Original Research Article

Impact of weather variables on phenophase and yield of kharif rice (*Oryza sativa* L.) in central zone of Kerala

ABSTRACT

A field experiment was conducted at the Agricultural Research Station, Mannuthy, Kerala Agricultural University, Kerala during kharif season 2023 to assess the impact of weather variables on the growth, development and yield of two short-duration rice varieties, Jyothi and Manuratna. The study revealed that the duration of phenophases varied significantly depending on planting dates and weather conditions. Jyothi variety took longer duration to reach physiological maturity compared to Manuratna. Maximum and minimum temperatures during active tillering to panicle initiation (P2) and heading to 50% flowering (P5) stages had a negative influence on phenophase duration for both varieties, while rainfall positively impacted the duration of active tillering (P1) and physiological maturity (P6). Grain yield varied significantly with planting dates. The higher temperatures during critical growth phases have resulted in reduced yield. Bright sunshine hour positively influenced the yield during 50% flowering to physiological maturity in Manuratna. The weather parameters, particularly temperature and rainfall play a crucial role in determining the growth, development and yield of kharif rice varieties in central zone Kerala.

Key words: Weather parameters, kharif rice, phenophase, yield, critical growth phases

INTRODUCTION

Each crop or variety require ideal weather condition for getting optimum yield. The growth and development of a plant in a given environment may vary from one variety to another within a species. They may also differ from one growth stage to the next within the same variety. Crop yield and final biomass are determined by the combined effects of weather conditions at various stages of growth. The most crucial factor in crop adaptability to various growing conditions is phenological development. The length of the season and the relative duration of important phenophases are significant variables that influence grain yield in field crops (Sattar *et al*.,2017).

Rice is the most commonly consumed crop worldwide, serving as a staple food for almost half of the global population (FAO, 2023). India is the world's largest exporter of rice, which makes it vital to global food security (FAO, 2O22). Since rice grows well in a variety of soil and climate conditions, it is cultivated in all the states of India (GoI, 2016; Salim and Sathidevi, 2023). Crop growth, development and yield are greatly influenced by weather, which are both vital and unpredictable. Key weather factors such as maximum and minimum temperatures, rainfall, relative humidity, evaporation and bright sunshine hours play a crucial role in agro-ecological processes, influencing crop production, yield and the progression of pests and diseases (Sharma *et al*., 2008; Garde *et al*., 2015; Kumari *et al*., 2019).

Rice cultivation has a long history and tradition in Kerala. Paddy farming has played a vital role in Kerala’s agricultural practices. However, in recent times, there has been a rapid decline in the area under paddy cultivation. Climate variability and changing weather patterns have become major factors affecting the production of many agricultural crops, including rice (Vaghefi *et al*., 2013).

This study aims to analyze the influence of weather parameters on phenological stages and yield of Kharif rice. This research seeks to provide insights that can aid farmers and policymakers in making decisions to enhance rice production.

MATERIALS AND METHODS

The field experiment was conducted at Agricultural Research Station, Mannuthy, Kerala Agricultural University, Thrissur, during kharif season 2023. The station situated at an altitude of 22 meters above mean sea level and positioned at 10° 32' N latitude and 76° 20' E longitude. The soil texture of the experimental plot was found to be sandy loam with average pH of 5.62 at a depth of 30 cm, available N (0.06 %), P2O5 (14.3 kg ha-1) and K2O (456.45 kg ha-1). The field experiment was conducted under rainfed condition based on package of practices of Kerala Agricultural University. A split plot design was employed with five planting dates viz. 5th June, 20th June, 5th July, 20th July and 5th August as the main plot treatments and two rice varieties Jyothi and Manuratna as the subplot treatments with four replications.

The variety Jyothi has a growth period of 110 to 115 days and is cultivated across Kerala throughout all seasons. This variety exhibits wide adaptability and is highly suited to wetland areas. Manuratna is a short-duration rice variety which matures in 95 to 100 days. The spacing adopted for both Jyothi and Manuratna were 15 cm x 10 cm. The phenophases of rice are 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 and P6 - 50% flowering to physiological maturity. The phenological observations were taken from main plot and sub plot. Maximum temperature, minimum temperature, rainfall, number of rainy days, relative humidity, bright sunshine hours, evaporation and wind speed data were collected from the Principal Agromet observatory at College of Agriculture, Vellanikkara. The daily weather variables were converted to weekly variables. Simple correlation coefficients were computed between weather parameters and phenophase and also between weather parameters and rice yield.

RESULT AND DISCUSSION

Influence of weather variables on phenophase

The duration of various phenophases of rice based on five dates of planting, revealed that there were variations in days required to attain different phenophases when the crop is grown under different micro-environmental conditions. The phenophase duration differs among varieties as well as different dates of planting. Jyothi and Manuratna are short duration rice varieties, but Jyothi took more number of days to reach physiological maturity compare to Manuratna. The correlation coefficients between weather variables and phenophase duration of both varieties are shown in the Table 1 and Table 2.

The maximum temperature and minimum temperature during transplanting to active tillering (P1) and active tillering to panicle initiation (P2) phenophase had negative influence on duration of both the varieties. Sridevi and Chellamuthu (2015) discovered that the duration from transplanting to active tillering was inversely related to temperature. A drop in temperature led to an increase in the number of days required for tillering. Similar trend was observed in this study. Jyothi variety planted on July 5th had taken maximum number of daysto reach active tillering stage (27 days), while June 20th and July 5th plantings of Manuratna variety had taken maximum number of days (24 days) to reach active tillering stage (Fig. 1). The crop had experienced higher rainfall and lower temperature during this period compared to other dates of planting. Sreenivasan (1985) observed that the period of tillering is prolonged with low temperature than at high temperature. Yano *et al*. (2007) reported that an increase in temperature leads to a decrease in vegetative phase. During the phenophase booting to heading (P4) Jyothi and Manuratna showed a significant negative correlation with maximum temperature. Jyothi showed significant negative correlation minimum temperature. The maximum temperature and minimum temperature during heading to 50% flowering (P5) had negative influence on duration of Jyothi. Kobayashi *et al*. (2010) concluded that increased air temperature and incident radiation tend to accelerate anthesis in rice. Variations in the duration of different crop phenophases may be attributed to changes in sowing dates, which either hastened or delayed the fulfillment of thermal requirements needed to reach specific phenophases.

In case of total rainfall and number of rainy days during transplanting to active tillering (P1) phase, Jyothi and Manuratna varieties show significant positive correlation. During 50% flowering to physiological maturity (P6) rainfall and number of rainy days had significant positive correlation with phenophase (Fig. 2), while bright sunshine hour had significant negative correlation (Fig. 3). Harithalekshmi *et al*. (2021) concluded that the maximum temperature during Transplanting to active tillering (P1), Panicle initiation to booting (P3) and 50% flowering to physiological maturity (P6) had negative influence, while rainfall had positive influence on duration of the same.

The forenoon and afternoon relative humidity and mean relative humidity showed a positive correlation during transplanting to panicle initiation in Jyothi. Similar trend was seen in Manuratna during the period of transplanting to active tillering (Fig. 4). Sunil (2000) observed that the duration from transplanting to panicle initiation was reduced with decrease in Relative humidity.

Influence of weather variables on yield

Rice varieties Jyothi and Manuratna had shown significant variations in grain yield with various dates of planting. Maximum temperature and minimum temperature during transplanting to active tillering (P2) showed significant negative impact on yield in Jyothi. Lalitha *et al*. (2000) reported that when temperatures dropped below 26^{O}C, the tillering phase extended to 7-8 weeks after planting. Elevated maximum and minimum temperatures during tillering were found to decrease yield. Additionally, the influence of temperature on tillering is moderated by sunlight levels, as noted by Mahbubul *et al*. (1985). Maximum and minimum temperature, bright sunshine hour and evaporation showed significant positive correlation with yield for Jyothi in active tillering to panicle initiation (P2) phase while the parameters such as morning and afternoon relative humidity, rainfall and number of rainy days showed negative impact on yield.

During the period of heading to 50% flowering the maximum temperature negatively influenced the yield in both the varieties (Fig 5). Higher temperature during heading affected the pollen sterility. Mackill *et al*. (1982) noted that reduced yield was due to poor pollen shedding and inadequate pollen growth under certain temperature conditions. Daytime temperatures between 32º and 38ºC led to sterility, while higher maximum and minimum temperatures during heading reduced yield. Vergara *et al*. (1972) found that increased temperatures during this phase negatively impacted yield. Sattar (2017) observed a significant negative correlation between grain yield and maximum temperature during the heading phase. Similarly, Riya and Ajithkumar (2023) reported a negative correlation between yield and maximum temperature during the flowering period [20]. Sridevi and Chellamuthu (2015) also concluded that higher maximum temperatures adversely affected floral initiation in rice, leading to reduced grain weight.

Minimum temperature during 50% flowering to physiological maturity negatively affected the yield of Jyothi. Tashiro and Wardlaw (1989) also found that grain yield was generally higher when temperatures during the ripening stage were relatively low, which is attributed to a more favorable balance between photosynthesis and respiration. Lower temperatures promoted an increase in grain weight and a reduced daily mean temperature extended the ripening period, allowing more time for grain filling. Abbas and Mayo (2021) reported that an increase in both minimum and maximum temperatures, especially from panicle initiation to anthesis, led to a significant yield decline. Similarly, Aswathi *et al*. (2021) concluded that higher temperatures result in reduced yields.

Bright sunshine hour positively influenced the yield during 50% flowering to physiological maturity in Manuratna. Sreedharan (1975) observed a positive correlation between yield attributes and grain yield with solar energy during the ripening stage. Thangaraj and Sivasubramanian (1990) noted that low light intensity during this phase reduced photosynthesis, leading to the mortality of weak and unproductive tillers, as the demand for photosynthates by the developing grains increased.

Manuratna yield showed negative significant correlation with rainfall and number of rainy days, while bright sunshine hour and evaporation showed significant positive correlation during transplanting to active tillering phase.

Table 1. Correlation coefficients of weather parameters with different phenophase duration for *Jyothi* variety

	Phenophases					
Weather variables	P1	P2	P3	P4	P5	P6
Tmax (°C)	-.838**	-.774**	-0.258	.753**	-.902**	-.811**
Tmin (°C)	-.931**	-.907**	-.531*	-0.417	-.557*	-0.063
TR	-.787**	-.628**	-0.134	.729**	-.617**	-.785**
RH I (%)	.855**	.694**	0.28	-0.394	.881**	.696**
RH II (%)	.665**	.826**	.546*	-.928**	.846**	.884**
RH mean	.701**	.812**	.513*	-.951**	.903**	0.437
WS (km/hr)	-.701**	-.682**	-0.276	-0.102	-.456*	-0.319
RF (mm)	.870**	.844**	.445*	-.951**	.954**	.985**
No. R	.632**	.768**	.504*	-.919**	.990**	.968**
BSS (hrs)	-.649**	-.855**	-.638**	.979**	-.885**	-.913**
EP (mm)	-.747**	-.826**	-.468*	.828**	-.954**	-.563**

Table 2. Correlation coefficients of weather parameters with different phenophase duration for *Manuratna* variety

	Phenophases					
Weather variables	P1	P2	P3	P4	P5	P6
Tmax (°C)	-.929**	-.601**	-.842**	-0.136	-0.416	-.957**
Tmin (°C)	-.811**	-.543*	-.453*	0.268	0.113	-.643**
TR	-.950**	-.584**	-.724**	-0.372	-.534*	-.876**
RH I (%)	.967**	0.333	.833**	-0.113	-0.295	.939**
RH II (%)	.968**	0.438	.821**	0.224	.741**	.982**
RH mean	.976**	0.438	.830**	0.176	.629**	.979**
WS (km/hr)	-.783**	-.823**	-.916**	-0.346	-0.248	-.664**
RF (mm)	.977**	.460*	.870**	0.373	.644**	.973**
No. R	.980**	0.225	.751**	0.089	.739**	.941**
BSS (hrs)	-.964**	-.543*	-.892**	-0.199	-.712**	-.894**
EP (mm)	-.995**	-.550*	-.888**	-0.139	-.552*	-.862**

Tmax - Maximum temperature
Tmin - Minimum temperature
TR - Temperature range
RH I - Forenoon relative humidity
RH II - Afternoon relative humidity
RH mean - Mean relative humidity
WS - Wind speed
RF - Rain fall
No. R - Rainy days
BSS - Bright sunshine hour
EP - Evaporation

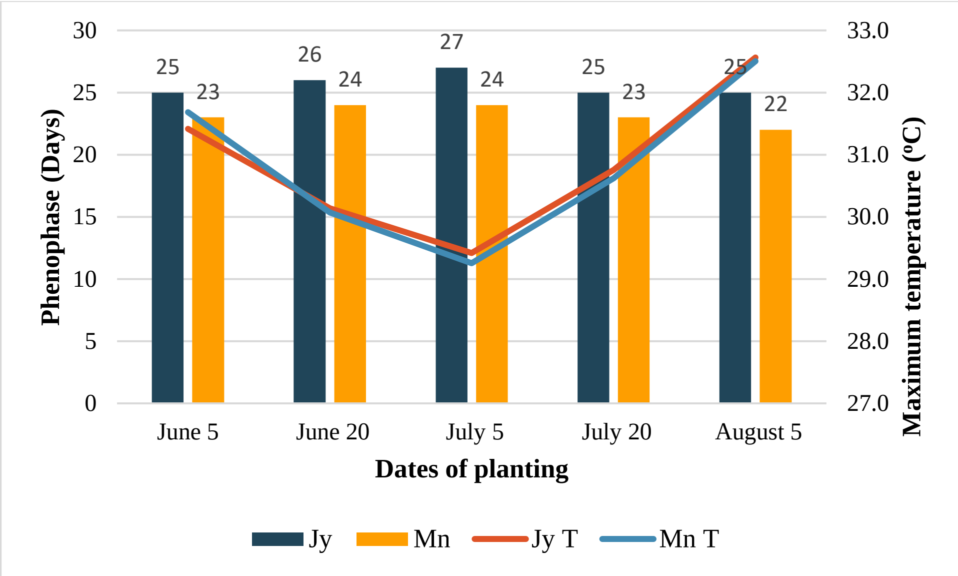


Fig. 1: Impact of maximum temperature (Tmax) on duration of active tillering stage of *Jyothi* (Jy) and *Manuratna* (Mn)

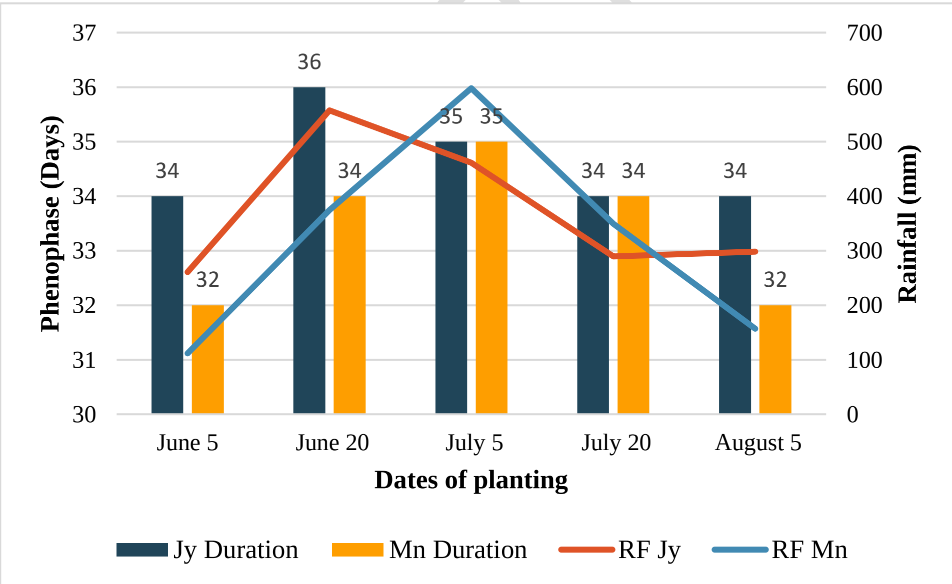


Fig. 2: Impact of rainfall (RF) on duration of physiological maturity stage of Jyothi (Jy) and Manuratna (Mn)

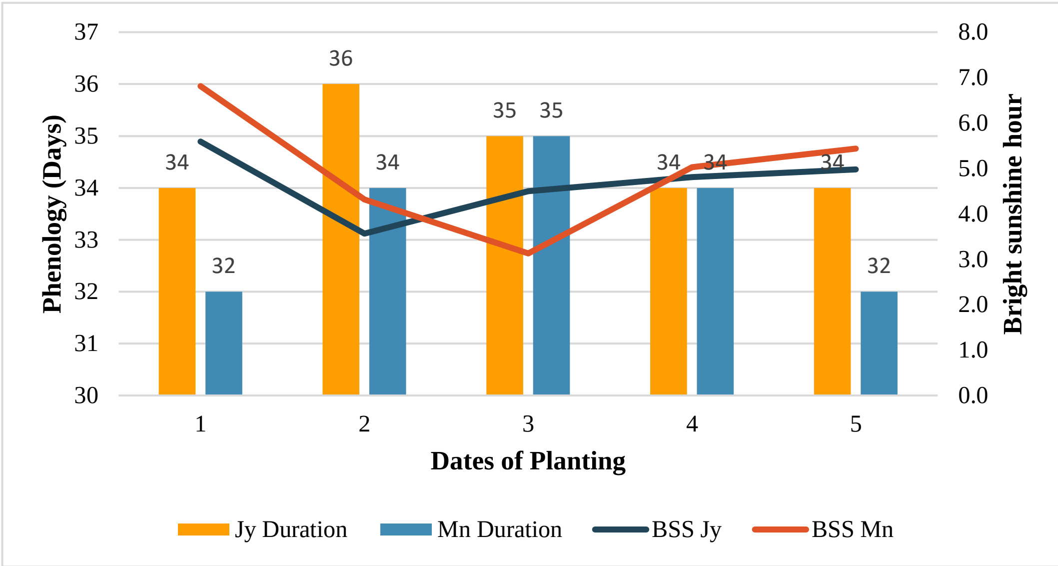
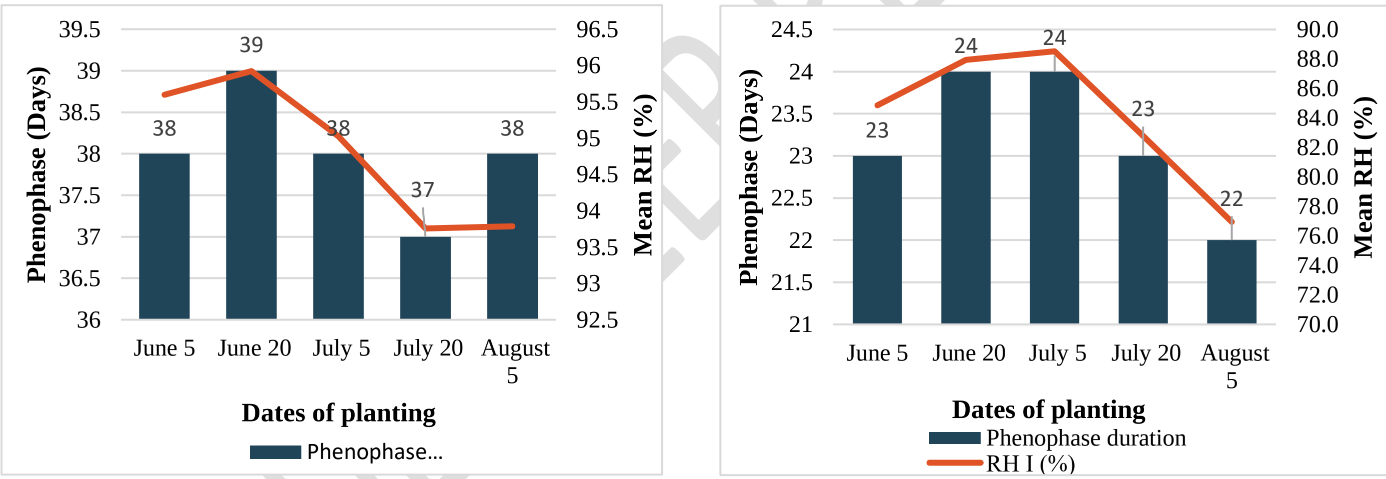


Fig. 3: Impact of bright sunshine hour (BSS) on duration of physiological stage of *Jyothi* (Jy) and *Manuratna* (Mn)



(a) (b)

Fig. 4: Impact of mean relative humidity (RHM) on duration of (a) active tillering and panicle initiation stages of *Jyothi* (Jy) (b) active tillering stage of *Manuratna* (Mn)

Table 3. . Correlation coefficients of weather parameters with yield for *Jyothi* variety

	Phenophases					
Weather variables	P1	P2	P3	P4	P5	P6
Tmax (°C)	-.613**	.488*	0.381	-0.351	-.838**	-0.439
Tmin (°C)	-.514*	.677**	0.114	0.415	-0.109	-.692**
TR	-.638**	0.344	.481*	-0.414	-.836**	-0.388
RH I (%)	.620**	-0.389	-0.435	0.13	.814**	.444*
RH II (%)	.445*	-.543*	-0.356	.829**	.746**	0.316
RH mean	.471*	-.525*	-0.376	.809**	.809**	-0.202
WS (km/hr)	-0.08	0.255	0.245	.524*	0.084	-.678**
RF (mm)	.516*	-.548*	-0.433	.596**	.788**	0.029
No. R	0.434	-.642**	-.472*	.783**	.770**	0.073
BSS (hrs)	-0.433	.633**	0.156	-.642**	-.844**	0.111
EP (mm)	-.514*	.551*	0.349	-0.345	-.763**	-0.226

Table 4. Correlation coefficients of weather parameters with Yield for *Manuratna* variety

	Phenophases					
Weather variables	P1	P2	P3	P4	P5	P6
Tmax (°C)	.468*	0.272	-0.068	-.711**	-.509*	.473*
Tmin (°C)	0.353	0.028	-0.392	-.679**	-0.096	-0.128
TR	.516*	0.386	0.39	-.655**	-.570**	.547*
RH I (%)	-.525*	-.630**	0.235	.641**	.596**	-.537*
RH II (%)	-.586**	-0.244	0.439	.657**	0.228	-.464*
RH mean	-.582**	-0.313	0.403	.663**	0.377	-.479*
WS (km/hr)	.764**	-0.395	-0.063	-0.313	-.472*	-0.209
RF (mm)	-.620**	-0.079	0.359	.563**	.546*	-0.433
No. R	-.591**	-0.245	.457*	.738**	.561*	-0.443
BSS (hrs)	.599**	0.143	-0.414	-.657**	-0.379	.456*
EP (mm)	.577**	0.272	-0.261	-.698**	-.574**	0.24

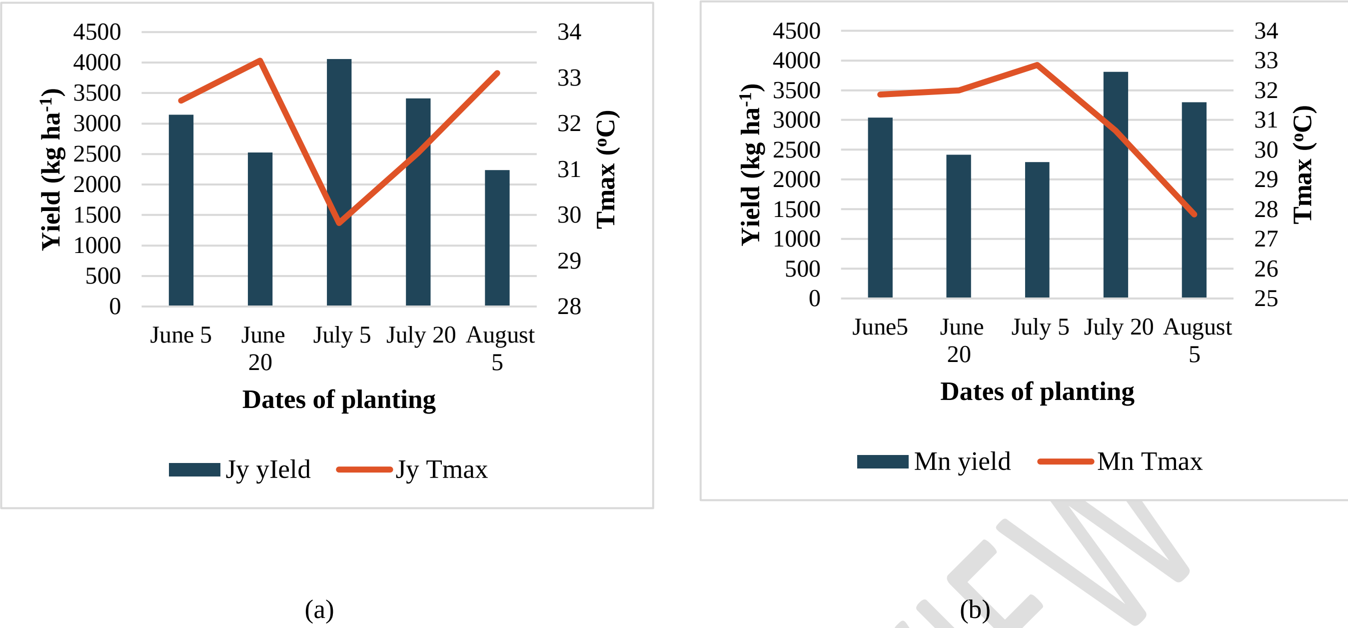


Fig. 5: Impact of maximum temperature (Tmax) during heading to flowering period on yield of (a) *Jyothi* (Jy) and (b) *Manuratna* (Mn)

CONCLUSION

The study highlighted the influence of weather variables on the growth, development and yield of two short duration rice varieties, Jyothi and Manuratna, during kharif season under different planting dates in central zone of Kerala. The findings showed significant variations in phenophase duration and yield based on micro-environmental conditions. Jyothi variety generally took longer days to attain physiological maturity than Manuratna. Maximum and minimum temperatures during the panicle initiation, booting and flowering stages negatively impacted phenophase duration and yield, while rainfall and the number of rainy days positively influenced growth, particularly in the active tillering and physiological maturity phases. The study concluded that optimization of planting dates, with respect to weather, can significantly enhance rice yield and productivity with particular emphasis can be given negative impacts of higher temperatures and the positive effects of adequate rainfall.

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