Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(4): 428-432
Received: 03-05-2018
Accepted: 07-06-2018

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Effect of high temperature studies on morphological traits of rice (*Oryza sativa* L.) genotypes for temperature tolerance

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Abstract
High temperature (HT) stress affects grain yield of rice. High temperature stress is the one of the most important environmental factors that influencing growth, development, and yield of rice crop. A field experiment consisted of 50 IRRI and Indian rice genotypes with five check (Local, national and international) varieties were evaluated during normal sown (December-2014) and late sown conditions (January 2015) on various morphological parameters at different stages of growth for high temperature tolerance. Results indicated that HT stress decreased the mean grain yield of late sown condition as compare to normal sown condition by 11.92 percent which was expected that plant experienced the high temperature stress mainly during flowering and grain filling stages. The results of mean sum of squares due to the genotypes and their interaction were significant for different morphological parameters and yield attributes viz..., late sown condition significantly decreased in rice genotypes particularly, in case of high temperature sensitive genotypes. The growth parameters leaf area index, numbers of productive tillers, flag leaf length, dry matter production per plant and grain yield per plant was higher in the following genotypes EC792239, EC792185, EC792179, EC792240 and EC792316 are identified as heat stress tolerant genotypes. They could be used as potential donors for development of heat stress tolerant variety.

Keywords: rice, high stress, heat tolerance, sowing dates, morpho-physiological, and yield

Introduction

Rice (*Oryza sativa* L.) is a the staple food for more than half of the human population. Asia is considered as "Rice Basket" of the world, as 90 per cent of world's rice is grown and consumed with 60 per cent of population and where, about two-thirds of world's poor live (Khush and Virk, 2005) [23]. In India, rice is the second most produced commodity cultivated on an area of 43.95 m ha, with a production and a productivity of 106.54 m t and 2424 kg ha^{-1}, respectively (Anon., 2015) [6].

Global warming is a serious peril to the rice production. The optimum temperature for the normal development of rice ranges from 27 °C to 32 °C. High temperature stress is the one of the most important environmental factors that influencing growth, development, and yield of crop. High temperature (HT) affects almost all the growth stages of rice, *i.e.* from emergence to ripening. The increase in temperature has been striking and can cause irreversible damage to plant growth and development (Wahid *et al.*, 2007). It has been shown a 7-8% rice yield reduction for each 1 °C increase in daytime temperature from 28 °C to 34 °C (Baker *et al.*, 1992). However, flowering (anthesis and fertilization) and booting (microsporogenesis) are considered to be the stages of development most susceptible to temperature in rice. High temperatures (≥ 35-40 °C) during anthesis stage of flowering induce spikelet sterility which in turn decreases the rice yield (Bhadana *et al.*, 2014) [8]. Plants possess a number of adaptive, avoidance or acclimation mechanisms to cope with HT situations.

Rice is being cultivated both in *kharif* and summer in Tungabhadra Project (TBP) command area of Karnataka state. Rice is being cultivated in an area of 4.92 lakh ha with a production of 13.6 lakh tonnes and a productivity of 2772 kg ha^{-1}. Due to late sowing of *kharif* crop because of late onset of monsoon harvest will be delayed and summer sowing is also delayed. Late sowing of rice in summer in the month of February lead to reduction the rice yields. The yield reduction is mainly due to late sowing coincide with high temperature during flowering and anthesis period. It is important to screen the rice germplasm for high temperature tolerance. Hence, with this background the present investigation was follow up.

Materials and Methods

A field experiment was conducted at Agriculture research station Gangavati, university of agriculture sciences, Raichur. The paper studies the effects of temperature regimes on various morpho-physiological parameters at different stages of growth using 50 IRRI and Indian rice genotypes with five (Local, national and international) check varieties were evaluated during *early summer*/Normal sown (07-Dec.-2014) and *late summer/* late sown (20-Jan-2015). The details of genotypes and check verities are given in (Table 1). In our experiments we tried to expose our genotypes to high temperature at different crop growth stages especially during reproductive stage, which is a serious problem of this region. To coincide with the high temperature during reproductive stage of crop two (Normal & Late) different dates of sowing was done. The seedlings were planted in Randomized Block Design (RBD) at Agricultural Research Station, Gangavati. Adopting a spacing of 20 cm × 15 cm, in a plot size of 0.8 m × 3.5 m width and length respectively. The genotypes were replicated twice. In each replication, each genotype was planted in four rows with 20 seedlings or hills per row. During crop growth period (December to May) summer 2014-2015, the maximum and minimum temperature was 41 ^oC and 26 ^oC, respectively and maximum and minimum relative humidity recorded was 99.5 and 29.7 per cent, respectively it is presented in (Fig. 1).

Table 1: List of rice genotypes used for present study

S. No.	Genotypes	S. No.	Genotypes	S. No.	Genotypes	S. No.	G Genotypes	S. No.	Genotypes
1	EC792216	12	EC792237	23	EC792215	34	EC792233	45	EC792270
2	EC792231	13	EC792267	24	EC792193	35	EC792179	46	EC792286
3	EC792227	14	EC792206	25	EC792185	36	EC792208	47	EC792289
4	EC792177	15	EC792234	26	EC792222	37	EC792219	48	EC792326
5	EC792226	16	EC792201	27	EC792240	38	EC792309	49	EC792217
6	EC792200	17	EC792257	28	EC792195	39	EC792203	50	EC792192
7	EC792224	18	EC792310	29	EC792235	40	EC792214	C1	Gangavati sona
8	EC792239	19	EC792199	30	EC792225	41	EC792176	C2	IR- 64
9	EC792194	20	EC792288	31	EC792316	42	EC792284	C3	MTU-1010
10	EC792236	21	EC792187	32	EC792204	43	EC792218	C4	N-22
11	EC792210	22	EC792205	33	EC792238	44	EC792186	C5	ES-18

Note: C1, C2, C3, C4 and C5 are check (Local, national and international) varieties

Five competitive plants were randomly selected from each entry, each replication and from each environment for the recording of the observations. The morphological parameters like plant height (cm), flag leaf length (cm), flag leaf width (cm), number of tillers per plant, days to 50 per cent flowering and days to physiological maturity. Whereas, physiological parameters like leaf temperature (^oC), chlorophyll content (mg/g FW), normalized difference vegetation index values, transpiration rate (mmol (H_2O) $m^{-2}s^{-1}$), stomatal conductance (mol (H_2O) $m^{-2}s^{-1}$), photosynthetic rate (µmol CO_2 $m^{-2}s^{-1}$), light interception (%), leaf area index and grain yield (kg/ha). The genotypes from normal and late sown condition were planted in randomised block design (RBD) with two replications and field observations were recorded during crop growth season.

The data collected from experiments were analysed statistically by following the procedure prescribed by Sundararaj *et al.* (1972) [2]. Whenever, 'F' test was found significant the critical difference (CD) values were calculated and the treatment mean were compared at five per cent.

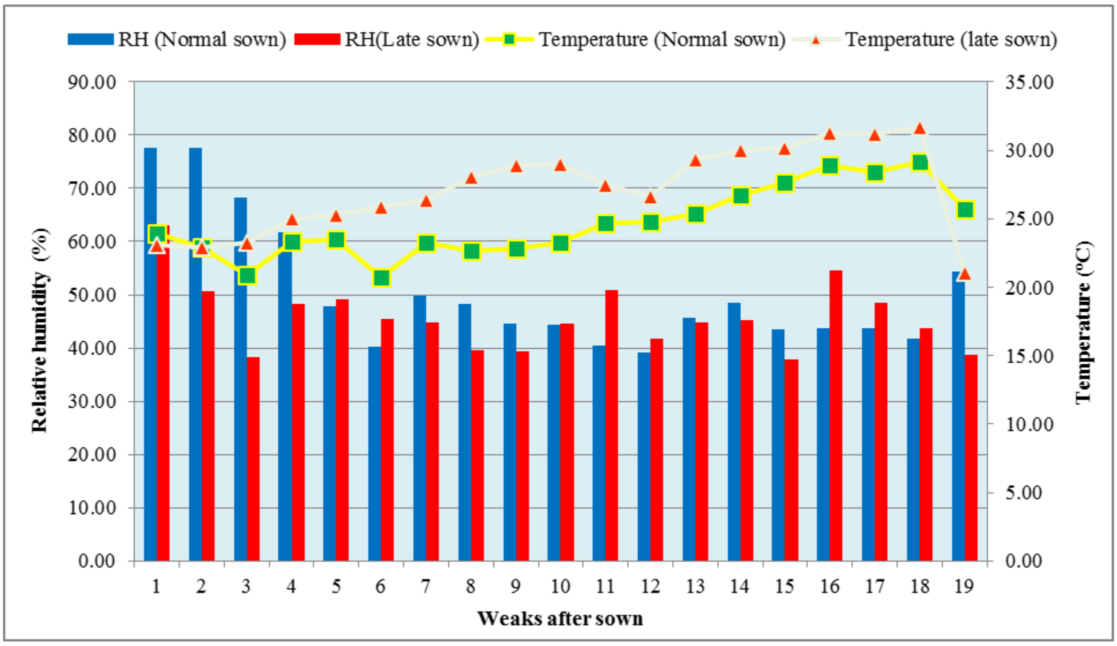

Fig 1: Standard meteorological week's data during the crop growth period (summer 2014-2015)

Results and Discussion

Morphological

Variability in the rice genotypes for different morphological and yield parameters is essential component for the genetic improvements of a crop. The results of mean sum of squares due to the genotypes and their interaction were significant for the all morphological and physiological traits under both normal and late sown conditions. Performance of rice genotypes on various morphological characters such as plant height, flag leaf length, flag leaf width, number of tillers per plant, days to fifty per cent flowering, days to physiological maturity, Grain weight per plant (gm), Test weight of seeds (gm) and Net plot yield (kg/ha) indicated significant differences for all the above characters. Under normal sown condition, at all stages responded better compared to all other treatments.

The maximum plant height was observed in the check N-22 (112.00 cm) followed by IR-64 (110.60 cm) under the normal sown condition at harvest stage. Plant height was significantly reduced in genotype EC792205 (67.90 cm) followed by EC792186 (70.90 cm) under late sown condition as compared to normal sown condition. During late sown condition such significant differences with respect to plant height was mainly due to higher temperature stress in rice genotypes also recorded by (Osada *et al.*, 1973) in rice, (Chaudhary *et al.*,1997) in wheat and (Oh-e *et al.*, 2007) in rice. The maximum flag leaf length and width was observed in genotype IR-64 (39.13 cm) and N-22 (2.19 cm) respectively, followed by N-22 (37.43 cm) under the normal sown condition at harvest stage and Significantly reduction of flag leaf length and width was recorded in genotypes EC792240 (17.75 cm) and EC792205 (1.07 cm), respectively. Flag leaf length and width was higher due to congenial environment under normal sown condition and significantly decreased leaf length and width in late sown condition. This is may be due to higher temperature stress. Such significant genotypic difference for flag leaf length and width were also recorded by (Liao *et al.*, 2011) [16] in rice. Flag leaf length and width was affected due to high temperature stress. Even the genotype EC792240 and EC792205 maintained higher leaf length and width at late sown conditions, indicated the tolerance of the genotypes for high temperature stress.

The number of tillers per plant was observed maximum in genotypes EC792239 (29.28) followed by EC792185 (27.15) under the normal sown condition at harvest. Significantly reduction of number of tillers was recorded in genotype EC792227 (16.93) followed by ES-18 (17.45) under late sown condition as compared to normal sown condition. Similar results were noticed by (Prerna *et al.*, 2012) in rice. However, the results on interaction effects of genotypes and temperature regimes revealed that the genotype EC792239 (29.28) recorded significantly highest number of tillers per plant during at harvest under normal sown condition. The results are in good agreement with those of (Safdar *et al.*, 2013) in rice, (Yugandhar *et al.*, 2013) [17] in rice and Ajay *et al.* (2014) [24] in wheat. Among the genotypes, the Gangavati sona recorded significantly higher number of days to 50 per cent flowering in both temperature regimes about 107 and 98 days under normal and late sown conditions respectively. And the genotype EC792215 and EC792239 were recorded earlier number of days for 50 per cent flowering about 84 and 79 days, respectively under normal and late sown conditions. There was a significant decrease in the number of days to taken 50 per cent flowering under late sown condition. This may be due high temperature reduces the crop cycle of the rice genotypes during late sown condition compared to normal sown condition. Similar results were reported by (Pandey and Parihar 1997) [25] in wheat, (Venkatramanan and Singh 2009) [19] in rice, (Arthi and Maragatham 2013) [7] in rice, (Yugandhar *et al.*, 2013) [17] in rice, (Tao *et al.*, 2008) in guodao, (Shah *et al.*, 2011) in rice and (Safdar *et al.*, 2013) in rice. Among the genotypes, EC792310 (126 days) and EC792186 (110 days) recorded significantly higher number of days to attain physiological maturity under normal and late sown conditions respectively. These genotypes were recorded more number of test weight and grain filling percentage. However, the EC792215 (98 days) and ES-18 (94 days) were recorded lesser number of days for physiological maturity under normal and late sown conditions, respectively. There was a significant decrease in the days to taken physiological maturity under late sown condition due to high temperature stress compared to normal sown condition. Similar results were reported by (Pandey and Parihar 1997) [25] in wheat, (Tao *et al.*, 2008) in guodao, (Venkatramanan and Singh 2009) [19] in rice, (Shah *et al.*, 2011) in rice, (Arthi and Maragatham 2013) [7] in rice, and (Yugandhar *et al.*, 2013) [17] in rice.

In general, the results indicated that due to high temperature stress under late sown conditions, recorded seven days earlier for days to 50 per cent flowering and six days for physiological maturity of all rice genotypes compared to normal sown condition. Similar results reported by (Tenorio *et al.*, 2013) [18] in rice and (Ajay *et al.*, 2014) [24] in wheat.

Yield and its components

The results on grain weight per plant and 1000 grain weight were significantly influenced by temperature regimes. Among the genotypes, the genotypes EC792204 (26.56cm), EC792288 (318.60 g), EC792215 (183.95), EC792179 (3.75 g) and EC792267 (29.06 g) recorded significantly higher values of grain weight per plant and 1000 grain weight respectively under normal sown condition. But lowest values for grain weight per plant and 1000 grain weight were significantly reduced under late sown condition in the genotypes EC792226 (13.36 cm), EC792201 (84.00 g), EC792186 (55.30), MTU-1010 (1.02 g) and EC792239 (24.91 g) respectively.

The higher values for yield components were recorded in normal sown condition due number favourable temperature (24.64 ºC) during its crop period. The reduction of these parameters under late sown due to high temperature (>32ºC). Similar results were observed by Chwen *et al.* (1993), Chaudhary *et al.* (1997), Cao *et al.* (2008), Hae-Ran *et al.* (2010), Prerna *et al.* (2012), Yugandhar *et al.* (2013) [17], Ajay *et al.* (2014) [24], and Gerson *et al.* (2015) [10].

However, interaction effects revealed that the genotypes EC792204, EC792288, EC792215, EC792179 and EC792267 recorded significantly higher values of grain weight per plant and 1000 grain weight normal sown condition compared to all other genotypes in both normal and late sown condition. The results are complete agreement with those of Liao *et al.* (2011) [16] and Pratap and Dwivedi (2015).

Table 2: Performance of rice genotypes under normal and late sown conditions and percent decrease of late sown over the normal sown condition for different morphological parameters during summer 2014-2015

Characters	Condition	Genotypes showing highest value		Genotypes showing lowest value		Overall mean	Per cent decrease
		Genotypes	Values	Genotype	Values		
Plant height (cm)	Normal	N-22	112.0	EC792240	76.9	92.7	6.26
	Late	EC792227	105.7	EC792205	67.9	86.9	
Flag leaf length (cm)	Normal	IR-64	39.1	EC792238	20.5	27.1	17.34

	Late	EC792326	26.5	EC792240	17.7	22.4	
Flag leaf width (cm)	Normal	N-22	2.2	EC792234	1.3	1.53	11.11
	Late	N-22	1.67	EC792205	1.1	1.36	
Number of tillers per plant	Normal	EC792239	29.2	ES-18	20.5	24.7	18.18
	Late	EC792239	24.4	EC792227	16.9	20.9	
Days to 50 per cent flowering (Days)	Normal	Gangavati sona	107	EC792215	84	92.6	7.45
	Late	Gangavati sona	98	EC792239	79	85.7	
Days to physiological maturity (Days)	Normal	EC792310	126	EC792186	110	107.5	5.86
	Late	EC792225	98	EC792216	94	101.2	
Plant height (cm)	Normal	N-22	112.0	EC792240	76.9	92.7	6.26
	Late	EC792227	105.7	EC792205	67.9	86.9	
Grain weight per plant (gm)	Normal	EC792179	3.75	EC792238	1.51	11.92	77.60
	Late	EC792217	3.30	MTU-1010	1.02	2.67	
Test weight of seeds (gm)	Normal	EC792267	29.1	EC792208	17.3	23.35	15.03
	Late	EC792239	24.9	EC792208	13.8	19.84	
Net plot yield (kg/ha)	Normal	EC792239	6,334	MTU-1010	2,557	3,670.91	14.94
	Late	EC792239	5,713	ES-18	1,553	3,122.55	

Conclusion

Genotypic variability was observed for physiological, morphological traits and yield for heat stress tolerance under normal and late sown conditions. Among the normal and late sown conditions, normal sown crops perform better for various morphological, physiological and yield attributes compared to late sown crops due to high temperature stress. Among the genotypes EC792239, EC792185, EC792179, EC792240 and EC792316 were responded better to heat stress in terms of morphological, physiological and yield parameters under both normal and late sown conditions. Thus the genotypes indicating the high temperature tolerance and those genotypes can directly used as heat tolerance variety under summer and also used for further heat tolerance genetic studies.

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