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Growing season weather impacts on rice phenology development in the central zone of Kerala

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Abstract
The present study was carried out to assess the impact of weather variables on rice phenology. The field experiment was conducted at agricultural research station, Vellanikkara during *kharif* season. The experiment was laid out in split plot design. Main plot treatments were five dates of planting *viz*. June 5th, June 20th, July 5th, July 20th and August 5th planting. Subplot treatments were two rice varieties, Jaya (medium duration) and Jyothi (short duration). The weather data was collected from principal agromet observatory, Vellanikkara on a daily basis. The crop life cycle was divided into different phenophases. The field was monitored on a daily basis and the time of occurrence of different phenophases were noted. The duration of each phenophases were counted and recorded. The correlation analysis between weather variables and duration of phenophases revealed a significant influence of weather variables on rice phenology. Total crop duration was found to be decreasing with delayed dates of planting. A higher duration was observed during June 20th planting for both Jaya and Jyothi. A lower duration for Jaya was observed during July 20th and August 5th planting and for Jyothi it was observed during July 20th planting. After the correlation analysis it was understood that maximum temperature experienced during transplanting to active tillering, panicle initiation to booting, 50% flowering to physiological maturity reduced number of days taken to reach each phenophase while relative humidity and rainfall showed a positive influence on duration.

Keywords: genetic combining ability, specific combining ability, okra, variance, growth, yield and quality

Introduction
The shift in rice phenology is a good indicator of climate change impacts on crops. Hence, the effect of climate change on crops can be better understood by relating weather variables with rice phenology. The optimum requirement of different weather variables varies with different stages. Among the different weather variables, temperature have the most significant influence on crop phenology. According to Fadzillah *et al.* (1996) [1], the minimum lethal temperature for the process of germination and shoot growth was found to be 4 °C. According to Yin and Kropff (1996) [8], the principle environmental determinant of crop leaf appearance is temperature. Optimum temperature for development was found to be markedly higher than that needed for floral development. If the duration of crop declines, the quantity of solar radiation intercepted will be less. Hence change in phenology have a pronounced influence in the yield. Different dates of planting offers different weather conditions for crops hence influences the phenology and there by yield. Harithalekshmi *et al*, (2020) reported a decline in yield with a delay in planting date. The present study was carried out to investigate the impact of weather variables on rice yield phenology under different dates of planting.

Materials and methods
Details of the field experiment
The field experiment was carried out during *kharif* season (May to November (2019)) at Agricultural Research Station, Mannuthy, Kerala Agricultural University, Thrissur. The station is located at 10^0 32' N latitude and 76^0 20' E longitudes, at an altitude of 22 m above mean sea level. The experiment was laid out in split plot design with 5 main plot treatment and 2 subplot treatments. Main plot treatments were five dates of planting *i.e* 5th June, 20th June, 5thJuly, 20th July and 5th August. Two subplot treatments were rice varieties, Jaya and Jyothi. Jaya is a medium duration variety having a duration of 120-125 days. Jaya is recommended for general cultivation all over the country either in *kharif* or *rabi* season. Jyothi is cultivated in all the

three seasons and in a wide range of field conditions. It is a short duration variety having a duration of 110-115 days. Four replication was used and the field was divided into 40 plots each with 4 x 4 m^2 size. A spacing of 15 x 10 cm was provided for Jyothi and 20 x 15 cm was provided for Jaya. Crop management practices were done as per package of practices recommended (KAU, 2016) [3].

Phenological observations

The study of life cycle of a plant is known as phenology. The life cycle of rice was subdivided into six different growth and development phases. Which were recognized as phenophases (Satish *et al.*, 2017) [6] *viz.* transplanting to active tillering (P1), active tillering to panicle initiation (P2), panicle initiation to booting (P3), booting to heading (P4), heading to 50% flowering (P5), 50% flowering to physiological maturity (P6). Field was monitored on a daily basis. Five random plant samples were taken from each replications of each treatment avoiding the border plants to take the observations of duration of different phenological stages and were recorded for the two varieties. Number of days for active tillering, panicle initiation, booting, heading, 50% flowering and physiological maturity from transplanting date were counted for both the varieties and recorded. Phenological calendars were prepared based on this observations.

Correlation analysis

Weather variables like maximum temperature, minimum temperature, forenoon and afternoon relative humidity, rainfall, wind speed, forenoon and afternoon vapour pressure deficit and pan evaporation were recorded on a daily basis from principal agromet observatory, Vellanikkara. The average value of weather variables experienced in each phenophase were calculated. The influence of weather variables on rice phenology was analyzed by correlating the weather parameters experienced during each phenophases and duration of each phenophase in days. Statistical Package of Social Sciences (SPSS) software was used for carrying out correlation analysis.

Results and discussion

Phenological calendars for both Jaya and Jyothi were prepared based on duration of each phenophases for different dates of planting (June 5^{th} – August 20^{th}) is represented in Fig. 1(a and b). In the calendar each phenophase was drawn against the respective standard meteorological week when it occurred. Duration taken for each phenological stage differs among different dates of planting and variety. Total crop duration was found to be decreasing with delayed dates of planting. Total duration was more observed in case of Jaya compared to Jyothi.

The number of days taken to reach each stages from transplanting is depicted in Table 1. Maximum crop duration was recorded during June 20^{th} planting in both Jaya and Jyothi. Minimum duration was taken during July 20^{th} and August 5^{th} planting for Jaya and July 20^{th} planting for Jyothi. Correlation analysis between the duration of each phenophases and weather variable experienced during that particular time revealed the significant influence of weather variables on rice phenology. Results of correlation analysis done for Jaya and Jyothi are represented in the Table 2 and 3.

Table 1: Duration of different phenophases of rice varieties, Jyothi and Jaya under different dates of planting

Crop Stages		Duration of different phenophases (days)									
		June 5th		June 20th		July 5th		July 20th		August 5th	
		Ja	Jy	Ja	Jy	Ja	Jy	Ja	Jy	Ja	Jy
Vegetative period	Active tillering	29	25	28	25	30	26	30	27	29	26
	Panicle initiation	36	31	38	33	40	38	41	35	42	34
Reproductive period	Booting	56	55	58	56	60	59	58	53	60	54
	Heading	66	63	64	64	64	61	66	58	65	59
	50% flowering	69	65	69	67	70	69	70	68	67	68
Ripening period	Physiological maturity	105	99	108	102	106	99	100	95	100	96

Jy – Jyothi Ja – Jaya

Table 2: Correlation between duration of phenophase and weather variables in Jaya

Crop stages	Tmax	Tmin	RHI	RHII	VPDI	VPDII	RF	RD	BSS	WS	Epan
P1	-0.557*	-0.507*	0.456*	0.303	**-0.616	**-0.570	-0.157	0.312	-0.353	-0.157	-0.616**
P2	-0.181	-0.833**	0.155	0.073	0.284	-0.394	0.110	0.344	-0.429	-0.679**	-0.537*
P3	-0.672**	0.000	0.234	0.313	0.143	** 0.760	0.497*	0.043	-0.510*	0.154	-0.616**
P4	0.357	0.730**	-0.097	-0.340	-0.005	* 0.544	0.299	0.583**	0.815**	-0.168	0.441
P5	0.250	0.368	-0.451*	0.390	*0.465	0.055	-0.075	0.481*	-0.447*	0.615**	0.107
P6	-0.578**	0.915**	0.652**	0.657**	-0.010	-0.244	0.549*	0.712**	-0.596**	-0.321	-0.386

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

Table 3: Correlation between duration of phenophase and weather variables in Jyothi

Crop stages	Tmax	Tmin	RHI	RHII	VPDI	VPDII	RF	RD	BSS	WS	Epan
P1	-0.901**	-0.571**	0.523**	0.704**	-0.770**	-0.931**	0.569**	0.778**	-0.787**	-0.568**	-0.631**
P2	-0.862**	-.507*	0.456*	0.997**	-0.221	-0.188	0.567**	0.312	-0.827**	-0.157	-.616**
P3	-0.622**	0.702**	-0.653**	-0.123	-0.468*	-0.949*	0.565**	-0.153	-0.134	0.463*	-0.476*
P4	0.393	0.744**	0.131	-0.603**	0.175	-0.122	-0.049	0.312	0.463*	0.660**	0.579**
P5	-0.420	-0.650**	0.658**	0.484*	0.132	0.088	-0.634**	-0.667**	-0.496*	-0.665**	-0.110
P6	-0.847**	-0.118	0.918**	0.901**	0.464*	0.771**	0.653**	0.767**	-0.584**	-0.557*	-0.581**

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

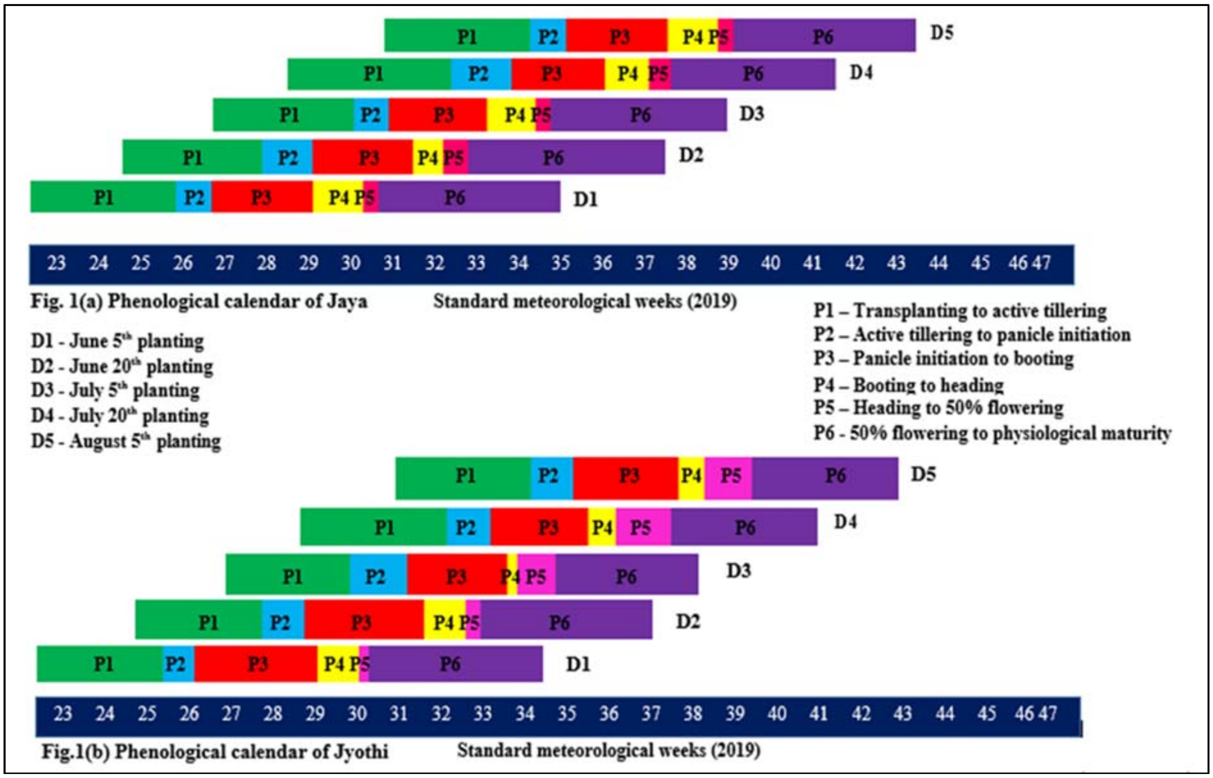

Fig. 1(a) Phenological calendar of Jaya

Fig.1(b) Phenological calendar of Jyothi

Number of days for active tillering

Among all the five dates of planting July 5th and July 20th planting of Jaya took more days (30 days) and June 20th planting took least number of days (28 days) to reach active tillering from transplanting. In case of Jyothi number of days to reach active tillering was more during July 20th planting (27 days) whereas, 5th June and 20th June planting of Jyothi took less number of days(25 days) from transplanting to active tillering. In case of Jaya, forenoon relative humidity showed a significant positive correlation with number of days taken from transplanting to active tillering, while maximum temperature, minimum temperature, pan evaporation, forenoon vapour pressure deficit and afternoon vapour pressure deficit showed a significant negative correlation with number of days taken from transplanting to active tillering. In case of Jyothi forenoon relative humidity, afternoon relative humidity, rainfall and rainy days showed a significant positive correlation with number of days taken from transplanting to active tillering whereas, maximum temperature, minimum temperature, wind speed, bright sunshine hours, pan evaporation, forenoon and afternoon vapour pressure deficit showed a significant negative correlation.

Number of days for panicle initiation

Maximum number of days taken to attain panicle initiation stage was more in Jaya (42 days) which is planted on 5th August. Jaya took minimum days to attain panicle initiation 5th June planting (36 days). In case of Jyothi it took a maximum of 38 days to reach panicle initiation in 5th July transplanting and minimum number of days taken to attain panicle initiation (31 days) was noticed during 5th June planting. In case of Jaya minimum temperature, wind speed and pan evaporation showed a significant negative correlation with number of days taken from active tillering to panicle initiation whereas, rainfall and afternoon vapour pressure deficit showed a significant positive correlation.

Number of days for booting

For Jaya maximum duration was observed during July 5th planting and August 5th planting (60 days) and least duration was observed during June 5th planting (56 days). For Jyothi maximum duration was seen during July 5th planting (59 days) and minimum duration was seen during July 20th planting (53 days). In Jaya maximum temperature, bright sunshine hours and pan evaporation showed a significant negative correlation with number of days taken from panicle initiation to booting. In Jyothi, minimum temperature, wind speed and rainfall showed a significant positive correlation while maximum temperature, forenoon relative humidity, pan evaporation, forenoon vapour pressure deficit and afternoon vapour pressure deficit showed a significant negative correlation with number of days taken from panicle initiation to booting.

Number of days for heading

Jaya took more number of days to reach heading stage during June 5th and July 20th planting (66 days) and minimum number of days during June 20th and July 5th planting (64 days). Jyothi took more number of days during June 20th planting (64 days) and July 20th planting showed a minimum number of days (58 days). Minimum temperature, bright sunshine hours, rainy days and afternoon vapour pressure deficit showed a significant positive correlation with number of days taken from booting to heading. Minimum temperature, wind speed, bright sunshine hours and pan evaporation showed a significant positive correlation but afternoon relative humidity showed a significant negative correlation with number of days taken from booting to reach heading.

Number of days for 50% flowering

Among the two varieties Jaya took maximum number of days (70 days) to reach 50% flowering during July 5th and July 20th date of planting and Jyothi took maximum days (69 days) during July 5th planting. In case of Jaya a minimum duration to 50% flowering was observed on August 5th planting *i.e* 67 days. In Jyothi, June 5th planting took minimum days (65 days) to attain 50% flowering. In Jaya, wind speed, rainy days and forenoon vapour pressure deficit showed a significant positive correlation with no of days taken from heading to 50% flowering while forenoon relative humidity and bright sunshine hours showed a significant negative correlation. In Jyothi, number of days taken from heading to 50% flowering was positively correlated with forenoon relative humidity and afternoon relative humidity while it showed a significant negative correlation with wind speed, minimum temperature, bright sunshine hours, rainfall and rainy days.

Number of days for physiological maturity

Among the two varieties Jyothi attained physiological maturity earlier than Jaya. In both the varieties maximum duration was observed during June 20th transplanting (Jaya-108 days and Jyothi- 102 days) and minimum duration was observed during July 20th transplanting (Jaya 100 days and Jyothi- 95days). Number of days taken to reach physiological maturity was equal during July 20th and August 5th for Jaya (100 days). Number of days to attain physiological maturity did not showed a linear trend. In June 5th planting Jaya took 105 and Jyothi took 99 days it increased to 108 and 102 for Jaya and Jyothi respectively during June 20th planting. It was then decreased during July 5th planting (Jaya-106 days and Jyothi-99 days). In Jaya, minimum temperature, forenoon relative humidity, afternoon relative humidity, rainfall and rainy days showed a significant positive correlation and maximum temperature and bright sunshine hours showed a significant negative correlation with number of days taken from 50% flowering to physiological maturity. In Jyothi, forenoon relative humidity, afternoon relative humidity, rainfall, rainy days, forenoon vapour pressure deficit and afternoon vapour pressure deficit showed a significant positive correlation while maximum temperature, wind speed, bright sunshine hours and pan evaporation showed a significant negative correlation with number of days taken from 50% flowering to physiological maturity.

Figure 2 represents the negative influence of maximum temperature and duration of phenophases. The maximum temperature experienced during P1 stage decreases and there is an increase in the duration of particular phenophase with delay in planting. In case of Jyothi maximum temperature during P3 stage decreases upto July 5th planting a reverse trend was also seen in the duration of phenophases. Maximum temperature during P6 stage was found to be increasing trend up to July 20th planting and then showed a slight decrease. As a result the duration of P6 stage is found to be decreasing upto July 20th planting and then show a slight increase. Accordance to Mahmood *et al*. (1996) [4], the length of growing season increases with decline in air temperature as there was a longer time requirement for the accumulation of heat to complete physiological cycles. The positive effect of rainfall on the duration of phenophase is represented in Figure 3. The rainfall received during P1 stage increases with delay in planting. A similar trend was seen in the duration of P1 stage. The duration of P6 stage is found to be decreasing with delay in planting in tune with decrease in rainfall received. The combined effect of rainfall and temperature might have influenced the duration of rice phenophase. The increase in rainfall and decrease in temperature might have increased the duration of vegetative period, whereas the increase in temperature and decrease in rainfall during reproductive and ripening phase might have reduced the duration of respective crop stages and total crop duration with delay in planting. At lower temperature, translocation of photosynthates to grain took place at a slower rate and thus maturity period got delayed (Tashiro and Wardlaw, 1983) [7] or vice versa Decrease in crop duration with with delayed dates of planting was also reported by Vysakh *et al.* (2015), Ravindran *et al.* (2018) and Haritharaj *et al.* (2019) [6, 5, 2]. Also reported decreased duration with delayed planting. Increased the rate of respiration with increase in temperature might have led to the advancement of physiological maturity stage. Since the rice crop was raised under rainfed condition, decreased rainfall might have created water deficit condition for crops and impaired the crop growth.

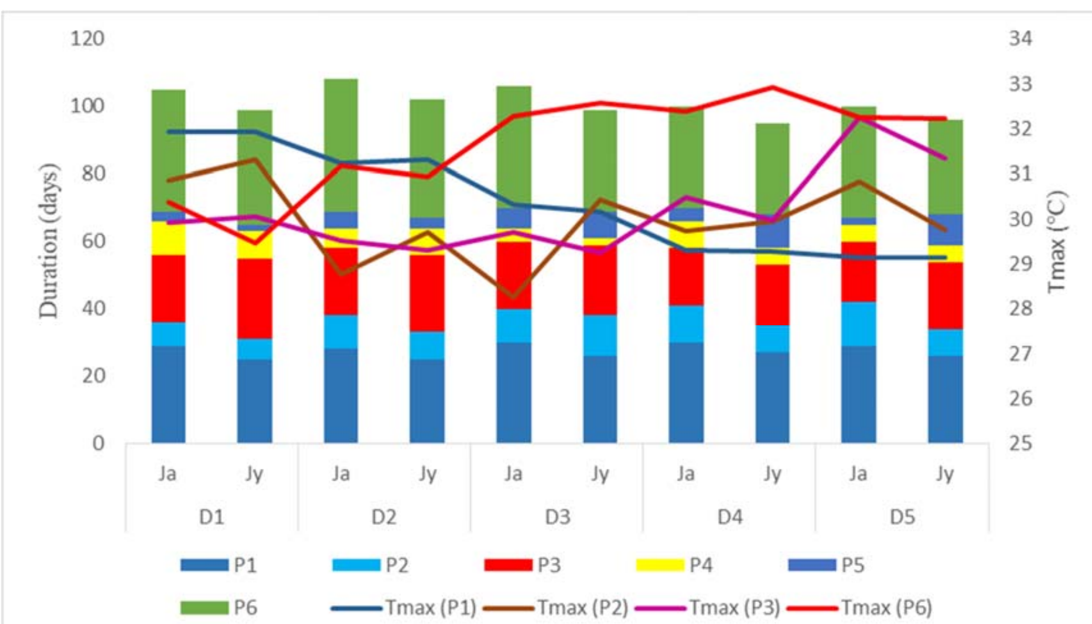

Fig 2: Effect of maximum temperature on different phenophase

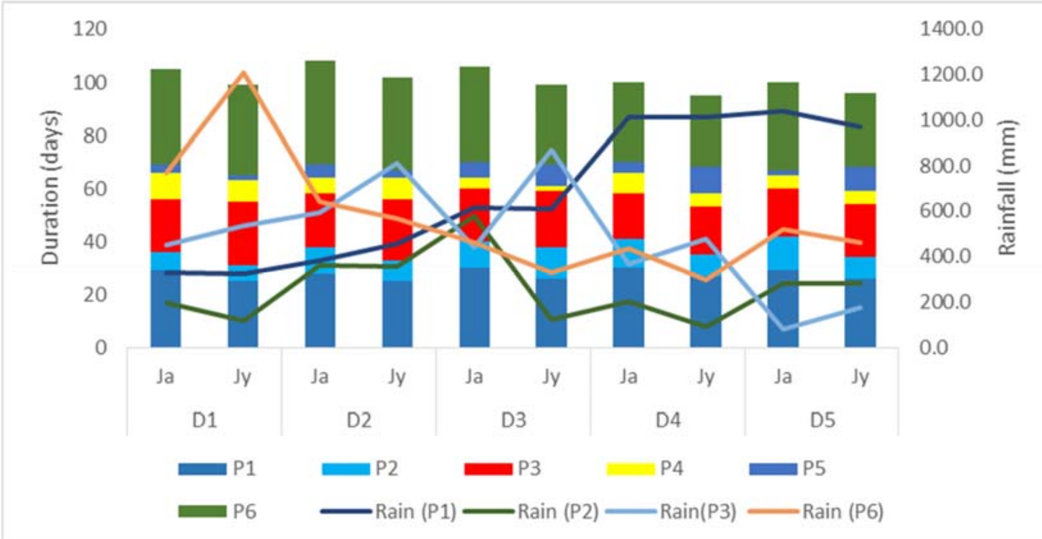

Fig 3: Effect of rainfall on duration of phenophase

Conclusion

The difference in duration among different dates of planting was due to prevailed weather conditions during each phenophases in each variety and varietal characters lead to the variation in phenology among different varieties. After the correlation analysis it was understood that maximum temperature experienced during transplanting to active tillering, panicle initiation to booting, 50% flowering to physiological maturity reduced number of days taken to reach each phenophases while relative humidity and rainfall showed a positive influence on duration. The decreased temperature and increased rainfall during P1 stage causes an increase in the duration of vegetative stage with delayed planting, but the decrease in total crop duration was attributed to the decrease in rainfall and increase in maximum temperature during reproductive and ripening stage of the crop. The temperature rise might have accelerated crop senescence and advanced attainment of physiological maturity stage through increased respiration along with deficit of water.

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