Environment and Ecology 37 (4B) : 1448—1454, October—December 2019
ISSN 0970-0420

Response of Aerobic Rice Cultivars to High Temperature Stress

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Received 30 July 2019; Accepted 14 September 2019; Published on 14 October 2019

ABSTRACT

A pot culture experiment was conducted during the summer season of 2017, Thrissur to study the response of selected aerobic rice cultivars to high temperature stress (2-3^{0}C above ambient temperature) at different growth phases. Four aerobic rice cultivars (V1 : Swarnaprabha, V2 : Sharada (MAS 946-1), V3 : Vaishak and V4: MDU-6) were selected and high temperature stress was artificially imposed at three different growth stages (S1 : Tillering to panicle initiation (PI), S2 : Panicle initiation to flowering and S3 : Flowering to maturity) along with control (S0). Completely Randomized Block Design (CRD) was adopted with three replications. Significant variation in number of filled grains per panicle, 1000-grain weight, grain and straw yield were observed among the cultivars. Plants exposed to high temperature stress from flowering to maturity stage recorded lowest number of filled grains per panicle, lowest grain (35.70 g/pot) and straw yields (47.42 g/pot). Vaishak, was the only variety which showed high temperature tolerance and recorded comparable grain yield to that of ambient condition when temperature stress was imposed at vegetative stage (tillering to PI). However it was sensitive to temperature stress during reproductive growth phase as in the case of other three varieties tried.

Keywords Aerobic rice, Growth stages, High temperature, Stress, Yield.

INTRODUCTION

Rice production around the world is under the threat of biotic and abiotic stresses. Most of the world's rice is grown in tropics and temperature is a crucial factor in rice growth and productivity. Global mean surface air temperature increased by about 0.5^{0}C in the 20th century and may further increase by 1.5 to 4.5^{0}C in this century (IPCC 2001). It is reported that the grain yield will decline by 10% with every 1^{0}C increase in minimun temperature (Peng et al. 2004). Low land rice has relatively highwater requirement and hence the sustainability rice production is threatened by increasing water shortage. Aerobic rice production method can address problem of water scarcity to some extent. Temperature above optimum (27 to 32^{0}C) will affect almost all the growth stages of rice, especially the flowering phase, resulting in yield reduction. Different phenological stages of plant growth

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differ in their sensitivity to high temperature. Selection of temperature tolerant cultivars can be a viable management strategy under the changing climate scenario as varietal sensitivity to temperature also can differ. Hence the objective of the research work was to assess the response of some high yielding aerobic rice cultivars to high temperature stress (2-3^{0}C above ambient temperature) at different growth phases.

MATERIALS AND METHODS

A pot culture experiment was conducted during the summer season (December 2017 to March 2018) at the College of Horticulture, Vellanikkara, Thrissur, Kerala located at 10^0 31´ N latitude and 76^0 13´ E longitude and an altitude of 40.3 m above mean sea level. The treatments included four aerobic rice cultivars, Swarnaprabha (V1), Sharada (MAS 946-1) (V2), Vaishak (V3), MDU-6 (V4) and high temperature stress was imposed at different growth stages of rice plant, from tillering to panicle initiation (S1), panicle initiation to flowering (S2) and flowering to maturity (S3). No stress (S0) was also included for each cultivar as control. The variety Vaishak is medium duration type (125 days) and Swarnaprabha, Sharada and MDU-6 are short duration types (105-110 days).

For imposing temperature stress, portable transparent polythene chambers with the dimensions of 2 m ×2 m ×1.5 m were fabricated. Top of the chamber was covered with UV stabilized polythene sheet and sides were covered using transparent polythene sheet, leaving a gap of 15 cm from the ground level at the base for free air passage. The potted plants were kept inside the chamber according to the growth phases during which temperature stress has to be imposed. Each chamber could accommodate 16 pots and four pots were maintained per treatment in each replication. The temperature inside chamber was monitored and was 2-3^{0}C above ambient condition. The maximum and minimum temperature during the crop growth period ranged from 32-38^{0}C and 20-25^{0}C, respectively (Fig. 1).

Completely Randomized Block Design (CRD) was followed with three replications. Crop management practices were done as per the recommendations given for upland rice according to Package of Practices-Crops (KAU 2016). The yield attributes like productive tillers, number of spikelets per panicle, percentage chaff and 1000-grain weight were recorded. The grain and straw yield were recorded on dry weight basis and expressed in g/pot.

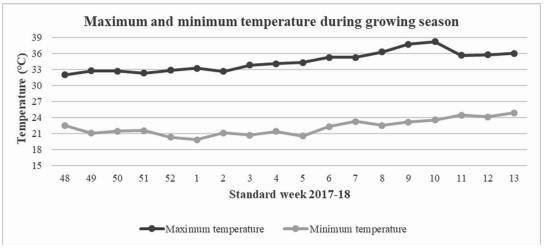

Fig. 1. Maximum and minimum temperature during growing season (December 2017 to March 2018).

RESULTS AND DISCUSSION

Number of tillers per hill

Among the cultivars, Sharada produced highest number of tillers per hill (14.06) which was superior to all cultivars and lowest tiller number per hill was for Swarnaprabha (10.74) (Table 1). Tillering in rice is influenced by many factors and varietal differences in tiller production is reported elsewhere. It is reported that optimun temperature range of 15^{0}C to 33^{0}C favors tillering in rice and average ambient temperature during the tillering phase during this study was 27 to 28^{0}C.

All cultivars showed higher tiller number per hill under ambient temperature compared to heat stressed condition. The higher number of tillers per hill was recorded for Sharada under high temperature stress compared to other cultivars. The cultivar Vaishak recorded lowest tiller number (10.11) when stress was induced from tillering to PI stage which was at par with other cultivars under stress except Sharada.

Venkataraman and Singh (2009) reported that rice variety Pusa Sugandh was more sensitive to temperature stress than Pusa 44 with respect to tiller production. Similar results were also reported by Sailaja et al. (2015). Kumar et al. (2015) also found that

Table 1. Effect of high temperature stress on yield attributes of aerobic rice cultivars.

Treatments	No. of tillers/hill	No. of panicles /hill	No. of filled grains/ panicle	Chaff percent	No. of total grains/ panicle	1000-grain weight (g)
			Cultivars			
VI–Swarnaprabha	10.74	9.10	80.73	19.46	100.47	23.88
V2–Sharada	14.06	11.98	80.44	8.81	88.27	21.58
V3–Vaishak	11.17	9.27	96.59	9.33	106.66	26.82
V4–MDU-6	12.16	10.13	87.02	9.69	96.36	22.93
CD (0.05)	0.91	0.75	4.29	0.71	4.88	1.46
			High temperature stress			
S0–Control	13.08	10.80	93.57	10.81	105.05	25.55
S1– Tillering to PI	11.37	9.39	86.91	8.93	95.50	23.92
S2–PI–Flowering	11.44	10.24	82.60	8.88	90.77	23.50
S3–Flowering-Maturity	12.23	10.05	81.71	18.67	100.44	22.23
CD (0.05)	0.91	0.75	4.29	0.71	4.88	1.46
			Interaction			
V1S0	11.56	9.53	86.13	20.10	107.80	24.69
V1S1	10.17	8.67	81.43	15.85	96.77	24.40
V1S2	10.44	9.08	79.63	14.83	93.50	23.76
V1S3	10.78	9.11	75.73	27.04	103.80	22.65
V2S0	15.78	12.89	85.10	7.50	92.00	22.76
V2S1	14.00	11.12	86.37	4.74	90.67	21.14
V2S2	12.44	11.48	77.17	4.85	81.10	22.56
V2S3	14.00	12.42	73.13	18.14	89.33	19.84
V3S0	12.00	9.83	109.55	8.36	119.55	28.99
V3S1	10.11	8.60	92.37	7.75	100.13	26.25
V3S2	11.00	9.78	88.53	7.10	95.30	26.38
V3S3	11.57	8.89	95.92	14.10	111.67	25.67
V4S0	13.00	10.95	93.50	7.27	100.83	25.74
V4S1	11.19	9.15	87.47	7.37	94.43	23.88
V4S2	11.89	10.64	85.07	8.72	93.20	21.31
V4S3	12.57	9.77	82.05	15.39	96.97	20.78
CD (0.05)	1.82	1.50	8.59	1.42	9.76	2.92

when rice plants were exposed to heat stress, number of tillers per hill tend to decrease with promoted shoot elongation. The highest number tillers per hill were recorded under ambient condition. High temperature stress induced during other stages produced lower number of tillers per hill.

Number of panicles per hill

The data on yield attributes as influenced by cultivars and high temperature stress at different growth stages are presented in Table 1. Among the cultivars, significantly higher number of panicles per hill was observed for Sharada (11.98) whereas it was lower for Swarnaprabha (9.10) which was comparable with Vaishak (9.27).

Plants grown under ambient condition produced comparable number of panicles to those under stress except stress during tillering to panicle initiation stage. Singh et al. (2010) also found that plants exposed to heat stress during vegetative and reproductive growth phases had decreased the number of panicles per m^2.

All cultivars produced higher number of panicles

under ambient temperature compared to heat stressed condition. It was seen that in variety Sharada tillering is not influenced by temperature 2-3^{0}C above normal as comparable productive tiller was seen when stress was induced at various growth phases. The lowest number of panicles was recorded in cultivar Vaishak (8.60) when high temperature stress imposed during tillering to PI stage. Aghamolki et al. (2014) reported that the effective tillers per hill were more in cultivar Fajr although heat stress was imposed during booting and flowering stages. The lower number of panicles in heat stressed plants was due to reduced biomass production and inability of heat stressed plants to maintain favorable blance between photosynthesis and respiration (Venkataraman and Singh 2009).

Number of filled grains per panicle

A trend similar to that of total spikelet number could be observed in the case of number of filled grains also. Vaishak produced the highest number of filled grains per panicle (96.59) compared to other three cultivars. Sharada and Swarnaprabha were inferior. It is clear that temperature stress had a significant influence on grain filling. The highest number of filled grains per panicle was recorded under control (93.57). It was also seen that the reproductive phase of rice is sensitive to high temperature as stress imposed during PI to maturity stage showed lower number of filled grains per panicle.

All cultivars produced higher number of filled grains per panicle under ambient condition. A lower number of filled grains per panicle was noticed in Sharada exposed to high temperature stress from flowering to maturity (73.13) which was at par with Swarnaprabha and Sharada exposed to high temperature from PI to flowering stage.Corroborating to this Sailaja et al. (2015) reported that exposure of rice cultivars to elevated temperature significantly reduced number of filled grains. She found that variety BPT5204 was sensitive to temperature stress and N22 was resistant to temperature stress.

Chaff percent

Varietal sensitivity to high temperature was evident in percent chaff also. The cultivar Swarnaprabha was found most susceptible with 19% chaff ande Sharada recorded lowest chaff percent of 8.81% which was at par witgh Vaishak (9.33%). High temperature stress imposed from flowering to maturity showed highest chaff percent (18.67%) indicating the sensitivity of this stage and response was similar in all the cultivars tried.

According to Beena et al. (2018), when various rice genotypes were exposed to high temperature stress from panicle initiation to maturity, most of the genotypes showed 70-80% spikelet sterility. The susceptibility to high-temperature-induced floret sterility is highest at the flowering stage, followed by booting stage (Satake and Yoshida 1978). The temperature at which sterility occurs varies with the cultivar. Sterility occurs at a temperature over 35^{0}C due to poor anther dehiscence, decrease in the number of pollen grains on the stigma and poor germination of pollen on the stigma (Matsui et al. 2000).

Total number of grains per panicle

Cultivar differences were significant. The total grain number was significantly higher in Vaishak (106.66) and the lowest number was for variety Sharada (88.28). Temperature stress during PI to flowering showed least number of grains per panicle (Table 1). According to Laza et al. (2015) generally high night temperature during early reproductive stage caused decline in total grains which results in yield reduction and response different with variety.

For all the cultivars, total grains per panicle were higher under ambient condition compared to high temperature stress. Higher and statistically comparable number of grains per panicle was observed for Vaishak under control and when exposed to stress from flowering to maturity. The lowest number of grains per panicle was recorded for Sharada when stress was imposed from PI to flowering (81.10) was at par with Sharada imposed to stress at other stages. Jumiatun et al. (2016) also found that high temperature stress fron 56 days after sowing to harvest, decreased the number of grains per panicle in Ciherang and Hipa 14 cultivars whereas number of grains increased in Menthik Wangl, IPB 3S, IR 64 and Wat Apo Buru cultivars. Similarly, heat-induced

MR 219 at flowering stage recorded lesser number of fertile spikelets (87.5) than normal condition at flowering stage (Aghamolki et al. 2014). High temperature might have affected the pollen viability and fertilization and thereby reduced the number of grains per panicle. It is reported that above 35^0C detrimental to pollen viability in rice.

Thousand grain weight

The test weight varied significantly with variety. The test weight of 26.82 g was noticed in Vaishak was significantly higher than other three cultivars and lowest was recorded in Sharada (21.58 g), which is mostly a varietal character.

Similar trend of filled grains per panicle as mentioned earlier was observed for thousand grain weight. The 1000-grain weight was higher under control (25.55 g) and plants exposed to high temperature stress from flowering to maturity recorded the lowest thousand grain weight (22.23 g), probably due to poor translocation to developing grains. The sink capacity under high temperature can be low due to increase in sterile spikelets and reduced activity for starch synthesis can result in reduction in 1000-grain weight (Oh-e et al. 2007). Even a brief exposure to high temperature during seed filling can diminish seed set and seed weight. This validates the above finding.

Grain yield

Significant difference in grain yield was noticed among the cultivars and they differed statistically from each other (Table 2). The highest grain yield was observed for Vaishak (44.06 g). High temperature stress imposed from PI to flowering and flowering to maturity resulted in lowest grain yield which was 10% lower than control. This was due to reduction in number of panicles, filled grains and 1000-grain weight. However, stress during vegetative phase did not result in significant reduction in grain yield.

Cultivar Vaishak produced higher grain yield under high temperature stress at all growth stages compared to others. The lowest grain yield was observed in MDU-6 when high temperature stress imposed from flowering to maturity. Reduction in yield can be attributed to reduction in number of panicles per hill, number of filled grains per panicle and thousand grain weight. Similar finding has been reported in rice variety, Pusa 44 by Singh et al. (2010). Wheeler et al. (2000), Morita et al. (2005) showed that high thermal regime at the time of flowering can reduce grain yield of rice. High temperature stress during anthesis increased pollen sterility and finally caused losses in grain yield (Oh-e et al. 2007).

Table 2. Effect of high temperature stress on grain yield, straw yield and harvest index of aerobic rice cultivars.

Treatments	Grain yield (g/pot)	Straw yield (g/pot)	Harvest index
Cultivars			
V1–Swarnaprabha	37.43	53.46	0.42
V2–Sharada	40.71	50.27	0.45
V3–Vaishak	44.06	57.60	0.44
V4–MDU-6	34.27	47.42	0.42
CD (0.05)	1.79	4.61	NS
High temperature stress			
S0–Control	41.53	50.27	0.45
S1–Tillering to PI	40.75	59.77	0.41
S2–PI–Flowering	38.50	51.79	0.43
S3–Flowering - Maturity	35.70	47.42	0.43
CD (0.05)	1.79	4.61	0.03
Interaction			
V1S0	39.58	48.83	0.45
V1S1	39.08	68.50	0.36
V1S2	37.08	52.75	0.42
V1S3	33.98	43.75	0.44
V2S0	43.58	47.67	0.48
V2S1	43.17	58.17	0.43
V2S2	40.33	50.08	0.45
V2S3	35.75	47.17	0.43
V3S0	46.92	57.17	0.45
V3S1	45.00	60.42	0.43
V3S2	42.92	59.75	0.42
V3S3	41.42	53.08	0.44
V4S0	36.02	47.42	0.43
V4S1	35.75	52.00	0.41
V4S2	33.66	44.58	0.43
V4S3	31.67	45.67	0.41
CD (0.05)	3.57	9.23	0.05

Straw yield

The data shows significant difference in straw yield among cultivars (Table 2). Vaishak, Swarnaprabha

and Sharada recorded comparable values and were superior to MDU-6. The variety MDU-6 was dwarf compared to others which resulted in lower straw yield. Temperature stress at Vegetative phase favorably influenced straw yield and the maximum straw yield was observed under high temperature stress from tillering to PI stage. This was due to increased tiller number recorded under high temperature stress during vegetative phase. Higher straw yield was recorded for Swarnaprabha, Vaishak and Sharada under when temperature stress was imposed in vegetative phase.

Harvest index

No significance difference was observed among the cultivars in relation to harvest index. High temperature stress imposed from flowering to maturity recorded lowest harvest index (0.41). This is due to low grain yield registered under this treatment. The maximum harvest index of 0.48 was recorded in under control (0.48). The cultivar MDU-6 exposed to high temperature stress from flowering to maturity and tillering to PI recorded lowest harvest index (0.41). This is attributed to the fact that increase in temperature caused reduction in both biomass and grain yield to almost the same extent which has led almost constant harvest index. Poor grain development and non-diversion of nutrients from vegetative shoot to panicle may possibly be one of the reasons for poor harvest index in plants subjected to high temperature (Johnson et al. 2011). The negative effects of high temperature on grain yields were much greater than on biomass, leading to significantly lower harvest index at high temperatures.

CONCLUSION

It can be concluded that aerobic rice cultivars have differential sensitivity to high temperature during different growth phases. Plants exposed to high temperature stress from panicle initiation to maturity stage showed maximum reduction in grain yield which was mainly attributed to marked decline in the number of panicle per hill, filled grains per panicle and 1000-grain weight. High straw yield was registered when stress was imposed during tillering to PI stage in all the varieties due to better tillering. The cultivar Vaishak showed higher yield and yield attributes compared to other cultivars under high temperature stress at critical stages and hence this cultivar is tolerant to high temperature stress.

ACKNOWLEDGEMENT

This paper forms a part of PhD research work of the first author and financial assistance from the Kerala Agricultural University is gratefully acknowledged.

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