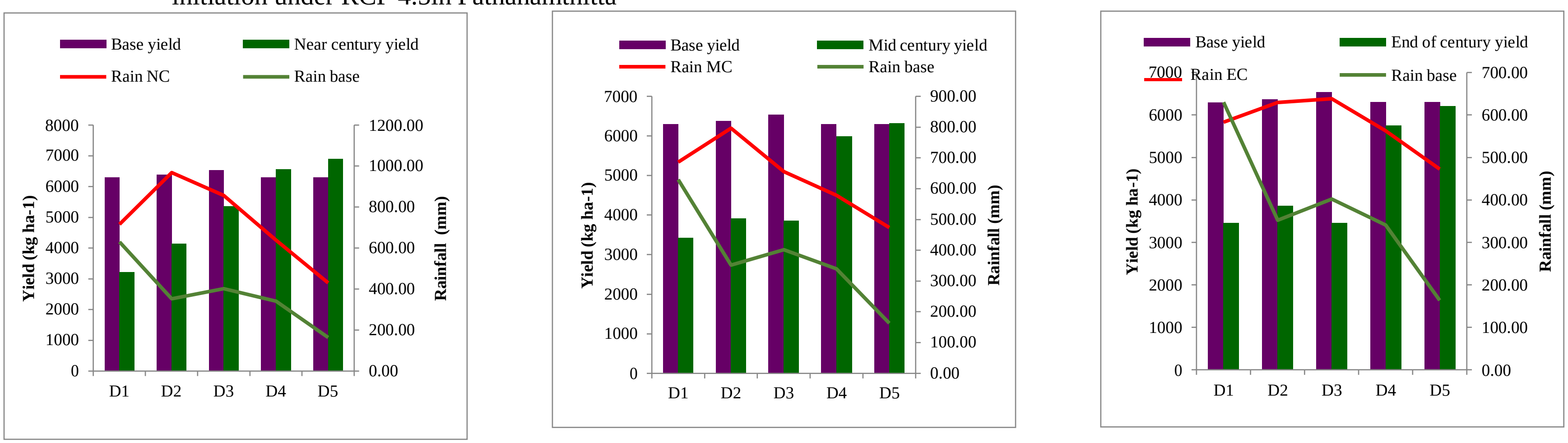
iii

Fig. 5.140. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Pathanamthitta



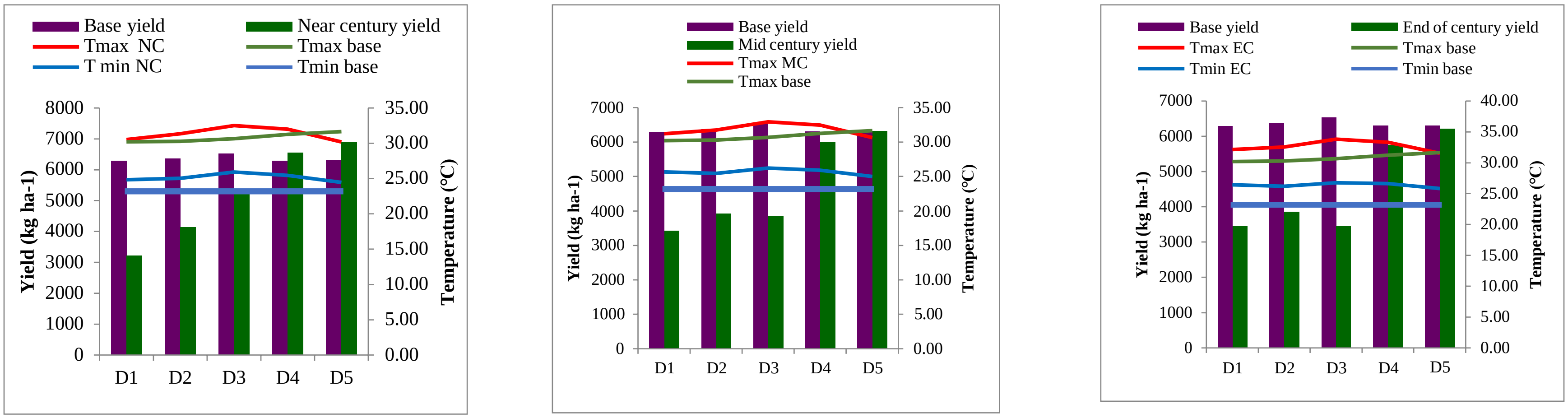
i ii iii

Fig. 5.141. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5in Pathanamthitta



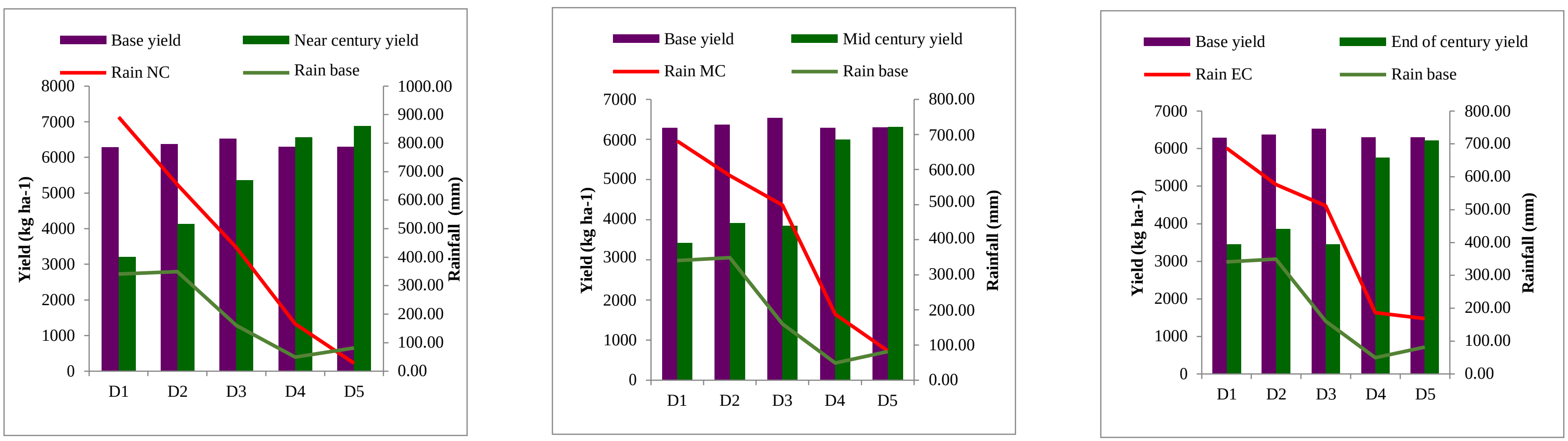
i ii iii

Fig. 5.141. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Pathanamthitta



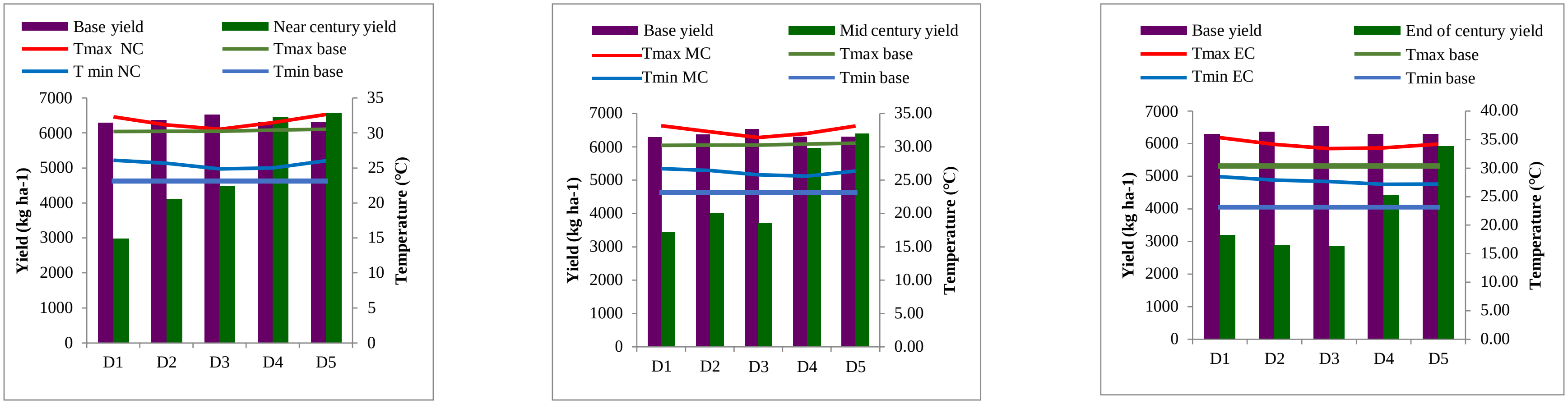
i ii iii

Fig. 5.142. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Pathanamthitta



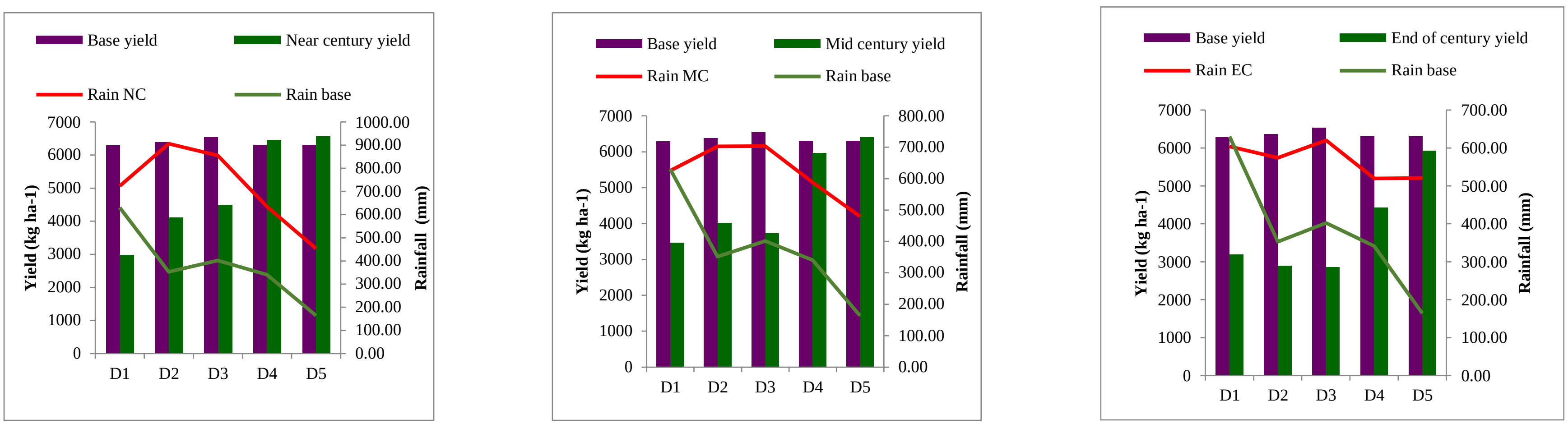
i ii iii

Fig. 5.142. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Pathanamthitta



i ii iii

Fig. 5.143. (a). Effect of temperature on yieldof Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Pathanamthitta



i ii iii

Fig. 5.143. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Pathanamthitta

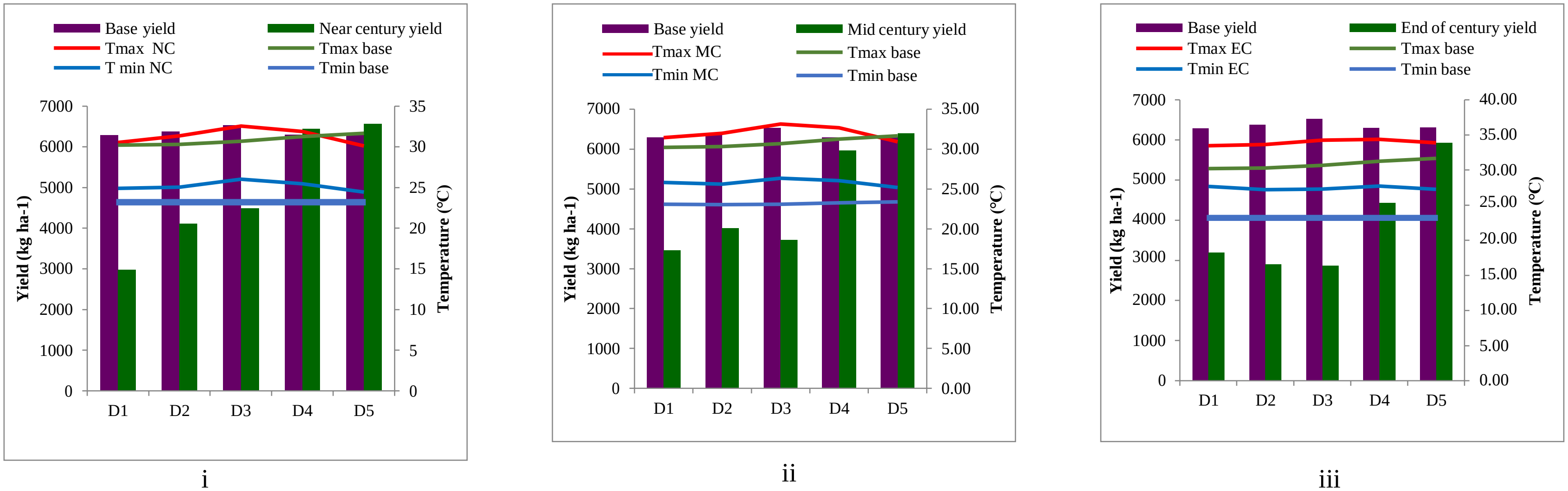


Fig. 5.144. (a). Effect of temperature on yieldof Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Pathanamthitta

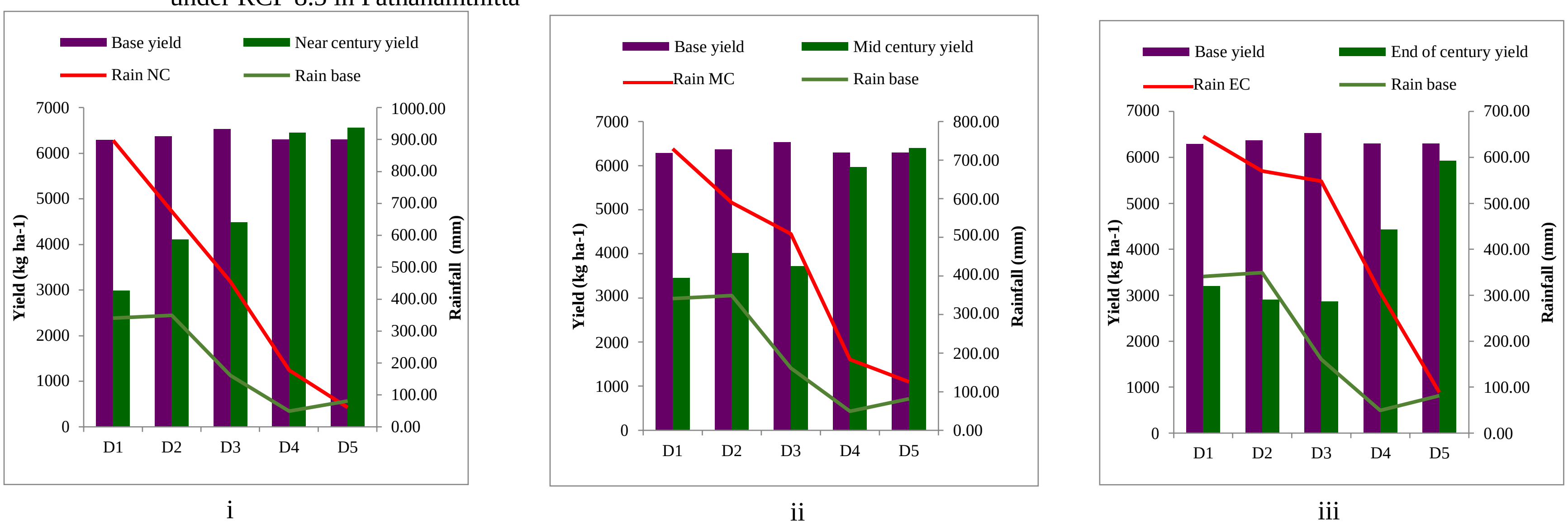
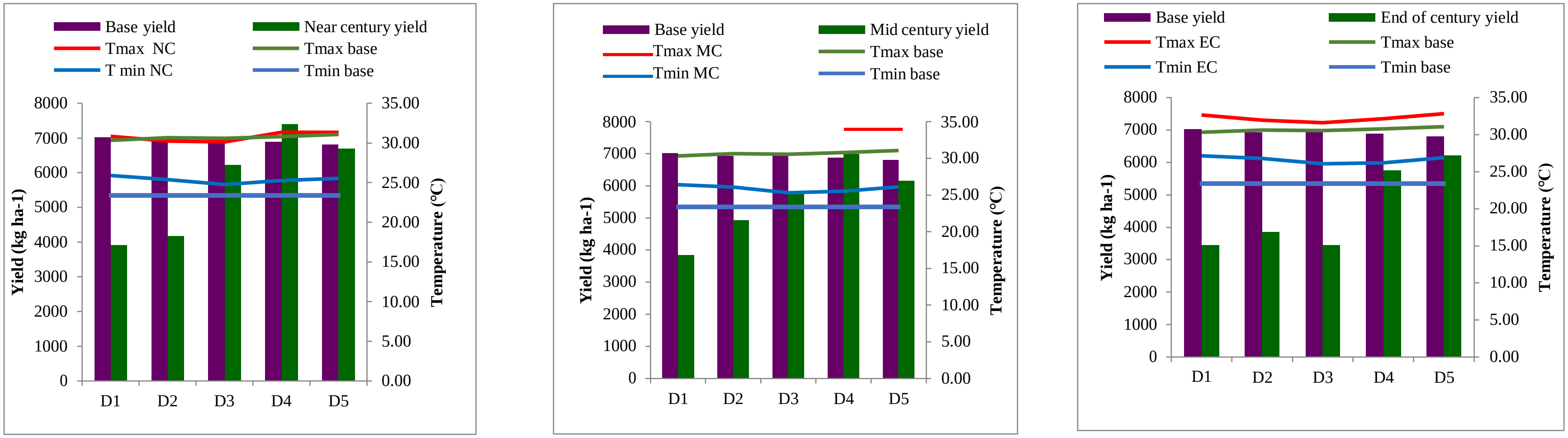
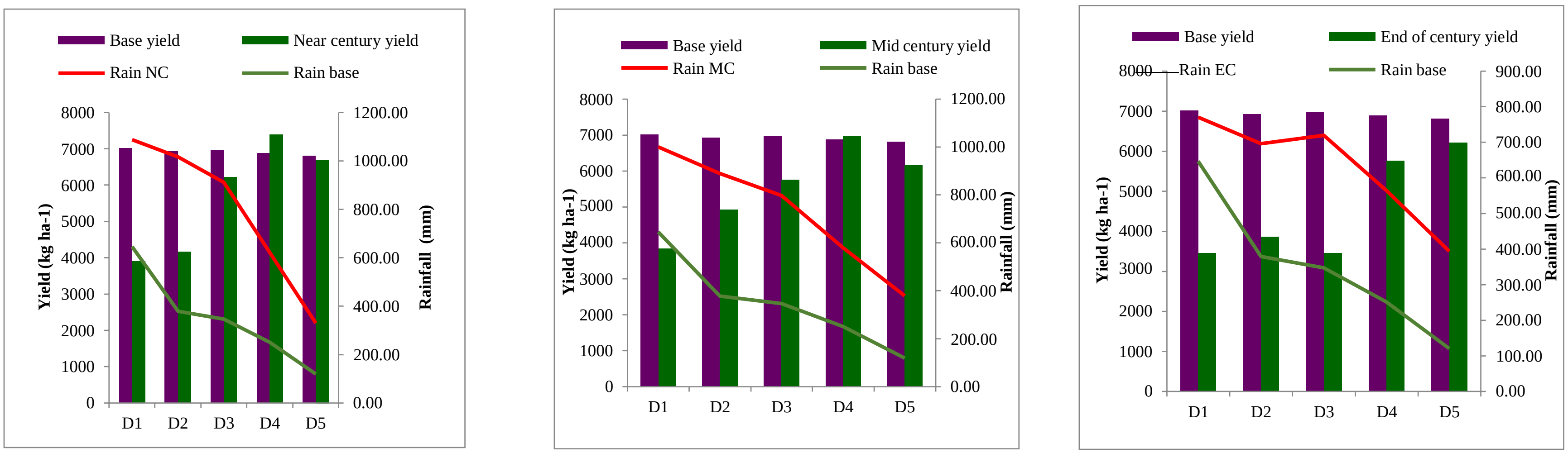


Fig. 5.144. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Pathanamthitta



i . ii iii

Fig. 5.145. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5in Kollam



i ii iii

Fig. 5.145. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Kollam

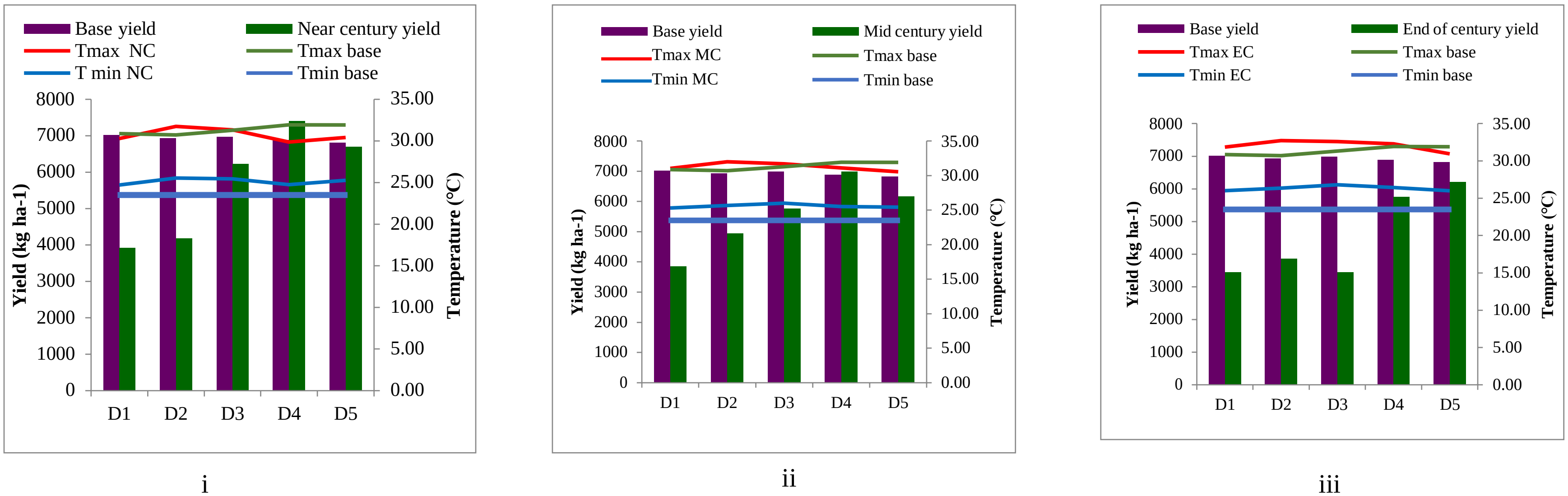


Fig. 5.146. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Kollam

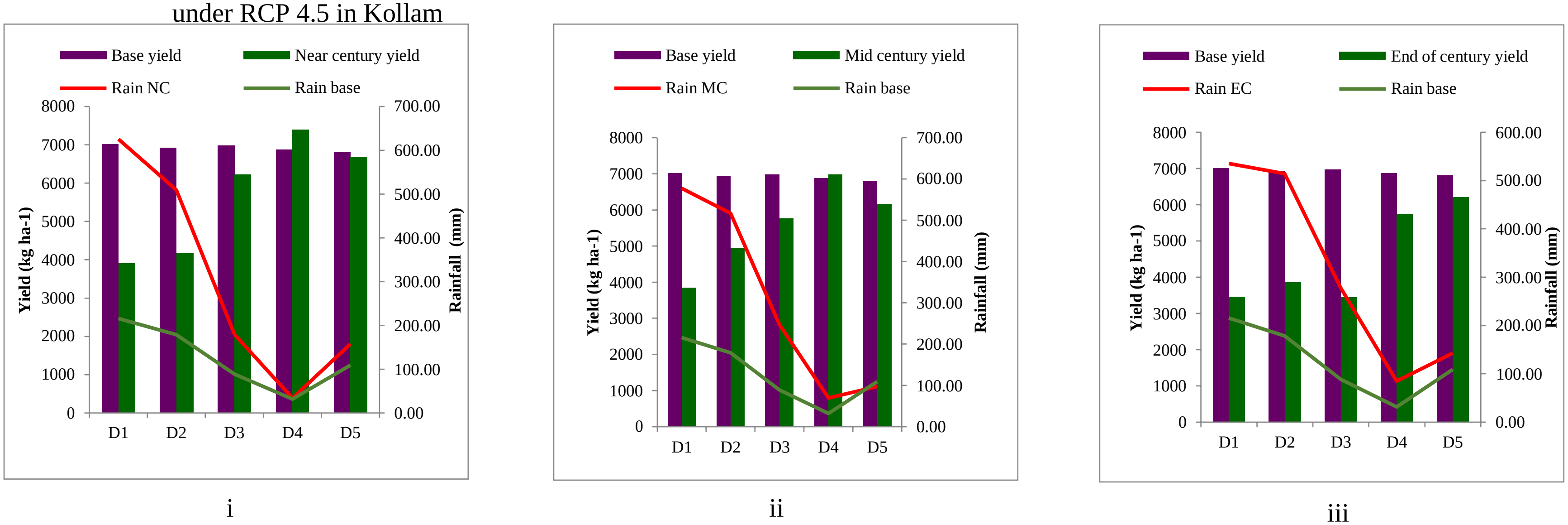
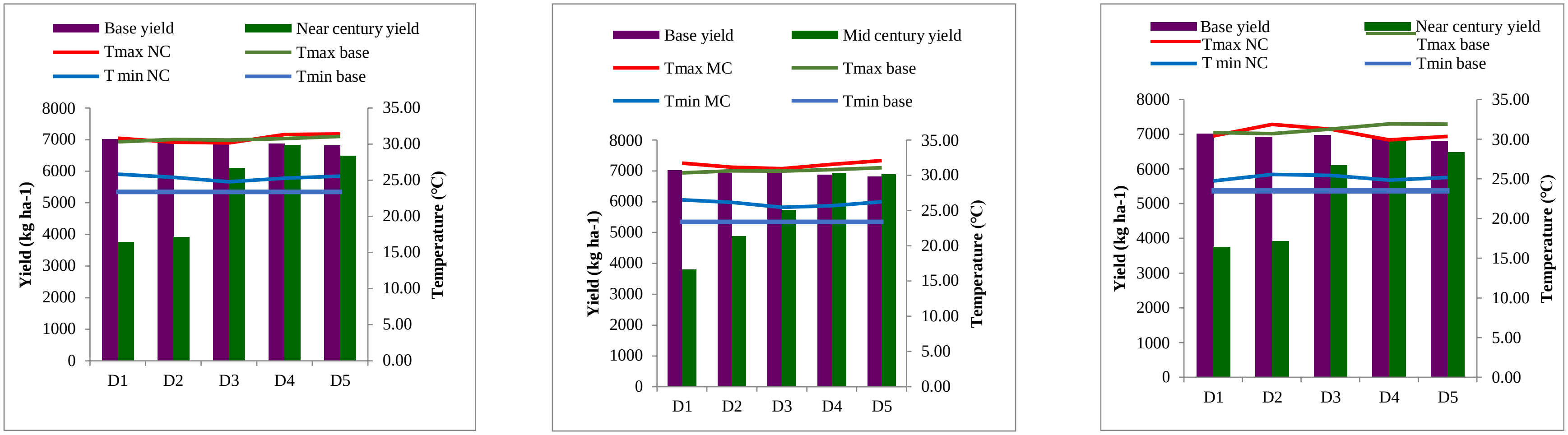
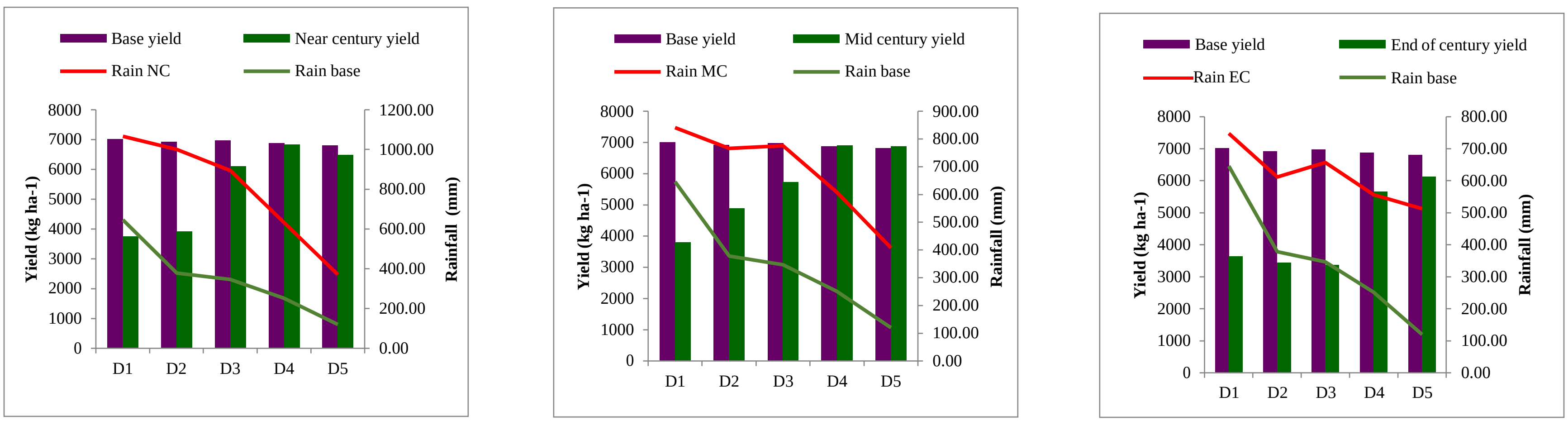


Fig. 5.146. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Kollam



i ii iii

Fig. 5.147. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5in Kollam



i ii iii

Fig. 5.147. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Kollam

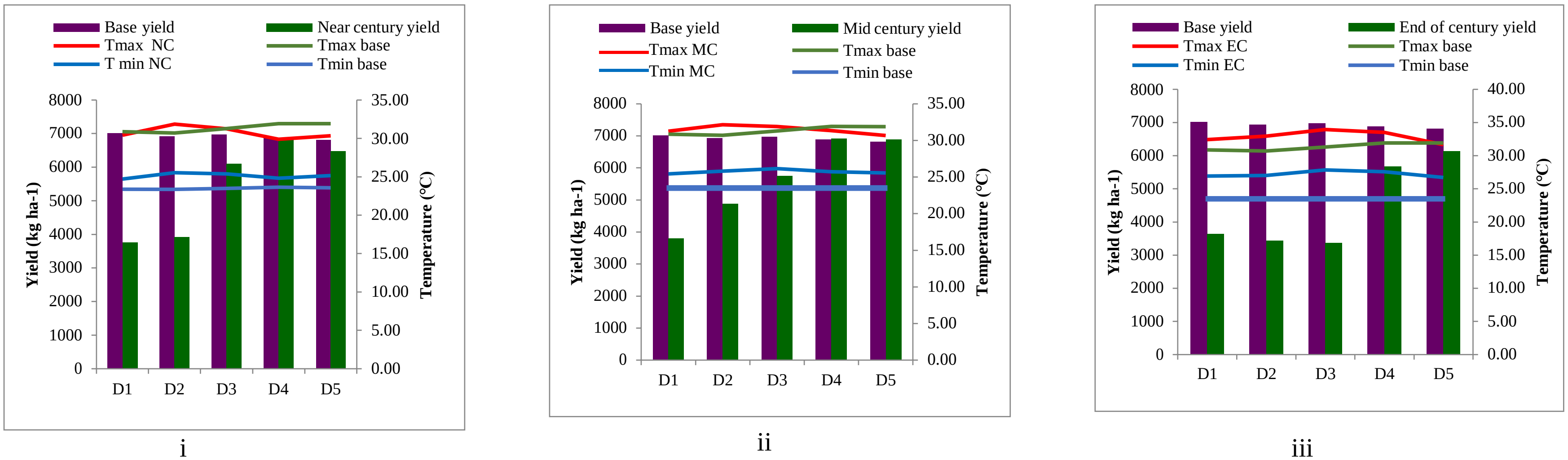


Fig. 5.148 (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Kollam

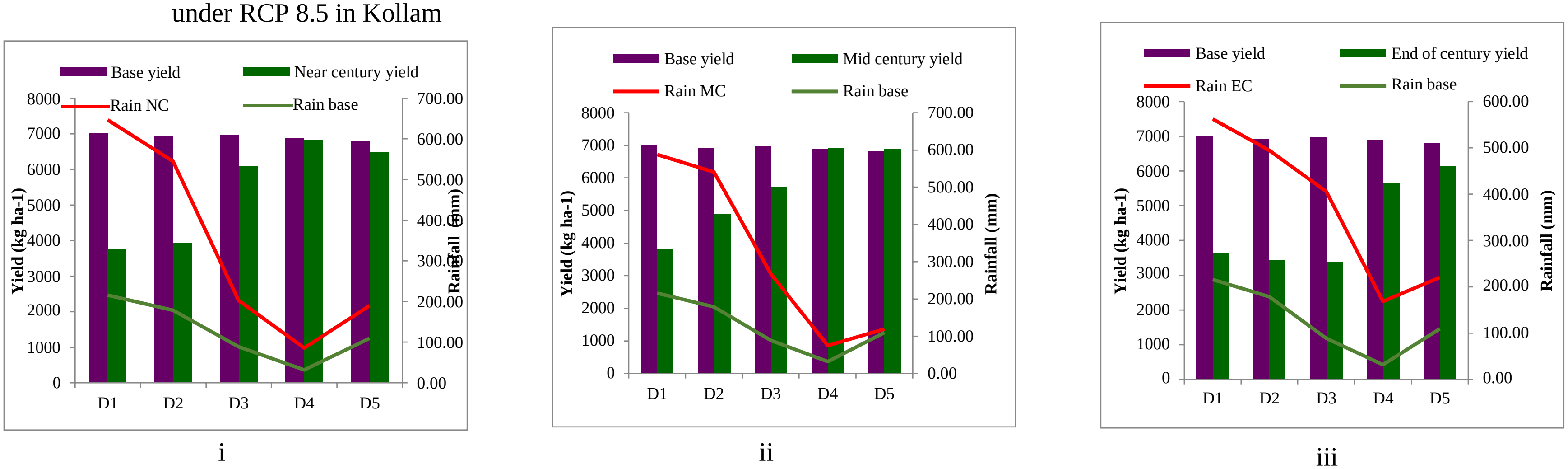
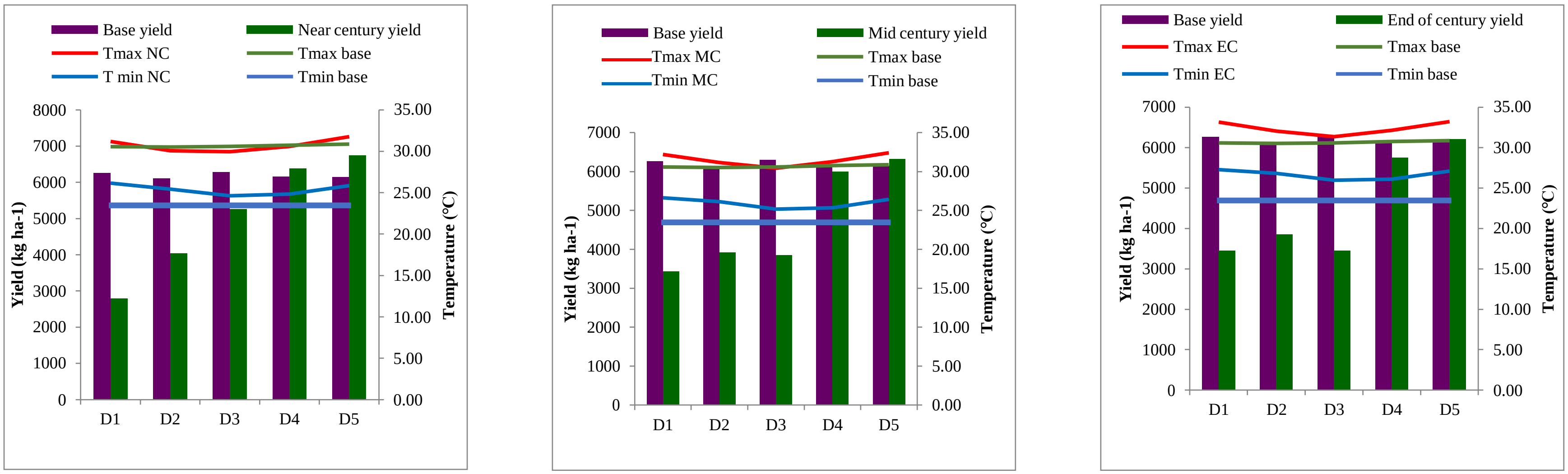
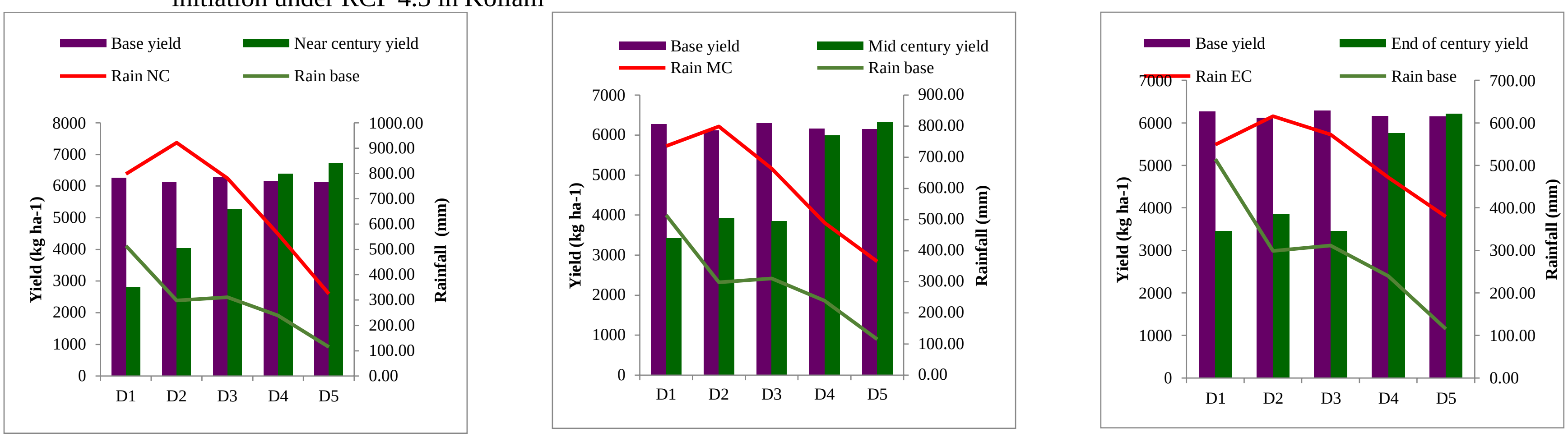


Fig. 5.148. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Kollam



i ii iii

Fig. 5.149. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Kollam



i ii iii

Fig. 5.149. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5in Kollam

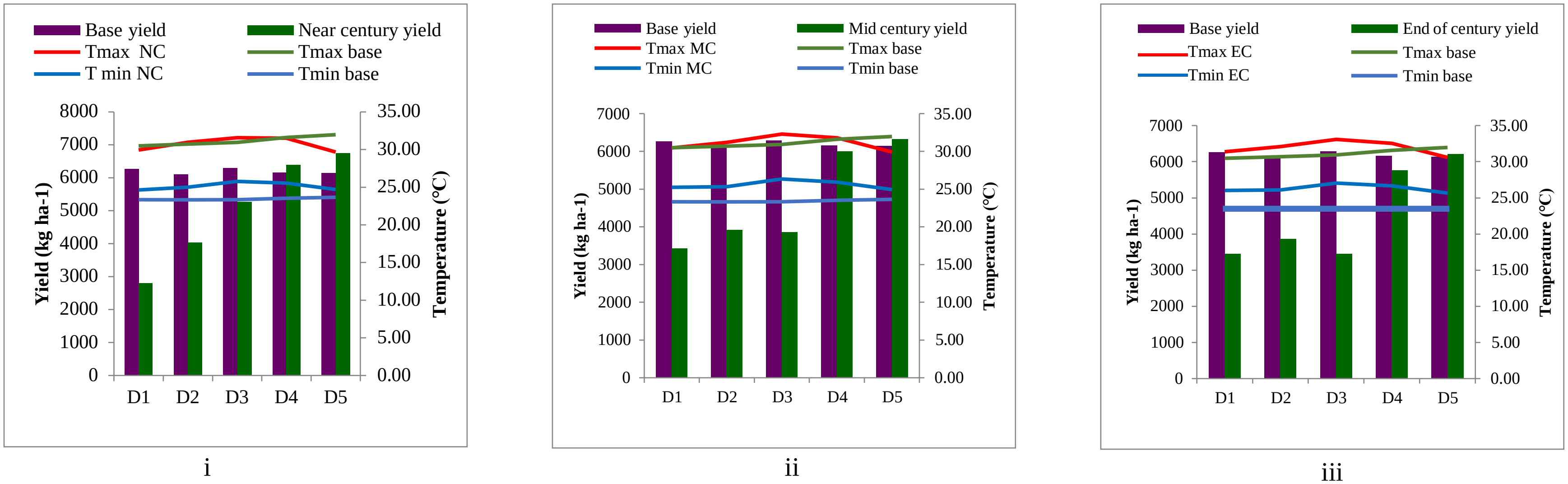


Fig. 5.150. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Kollam

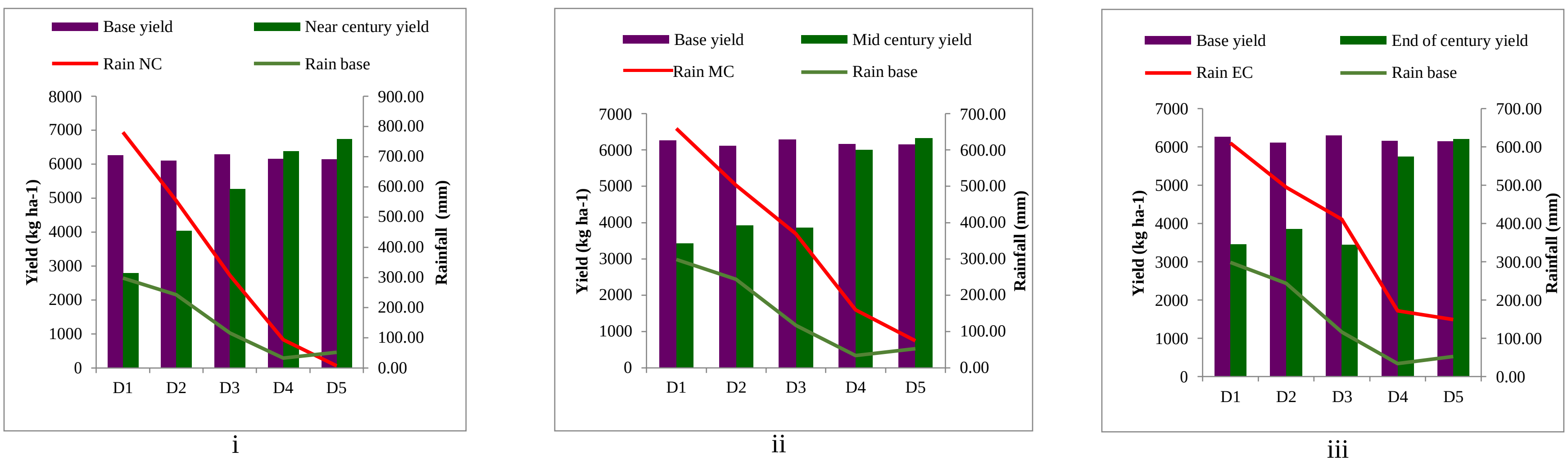
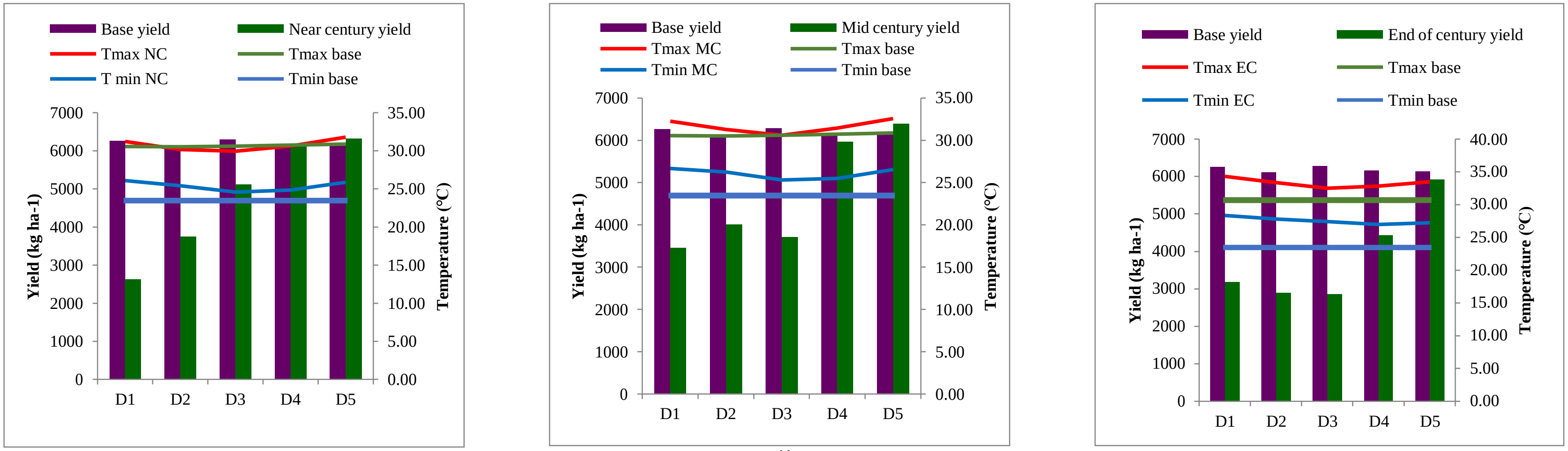
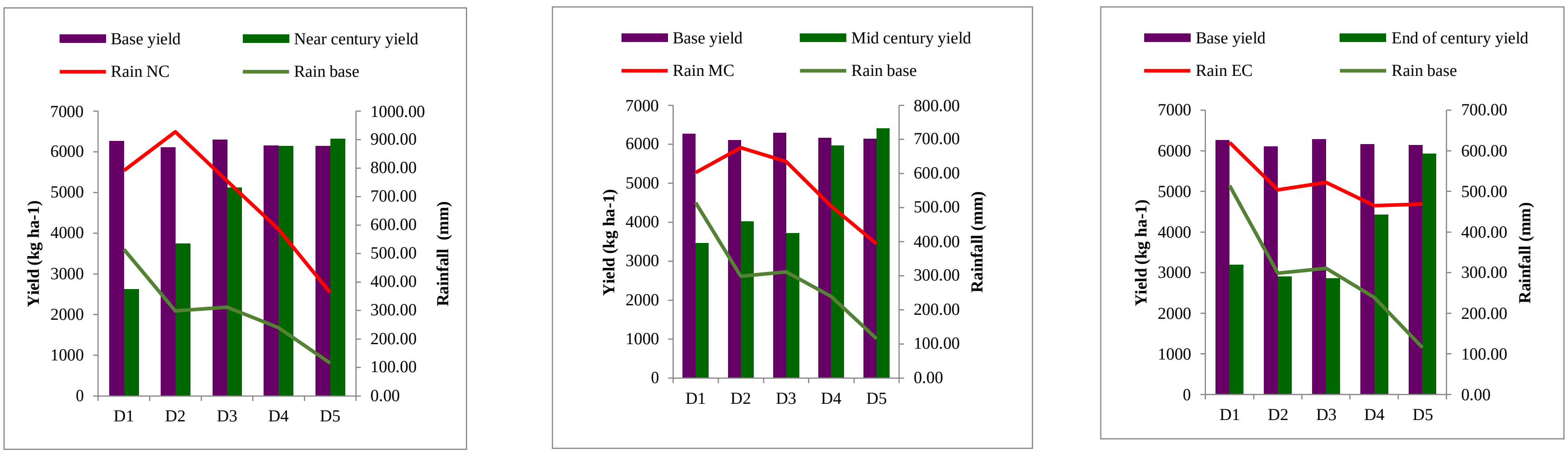


Fig. 5.150. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Kollam



i ii iii

Fig. 5.151. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Kollam



i ii iii

Fig. 5.151. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Kollam

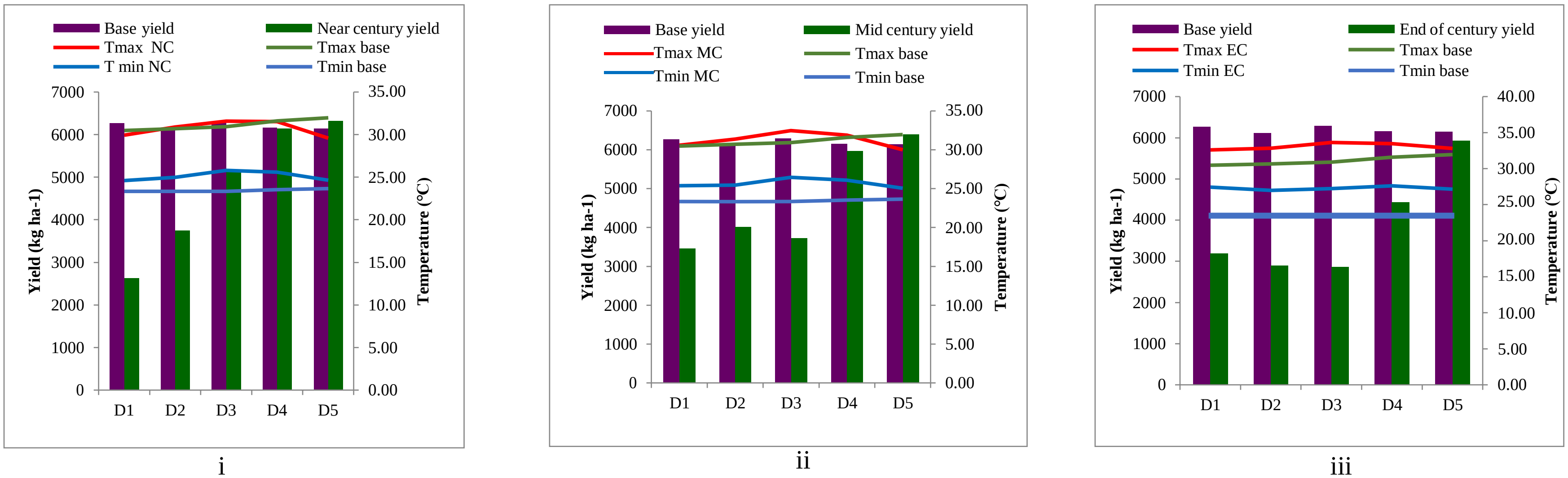


Fig. 5.152 (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5in Kollam

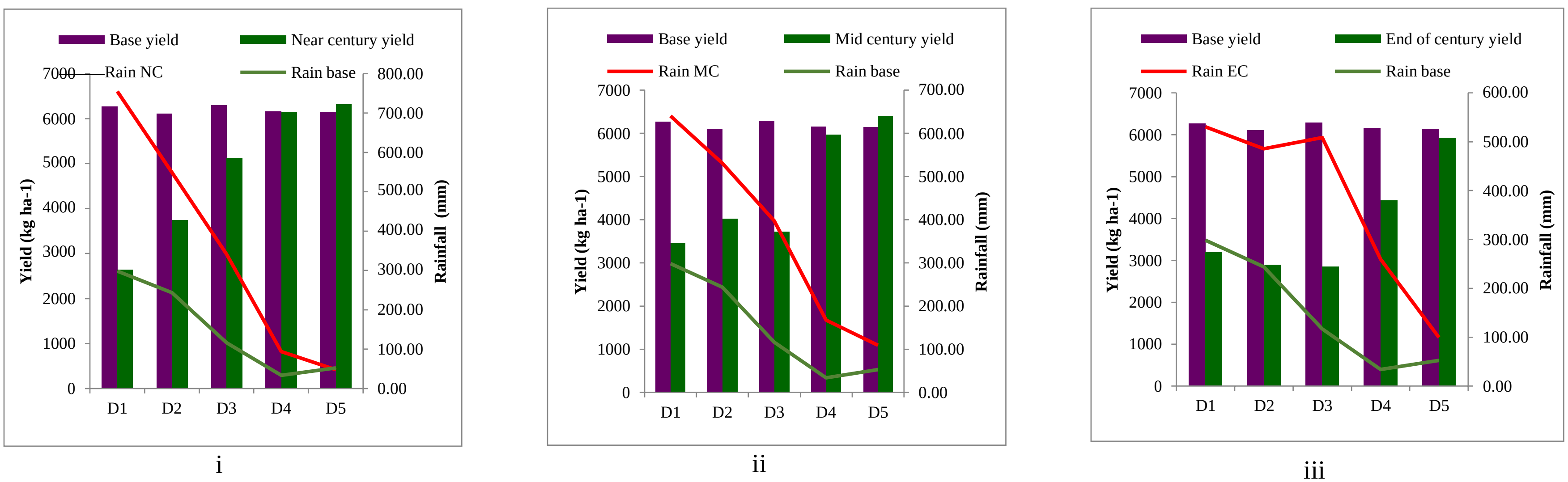


Fig. 5.152. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Kollam

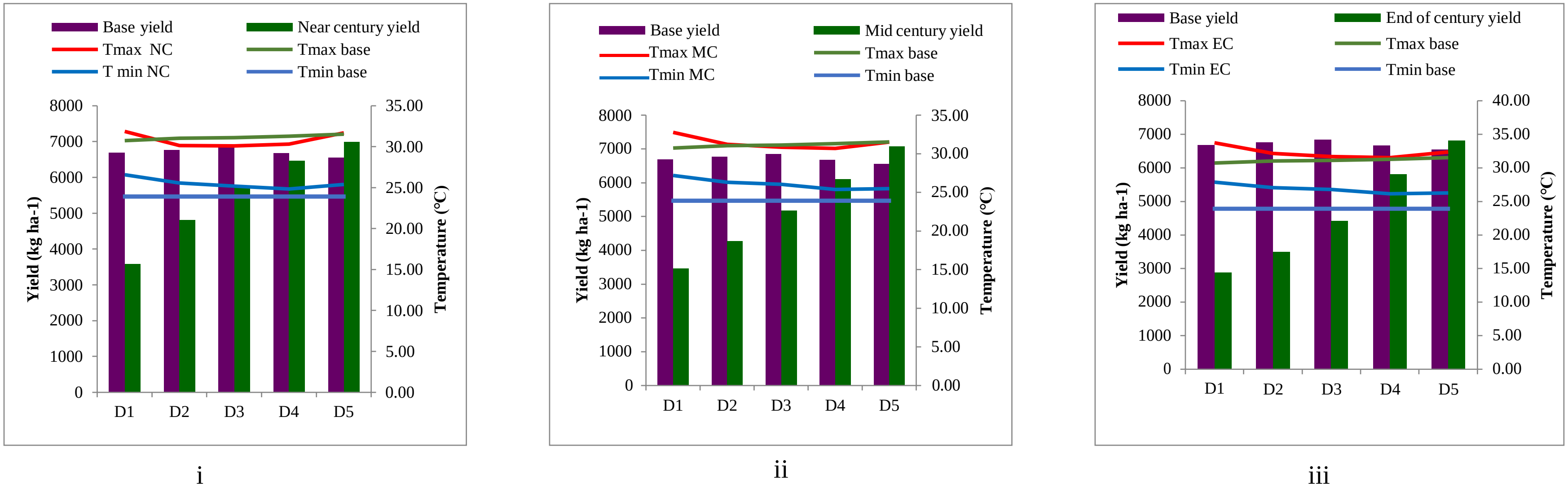


Fig. 5.153. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Thiruvananthapuram

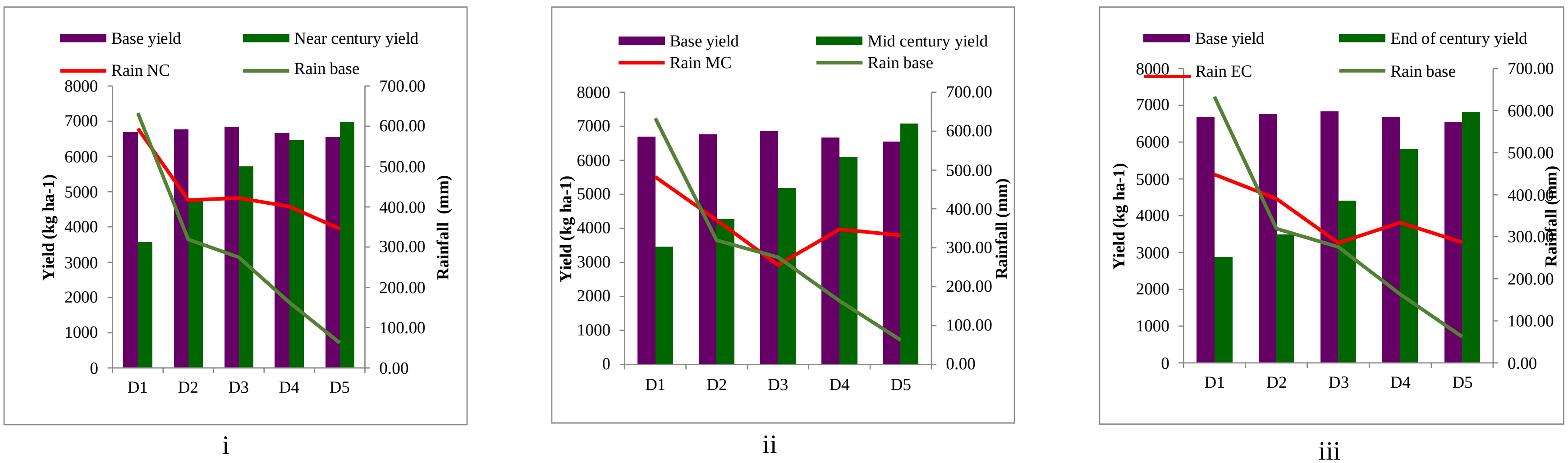
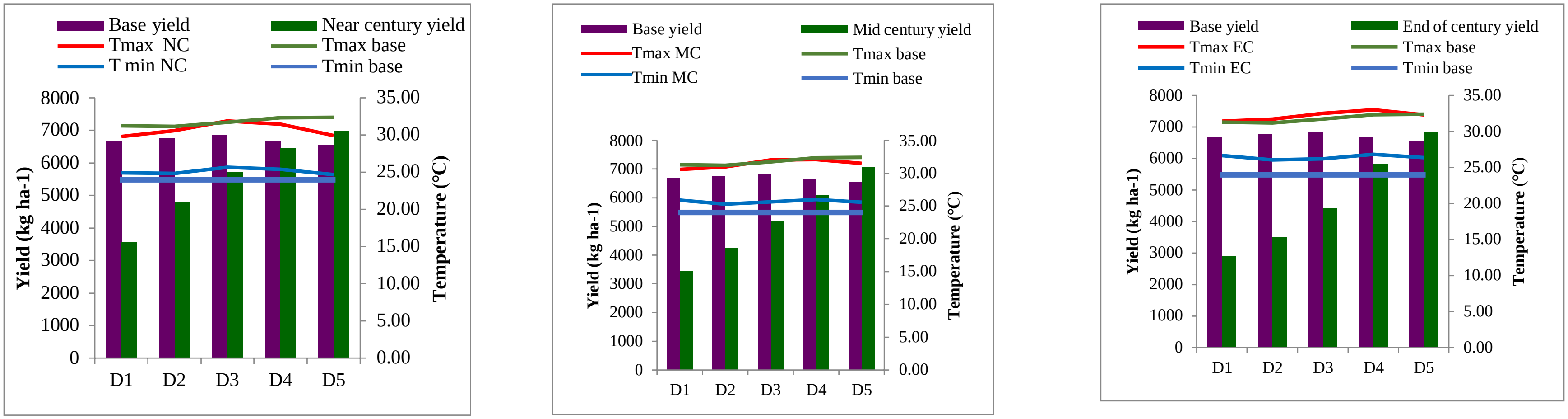
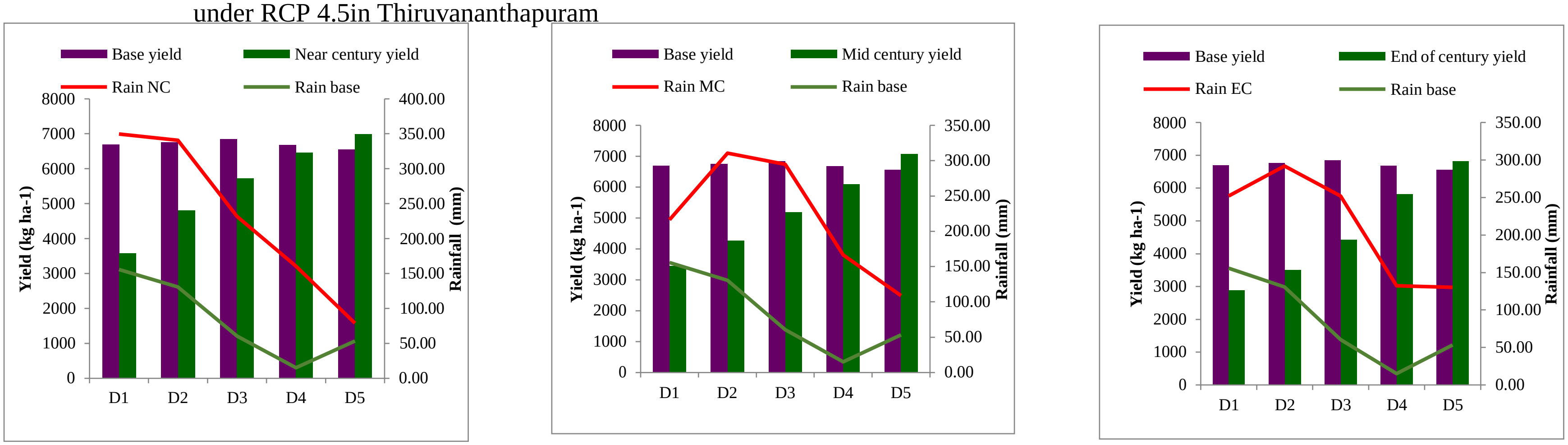


Fig. 5.153. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Thiruvnanthapuram



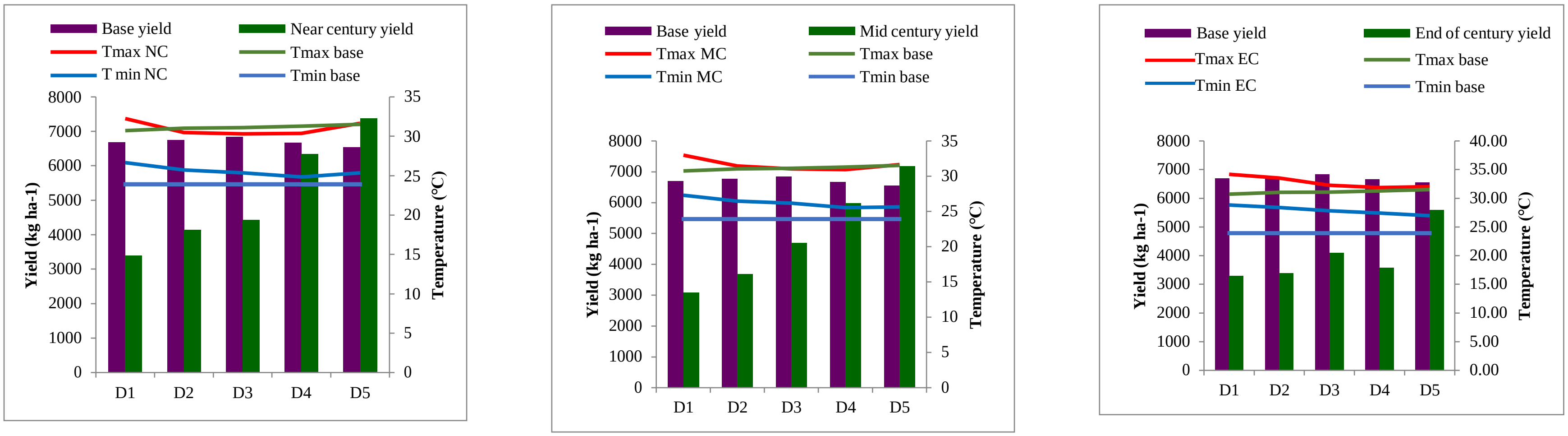
i ii iii

Fig. 5.154. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5in Thiruvananthapuram



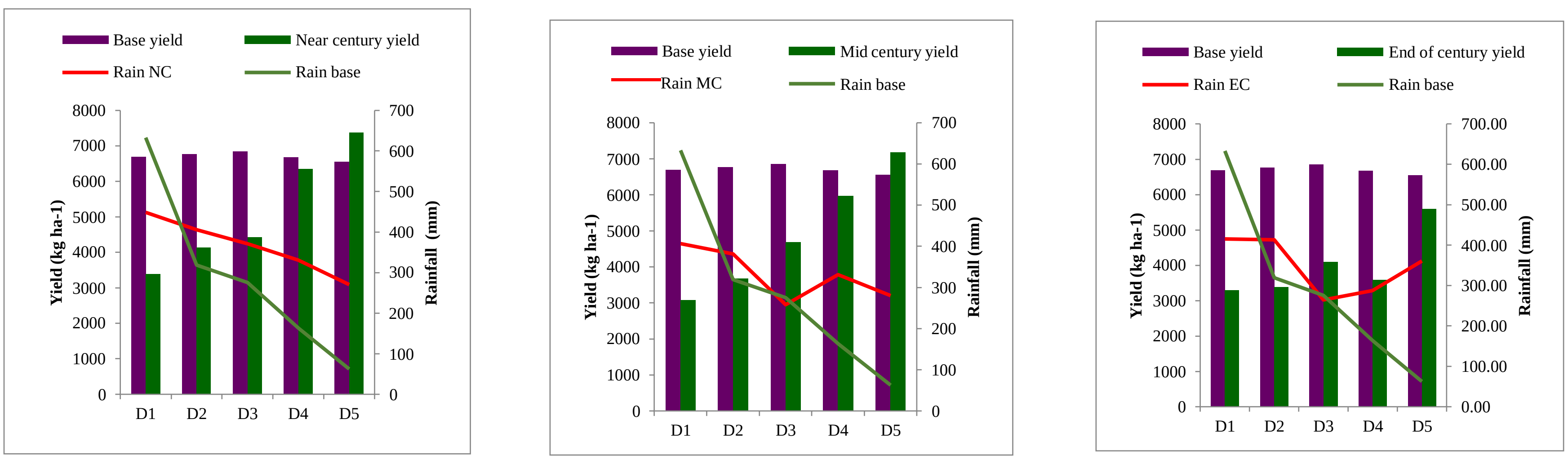
i ii iii

Fig. 5.154. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Thiruvnanthapuram



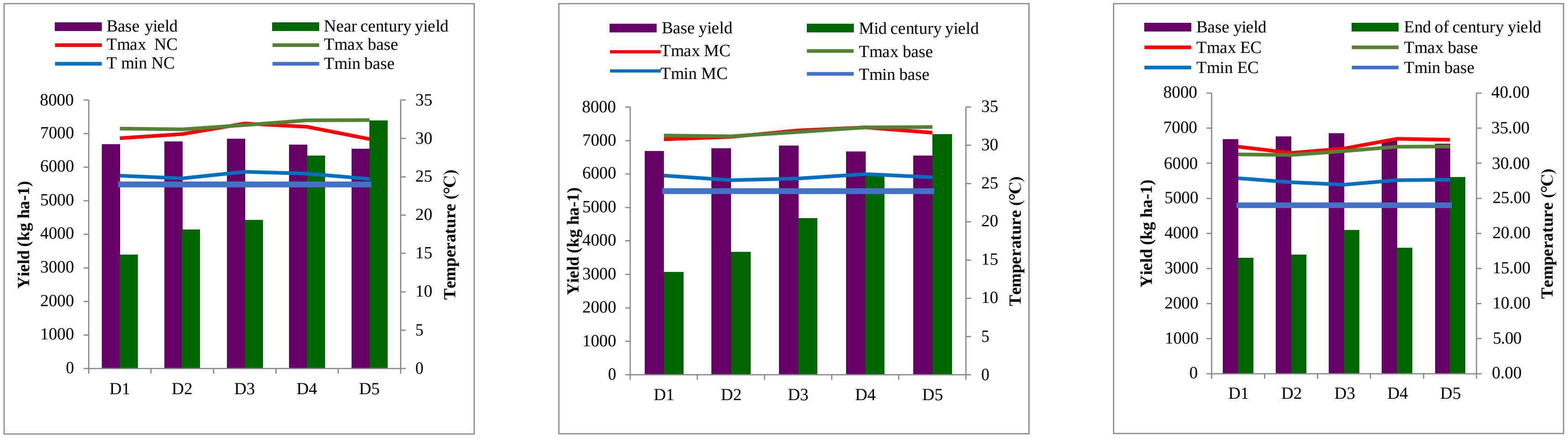
i ii iii

Fig. 5.155. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Thiruvananthapuram



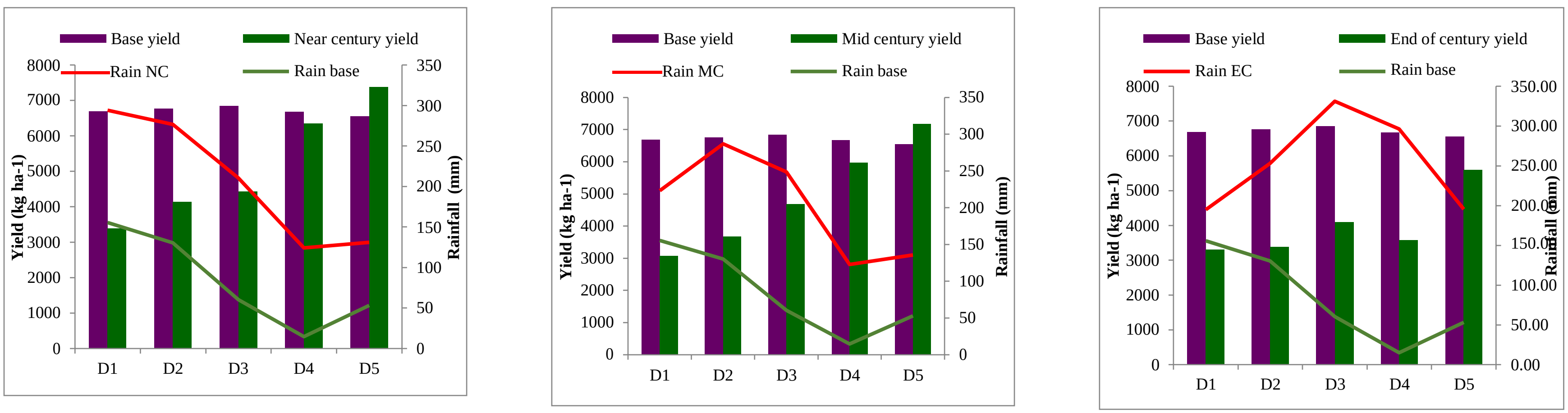
i ii iii

Fig. 5.155. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Thiruvnanthapuram



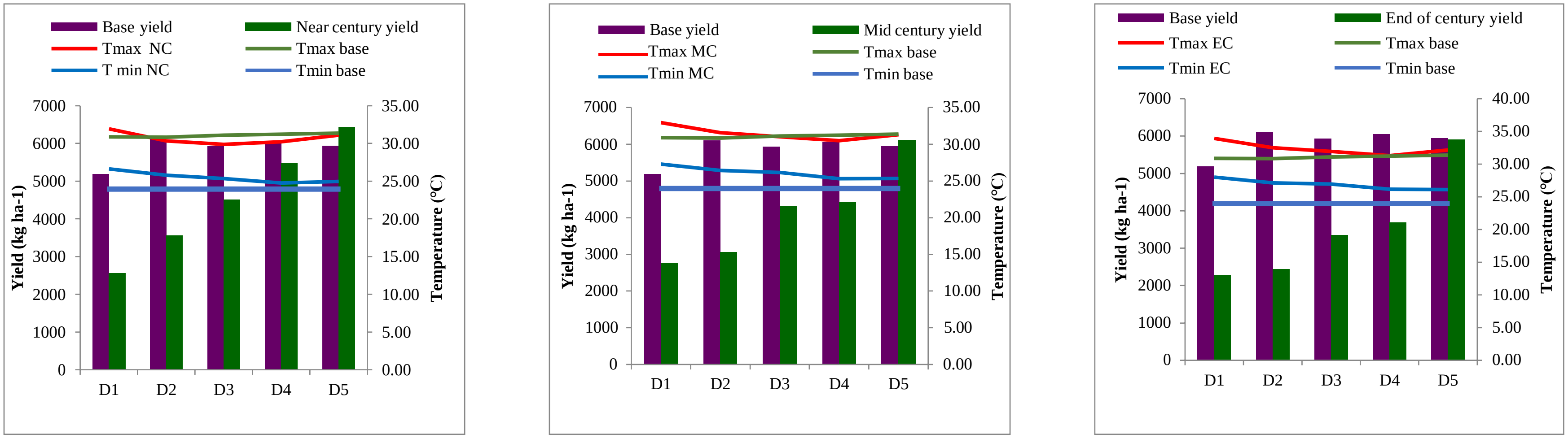
i ii iii

Fig. 5.156. (a). Effect of temperature on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Thiruvananthapuram



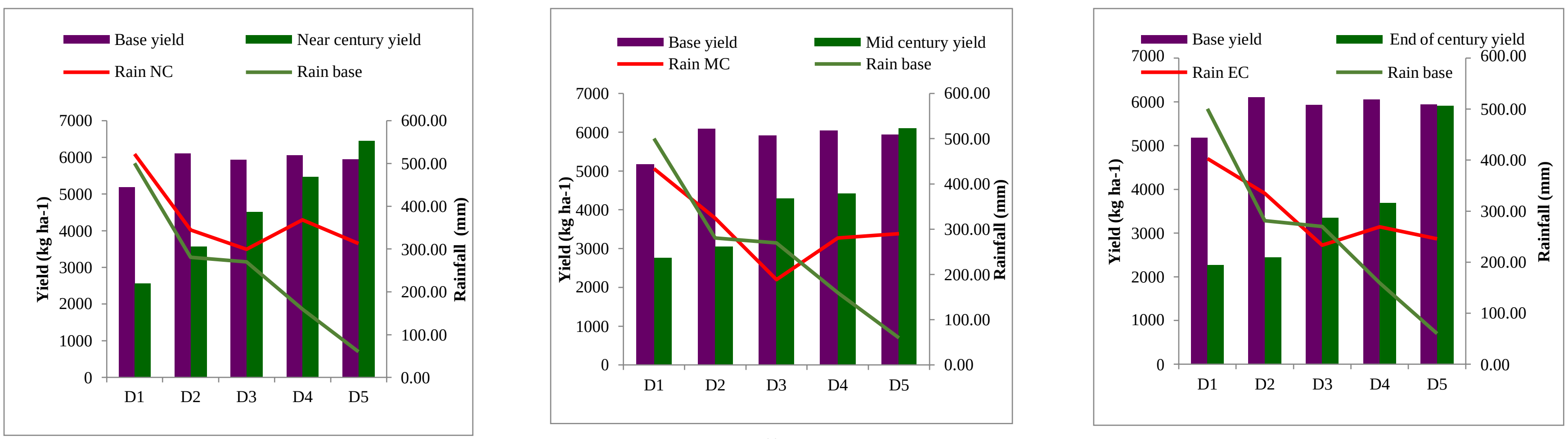
i ii iii

Fig. 5.156. (b). Effect of rainfall on yield of Jaya in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Thiruvnanthapuram



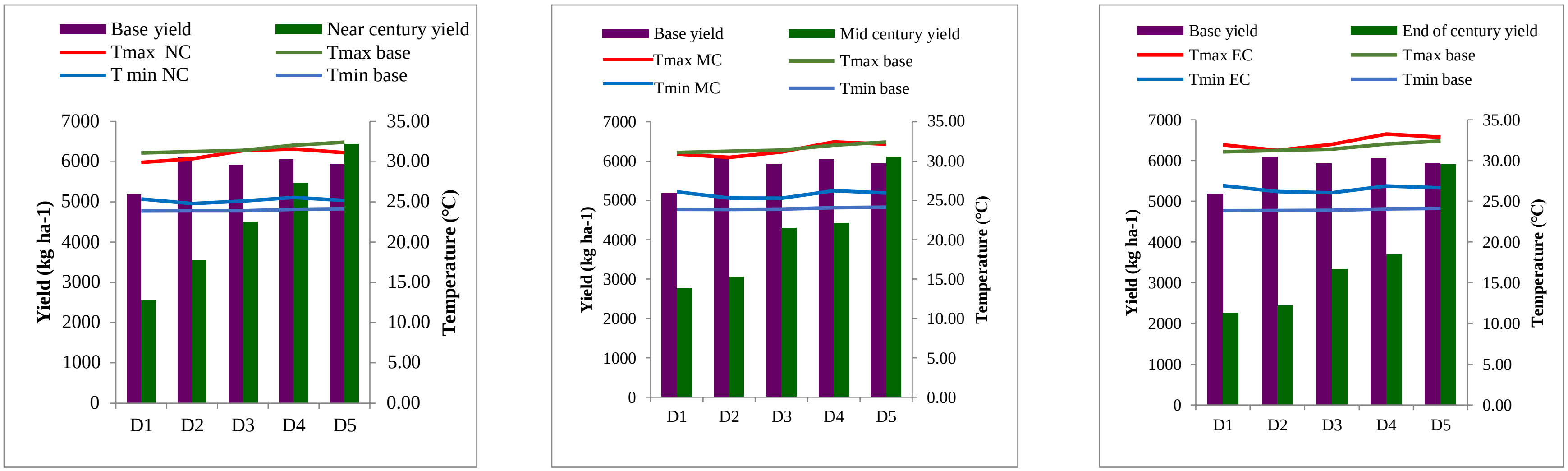
i ii iii

Fig. 5.157. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5in Thiruvananthapuram



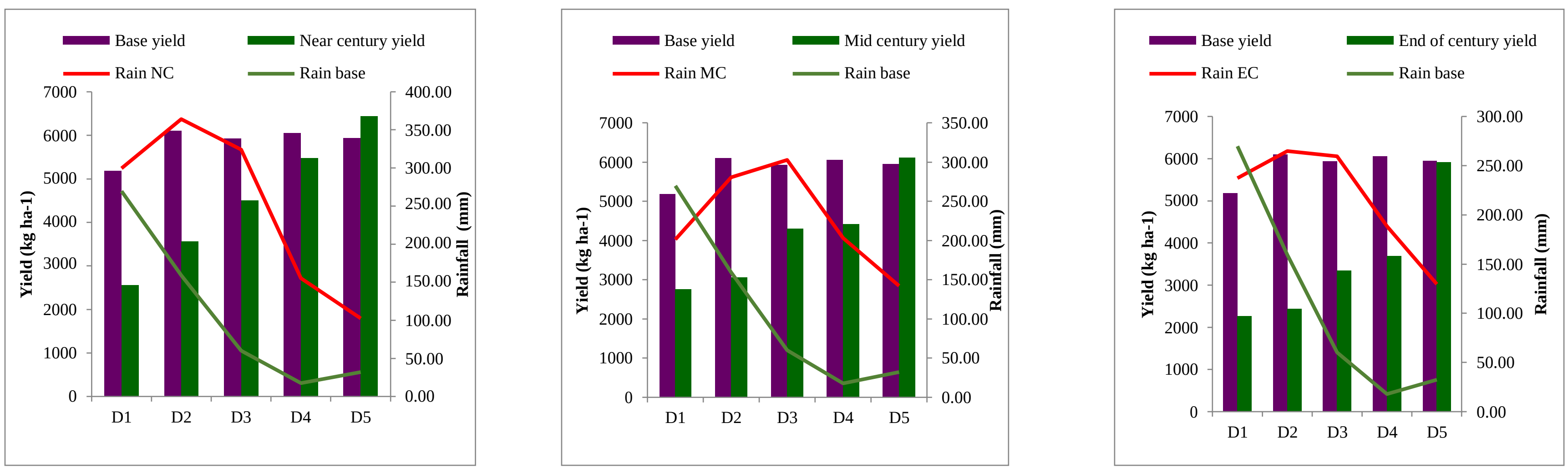
i ii iii

Fig. 5.157. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 4.5 in Thiruvnanthapuram



i ii iii

Fig. 5.158. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Thiruvananthapuram



i ii iii

Fig. 5.158. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 4.5 in Thiruvnanthapuram

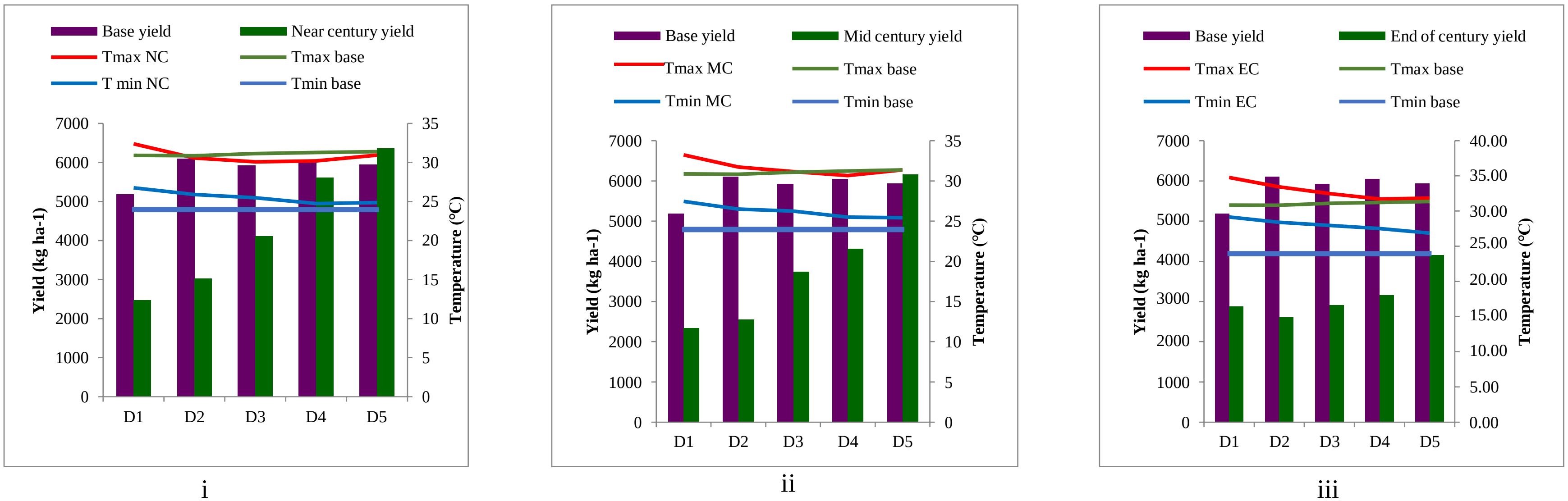


Fig. 5.159. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Thiruvananthapuram

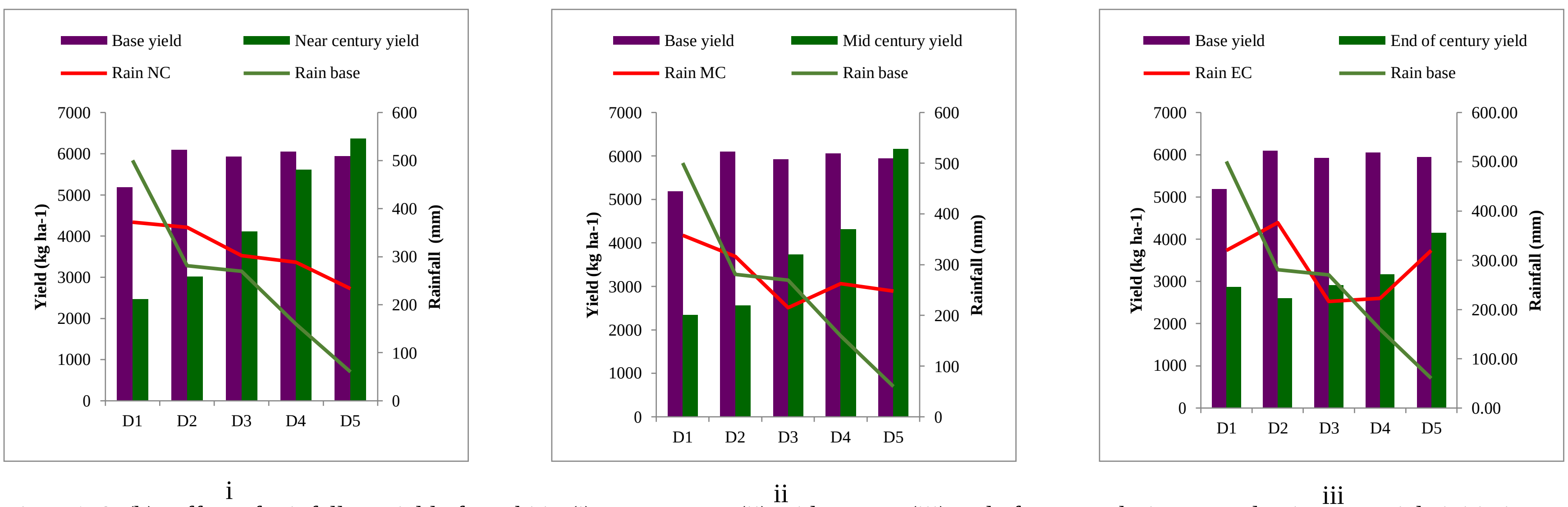
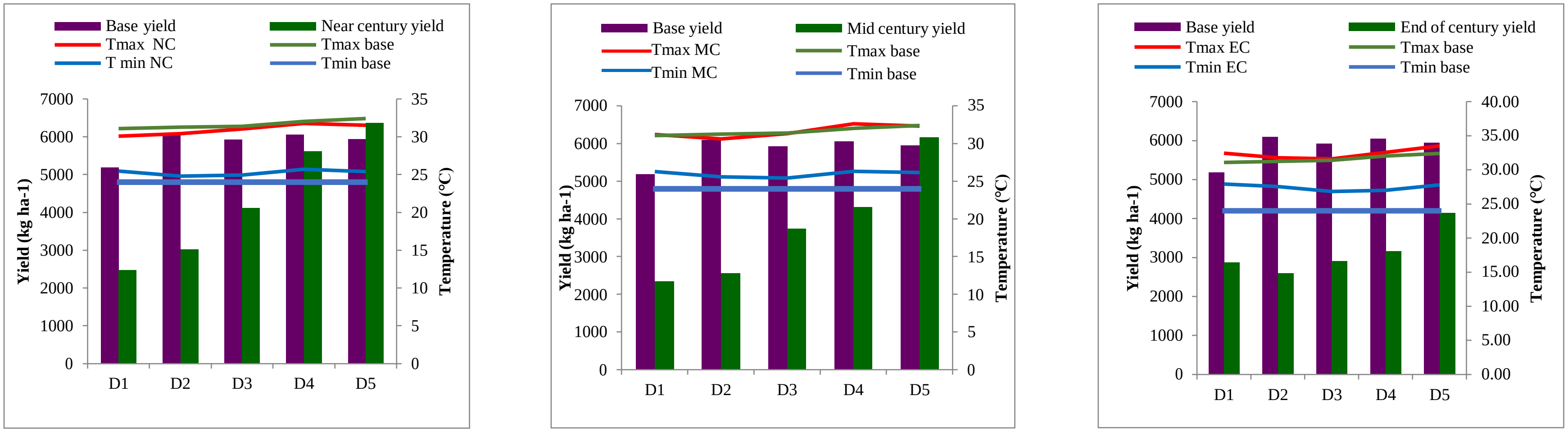
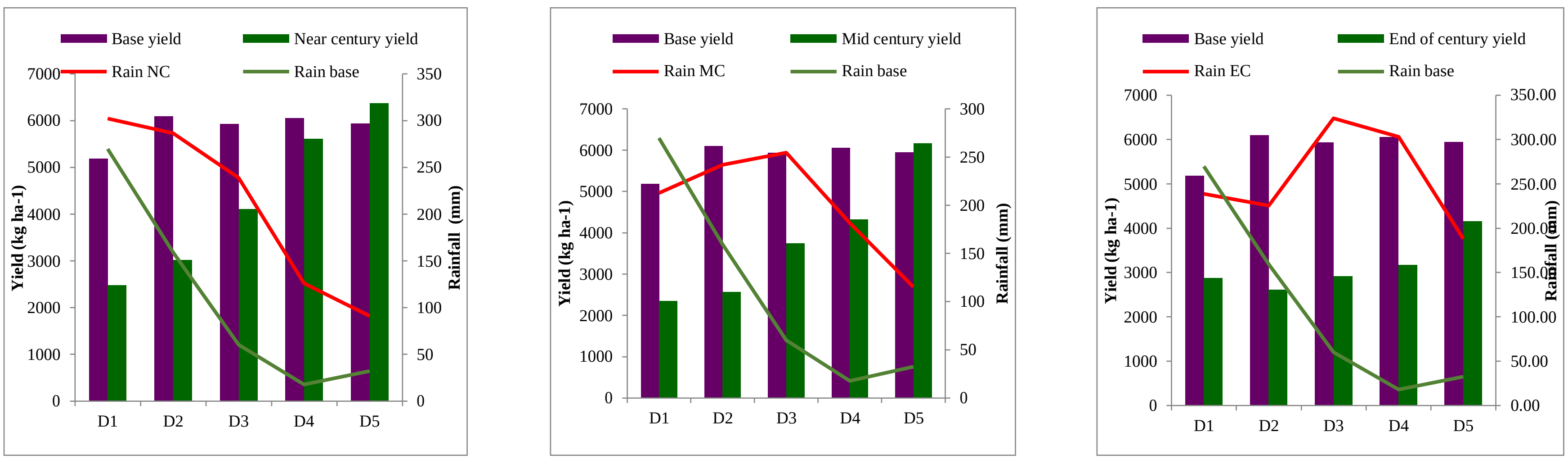


Fig. 5.159. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during transplanting to panicle initiation under RCP 8.5 in Thiruvnanthapuram



i ii iii

Fig. 5.160. (a). Effect of temperature on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Thiruvananthapuram



i ii iii

Fig. 5.160. (b). Effect of rainfall on yield of Jyothi in (i) near century (ii) mid century (iii) end of century during panicle initiation to anthesis under RCP 8.5 in Thiruvnanthapuram

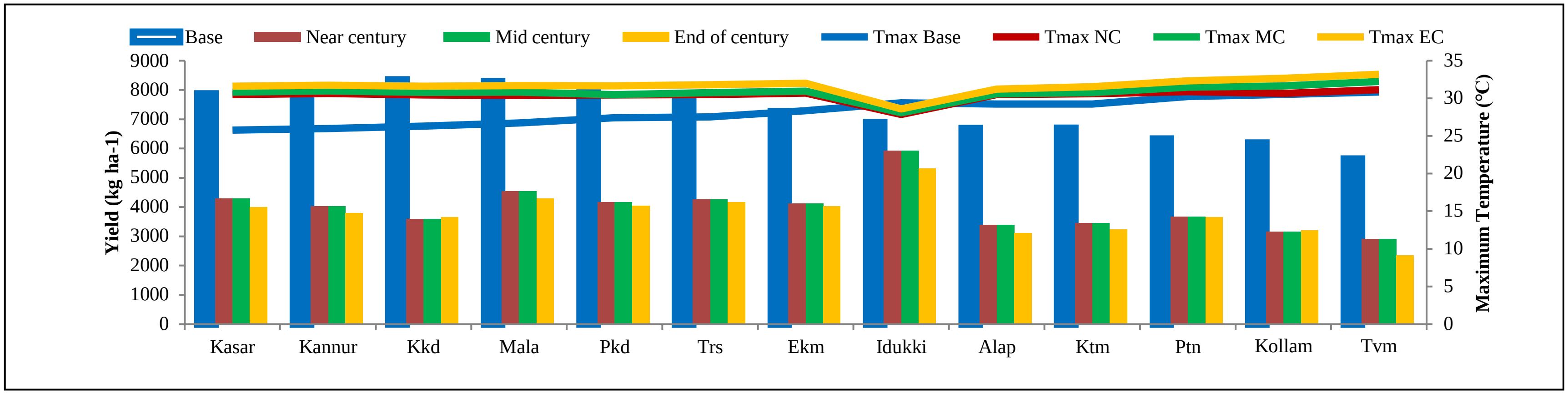


Fig.5.161. Impact of maximum temperature during panicle initiation to anthesis on yield in base period and under RCP 4.5 in early plantings in Jyothi

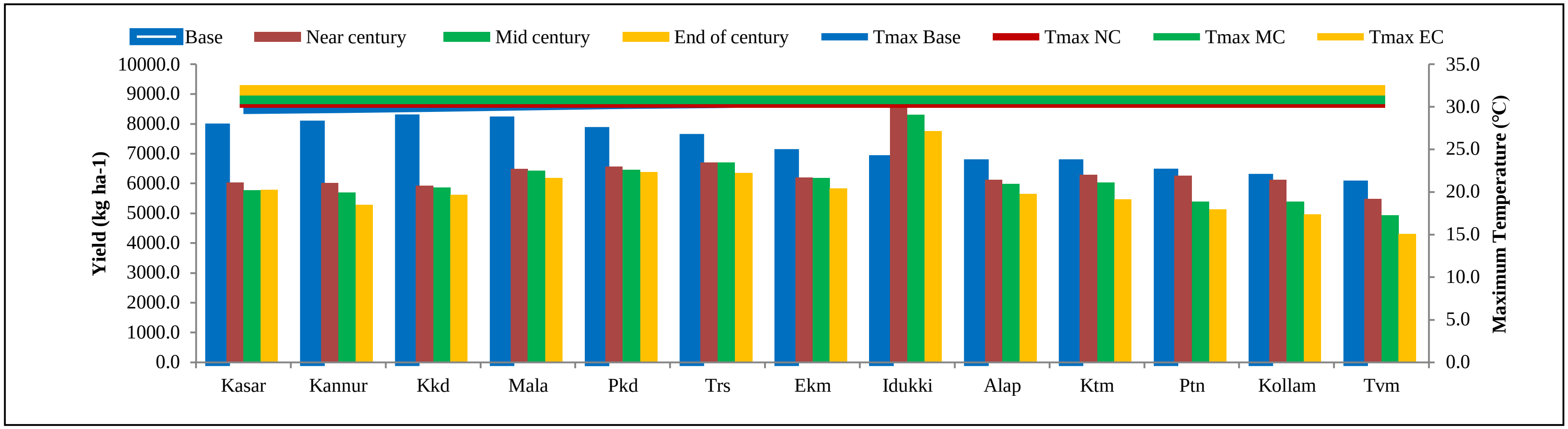


Fig.5.162. Impact of maximum temperature during panicle initiation to anthesis on yield in base period and under RCP 4.5 in late plantings in Jyothi

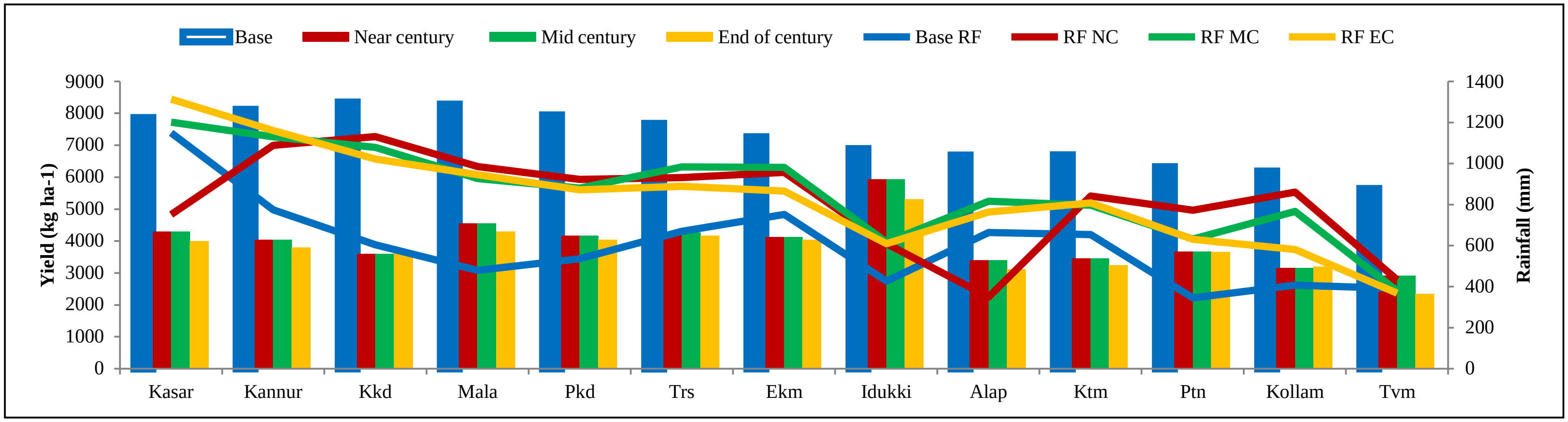


Fig.5.163. Impact of rainfall during panicle initiation to anthesis on yield in the base period and under RCP 4.5 in early plantings in Jyothi

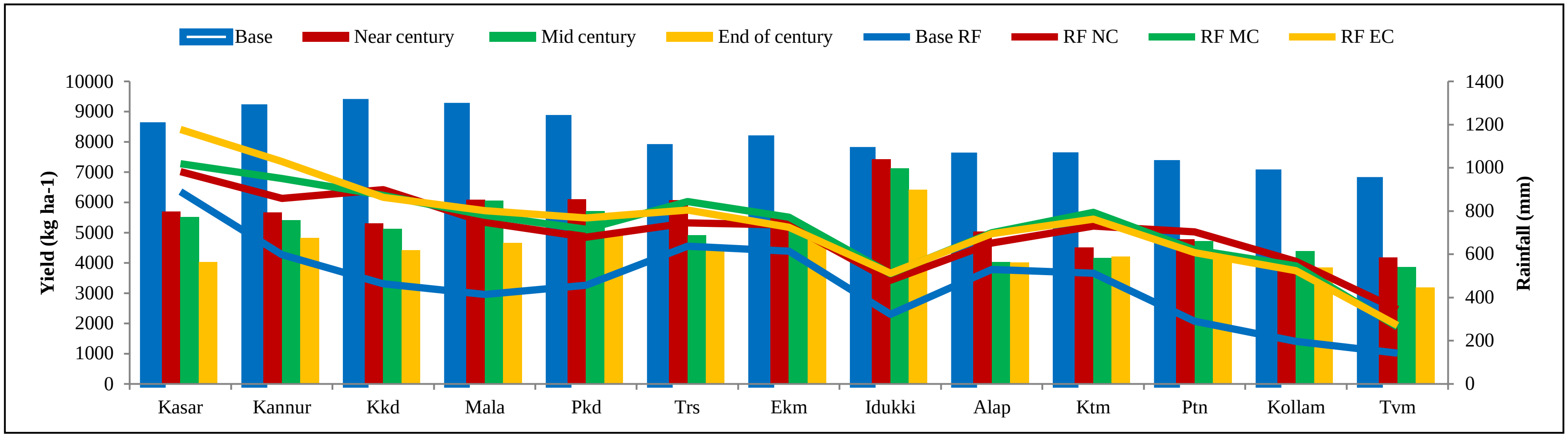


Fig.5.164. Impact of rainfall during panicle initiation to anthesis on yield in the base period and under RCP 4.5 in late plantings in Jyothi

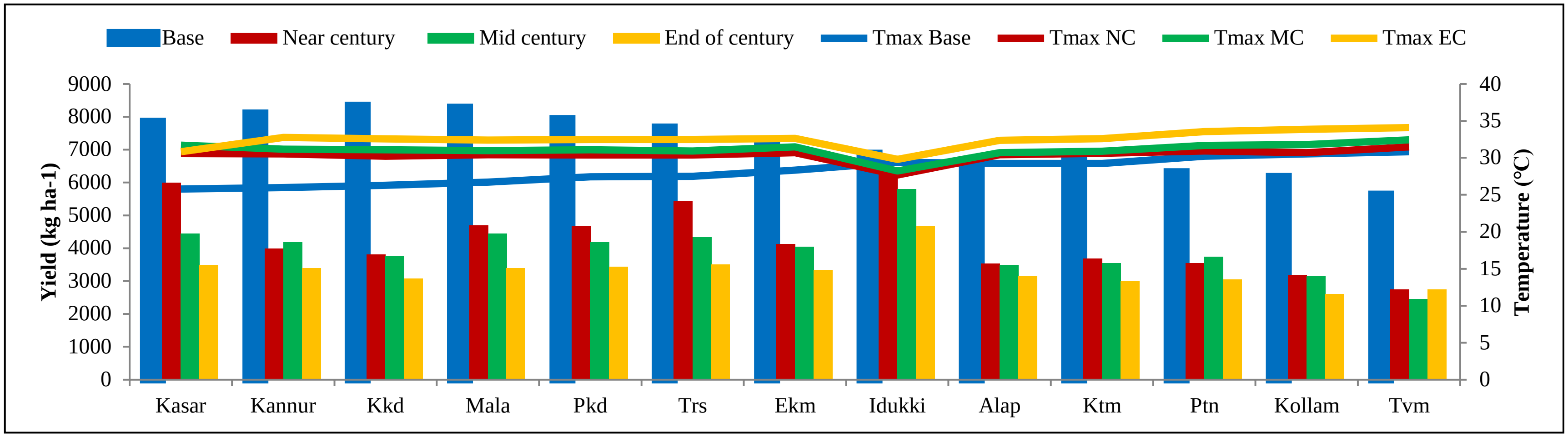


Fig.5.165.Impact of maximum temperature during panicle initiation to anthesis on yield in base period and under RCP 8.5 in early plantings in Jyothi

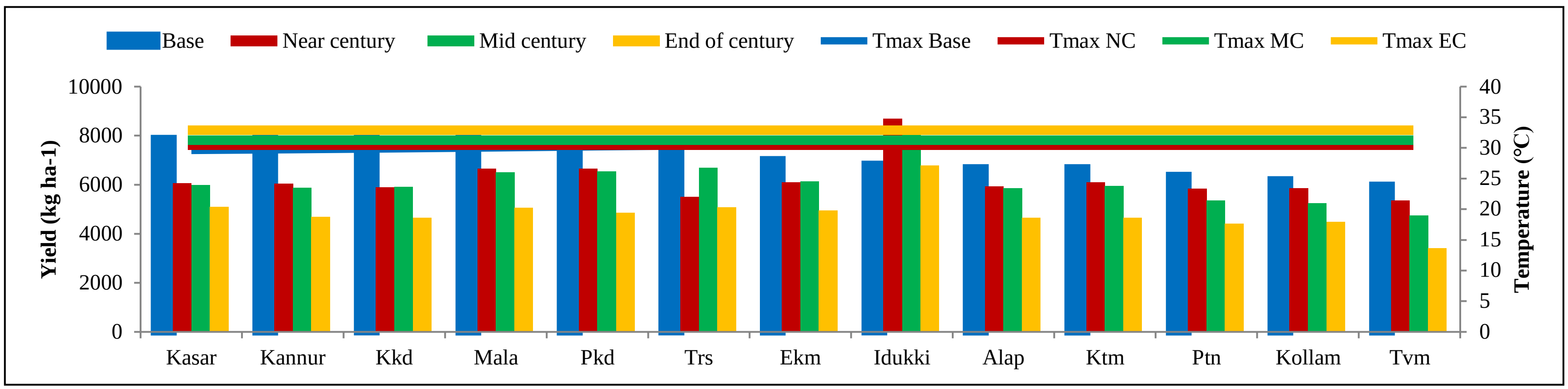


Fig. 5.166. Impact of maximum temperature during panicle initiation to anthesis on yield in base period and under RCP 8.5 in late plantings in Jyothi

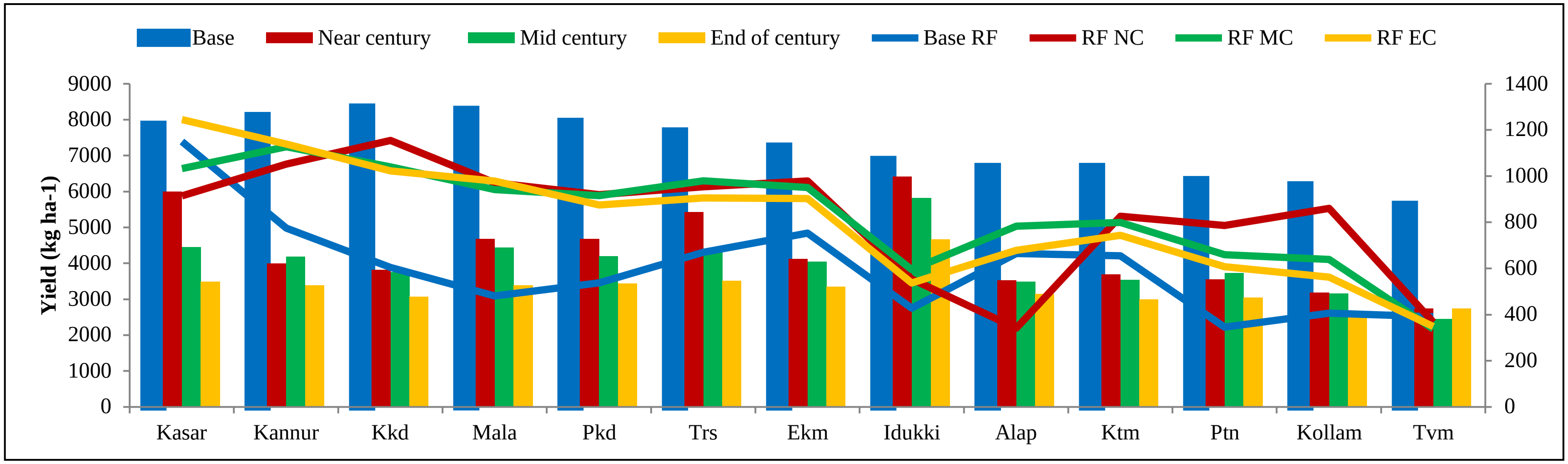


Fig. 5.167. Impact of rainfall during panicle initiation to anthesis on yield in the base period and under RCP 8.5 in early plantings in Jyothi

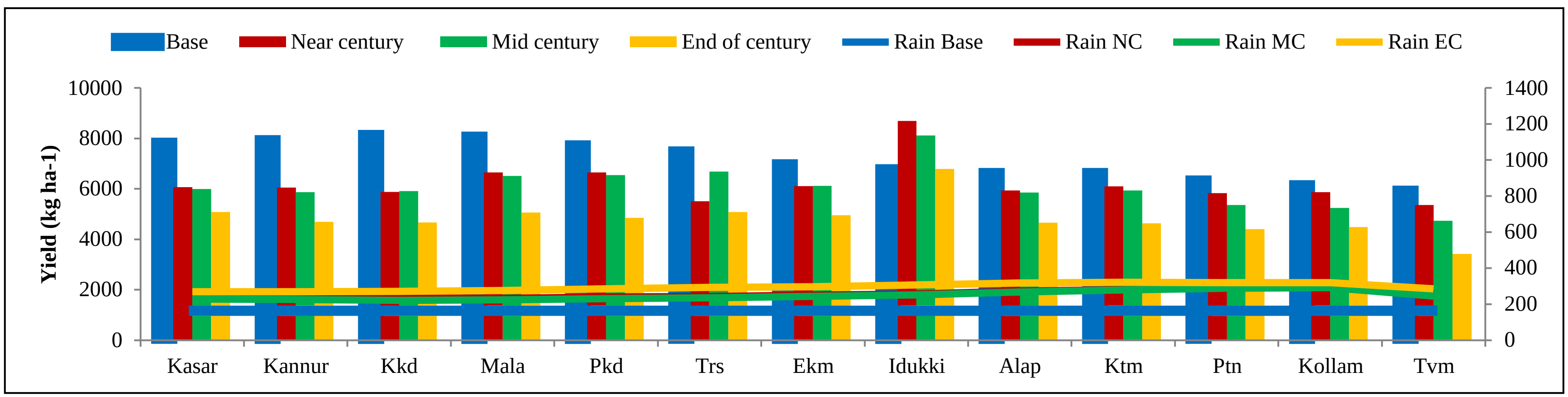


Fig. 5.168. Impact of rainfall during panicle initiation to anthesis on yield in the base period and under RCP 8.5 in late plantings in Jyothi

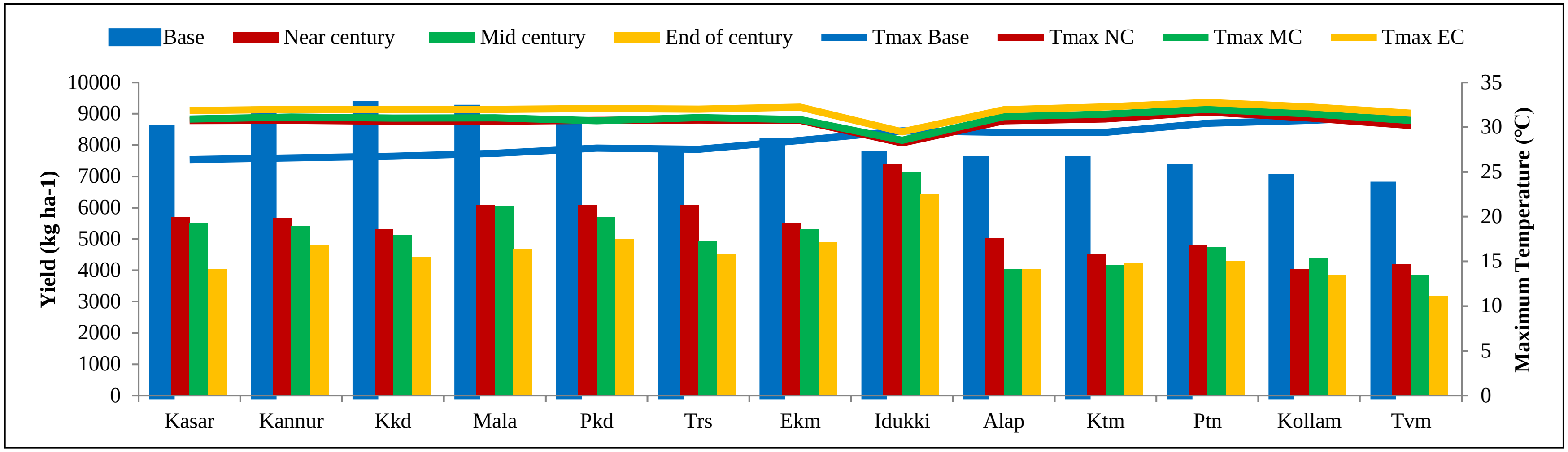


Fig. 5.169. Impact of maximum temperature during panicle initiation to anthesis on yield in base period and under RCP 4.5 in early plantings in Jaya

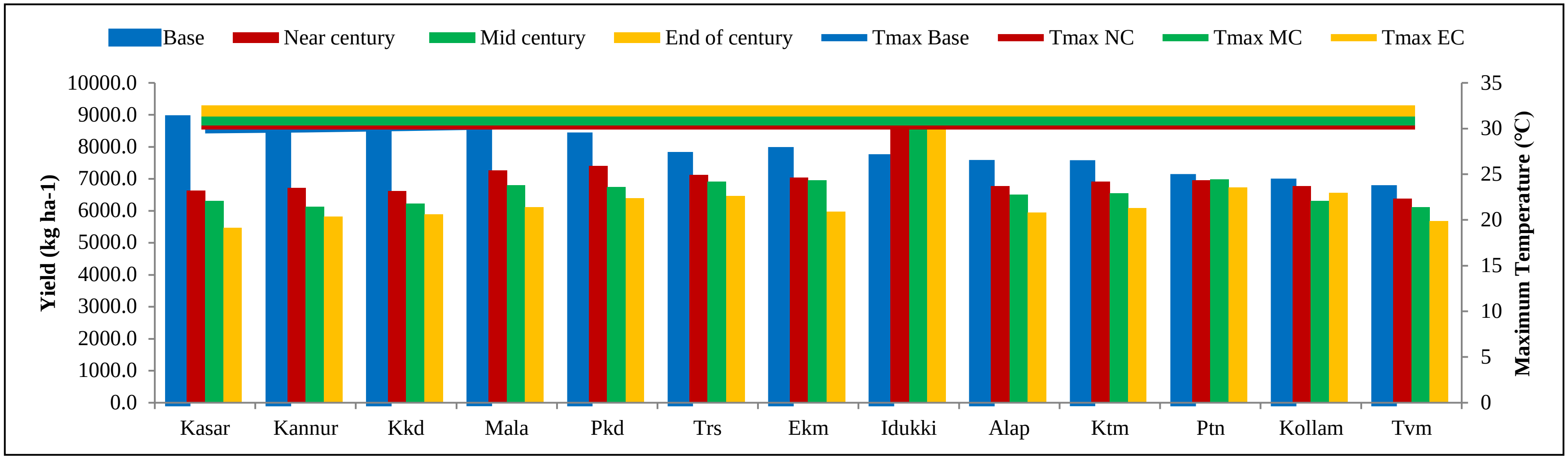


Fig. 5.170. Impact of maximum temperature during panicle initiation to anthesis on yield in base period and under RCP 4.5 in late plantings in Jaya

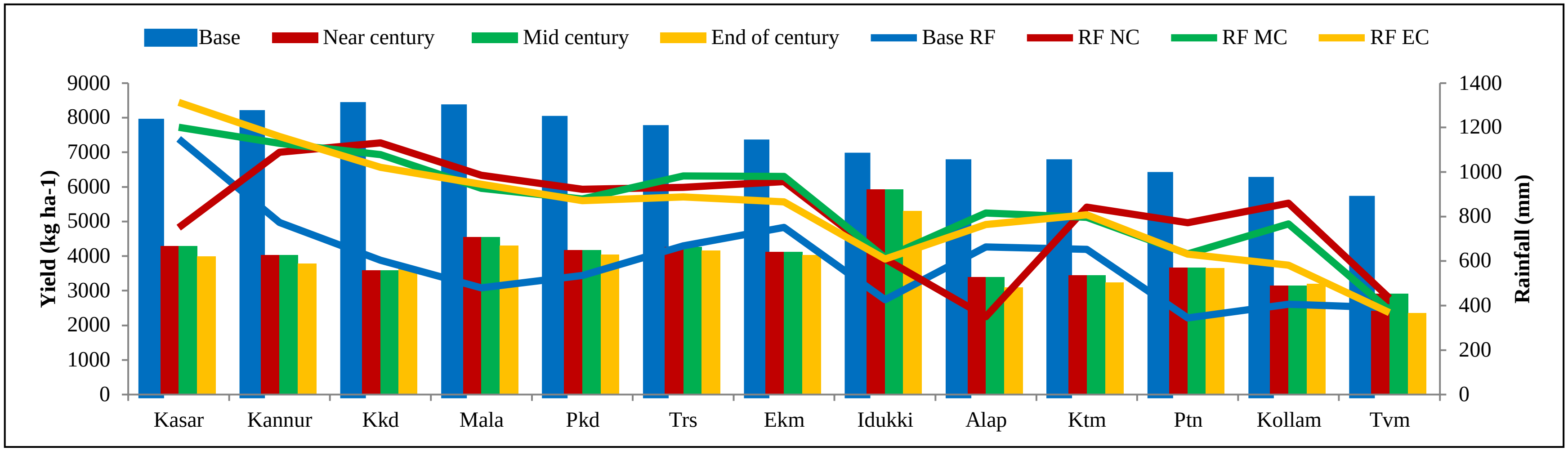


Fig. 5.171. Impact of rainfall during panicle initiation to anthesis on yield in the base period and under RCP 4.5 in early plantings in Jaya

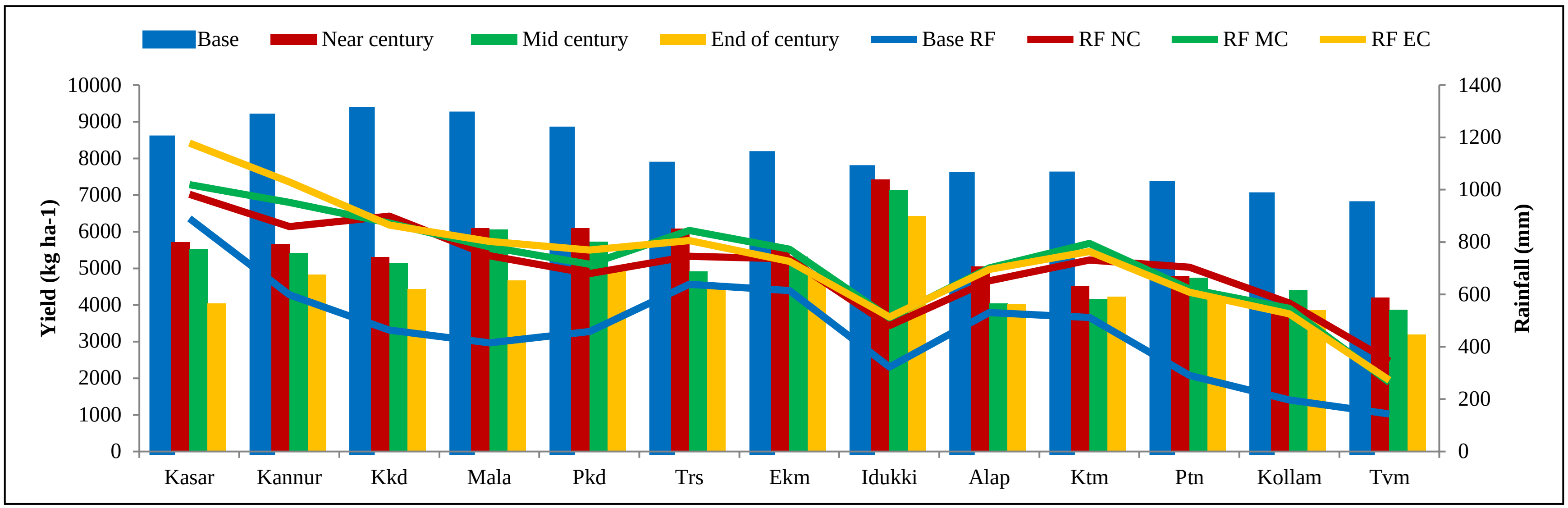


Fig. 5.172. Impact of rainfall during panicle initiation to anthesis on yield in the base period and under RCP 4.5 in late plantings in Jaya

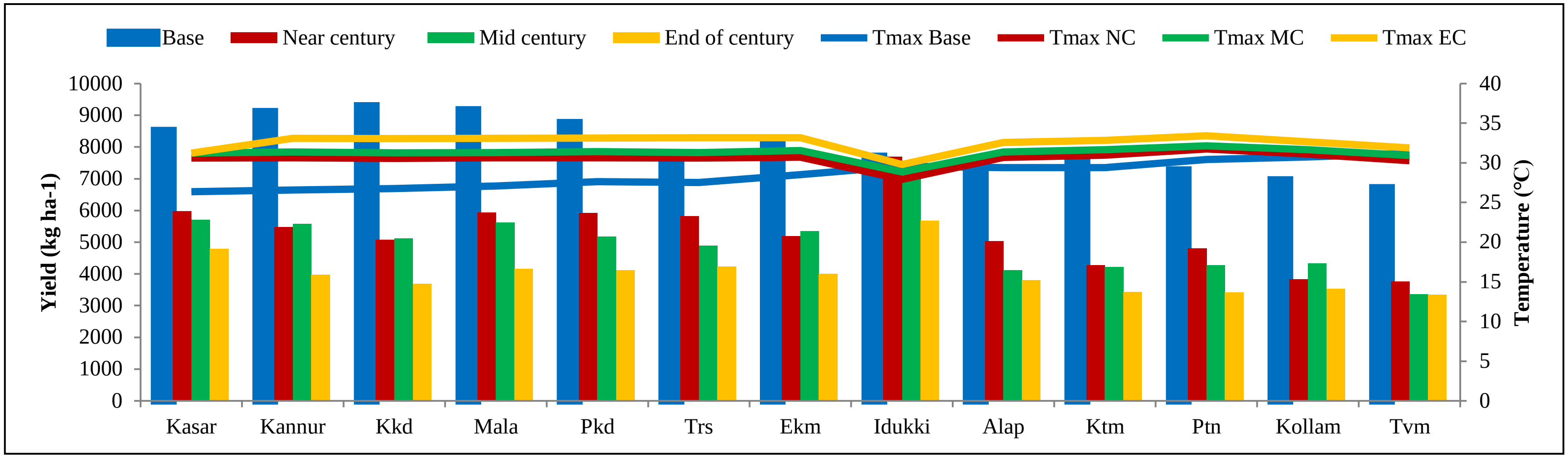


Fig. 5.173. Impact of maximum temperature during panicle initiation to anthesis on yield in base period and under RCP 8.5 in early plantings in Jaya

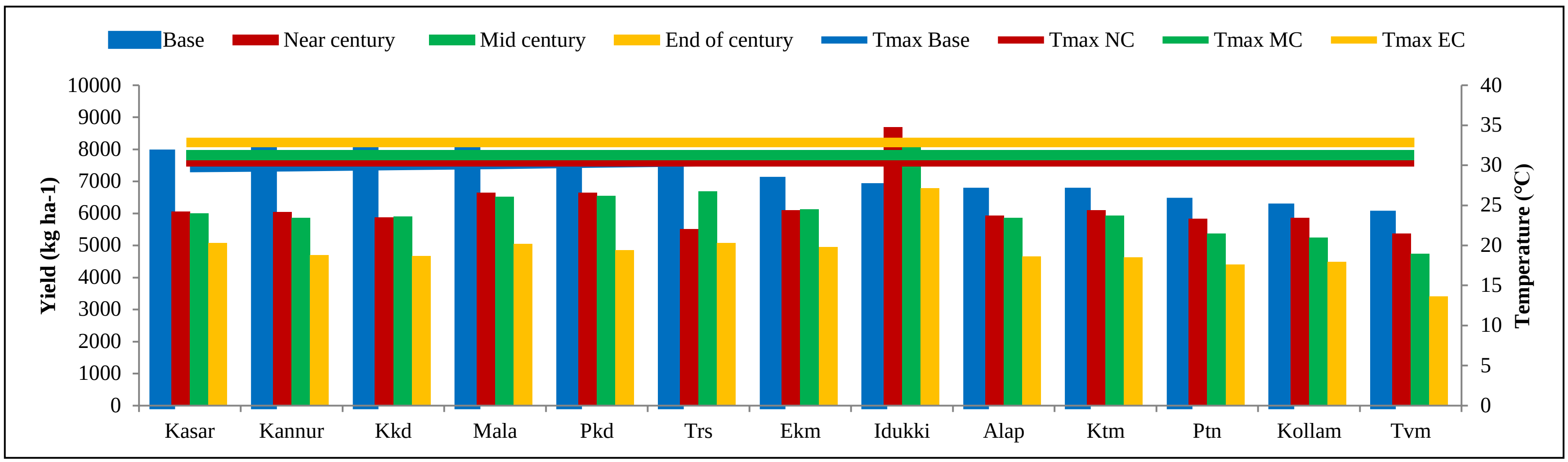


Fig. 5.174. Impact of maximum temperature during panicle initiation to anthesis on yield in base period and under RCP 8.5 in late plantings in Jaya

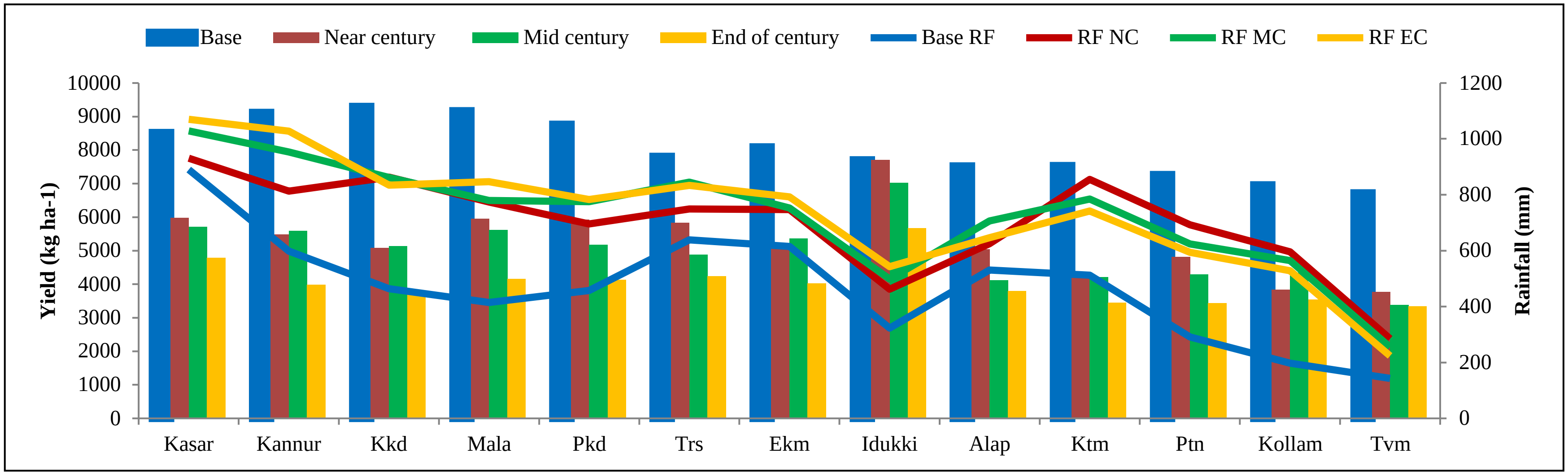


Fig. 5.175. Impact of rainfall during panicle initiation to anthesis on yield in the base period and under RCP 8.5 in early plantings in Jaya

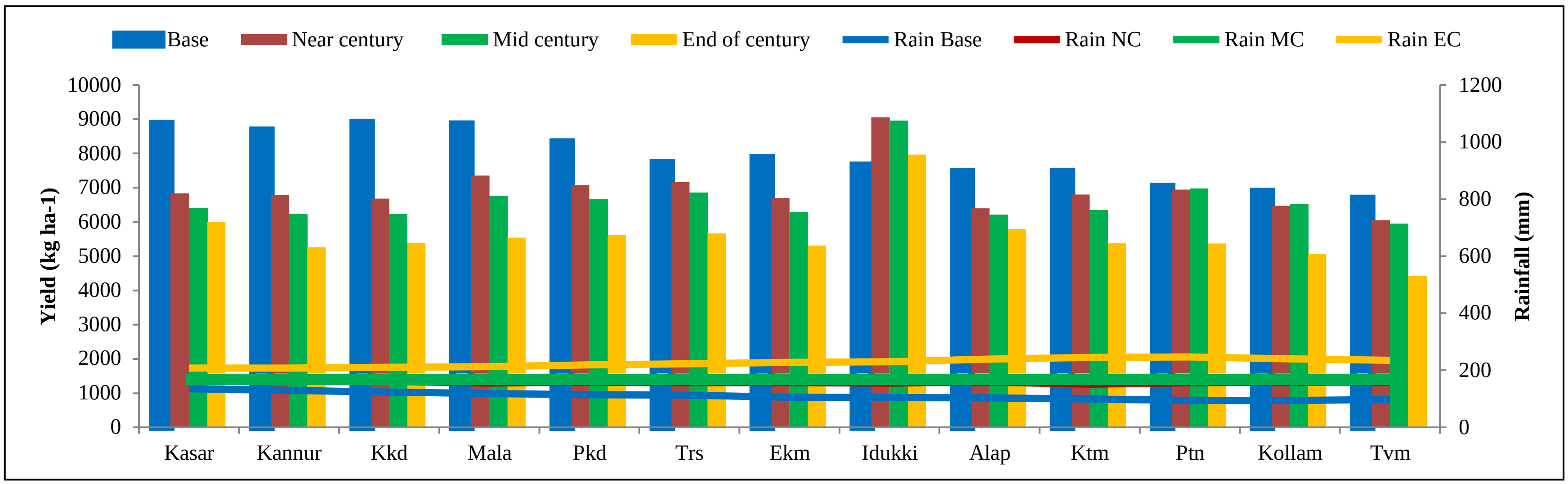


Fig. 5.176. Impact of rainfall during panicle initiation to anthesis on yield in the base period and under RCP 8.5 in late plantings in Jaya

Summary

6. Summary

The research work entitled "Spatial variability of climate change impacts on rice (*Oryza sativa* L.) yield in Kerala" was conducted in the Department of Agricultural Meteorology, College of Agriculture, Vellanikkara in the year 2020. The impact of climate change on the phenophase and yield of rice in 14 districts of Kerala had been studied.

The main objective was to study the impact of climate change on phenophase and yield aspects of rice varieties under climate change scenarios of RCP 4.5 and 8.5. Short-duration rice variety, Jyothi and medium-duration, Jaya have been selected for the experiment. The experiment was carried out split-plot design. The main plot treatments were five dates of plantings (June 5th, June 20th, July 5th, July 20th and August 5th) and subplot treatments were two varieties with four replications. A various observations like weather, phenological, biometric, physiological, yield and yield attributes had been recorded to study the crop weather relationship. Daily weather data during the experimental period had been recorded. Biometric, phenological and physiological observations were recorded for different dates of plantings in both the varieties. Observations of yield and yield attributes were noted at the harvesting time. The analyses of these observations were carried out using SPSS and R studio. Using the data obtained from the experiment the validation of genetic coefficient DSSAT- CERES model had been done and using this phenophase and yield of 13 districts of Kerala had been predicted for the future simulations. The results of this study are summarized here.

- Planting dates had a significant influence on weekly plant height during the first, third, fourth, fifth, sixth, seventh, and eighth weeks, regardless of variety.
- Among the varieties in Jyothi plant height was found to be higher when compared to Jaya. An interaction effect was found to be significant during 3rd, 4th, 5th, 9th, 10th, 11th, 12th and 13th week.
- Among the two varieties, a significant difference was observed during all intervals in dry matter accumulation was observed. Dry matter accumulation of Jyothi variety was found to be higher.

- Significant differences in the number of tillers per unit area were observed as an effect of dates of planting. Among five dates of planting, on June 20th, June 5th and August 5th plantings were found to be on par.
- It was found that the maximum leaf area index (LAI) and leaf area duration (LAD) had been recorded 75 days after planting irrespective of variety.
- The crop growth rate was obtained maximum at an interval of 45 to 60 days after planting irrespective of variety.
- A significant difference was found in the number of filled grains as an effect of dates of planting. Filled grains in Jyothi was found to be superior in June 5th planting and in Jaya, July 5th and August 5th planting was found to be on par. Number of filled grains showed a negative correlation with rainfall.
- In Jaya, July 20th and August 5th planting were found to be superior and on par. While in the case of Jyothi, June 5th planting and August 5th plantings were found to be superior and on par.
- To assess the change in the future climate of Kerala, the current climate (1980 – 2020) was evaluated against the simulated weather data obtained from the MarkSim GCM-DSSAT weather file generator using the climate model GFDL CM3. The current climate (1980 – 2020) has been compared with three different future 2010-2030 (near-century), 2021-2050(mid-century) and 2051-2080 (late-century) simulations for the 14 districts of Kerala which has been divided into five agro-climatic zones *i.e.* Northern zone, central zone, high range zone, problematic zone, and southern zone under Representative concentration pathway (RCP) 4.5 and 8.5.
- The annual and seasonal (southwest monsoon, northeast monsoon, winter and summer season) analysis has been carried out. The analysis of the annual weather data for solar radiation, maximum temperature, and minimum temperature showed an increasing trend in almost all the districts of Kerala under different future simulations under both the RCPs.
- Under RCP 4.5 large excess rainfall was expected in Kollam, Wayanad and Pathanamthitta. An excess rainfall is expected in northern zone and central zone. The

rainfall was expected to be normal in Idukki, Alappuzha, and Kasargod during the near and mid centuries. By the end of century in almost all parts of Kerala, an excess rainfall was predicted except in the problematic zones of Kerala and in Idukki and Kasargode.

- Under RCP 8.5 in near-century a large excess and excess annual rainfall is predicted in most parts of Kerala expect in Idukki, Alappuzha, Thiruvananthapuram and Kasargod.
- During the southwest monsoon season, an increase in temperature (maximum and minimum) is expected in all the future simulations except in high ranges. In high ranges, temperatures showed a decreasing trend in the near and mid-centuries and by the end of century an increasing trend was observed under both RCPs.
- Under RCP 4.5 solar radiation showed an increasing trend in most parts of Kerala except in Kannur, Ernakulam, Idukki, and Thiruvananthapuram by mid-century. By the end of century a normal departure in solar radiation is expected during the southwest monsoon season. Under RCP 8.5, by the end of century a normal departure in solar radiation is expected expect in Kasargod, Kozhikode, Wayanad and Thiruvananthapuram where the solar radiation is expected to decrease.
- Southwest monsoon is expected to show a large excess and excess departure in most parts of Kerala except in Kasargod where a normal departure is expected. Under RCP 4.5 a decrease rainfall is expected to decrease in Wayanad and Alappuzha by the end of century while under RCP 8.5 an increase in rainfall is expected in Thiruvananthapuram and Wayanad.
- From the analysis of northeast monsoon season it was observed that under RCP 4.5 solar radiation showed an increase in most places in all the future simulations. By the end of century the solar radiation expected to increase in most parts of Kerala. In northern zone a normal departure is expected except in Kannur which showed a markedly above normal increase in solar radiation. In central and problematic zone also markedly above normal increase in solar radiation is observed except in Palakkad and Alappuzha where an above normal increase is expected. . In southern zone of

Kerala an above normal departure is expected except in Thiruvananthpuram where there is a normal departure of solar radiation.

- Under RCP 8.5 by the end of century departure was found be normal in most places with few exceptions. Kannur and Kottayam showed an above normal increase in solar radiation. Kozhikode and Thiruvanthpuram showed a markedly below normal departure in solar radiation and Idukki showed below normal departure in solar radiation.
- The Northeast monsoon is predicted to decrease from normal in almost all parts of Kerala under RCP 4.5. While under RCP 8.5 a normal departure of rainfall has been expected in most parts in near century.
- During the winter season, an increase in maximum temperature is expected in the northern zone while in the southern zone a normal departure is expected in the near and mid-century, and by the end of century the temperature is expected to increase except in high ranges.
- The minimum temperature is expected to increase in most parts (> 1.5°C) except in the high range zone in winter season in both RCPs.
- Winter rainfall is predicted to decrease from normal in almost all parts of Kerala in near century. But by the end of century under RCP 4.5 and by mid and end of the century under RCP 8.5 an excess rainfall is predicted in parts of the Northern zone and problematic zone.
- From the analysis of temperature during the summer season, it was observed that maximum and minimum temperatures had an increasing trend during all the future simulations except in high ranges. In the high range zone, a normal and below normal departure is observed in Wayanad and Idukki respectively during the near and mid-centuries. By the end of century a normal departure is expected.
- There was a spatial variation in summer rainfall, with excess or normal rainfall in some parts at the same time deficiency in other parts of Kerala is expected. A large excess and excess rainfall are expected in the northern zone and central zone of Kerala during the summer season. In the high range zone, a reduction in rainfall is

expected in Idukki while it showed an increase in Wayanad during all future simulations. In the problematic zone, normal summer showers are expected. In the southern zone, an excess rainfall is expected in the near century and then it showed a decreasing trend *i.e.* by mid and end of century, normal departure is expected except in Thiruvananthpuram where a deficient rainfall is expected.

- A normal departure of solar radiation is expected to increase in most parts of Kerala (central zone, problematic zone, and southern zone except Thiruvananthpuram). In Kannur, Kozhikode, Thiruvananthapuram and Wayanad solar radiation is expected to decrease less than -1.5 MJ m^{-2} by the end of century under RCP 8.5 except in Malappuram where an above normal increase is expected.
- The potential yield had been predicted using the predicted weather for 13 districts of Kerala. Yield reduction is expected in future simulations under both the RCPs in most places of Kerala.
- The duration of crop showed a negative correlation with the temperature. As result a decrease in duration of phenophase had been observed in future simulations.
- By the end of century a decrease the duration Jyothi decreased and was found to be between 91 to 94 days. In Idukki the duration of Jyothi is expected to increase *i.e.* 115, 112 and 107 days in near mid and end of century respectively.
- In Jaya by the end of century the duration of crop decreased to 104 to 102 days. In Idukki the duration of Jaya is expected to increase *i.e.* 116, 125 and 123 days in near mid and end of century respectively.
- Under RCP 4.5 the yield of Jyothi planted on June 5th showed maximum deviation from base period. The maximum deviation was observed in Kozhikode *i.e.* in near (-58%), mid (-63%) and end of century (-60%) under RCP 4.5 and in near (-62%), mid (-60%) and end of century (-64%) under RCP 8.5.
- The least deviation was found in July 20th planting in all the future simulations. In Idukki an increase in yield had been observed in July 5th, July 20th and August 5th plantings. An increase by 34%, 28% and 23% in near, mid and end of century respectively under RCP 4.5.

- Under RCP 8.5 in July 20th planting higher yield has been observed and shows a positive deviation of 38%, 28% in near and mid-century respectively. By the end of century, yield is expected to decrease except in August 5th planting which showed a positive deviation of 12%. In southern zone the highest potential yield had been observed in August 5th planting.
- In Jaya, maximum deviation in yield had been observed during June 5th planting in Kozhikode *i.e.* in near (-58%), mid (-63%) and end of century (-60%) under RCP 4.5 and in near (-62%), mid (-60%) and end of century (-64%) under RCP 8.5.
- In Idukki under RCP 4.5 an increase in yield was observed during July 20th planting with an increase by 27% in near and mid-century and by the end of century a deviation of 20% was observed.
- Under RCP 8.5 in July 20th planting higher yield has been observed and shows a positive deviation of 27%, 24% and 10% in near, mid and end of century respectively in Idukki.
- In southern zone of Kerala highest potential yield of Jaya has been observed in July 20th planting in all the future simulations under both RCPs.
- An increased temperature and precipitation patterns during panicle initiation to anthesis may be the reason for the yield variability.
- During the base period higher yield was obtained during June 5th and June 20th planting *i.e.* early plantings while in future simulations the higher yield is expected in July 5th, July 20th and August 5th plantings *i.e.* late plantings. Hence there is a chance of shift in date of planting in Kerala in future.

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Appendices

(i)

Appendix I

Abbreviations and units used

Weather parameters

Tmax : Maximum temperature

Tmin : Minimum temperature

Trange : 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

T – AT : Transplanting – active tillering

T – PI : Transplanting – panicle initiation

T – B : Transplanting – booting

T – H : Transplanting - heading

T – F : Transplanting - flowering

T - PM: Transplanting- Physiological maturity

Varieties

Jy – Jyothi

Ja - Jaya

Units

g : gram

kg ha^{-1} : kilogram per hectare

kg : kilogram

% : per cent

km hr^{-1}: kilometre per hour

^{0}C : degree Celsius

Growth indices

LAI – Leaf area index

CGR – Crop growth rate

LAD – Leaf area duration

NAR- Net assimilation rate

Districts

Kasargod- Kasar

Kannur- Kannur

Kozhikode- Kkd

Malappuram- Mala

Palakkad- Pala

Thrissur- Tsr

Ernakulam- Ekm

Idukki- Idukki

Wayanad- Waya

Alappuzha- Alp

Kottayam-Ktm

Pathanamthitta- Ptn

Kollam – Kollam

Thiruvananthapuram - Tvm

Appendix II

ANOVA of different plant growth characters of 2020 experiment

Plant height at different weeks after planting

Source of variation	**DF**	**Mean sum of squares**							
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Date of planting	4	24.14**	9.35	22.36*	204.41***	472.71***	793.57***	295.69**	167.27**
Error(a)	12	3.32	4.79	6.50	11.62	17.24	35.00	32.38	21.35
Variety	1	47.22**	71.98**	117.24**	362.52***	582.86***	1113.45***	426.28*	613.40**
DOP x Variety	4	1.99	13.34	80.98***	99.78**	100.15***	48.71	41.32	57.23
Error(b)	15	4.07	6.80	8.01	13.53	8.04	20.44	53.57	38.03

Source of variation	**DF**	**Mean sum of squares**				
		Week 9	Week 10	Week 11	Week 12	Week 13
Date of planting	4	57.44	100.39	102.98	67.04	127.66
Error(a)	12	25.54	70.84	64.99	57.71	64.06
Variety	1	720.63***	1006.81***	1067.71***	122.11***	851.47***
DOP x Variety	4	136.97*	180.06**	151.74**	125.49*	165.32*
Error(b)	15	37.50	23.54	27.97	27.05	35.62

DF – degrees of freedom -***Significant at 0.1% level -** Significant at 1% level -* Significance at 5% level

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
Date of planting	4	50190	698109	1948476	4017394	8616250*	10376918**
Error(a)	12	32587	312211	761711	1413201	1987279	1868859
Variety	1	356170*	6221147**	40647870***	175743195*	291926521***	88800224***
DOP x Variety	4	23752	754753	689342	2039710	2249533	7409800
Error(b)	15	45545	661814	721679	1519809	2035156	3552716

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	Panicles per m^2	Spikelets per panicle	Number of filled grains per panicle	1000 grain weight	Chaff per panicle	Straw yield	Tillers per m^2
Date of planting	4	9823535***	3924.3**	698.88*	1241.50	6.98	1118.12	2344131	15005***
Error(a)	12	809228	1216.6	204.31	257.17	3.72	92.58	1299350	851.3
Variety	1	605160	18757.6*	165.24	765.19	7.66	139.32	4291392	3496.9
DOP x Variety	4	9974285**	9423.6*	83.05	1069.17	12.52	957.35	2019436	15891.1*
Error(b)	15	1222407	2830.9	122.38	150.13	2.75	140.94	3253780	4083.9

DF – degrees of freedom -***Significant at 0.1% level -** Significant at 1% level -* Significance at 5% level DAT – days after planting

Appendix II (Contd.)

Leaf area index at fortnightly intervals

Source of variation	**DF**	**Mean sum of squares**					
		15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Date of planting	4	0.036**	0.44	1.66	2.71	2.48	1.35
Error(a)	12	0.047	0.14	0.52	1.20	1.21	1.26
Variety	1	0.148***	6.13***	14.00***	24.93***	32.48***	23.36***
DOP x Variety	4	0.022*	0.09	1.07	1.46	4.08**	2.27
Error(b)	15	0.006	0.133	0.512	0.99	0.814	0.95

Leaf area duration at fortnightly intervals

Source of variation	**DF**	**Mean sum of squares**				
		15-30 DAT	30-45 DAT	45-60 DAT	60-75 DAT	75-90 DAT
Date of planting	4	24.95	93.26	152.48	139.52	75.82
Error(a)	12	8.16	29.64	67.53	68.11	70.81
Variety	1	345.28***	787.80***	1402.37***	1826.92***	1314..27***
DOP x Variety	4	5.08	60.40	82.52	229.73**	128.07
Error(b)	15	7.50	28.83	56.0	45.76	53.74

DF – degrees of freedom -***Significant at 0.1% level -** Significant at 1% level -* Significance at 5% level
DAT – days after planting

Appendix II (contd.)

Crop growth rate at fortnightly intervals

Source of variation	**DF**	**Mean sum of squares**				
		15-30 DAT	30-45 DAT	45-60DAT	60-75 DAT	75-90 DAT
Date of planting	4	6.71	77.42*	350.97***	64.97*	268.53***
Error(a)	12	11.92	18.20	22.48	14.68	13.45
Variety	1	133.59**	27.24	318.72*	64.40	2143.46***
DOP x Variety	4	20.02	22.91	53.32	34.44	115.70
Error(b)	15	15.10	25.82	41.59	23.03	29.60

DF – degrees of freedom -***Significant at 0.1% level -** Significant at 1% level -* Significance at 5% level DAT – days after planting

Net assimilation rate at fortnightly intervals

Source of variation	**DF**	**Mean sum of squares**				
		15-30 DAT	30-45 DAT	45-60DAT	60-75 DAT	75-90 DAT
Date of planting	4	87.82**	47.55**	10.10**	1.32	1.04***
Error(a)	12	13.06	6.281	1.68	0.97	0.106
Variety	1	140.34	5.621	4.80	16.83***	6.46***
DOP x Variety	4	91.52	8.439	6.26*	0.43	0.97*
Error(b)	15	33.701	4.302	1.82	0.84	0.24

DF – degrees of freedom -***Significant at 0.1% level -** Significant at 1% level -* Significance at 5% level DAT – days after planting

SPATIAL VARIABILITY OF CLIMATE CHANGE IMPACTS ON RICE(*Oryza sativa* L.) YIELD IN KERALA

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Rice is one of the essential food crops of the world. Almost 40% of the world's population consumes rice as their staple food. Nearly 12% of the total cultivated area in Kerala accounts for rice cultivation. It is cultivated in both plains and high altitudes, therefore long-term climatic changes within a region and their impact on productivity is very important. Crop weather models have a vital role in climate change studies. Rice studies are mainly carried out in the CERES- Rice (Crop Environment Resource Synthesis- Rice) model. The CERES - Rice has been calibrated and validated and found suitable for simulation of rice growth and development in the tropical humid climate. The present experiment was aimed to study the impact of climate change on phenophase and yield aspects of rice varieties under climate change scenarios of RCP 4.5 and 8.5 in 14 districts of Kerala.

Short-duration rice variety, Jyothi and medium-duration variety, Jaya have been selected for the experiment. The experiment was carried out with the split-plot design. The main plot treatments were five dates of plantings (June 5th, June 20th, July 5th, July 20th and August 5th) and subplot treatments were two varieties (Jyothi and Jaya) with four replications. Various observations like weather, phenological, biometric, physiological, yield and yield attributes had been recorded to studythe crop weather relationship. The crop weather analysis has been carried out with SPSS software. The results indicated that duration of phenophases had a negative correlation with the maximum temperature. A significant variation in the biometric observations was also obtained. Plant height and dry matter accumulation were found to be higher in Jyothi when compared to Jaya. Both varieties recorded the maximum leaf area index (LAI) and leaf area duration (LAD) at 75 days after planting. The crop growth rate was obtained maximum at an interval of 45 to 60 days after planting irrespective of the variety. The highest grain yield in Jyothi was obtained during June 5th and August 5th plantings which were found to be on par. In Jaya, July 20th planting and August 5th planting were found to be on par. Using the observations from the field, validation of genetic coefficient of DSSAT- CERES model.

To study the impact of climate change on rice production, climate change in Kerala had been estimated. The current climate (1980 – 2020) has been compared with three different future 2010-2030 (near-century), 2021-2050 (mid-century) and 2051-2080 (late-century) simulations for the 14 districts of Kerala under Representative Concentration Pathway (RCP) 4.5 and 8.5. The annual and seasonal (southwest monsoon, northeast monsoon, winter and summer season) comparison of weather data has been carried out. Under RCP 4.5 the amount of solar radiation is expected increase by greater than 1 MJ/m^2 districts like Wayanad, Malappuram, Thrissur, Ernakulam, Kottaym and Pathanamthitta by the end of century. Under RCP 8.5 a normal departure (-1 to 1 MJ/m^2) is expected by the end of century in most parts except in Wayanad and Thrissur, where an above normal increase is predicted. At the same time in Palakkad a below normal decrease is expected in solar radiation. During the southwest monsoon an increase in solar radiation is expected in mid-century and by the end of century a normal departure is expected except in Malappuram, Palakkad and problematic zone where the solar radiation is expected to increase. Under RCP 8.5 a normal departure is expected by the end of century except in Kasargod, Kozhikode, Wayanad and Thiruvananthapuram where a below normal departure is expected. In northeast monsoon season solar radiation is expected to increase in central and problematic zone and a normal departure is expected in other parts under RCP 4.5. In RCP 8.5 by the end of century solar radiation is expected to decrease in Kozhikode, Idukki and Thiruvananthapuram during northeast monsoon. An increase in solar radiation is expected in central, problematic and southern zone during RCP 4.5 in winter season while in northern zone solar radiation is expected to be normal in RCP 4.5 and a below normal departure is expected in RCP 8.5. In Thiruvananthapuram a solar radiation is expected to decrease in both scenarios. A normal departure of solar radiation is expected to increase in most parts of Kerala during the summer season. In Kannur, Kozhikode, Thiruvananthapuram and Wayanad solar radiation are expected to decrease by -1.5 MJ m^2 or less than that by the end of century under RCP 8.5 except in Malappuram where an above-normal increase is expected.

An increasing trend in maximum and minimum temperature is expected in future simulations. The annual temperature is expected to increase in all parts of Kerala except in Idukki where a below normal departure (-1.5 to 1.5°C) is expected in near and mid-century. By the end of century a normal departure of annual maximum temperature is expected in high range zone and Thiruvananthapuram under RCP 4.5 and while under RCP 8.5 only Idukki and Thiruvananthapuram is showing a normal departure. In southwest monsoon season temperature is expected to rise by 1.5°C by end of century under RCP 8.5 while under RCP 4.5 a normal departure is expected in Wayanad, Idukki and Kollam. During the northeast monsoon season and summer season the maximum temperature is expected to increase in all parts expect in Idukki in near and mid-century under both RCPs. In RCP 4.5, a normal departure of annual maximum temperature is projected in the high range zone and Thiruvananthapuram by the end of the century, but only Idukki and Thiruvananthapuram will show a normal departure under RCP 8.5. During the winter season a decrease in temperature is expected in Idukki while in other districts the temperature is expected to increase. The minimum temperature is expected to increase in Kerala except in Idukki in all the future simulations under both RCPs in all seasons. In Idukki the minimum temperature is expected to decrease in near century and then increase in mid and end of century with a normal depature.

A spatial variation in rainfall is expected in Kerala in future simulations, with an excess or normal rainfall in some parts at the same time deficiency in other parts of Kerala. The annual rainfall is expected to increase in most parts of Kerala. In districts like Kasargod, Idukki and Alappuzha a normal departure (+19 to -19%) in annual rainfall is expected in all the future simulations under RCP 4.5 ad 8.5. During the southwest monsoon season, rainfall is expected to show a large excess and excess in most parts of Kerala except in Kasargod where a normal departure is expected. Under RCP 4.5 the rainfall is expected to decrease in Wayanad and Alappuzha by the end of century. While under RCP 8.5 the rainfall is expected to increase in Wayanad and Thiruvanathapuram by the end of century. Northeast monsoon is expected to be show a normal departure in most places. Under RCP 4.5 it is expected to decrease in Idukki, Pathanamthitta, Kollam and Kasargod. While under

RCP 8.5 it is expected to increase in Ernakulam, Alappuzha, Pathanamthitta and Kollam at the same time a deficit rainfall is expected in Kannur and Thrissur. Winter rainfall was predicted to decrease from normal in almost all parts of Kerala in near and mid-century. By the end of century under RCP 4.5 and by mid and end of the century under RCP 8.5 and excess rainfall is predicted in parts of the northern zone and problematic zone. Summer rainfall is expected to be large excess and excess in most parts during near and mid century under RCP 4.5 and in the near century of RCP 8.5. In the end of century under RCP 4.5 and in mid and end of the century under RCP 8.5 a normal rainfall is expected in most places. In Idukki and Thiruvananthapuram the rainfall is expected to be deficient.

The potential yield had been predicted with the DSSAT- CERES model using the genetic coefficient validated using field experiment. the predicted weather for 13 districts of Kerala. The duration of crop is expected to decrease as a result of increase in temperature in both varieties. Yield reduction is expected in future simulations under both the RCPs in most places of Kerala. Under RCP 4.5 in Jyothi, June 5th planting showed maximum deviation from base period (2020). The maximum deviation was observed in Kozhikode *i.e.* in near (-58%), mid (-63%) and end of century (-60%) under RCP 4.5 and in near (-62%), mid (-60%) and end of century (-64%) under RCP 8.5. The least deviation was found in July 20th planting in all the future simulations. In Idukki, an increase in yield had been observed in July 5th , July 20th and August 5th plantings. An increase by 34%, 28% and 23% in near, mid and end of century respectively is expected. Under RCP 8.5 in July 20th planting higher yield has been observed and shows a positive deviation of 38%, 28% in near and mid century respectively in Idukki. By the end of century yield is expected to decrease except in August 5th planting which showed a positive deviation of 12%. In southern zone the highest potential yield had been observed in August 5th planting. In Jaya also the maximum deviation had been observed during June 5th palnting in Kozhikode *i.e.* in near (-58%), mid (- 63%) and end of century (-60%) under RCP 4.5 and in near (-62%), mid (-60%) and end of century (-64%) under RCP 8.5. In Idukki under RCP 4.5 an increase in yield was observed during July 20th planting with an increase by 27% in near and mid century and by the end of century a deviation of 20% was observed. Under RCP 8.5 in July

20th planting higher yield has been observed and shows a positive deviation of 27%, 24% and 10% in near, mid and end of century. In southern zone of Kerala, highest potential yield of Jaya has been observed in July 20th planting in all the future simulations under both RCPs. The duration of crop showed a negative correlation with the temperature. As a result decrease in duration of phenophase had been observed in future simulations. An increased temperature and precipitation patterns during panicle initiation to anthesis may be the reason for the yield variability. During the base period higher yield was obtained during June 5th and June 20th planting *i.e.* early plantings while in future simulations the higher yield is expected in July 5th, July 20th and August 5th plantings *i.e.* late plantings. Hence there is a chance of shift in date of planting in Kerala in future.