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Response of Yield and Morphological Characteristic of Rice Cultivars to Heat Stress at Different Growth Stages

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***Abstract*—**The high temperatures during sensitive growth phases are changing rice morphology as well as influencing yield. In the glass house study, the treatments were growing conditions [normal growing (32^{o}C$\pm$2) and heat stress (38^{o}C$\pm$2) day time and 22^{o}C$\pm$2 night time], growth stages (booting, flowering and ripening) and four cultivars (Hovaze, Hashemi, Fajr, as exotic and MR219 as indigenous). The heat chamber was prepared covered with plastic, and automatic heater was adjusted for two weeks in every growth stages. Rice morphological and yield under the influence of heat stress during various growth stages showed taller plants in Hashemi due to its tall character. The total tillers per hill were significantly higher in Fajr. In all growing conditions, Hashemi recorded higher panicle exertion. The flag leaf width in all situations was found higher in Hovaze. The total tillers per hill were more in Fajr, although heat stress was imposed during booting and flowering stages. The indigenous MR219 in all situations of growing conditions, growth stages recorded higher grain yield. However, its grain yield decreased when heat stress was imposed during booting and flowering. However, plants had no effect on heat stress during ripening stage.

***Keywords*—**Rice, growth, heat, stress, morphology, yield.

I. Introduction

THE increase in annual temperature has exposed most of the crops including rice at risk during some heat sensitive stages of their life cycle, and yield projections remained uncertain [8]. In rice growing regions, the current temperature is already close to optimum temperature for rice production. The further increases in mean temperature during sensitive stages may be harmful and could drastically reduce grain yield. By the end of 21st century, the rice yields have been estimated to be reduced by 41% due to temperature stress [1]. According to [4], rice yields in the existing cropping areas could be completely wiped out if most severe climate predications were correct.

The optimum temperature for the normal development of rice ranges from 27 to 32°C [9]. The temperature above these ranges affects almost all the growth stages of rice, i.e. from emergence to ripening and harvesting. Since rice plants can tolerate only narrow temperature ranges, especially during the flowering phase, fertilization and seed production are damaged, resulting in reduced yield [6]. The vegetative and reproductive stages are greatly affected by heat stress. A high day temperature can damage leaf gas exchange properties during the vegetative stage. Even a short period of heat stress can cause significant increases in the abortion of floral buds and opened flowers during the reproductive stage [2].

Reference [7] found that flowering and booting stages of rice are most susceptible to high temperatures. Reproductive stage in rice is more sensitive to heat than the vegetative stage [11]. Heat stress tolerance in different growth phases in rice is an intricate phenomenon affecting morphological and yield responses. Determination of these responses could make possible strategies for heat stressed regions to improve yield. In this perspective, this research is an attempt to explicit growth and yield responses of indigenous and exotic cultivars.

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II. Materials and Methods

The glass house study was laid out at Universiti Putra Malaysia during 2012 (latitude 02°59' N, longitude 101°43 E' and altitude 64m above the sea level). The experimental soil was silt clay loam, with 5.5 pH, 0.55% total nitrogen, 131 mg L^{-1} available phosphorus and 0.32mg g^{-1} potassium. The experiment was laid down in split-split plot experiment, using Randomized Complete Block Design (RCBD) with four replications. The growing treatments were [normal growing (32^{o}C$\pm$2) and heat stress (38^{o}C$\pm$2) day time and (22^{o}C$\pm$2) night time] as main plots, growth stages (booting, flowering and ripening) as sub plot and four cultivars (Hovaze, Hashemi, Fajr, as exotic and MR219 as indigenous) were set as sub-sub plots. The heat chamber was prepared and covered with plastic, and heater was adjusted at 38^{o}C $\pm$2 (day) and 22^{o}C$\pm$2 (night).

Cultural Practices: The seedlings were grown in the plastic tray (40cm length, 30cm width and 10cm height) with soil. The three seedlings of 20 days old of each cultivar were transplanted in pots containing 10kg well-puddled soil. About 3-4cm water level was maintained until the physiological maturity. The N-P_2O_5-K_2O was applied at 125-60-45 kg ha^{-1}. The whole P and K in the form of Single Super Phosphate and Muriate of potash were applied during the soil puddling. However, N (Urea) was split applied in three doses i.e. 40% at the time of seedling transplanting, 30% at the active tillering and 30% in the beginning of the reproductive stage.

Plant Determinations: The flag leaf length and width were measured by ruler in cm. The plant height was measured by using three hills of each pot and same plants were selected to count the number of tillers. Each pot was harvested and threshed manually to determine grain yield per pot at 14% moisture content.

Statistical Analysis: The data were analyzed through complete randomized design, with four replications using analysis of variance (ANOVA). The treatment means were compared through Duncan test at 5% probability level using Statistical Analysis System (SAS) software version 9.2.

III. Results and Discussion

Plant Height: Hashemi as a tall character cultivar produced taller plants (139.3-140.0cm) grown in heat stress as well as in normal condition across growth stages (Table I). In this study, plant height was genetic character of the cultivar and no clear effect of heat stress was noticed. In a study, [5] reported that the increase in plant height was steeper under high temperature (30-35^{o}C) than under ambient temperature condition.

Total Tillers: Total tillers per hill were significantly higher (19.8) in Fajr receiving heat stress during booting stage. This cultivar equally produced higher number of tillers upon reception of normal conditions during flowering stage. Similarly, Hovaze had maximum tillers (19.4) when normal conditions were provided during ripening stage. The overall results showed that most of the cultivars had better performance for tiller production except Hashemi which recorded fewer numbers of tillers per hill (Table I). It could be seen that total tillers differed significantly in various rice cultivars due to genetic character of the cultivars. However, growing no increase or decrease trend was found. Reference [10] reported that higher temperatures increased tiller numbers. At 3–5 weeks after sowing, temperature only slightly affected the tillering rate. Tiller number per plant determines panicle number which is a key component of grain yield [11]. There appears to be a synchronism in emergence between main stems and tillers and further, between tillers themselves. High temperatures may affect this synchronism and in the mobilization of assimilates and nutrients among tillers.

Flag Leaf Length and Width: Hashemi had a maximum flag leaf length when grown in normal condition as well as in heat stress. Among the rest of varieties, Hovaze was found to have 2nd lowest values of flag leaf length regardless of growing conditions or growth stages (Table I). The flag leaf width in all situations was found higher in Hovaze. This cultivar significantly recorded greater flag leaf width even though heat stress was imposed during booting, flowering and ripening stages. Similarly, Hovaze had better performance for flag leaf width when heat stress was introduced during the ripening stage. However, the rest of cultivars had lower flag leaf width. The width of flag leaf is dependent on genetic potentiality of the cultivar as found in Hovaze (Table I). The reproductive phase, which is characterized by the stem elongation, emergence of the flag leaf, booting, heading, and filling of the spikelets begins just before or after the maximum tillering. When rice is exposed to high temperatures during the initial reproductive stages, it considerably reduces flag leaf length as well as width. High temperature can reduce photosynthetic rate by 40–60% at mid-ripening, leading to more rapid senescence of the flag leaf [5].

Grain Yield: The indigenous MR219 in all situations of growing conditions, growth stages recorded higher grain yield. However, its grain yield reduced when heat stress was imposed during booting and flowering. This situation also appeared in the other exotic cultivars, being lower yield in the heat stress condition especially when heat treatment was given during booting and flowering (Table I). The effect of heat stress on grain filling and yield has been studied when high temperature occurred during flowering and filling period [3]. In this study, temperature stress was carried out at booting, flowering and ripening stages. Under the heat stress during initial growth phases i.e. booting and flowering greater yield reduction was noticed due to reduction in all the important yield components. However, heat stress has no effect on the later growth stage (ripening). In the initial growth stages, usually infertile spikelets increase due to pollen infertility and anther dehiscence and accordingly the number of pollen scattered on stigma and the fertility and fertilization of pollens markedly declined. However, such effects were subject to the heat-tolerance of varieties.

TABLE I
RICE MORPHOLOGICAL TRAITS AND YIELD UNDER THE INTERACTIVE EFFECT OF HEAT STRESS AND GROWTH STAGES

Heat stress	Growth stage	Cultivars	Plant height (cm)	Total Tillers per hill	Flag leaf length (cm)	Flag leaf width (cm)	Grain yield (g pot^{-1})
Heat (38±2 °C)	Booting	Hovaze	112.8 b	18.9 abc	39.8 bc	1.93 b	28.3 g
		Fajr	96.8 cde	19.8 a	33.8 efg	1.34 fgh	28.0 g
		MR219	94.3 f	17.3 d	30.5 h	1.33 gh	36.3 def
		Hashemi	139.3 a	9.6 e	37.5 cd	1.29 h	12.5 j
	Flowering	Hovaze	112.8 b	19.0 abc	42.0 ab	1.98 ab	26.5 g
		Fajr	96.3 cde	19.0 abc	34.0 efg	1.41 c-f	20.5 h
		MR219	95.3 def	17.9 cd	32.5 fgh	1.36 e-h	27.5 g
		Hashemi	140.0 a	9.9 e	41.3 ab	1.33 gh	6.8 k
	Ripening	Hovaze	113.0 b	18.9 abc	41.5 ab	2.01 a	35.3 def
		Fajr	96.3 cde	19.0 abc	32.8 e-h	1.46 cd	35.3 def
		MR219	95.0 ef	17.5 d	32.8 e-h	1.41 c-f	41.0 bc
		Hashemi	139.5 a	10.3 e	41.5 ab	1.33 gh	16.3 i
Normal (32±2 °C)	Booting	Hovaze	113.5 b	19.0 abc	41.5 ab	2.01 a	33.5 f
		Fajr	97.5 c	19.0 abc	35.3 de	1.45 cd	38.5 cd
		MR219	95.0 ef	17.8 cd	32.8 e-h	1.41 c-f	45.0 a
		Hashemi	139.5 a	9.8 e	41.5 ab	1.30 h	16.3 i
	Flowering	Hovaze	113.8 b	19.3 ab	42.3 ab	2.05 a	34.8 ef
		Fajr	96.0 c-f	19.6 a	35.0 def	1.48 cd	37.8 cde
		MR219	96.0 c-f	18.0 bcd	32.0 gh	1.43 cde	44.8 a
		Hashemi	139.5 l	10.1 e	42.5 á	1.40 d-g	16.5 i
	Ripening	Hovaze	113.3 b	19.4 a	41.8 ab	2.03 a	36.0 def
		Fajr	97.0 cd	19.3 ab	33.8 efg	1.49 c	36.5 def
		MR219	95.3 def	18.5 a-d	32.5 fgh	1.43 cde	42.3 ab
		Hashemi	139.8 a	9.9 e	42.3 ab	1.34 fgh	16.8 i
LSD (5%)			1.86	1.19	2.48	3.36	0.077

In each row, means followed by common letter are not significantly different at 5% probability level by LSD.

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