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Effect of heat stress on yield and economics of rice (*Oryza sativa* L.) cultivars under different sowing dates

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ABSTRACT

An experiment was carried out during *rabi* 2017-18 and 2018-19 at Regional Research and Technology Transfer Station, Chiplima, Sambalpur, Odisha of Odisha University of Agriculture and Technology to study the influence of temperature stress at different sowing dates to on yield attributing characters, yield and economics of rice (*Oryza sativa* L.) cultivars. Rice sown on 10th December utilized more thermal and heat units as compared to 30th December and 10th January sown crop. The differential yield response of cultivars to various sowing dates was found to be due to their differential tolerance against high temperature at reproductive growth phase. On an average, 15.7 to 25% reduction in rice yield was obtained in case of sowing dates where temperature stress coincided with reproductive growth phase. The crop sown on 10th December took maximum growing degree days units to attain different phenological stages till physiological maturity. Number of grains panicle^{-1} and rice yield increased with delay in sowing time up to 30th December, whereas there was a decrease in duration and tillers m^{-2}. December 30 sown rice registered the highest grain yield (7.3 t ha^{-1}), grain yield heat use efficiency (3.2 kg ha^{-1} ^{0}C day^{-1}) and dry matter heat use efficiency (6.8 kg ha^{-1} ^{0}C day^{-1}). Maximum number of grains panicle^{-1}, grain yield, grain yield heat use efficiency, dry matter heat use efficiency and benefit cost ratio of rice cultivar MTU 1156 sown on 30th December seems to be associated with non-coincidence of their reproductive growth period with heat stress and seedling growth periods with cold stress. Cultivar MTU 1001 showed moderate tolerance to temperature stress and thus recorded lower heat susceptibility index (0.65) and higher yield stability ratio (84.5).

Key words: Heat use efficiency, reproductive phase, rice cultivars, sowing dates, sterile grains, susceptibility index, yield

Atmospheric temperature plays a significant role in deciding grain yield in rice. The temperature requirement for growth and development at different growth phases are also different. It may vary from variety to variety within a species. In the same variety, it may also vary from one growth stage to another. The final biomass and yield of crops depend on the integrated effect of all the phenological stages. Phenological development is the most important attribute involved in crop adaptation to varied growing environments. The crop duration under different dates of sowing of rice are greatly influenced by temperature and may be estimated by accumulated heat unit (Gauri *et al.,* 2005). The relative duration of key phenophases are critical determinants of grain yield of *rabi* rice.

In Hirakud Command area of Odisha, sowing date of winter season rice plays a major role in rice- rice cropping system. The mean minimum temperature during sowing time (December and January) of *rabi* rice varies from 9-12^{0}C.The mean maximum temperature at reproductive phase varies from 38 to 41^{0}C. The yellowing of leaves starts when temperature falls below 12^{0}C for 3-4 days at seedling stage(Yoshida, 1981). Similarly, grains became chaffy when flowering period coincide with temperature more than 35^{0}C (Matsui *et al*. 1997), resulting in significant yield loss (Moniruzzaman, 2009). In green house experiments with both indica and japonica genotypes less than 1 hour of exposure to temperature above 33.7^{0}C was sufficient to induce sterility (Jagdish *et al.* 2007). So choosing optimum date of sowing rice crop occupies an important part of high production package. Neither too early nor too late sowing proved to give better yield response by offering prolonged growing period while eliminating chances of heat stress during reproductive growth phase of rice (Baloch *et al.* 2006, Safdar *et al.* 2008, Laborte *et al*. 2012).

In rice, the reproductive process occurs within 1 hour after dehiscence of anthers. It is followed by shedding of pollens, germination of pollen grains on stigma and elongation of pollen tubes. It is sensitive to night temperatures below 20^0C, which results in spikelet sterility with subsequent reduction in seed set and grain yield (Ziska *et al.* 1996). Although sowing dates affect rice yield providing various environmental conditions, yet temperature is the key factor to be affected by sowing dates in rice. This is because, growth and yield of high yielding rice is little or not affected by other weather factors especially day length due to its non-photosensitive nature (Akhtar *et al.,* 2007). Heat use efficiency (HUE) in terms of economic yield or dry matter accumulation of rice depends on solar radiation interception, leaf area development and crop management practices (Aggarwal *et al*., 2015). Keeping the above facts in to consideration, the present study was planned to examine varietal response of rice to sowing dates with respect to seedlings growth and yield during winter season at Hirakud command area of Odisha.

MATERIALS AND METHODS

The experiment was conducted during winter season of 2017-18 and 2018-19 at the Regional Research and Technology Transfer Station, Chiplima of Odisha University of Agriculture and Technology under West Central Table Land Zone Odisha. The soil of experimental field was clay loam, bulk density 1.50 M gm^{-3}, porosity 39.28%, infiltration rate 0.26 cmhr^{-1}, water holding capacity 25.56% on weight basis, field capacity 19.7% on weight basis, permanent wilting point 10%, acidic (pH 5.65), low in organic carbon content (0.47%) and available N, P_2O_5 and K_2O content were 242, 9.2 and 155 kg ha^{-1}, respectively. Sixteen treatment combinations of 4 sowing dates (10th December, 20th December, 30th December, 10th January) and 4 rice cultivars (MTU 1001, MTU 1010, MTU 1156 and ODR- 24) were tested in randomized split plot design with three replications.

Seeds were soaked for 24 hours and incubated in moist gunny bags for 2 days. Pre-germinated seeds were broadcast uniformly on nursery beds. Soil: farmyard manure mixture (1:1) was spread in a thin layer over the seeds. The nursery bed was fertilized with 10, 15 and 20 g m^{-2}N, P_2O_5 and K_2O at 10 days after sowing. The beds were irrigated daily and thoroughly before lifting the seedlings. The FYM @ 2 t ha^{-1} was incorporated 2 weeks before transplanting. Seedlings of 3-4 leaf stage were used for transplanting. Recommended dose of fertilizer, i.e. 80, 40 and 40 kg ha^{-1} N, P_2O_5 and K_2O was applied. All P_2O_5 was applied as basal and N was applied in 3 splits, i.e. 50% as basal, 25% at 20 days after transplanting (DAT) and 25% at 40 DAT, while K_2O was applied in two splits, i.e. 50% as basal and 50% at 40 DAT. The plant protection measures were taken as and when required. All other cultural operations were carried out as per recommendation. Rainfall received during the crop growth period was 50 mm (6 rainy days) in 2017-18 and 62 mm (9 days) in 2018-19, respectively during crop growing season. The yield parameters were recorded and the economics was calculated at the prevailing price of inputs and produce. The crop reached physiological maturity when 95% of spikelets had turned yellow. At panicle emergence, 12 randomly selected panicles (one from each separate plant) were tagged in each cultivar. These tagged panicles were harvested at physiological maturity and data on numbers of filled, unfilled grains per panicle and test weight were recorded. Each spikelet was pressed between forefinger and thumb to determine if the grain was filled or not. Number of filled grains included both completely and partially filled grains. Grain yield was calculated on 14% moisture basis. Correlation analyses were performed to determine the relationship between weather variables at different phenophases with yield. Average mean temperature received by the rice cultivars from sowing to harvesting under different transplanting dates have been depicted in figure 1. The harvest index was calculated using the formulae of Donald and Hambline (1976).

Heat susceptibility index (S) was calculated for seed yield as per Fisher and Maurer (1978). S = (1-Y/Yp)/1-X/Xp, where, Y is mean grain yield of genotype in a stress environment, Yp is mean grain yield of a genotype in a stress free environment, X is mean Y of all the cultivars and Xp is mean Yp of all cultivars. S is the relative heat stress tolerance (SÂ 0.5 stress tolerant, S > 0.5-1.0 moderately stress tolerant and S1.0 susceptible).

Yield stability ratio (YS) was calculated by taking the ratio of seed yield under (late) and Normal conditions as per Lewis (1954); YS = Grain yield under late planting (10th January)/Grain yield under normal planting (30th December) × 100.

The accumulated Growing-Degree-Day (GDD) or heat unit was worked out for different phases of growth using the following equation (Nuttonson, 1955).

GDD = S [(Tmax +Tmin)/2]-Tb

Where, Tmax is the maximum temperature of the day in ^{0}C, Tmin is the minimum temperature of the day in ^{0}C; Tb is base temperature in ^{0}C (10^0C).

Heat use efficiency (HUE) was computed as

Grain yield heat use efficiency (GY-HUE) = Grain yield Kg ha^{-1}GDD^{-1}.

Dry matter heat use efficiency (DM-HUE) = Dry matter Kg ha^{-1}GDD^{-1}.

The recorded data for various parameters were statistically analyzed using standard procedures (Gomez and Gomez, 1984).

Table 1: Growing degree days (GDD) at different phonological stages of rice as affected by sowing dates and cultivars

Treatment	Seedling		Vegetative		Reproductive	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Date of sowing						
10th Dec.	995	1035	1970	1977	2252	2394
20th Dec	975	1028	1950	1937	2250	2373
30th Dec.	964	1009	1939	1911	2199	2362
10th Jan.	956	942	1922	1835	2099	2345
SEm±	2.6	3.1	5.7	6.3	10.1	5.6
CD (P=0.05)	7.8	9.1	17.6	18.4	29.3	16.8
Cultivars						
MTU 1001	1063	1094	2127	2096	2381	2550
MTU 1010	1023	1053	2046	2015	2300	2469
MTU 1156	982	1012	1964	1933	2218	2387
ODR 24	823	853	1646	1615	1900	2069
SEm±	2.6	3.1	5.7	6.3	10.1	5.6
CD (P=0.05)	7.9	9.1	17.6	18.4	29.3	16.8

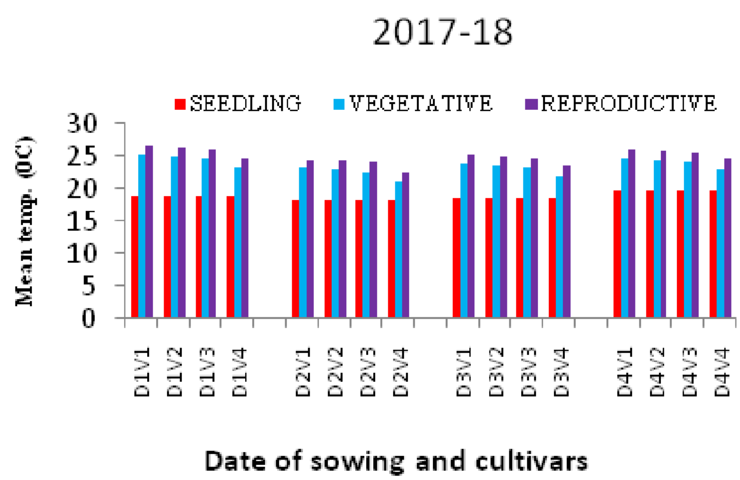

Fig. 1: Mean ambient temperature received at different phonological stages by rice cultivars under different sowing dates during year 2017-18 and 2018-19.

RESULTS AND DISCUSSION

Sowing dates and cultivars on agro-meteorological indices

Higher growing degree days ((GDD) accumulation was observed during 2018-19 at seedling and reproductive stage, where as it was lower at vegetative stage in most of the dates of sowing which shows mean minimum temperature and mean maximum temperature were higher in seedling and reproductive stage in 2018-19 than in 2017-18. The duration of various phenological phases of rice cultivars in two consequent years of observations (Table 1) revealed that the accumulated growing degree days (GDD) to reach seedling decreased with delay in sowing and also for attaining other growth phases. In comparison to 10 December sown rice crop, the crop sown on 10 January availed more GDD for attaining vegetative stage. At reproductive stage, the accumulated GDD were 2252, 2250, 2199 and 2099 ^{0}C days for 10, 20, 30 December and 10 January sown rice crops, respectively during 1st year of experiment. Similar trend of GDD at different phenophase of crop growth was also found in the second year. This is in conformity with Singh *et al.* (2009) and Abhilash *et al.* (2017), who reported that accumulated GDD were higher under early sown rice. MTU 1001 variety accumulated the highest GDD in all

Table 2: Mean minimum and maximum temperature (^{0}C) during various growth stages of rice

Growth stages	Sowing dates			
	10th Dec.	20th Dec.	30th Dec.	10th Jan.
Seedling phase	9.4-26.9	9.4-27.3	9.5-28	10.5-28.7
Vegetative phase	18-32.8	18.8-33.2	19.3-33.9	19.6-33.9
Reproductive phase	22.9-38.8	23-39.6	23-39.7	23.1-40.6

Table 3: Days to 50% flowering and yield attributes of rice as influenced by date of sowing and cultivars (Data pooled over 2 years)

Treatments	Days to 50% flowering	Plant height (cm)	Tillers m^{-2}	Panicle length (cm)	Test wt. (g)	Grains $panicle^{-1}$	Sterile grains $panicle^{-1}$
Date of sowing							
10th Dec.	111	87.6	438	23.2	21.2	118	25
20th Dec	106	90.8	387	23.2	21.3	125	26
30th Dec.	99	99.4	367	23.9	21.3	139	29
10th Jan.	92	97.5	364	23.6	22.2	119	26
SEm±	0.3	1.8	11.9	0.2	1.6	3.4	0.6
CD (P=0.05)	1.0	6.1	41	NS	NS	11.7	2.0
Cultivars							
MTU 1001	115	107.5	392	24.3	22.2	126	28
MTU 1010	111	102.0	421	24.3	21.5	134	27
MTU 1156	104	102.0	445	25.2	21	141	29
ODR 24	78	64.0	298	20.1	21.3	99	21
SEm±	0.03	1.2	12.2	0.2	1.5	3.5	0.5
CD (P=0.05)	0.1	3.5	35.5	0.7	NS	10.1	1.5

phenophases followed by MTU 1010 and MTU 1156 because crop took more of days to mature under early planting. More pronounced variation was recorded during 1st year than that of 2nd year. Similar findings on crop cultivar with sowing dates were also reported by Singh and Singh (2007).

Phenology

Mean minimum and maximum temperature prevailing during seedling phase increased with delay in sowing (Table 2). Therefore, rice cultivars sown earlier, i.e. 10th Decemberand20th December completed their growth cycle under relatively lower temperature regime as compared to that experienced by late sown (30th December and 10th January) rice cultivars. In contrast mean minimum and mean maximum temperature prevailing during reproductive phase increased (more than 39^{0}C) with delay in sowing. That is why, last date of sowing (10th January) had relatively higher temperature during reproductive phase (40.6^{0}C) compared with all former sowing dates, i.e. (10th December, 20th December and 30th December).The result was that, cultivars sown late (10th Jan.) remained stress free during seedling phase but had to face heat stress during reproductive phase. On the other hand, cultivars kept early sown condition especially 10th December and 20th December found cold stress at seedling phase but were stress free at reproductive phase. Cultivars in sowing date 30th December enjoyed a favourable optimum temperature regime throughout the growth period, i.e. remained stress free during seedling and reproductive growth phase.

Days to 50% flowering

Late sown crop came to flowering in 92 days; whereas early sown crops took longer period (111 days) for flowering, primarily due to cold weather conditions in December that prolonged at seedling stage (Table 3). Among the cultivars, MTU 1001 took 115 days for coming to 50% flowering followed by MTU 1010 (111 days). ODR-24 was the shortest duration variety and took 78 days for flowering.

Table4: Effect of sowing date and cultivars on yield, harvest index, grain and dry matter heat use efficiency in rice during winter season of 2017-18 and 2018-19

Treatments	Grain yield (t ha^{-1})		Straw yield (t ha^{-1})		HI (%)		GY HUE		DM HUE	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Sowing date										
10th Dec.	6.8	5.5	7.4	6.1	48.1	47.6	2.9	2.5	5.9	5.1
20th Dec	6.1	6.9	7.4	8.4	45.5	45.4	2.6	3.1	5.6	6.8
30th Dec.	7.0	7.3	8.0	8.1	47.6	47.6	3.1	3.4	6.4	7.1
10th Jan.	6.4	6.1	6.8	6.5	48.4	48.3	2.7	2.9	5.5	6.1
SEm±	0.3	0.4	0.3	0.4	0.04	0.09	0.1	0.2	0.2	0.4
CD(P=0.05)	0.7	1.1	0.8	1.2	0.12	0.26	0.4	0.5	0.6	1.2
Cultivars										
MTU 1001	7.1	6.1	9.1	6.8	47.5	47.3	2.8	2.6	5.8	5.5
MTU 1010	6.5	7.7	7.2	8.5	47.4	47.4	2.6	3.3	5.5	7.0
MTU 1156	8.7	6.2	8.2	7.1	47.6	47.2	3.6	2.8	7.6	5.9
ODR 24	4.4	5.9	5.0	6.7	47.0	47.2	2.2	3.2	4.6	6.7
SEm±	0.3	0.4	0.3	0.4	0.04	0.09	0.1	0.2	0.2	0.4
CD(P=0.05)	0.7	1.1	0.8	1.2	0.12	NS	0.3	0.6	0.6	1.2

Table 5: Effect of sowing date and cultivars on yield, harvest index, grain and dry matter heat use efficiency, net return and B: C ratio in rice during winter season (Data pooled over 2 years).

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	HI (%)	GY HUE	DM HUE	Net return (Rs ha^{-1}) ('000)	B:C ratio
Sowing date							
10th Dec.	6.2	6.7	48.5	2.7	5.6	51.94	0.83
20th Dec	6.6	7.9	48.3	2.8	6.2	61.29	1.04
30th Dec.	7.3	8.1	48.4	3.2	6.8	80.45	1.52
10th Jan.	6.3	6.7	47.6	2.8	5.8	62.63	1.22
SEm±	0.2	0.2	0.03	0.07	0.16	3.27	0.08
CD(P=0.05)	0.6	0.6	0.11	0.22	0.49	11.31	0.31
Cultivars							
MTU 1001	6.6	7.9	49.0	2.7	5.6	61.49	1.02
MTU 1010	7.1	7.8	49.1	2.9	6.2	73.61	1.35
MTU 1156	7.4	7.6	49.7	3.2	6.8	80.51	1.48
ODR 24	5.2	5.8	45.1	2.6	5.6	40.69	0.76
SEm±	0.2	0.2	0.03	0.07	0.16	3.36	0.07
CD(P=0.05)	0.5	0.7	0.11	0.22	0.47	9.81	0.21

Yield attributes

All cultivars showed increasing trend for grains panicle^{-1}, sterile grainspanicle^{-1}, panicle length and plant height with delayed sowing, reaching maximum at 30th December, thereafter declined (Table 3). Among cultivars, MTU 1156 showed highest value of grains panicle^{-1} (141),

Table 6: Interaction effect of sowing dates and cultivars on grain yield (t ha^{-1}) of rice (Data pooled over 2 years)

Cultivars	Date of sowing			
	10th Dec.	20th Dec.	30th Dec.	10th Jan.
MTU 1001	6.9	7.1	6.5	6.0
MTU 1010	7.1	7.1	7.9	6.0
MTU 1156	6.6	7.6	8.4	7.1
ODR 24	4.3	4.5	6.3	5.8
SEm±			0.4	
CD (P=0.05)			1.1	

Table 7: Heat susceptibility index and yield stability index of rice cultivars growing during winter season (Data pooled over 2 years)

Rice cultivars	Heat susceptibility index (S)	Yield stability index (YS)
MTU 1001	0.65	84.5
MTU1010	1.04	75.9
MTU1156	0.91	78.6
ODR24	1.39	68.2

Table8: Correlation coefficients of weather variables at different phonological phases with grain yield of rice

Weather parameter	Seedling		Flowering		Maturity	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Tmax	-0.07	-0.04	0.02	0.22	-0.42	-0.38
Tmin	-0.88**	-0.89**	0.12	0.42	0.57*	-0.04
Tmean	-0.70	-0.51*	0.11	0.33	-0.88*	-0.22

sterile grains $panicle^{-1}$(29) and panicle length (25.2 cm), whereas ODR 24 produced lowest number of grains $panicle^{-1}$ (99), sterile grainspanicle^{-1} (21) and panicle length (20.1 cm) and plant height (64 cm).Most of the cultivars decrease their tillers m^{-2} with delayed sowing. The highest number of tillers m^{-2}(438) was recorded on 1st date of sowing (10th December) followed by 20th December, however the tillers $m^{-2}$was not significant among 20th December, 30th December and 10th January. Among all cultivars, MTU 1156 achieved the highest number of tillers m^{-2} (445), whereas ODR 24 produced the lowest number of tillers m^{-2} (298).

Out of all yield attributing parameters, grains $panicle^{-1}$ of almost all cultivars showed a similar response to sowing date as shown by rice yield, i.e. this yield component increased until 30th December while tillers m^{-2}, days to 50% flowering decreased with the delay in sowing. Days to 50% flowering represents vegetative growth duration of crop. Rice being a thermos-sensitive plant had to shift from vegetative to reproductive growth phase at specific temperature. That is why, late sown rice cultivars showed reduced vegetative phase and thereby total growth duration. On the other side, the reproductive growth indicators such as grains $panicle^{-1}$ was adversely affected by heat stress and remained low when sown on 10th January. It shows rice yield is more dependent upon number of grains/panicle, panicle length and sterile grains/panicle rather than number of tillers per plant. Noorka *et al*. (2009) and Akhter *et al.* (2011) also attributed higher rice yield in rice to more productive panicles rather than more tillers per plant.

Grain yield

Grain yield increased with delayed date of sowing up to 30th December in both the years and decreased thereafter (Table 4). Higher yield was achieved during 2018-19 than that of 2017-18 up to 30th December. Mean grain yield of 4 cultivars increased with delayed sowing until peak was achieved for30th December sowing (Table 5). Individually, all cultivars responded differently to different sowing dates (Table 6). This variation was the highest (6.3 to 8.4 t ha^{-1}) at sowing date 30thDecember, whereas the lowest (5.8 to 7.1t ha^{-1}) at sowing date 10th Jan. Variety MTU 1156 showed the highest yield performance (8.4 t ha^{-1}) at 30thDecember, whereas the lowest at 10th Jan. The cultivars MTU 1010 and MTU 1156 gave higher yields at sowing dates 10th, 20th and30th December. However, these cultivars fail to show good performance when sown on 10th Jan. Variety MTU 1156 achieved the highest grain yield in 30th December sowing date, whereas the lowest grain yields at 10th December sowing date. However, variety MTU 1010 showed a consistent yield performance over sowing date 10thand 30th Dec, thereafter presented a declining trend. Among cultivars MTU 1010 had lowest percentage of reduction in grain yield (15.7%) due to different dates of sowing, whereas the other varieties showed 21-25% reduction in yield. Highest reduction was in case of ODR 24 (25%). January 10 sowing reduced the yield irrespective of varieties and their duration due to incidence of high temperature at anthesis.

All the cultivars attained higher yield when sown on 30th Decemberonly except MTU 1001 which gave the highest, when sown on 20th December and it also gave lowest variation in respect to date of sowing (Table 6), though the earlier sowings were found to be better. In case of ODR 24 the late sowings were better. So it can be concluded that for long duration variety 20th December and for medium and short duration variety 30th December can be taken as optimum sowing date. Irrespective of cultivar sowing on 30th December is more advisable than that of early sowing looking at reduction in grain yield.

Harvest index

Inspire of variation in average mean minimum and maximum temperature in 2017-18 and 2018-19, the harvest index remained more or less same during both the year (Table 4). The crop sown on 10th December had higher harvest index (48.5%) than that of 10th Jan. sowing (47.6%), however they were statistically at par (Table 5). Better assimilate partitioning from the source (leaf and non-laminar organ, i.e. leaf sheath, stem, flag leaf) to the panicle (sink) occurred in two cultivars namely MTU 1156 and MTU 1010 compared with ODR 24. Higher harvest index in MTU 1156 was related to their higher grain yields (Jalil *et al.,* 2016), while low harvest index in the ODR 24 was likewise related to low grain yield.

Economics

Net monetary returns and benefit to cost ratio of different treatments were worked out (Table 5). Economic analysis showed higher net return (Rs 80450 ha^{-1}) and benefit: cost ratio (1.52) with 30th December sowing followed by 10th January and 20th December sown crop. Among cultivars MTU 1156 recorded significantly higher net return Rs. 80510 ha^{-1} and benefit cost ratio (1.48) followed by MTU 1010. Higher net return and benefit to cost ratio were realized due to higher grain and dry matter yields.

Heat use efficiency

The variety MTU 1156 registered the highest grain yield heat use efficiency (3.2 kg ha^{-1} ^0C day^{-1}), which was significantly superior to MTU 1010 and MTU (Table 5). Similar trend was noticed in dry matter heat use efficiency. The sowing on 30th December produced the highest grain yield heat use efficiency (3.2 kg ha^{-1} ^0C day^{-1}) and dry matter heat use efficiency (6.8 kg ha^{-1} ^0C day^{-1}), which was significantly superior to other sowing dates. These results are in agreement with the findings of Nayak *et al*. (2017).

Heat susceptibility index

Heat susceptibility index (S) ranged from 0.65% (MTU 1001) to 1.39% (ODR 24) and yield stability ratio (YS) range from 68.2% (ODR 24) to 84.5% (MTU 1001) among different rice cultivars (Table 7). Cultivars MTU1001 showed tolerance to temperature stress at later stages (anthesis) and thus recorded low heat susceptibility index and higher yield stability ratio. On the other hand, cultivar MTU 1156 registered comparatively higher heat susceptibility index (0.91) and low yield stability ratio (78.6%), showing their sensitivity to late sowing. This cultivar is susceptible to temperature increase at later stages. Therefore, an optimum sowing time 30th December for this cultivar was identified, which reduced the possibility of high temperature stress at later stages of rice crop.

Correlation analysis

Correlation coefficients (Table 8) between weather parameters at different phenophases of rice cultivars and grain yield indicated that there was a significant positive correlation of Tmax with grain yield during vegetative and negative correlation during seedling and reproductive phase of both the years. Except at vegetative and 1st year of reproductive phase, Tmin showed negative correlation with grain yield. The negative association of Tmean at seedling and reproductive phases demonstrates decrease in grain yield with rise in temperature.

CONCLUSION

It is evident from two years' study that sowing dates of rice should be adjusted such that its reproductive growth phase and seedling growth phase do not coincide with high temperature or low temperature stress respectively as it results lower number of grain/panicle and higher number of sterile grains/panicle resulting in lower grain yield. Rice variety MTU 1156 produced economically higher grain yield, dry matter as well as grain heat use efficiency with sowing on 30th December during winter season in Hirakud command area of Odisha.

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