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Effect of drought, flood and heat at flowering stage on canopy cooling related traits in rice

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Abstract

Standing water is an important contributor for yield formations and physiological activities at flowering stage of the rice crop. It may help to maintain tissue temperature below the critical level by transpiration cooling. Drought and heat stress arising from late planting may affect on transpiration cooling, resulting in high canopy temperature. Canopy temperature can be used as a selection criteria for drought tolerant variety screening. Thus, it is important to study the importance of canopy temperature related traits and trait diversity on heat and drought stress. This field trial was conducted at the Field Crops Research and Development Institute, Mahailluppallama, to investigate the changes of pattern and distribution of morphological traits across eight rice varieties under four management conditions (*i.e.*, early planting flood, late planting flood, early planting drought and late planting drought), to identify the transpiration cooling related traits. Morphological traits were subjected to factor analysis across the management conditions. Factor coefficients of each selected trait were used as an explanatory variable for regression on canopy temperature. Factor one highly correlated with plant height and panicle length. Tiller angle and number of tillers were highly correlated with Factor two. Pollen fertility was highly correlated with Factor three. Factor one negatively and Factor two positively correlated with canopy temperature across flooded, drought stress and heat stress conditions. Thus, canopy angle, pollen fertility index, plant height and tiller angle are important characters in variety selection for drought and heat stress. The variety Bg 366, *Pachchaperumal* and *Kaluheenati* have high transpiration cooling ability among the tested varieties.

Key words: Canopy temperature, Management condition, Pollen fertility, Rice varieties, Variety selection

Introduction

Sri Lanka is a tropical country with a rich biodiversity. Rice (*Oryza sativa* L.) is a major component in many agro-ecosystems. As the staple food crop, traditional and improved varieties, which are morphologically different, are cultivated across diverse environments in Sri Lanka. Research on morphological diversity of rice has been mainly conducted under favorable conditions in Sri Lanka. Among them, Suriyagoda *et al*. (2011) highlighted the superior morphological diversity among the varieties and their morphological characters are highly contributed to yield. Meanwhile, pattern and distribution of morphology on water stress at vegetative phase was studied by Illangakoon and Somaratne (2014); Silva *et al*. (2018) reported that, flag leaf characters are important to maintain pollen fertility under heat stress conditions. Drought is directly linked with morphological variations but these variations do not link with gene level expression (Munasinghe *et al*., 2017). Transpiration is indicated by leaf surface temperature (canopy temperature), which is measured by handheld infrared thermometers. Leaf surface temperature is a physiological measurement (Belco *et al*., 2013). Low leaf surface temperature better stomatal conductance, higher leaf transpiration and efficient photosynthesis (Yan *et al*., 2012). Canopy emits infrared waves under stress conditions and it could be result in higher canopy temperatures than no stress conditions (Fischer *et al*., 2008). Leaf surface temperature is considered as a good indicator for moisture stress of plants (Blum *et al*., 1982; Guendouz *et al*., 2012). Therefore, leaf surface temperature can be used to select drought and heat tolerant rice varieties for future changing climate. However, studies related to morphological variation on transpiration cooling at flowering under drought stress are lacking. Weerakoon *et al*. (2008) mentioned that sufficient standing water helps to maintain tissue temperature below the critical range by transpiration cooling. In this study, morphologically different eight rice varieties were characterized with leaf surface temperature under different management conditions. For this field experiment was conducted to determine the pattern and distribution of morphological traits under multiple management conditions (drought and flood conditions with early and late planting); to identify the transpiration cooling related traits under each stress conditions; to determine the relationship of leaf surface (canopy) temperature on filled grain percentage and grain yield of rice.

Materials and methods

This field trial was established at the Field Crops Research and Development Institute, *Mahailluppalama* during 2016/17 *Maha* and 2017 *Yala* seasons, where the experimental site was consisted of Reddish Brown Earth associated sandy loam paddy soils. Four separate management conditions were tested during reproductive stage as main plots in a split plot design with two replicates; early season planting + drought stress at heading (C1.ED), late season planting + drought stress at heading (C2. LD), early season planting + flooded condition (C3. EF) and late season planting+ flooded condition (C4. LF) Planting time was changed to separate early and late season flowering. According to Weerakoon *et al*. (2009) the environment temperature increased beyond 36 ^{o}C in many areas of Dry Zone during mid-March, and end of July and August. Therefore, late planting could be subjected to heat stress at flowering stage.

Morphologically different eight rice varieties *i.e*., Bg 357, Bg 358, Bg 359, Bg 360, Bg 366, Bg 94-1, Pachchaperumal and Kalu Heenati were screened in eight subplots. Rice varieties were planted as a single plant per hill in well prepared sub plots as three rows in five m length, with 20 cm × 15 cm spacing and each variety separated by 40 cm spacing. Fertilization and other cultural practices were done according to the Department of Agriculture recommendations. Water was drained off at panicle initiation stage of C1 and C2 management conditions. Soil moisture was monitored during the stress period as volumetric soil moisture content. Climate data (maximum temperature, minimum temperature and RH) were collected from the weather station which was 500 m away from the experimental site. Number of tillers per m^2, plant height (cm), tiller angle (angle between upper most leaf blade to main culm) and canopy angle (180 - angle of widest tillers from horizontal plane) were recorded using five random samples at late booting stage. Another five random samples were used to record data at heading stage where panicle length, Infra-Red Thermometer (IRT) reading at 13:00 hour and pollen fertility (day after IRT reading) were measured. The filled grain percentage per panicle and grain yield per plant were recorded at physiological maturity.

Grain yield, IRT reading and filled grain percentages among management conditions, varieties and their interactions in both *Maha* and *Yala* seasons were analyzed using SAS 9.1 computer program. Morphological data of each variety were pooled across the seasons and analyzed. (Since yield and filled grain percentages among the seasons were not significantly different). Leaf surface temperature data were analyzed using ANOVA and main effect were presented. Morphological data were analyzed and diversity of pooled seasonal data among the management conditions was presented. In addition, soil moisture of each treatment, ambient temperature (maximum and minimum) and relative humidity data were subjected to descriptive analysis to explain variations among the management conditions. Selected morphological traits were subjected to multivariate analysis using PROC FACTOR procedure across the management conditions and defined the pattern and distribution of all morphological traits. Grouping of each morphological traits into factors for each stress conditions was verified. Regression analysis (stepwise) was done on canopy temperature with factor coefficients as explanatory variables across the management conditions and importance of morphological traits on canopy temperature was decided. In order to find the relationship of canopy temperature with filled grain percentage and yield, linear and quadratic relationships were tested using minitab 14.0 version.

Results and discussion

Soil and climate

Maximum ambient temperature of early season 2016/17 *Maha* was favorable than that of 2017 *Yala* for flowering period (Table 1). Early season minimum temperature was less than the critical temperature (20 ^{o}C) for rice (Godwin *et al*., 1994), which might cause pollen sterility (Silva *et al*., 2012).The minimum ambient temperature of the late season was favorable for flowering in both the seasons because it was higher than critical lower temperature (Silva *et al*., 2012). However, late season maximum temperature of 2017 *Yala* was greater than 35 ^{o}C, which was comparatively higher than 2016/ 17 *Maha*. Relative humidity varied from moderate to high in all conditions.

Table 1. Descriptive analysis of climatic conditions at early and late season flowering stages of rice in *Yala* and *Maha* seasons

Flowering period	Climatic parameter	2016/17 *Maha*		2017 *Yala*	
		Average ± SE	Range	Average ± SE	Range
Early season	Maximum T	28.8 ± 0.8	25.2-31.3	33.1 ± 0.3	32.3-34.4
	Minimum T	22.0 ± 0.6	17.7-23.7	25.3 ± 0.1	25.0-25.7
	RH (%)	93.4 ± 1.0	90.0-97.0	79.3 ± 1.3	75.0-89.0
	Maximum T	31.3 ± 0.4	30.1-33.2	33.2 ± 0.4	28.4-36.3
Late season	Minimum T	21.0 ± 0.3	19.5-22.7	24.5 ± 0.2	22.2-25.6
	RH (%)	92.9 ± 1.1	87.9-97.8	80.3 ± 1.2	72.0-90.0

Note: SE – standard error

When the ambient temperature exceeded 35 ^{o}C, rice pollen fertility could be affected and it may cause a reduction in yields (Yoshida, 1981; Kumar *et al*., 2015). According to Abeysiriwardhana *et al*. (2002) grain sterility was recorded in Sri Lanka due to temperature stress with high RH. Relative humidity is an important climatic factor that governs the grain sterility during flowering stage where high RH and high temperature could decrease the filled grain percentage. The prevailing climatic condition revealed that, ambient maximum temperature of the late season flowering in LF and LD conditions were comparatively higher than that in EF and ED conditions. Furthermore, ambient temperature of the flowering time of late planting in *Yala* season was greater than the temperature threshold (heat stress).

The soil moisture content of ED and LD treatments recorded less than 20% of volumetric soil moisture content. In *Yala* season, water stress in ED and LD management conditions were greater than that of *Maha* season (Figure 1).

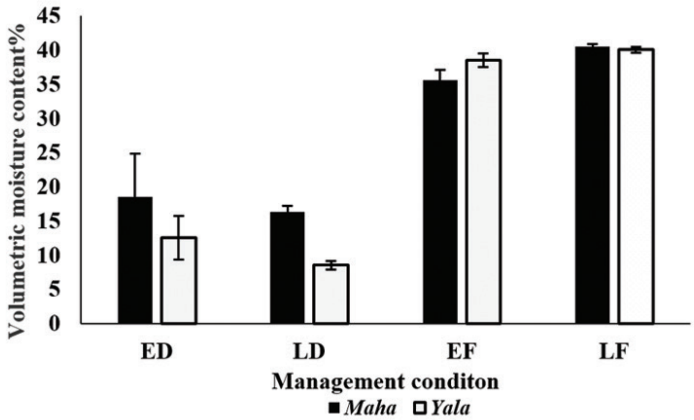

Figure 1. Soil moisture content during flowering in different treatments.
Error bars indicate the standard error. ED – Early season planting + drought at flowering, LD – Late season planting + drought at flowering, EF – Early season planting + flooded, LF – Late season planting + flooded

Grain yield and filled grain parentage

Grain yield was significantly affected by ED and LD conditions compared to EF and LF conditions in both *Yala* and *Maha* seasons (Table 2). The lowest grain yield was recorded under LD condition. This may be due to the dry environment, which coupled with heat stress in LD condition. The highest grain yield was recorded in EF condition because the favorable ambient temperature and ample amount of soil moisture content observed in the environment facilitated the efficient photosynthesis and assimilate partitioning under EF condition. Rice variety Bg 360 recorded the highest yield per plant in both *Yala* and *Maha* seasons across the management conditions (Table 2). Therefore, Bg 360 has an ability to produce higher yield under both stress and favorable conditions. Bg 94-1, Bg 366 and Kalu Heenati recorded the lowest grain yield compared to other varieties in *Yala* season. Ambient temperature condition in *Yala* season was above the critical limit. Therefore, the grain yield of these rice varieties could be decreased across the management condition in *Yala* season. Interaction effect of variety and management condition on yield was not significantly different.

Table 2. Main effects of management condition and rice varieties on grain yield and filled grain percentage

Treatment	Grain yield per hill (g)		Filled grain (%)	
	Maha	*Yala*	*Maha*	*Yala*
Main treatment (management condition)				
C1.ED	11.9 [bc]	12.4 [c]	81.3 [b]	81.0 [b]
C2.LD	10.0 [c]	9.7 [d]	72.1 [c]	73.1 [c]
C3. EF	21.4 [a]	21.1 [a]	82.6 [ab]	88.0 [a]
C4. LF	13.6 [b]	14.7 [b]	88.3 [a]	86.7 [a]
LSD	2.4	2.1	6.1	4.6
P> f (C)	<0.0001	<0.0001	0.0001	<0.0001
Sub treatment (variety)				
V1. Bg 357	14.5 [ab]	13.4 [bc]	76.6 [c]	77.4 [c]
V2. Bg 358	17.0 [a]	16.3 [ab]	78.0 [bc]	78.4 [c]
V3. Bg 359	14.4 [ab]	15.1 [abc]	86.1 [ab]	87.1 [ab]
V4. Bg 360	16.7 [a]	17.0 [a]	75.1 [c]	76.8 [c]
V5. Bg 366	12.7 [b]	12.9 [c]	75.5 [c]	77.8 [c]
V6. B g 94-1	12.5 [b]	13.1 [c]	78.7 [bc]	81.5 [bc]
V7. Kalu Henneati	12.9 [b]	13.1 [c]	90.9 [a]	90.3 [a]
V8. Pachchaperumal	12.9 [b]	14.9 [abc]	87.8 [a]	88.0 [a]
LSD	3.4	3.0	8.7	6.5
Pr> f (V)	0.05	0.04	0.002	0.002
Pr>f Interaction (C x V)	0.07	0.06	0.67	0.13
CV %	23.8	20.2	10.5	7.7

Note: Flowering time coupled with soil moisture conditions, ED – Early season planting + drought at flowering, LD – Late season planting + drought at flowering, EF – Early season planting + flooded, LF – Late season planting + flooded
LSD- Least significant difference.

The values accompanied by the same letters are not significantly different at alpha = 0.05.Filled grain percentage of EF and LF management conditions were the highest across the varieties in both seasons (Table 2). The lowest filled grain percentage was recorded in LD condition for both seasons. Kalu Heenati and Pachchaperumal recorded the highest filled grain percentage irrespectively of the season. Although, Bg 357, Bg 366 and Bg 360 recorded the lowest filled grain percentage, those were able to maintain the filled grain percentage higher than 75% in both seasons. Interaction effect of variety and management condition on filled grain percentage was not significantly different.

Canopy temperature (IRT reading)

Canopy temperature is a physiological measurement that represents the rate of transpiration (Guendouz *et al*., 2012) and highly correlated with the ambient temperature and soil moisture condition (Silva *et al*., 2016). The management condition of ED recorded significantly the highest canopy temperature in both *Yala* and *Maha* seasons (Table 3).

Table 3. Main effects of management condition and rice varieties on Infar Red Thermometer reading

Treatment	IRT reading (^{o}C)	
	Maha	***Yala***
Main factor (condition)		
C1.ED	33.2 ^{a}	32.2 ^{a}
C2.LD	32.8 ^{a}	28.6 ^{b}
C3. EF	30.3 ^{b}	31.9 ^{a}
C4. LF	30.4 ^{b}	26.0 ^{c}
LSD	0.48	0.41
P> f (C)	<0.0001	<0.0001
Sub factor (variety)		
V1. Bg 357	31.7 ^{a}	30.3 ^{cd}
V2. Bg 358	31.0 ^{b}	33.4 ^{a}
V3. Bg 359	31.9 ^{a}	29.8 ^{d}
V4. Bg 360	32.0 ^{a}	30.6 ^{c}
V5. Bg 366	31.9 ^{a}	27.5 ^{e}
V6. Bg 94-1	31.8 ^{a}	31.3 ^{b}
V7. Kalu Hennati	31.4 ^{ab}	27.2 ^{e}
V8. Pachchaperumal	31.7 ^{a}	247.4 ^{e}
LSD	0.68	0.58
P> f (V)	0.11	<0.0001
P>f Interaction (C × V)	0.13	<0.0001
CV %	2.1	1.9

Note: Flowering time coupled with soil moisture conditions, C1. ED, C2. LD, C3.EF and C4. LF represents early planting +drought at flowering, late planting + drought at flowering, early planting + flood and late planting+ flood, respectively. LSD - Least Significant Difference. The values accompanied by the same letters are not significantly different at alpha=0.05.

The management conditions of ED and LD recorded a greater canopy temperature compared to EF and LF conditions in *Maha* season. During *Yala* season, management conditions of ED and EF recorded a comparably higher canopy temperature followed by LD, and LF recorded the lowest canopy temperature.

According to Table 1, the early planting, both management conditions of ED and EF were exposed to a higher ambient temperature (32.3 to 34.4 ^{o}C) during the *Yala* season. Therefore, the highest canopy temperature was observed in both these two management conditions during the *Yala* season. Further, a significant interaction effect of variety and management condition on IRT reading was observed in *Yala* season.

Although, Bg 357 and Bg 360 recorded the lowest canopy temperature (23.25 ^{o}C) under EF condition reflecting their higher transpiration cooling abilities, their canopy temperature increased up to 32.5 and 31.5 ^{o}C, respectively in ED conditions reflecting their higher susceptibility to drought conditions (Figure 2). Significant canopy temperature reduction was observed in Bg 94-1, from ED to EF in *Yala* season. Under LF condition, comparatively lower canopy temperatures were observed in Kalu Henneati, Pachchaperumal, Bg 366 and Bg 359 varieties where the observed canopy temperatures were 25.0, 26.0, 27.5 and 29.5 ^{o}C, respectively under ambient temperature ranges from 28.4 to 36.3 ^{o}C (Figure 2 and Table 1). Further, the varieties Bg 366, Kalu Henneati and Pachchaperumal recorded lower canopy temperatures such as 30.0, 25.5 and 25.2 ^{o}C, respectively under LD management condition exhibiting their higher transpiration cooling ability under heat and drought stresses. Variety Bg 358 has increased its canopy temperature from 29.5 to 38.5 ^{o}C and 29.2 to 36.5 ^{o}C with increasing drought stress at early and late season flowering, respectively.

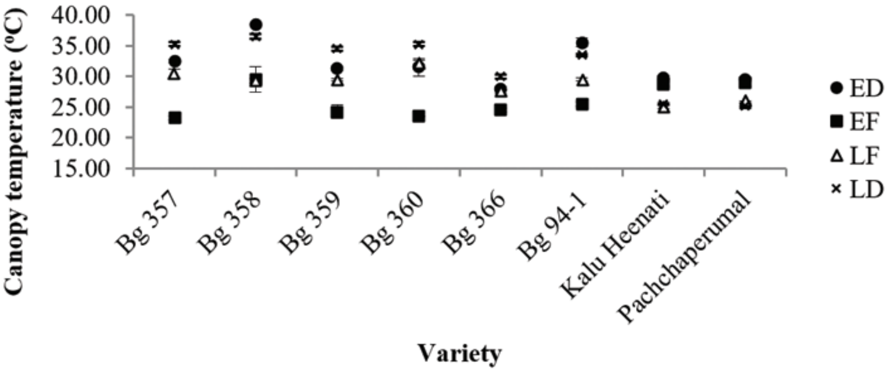

Figure 2. Variation of canopy temperature of different rice varieties under different management conditions

(Error bars indicate the standard error)ED – Early season planting + drought at flowering, LD – Late season planting + drought at flowering, EF –Early season planting + flooded, LF – Late season planting + flooded

Impact, pattern and distribution of morphological traits

According to Blum *et al*. (1982) and Guendouz *et al*. (2012) canopy temperature indicates the tolerance of different varieties to stress levels. Agreeing with their findings the canopy temperature of this experiment also indicated significant differences among different varieties, indicating their differences in tolerating drought and heat stress during the *Yala* season. This response variation under the same management condition should be due to the morphological variations of different varieties. Thus, pattern and distribution of selected morphological variations and their impact on transpiration, yield and filled grain percentage were further discussed using pooled morphological data across 2016/17 *Yala* and 2017 *Maha* seasons.

Morphological diversity of rice varieties under different management conditions

Table 4 explains that, pollen fertility index varied from 48.6 to 72.8, 43.0 to 61.3, 73.7 to 100.0 and 67.8 to 82.7% in ED, LD, EF and LF conditions, respectively. All tested varieties recorded the greater reduction in pollen fertility index under ED and LD management conditions. Plant height also recorded wider variations among the management conditions where it varied from 58.9 to 93.1, 62.6 to 98.3, 79.2 to 120.2 and

82.5 to 115.5 cm in ED, LD, EF and LF conditions, respectively (Table 4). Pachchaperumal and Kalu Heenati recorded a greater plant height than other varieties. Wide variation of tiller angle was also observed among different rice varieties. The recorded tiller angles varied from 11.2 to 15.4, 8.3 to 12.9, 11.7 to 15.4 and 7.9 to 17.9 (°) in ED, LD, EF and LD management conditions, respectively (Table 4). The widest variation in tiller angle was recorded under LF condition. Canopy angle varied from 40.5 to 60.6, 25.4 to 39.1, 42.5 to 56.4 and 26.3 to 32.8 under ED, LD, EF and LF conditions, respectively where the widest variation was recorded in ED condition. Panicle length is particularly an important morphological character, which indicates the sink size of the rice panicle. Panicle length facilitates the space to arrange number of spikelets and primary branches of the panicle. Panicle length varied from 15.2 to 18.0, 14.6 to 19.4, 20.0 to 23.9 and 19.6 to 24.4 cm in ED, LD, EF and LF management conditions respectively (Table 5). Therefore, panicle length significantly differed among the varieties under different management conditions of ED, LD, EF and LF. Although, the diversity of panicle length varied among different varieties, drought condition at flowering stage decreased the panicle length irrespective to that of early or late planting compared to the flood condition. Therefore, drought significantly affects on the sink capacity of the rice varieties. Number of tillers directly affects on the number of leaves as well as panicles formed, which are representing the source and sink capacity.

Table 5, revealed that, there was no significant difference among the number of tillers per square meter under tested management conditions. However, the diversity of number of panicles was greater in all management conditions and planting time and drought condition affected on the number of tillers.

Table 4. Diversity of pooled seasonal pollen fertility index, plant height, tiller angle and canopy angle in management conditions

Variety	Pollen fertility index (%)				Plant height (cm)				Tiller angle (degrees)				Canopy angle (degrees)			
	C1. ED	C2. LD	C3. EF	C4. LF	C1. ED	C2. LD	C3. EF	C4. LF	C1. ED	C2. LD	C3. EF	C4. LF	C1. ED	C2. LD	C3. EF	C4. LF
Bg 357	58.2	48.8	99.2	82.1	58.9	62.6	79.2	82.5	14.6	8.8	11.7	7.9	49.6	28.3	52.8	31.4
Bg 357	58.2	48.8	99.2	82.1	58.9	62.6	79.2	82.5	14.6	8.8	11.7	7.9	49.6	28.3	52.8	31.4
Bg 358	66.3	61.3	73.7	74.8	71.8	77.0	83.8	100.9	15.0	8.3	11.7	8.9	53.8	29.1	56.4	26.7
Bg 359	60.4	53.3	96.1	82.0	68.1	82.2	96.5	101.5	13.7	11.7	12.9	12.9	47.5	28.3	45.8	29.5
Bg 360	48.6	43.0	97.0	67.8	64.3	69.4	89.9	86.1	12.9	10.3	12.9	8.4	51.2	25.4	52.5	31.5
Bg 366	69.3	52.1	98.1	70.4	66.6	71.9	97.9	99.0	11.7	10.7	12.9	8.7	40.8	27.5	48.1	30.4
Bg 94-1	51.4	57.2	75.4	82.7	60.7	70.0	90.6	87.5	15.4	9.9	15.4	8.4	60.6	30.8	52.9	32.1
Kalu Heenati	72.8	54.3	100.0	69.0	85.8	96.1	116.8	102.8	11.2	12.9	15.4	17.9	40.5	39.1	42.5	32.8
Pachchaperumal	52.5	50.4	100.0	80.0	93.1	98.3	120.2	115.5	15.4	9.6	15.4	10.2	46.3	29.0	45.4	26.3
LSD	33.9	26.4	16.7	35.9	7.3	27.7	20.7	28.6	4.3	3.7	7.5	5.1	11.1	14.1	13.5	12.0

Note: Flowering time coupled with soil moisture conditions, C1. ED, C2. LD, C3. EF and C4. LF represents early planting +drought at flowering, late planting + drought at flowering, early planting + flood and late planting+ flood respectively. LSD- Least Significant Difference

Table 5. Diversity of pooled seasonal panicle length and tillers per square meter among the management conditions

Variety	Panicle length (cm)				Tillers per m^2			
	C1. ED	C2. LD	C3. EF	C4. LF	C1. ED	C2. LD	C3. EF	C4. LF
Bg 357	16.8	15.7	21.5	21.5	379.2	256.3	397.9	231.3
Bg 358	15.2	18.6	20.6	22.1	362.5	287.5	392.5	327.1
Bg 359	18.0	19.4	22.5	22.6	352.1	268.8	412.5	300.0
Bg 360	16.7	17.3	22.4	21.3	435.4	225.0	470.8	287.5
Bg 366	17.0	18.5	24.1	24.4	318.8	275.0	379.2	279.2
Bg 94-1	17.5	19.3	23.9	20.8	393.8	262.5	527.1	356.3
Kalu Henneati	17.0	14.6	20.0	19.6	339.6	283.3	375.0	375.0
Pachchaperumal	17.7	18.0	23.1	22.5	408.3	306.3	427.1	320.8
LSD	4.6	2.5	3.4	3.6	241.0	170.0	242.0	195.9

Note: Flowering time coupled with soil moisture conditions, C1. ED, C2. LD, C3.EF and C4. LF represents early planting +drought at flowering, late planting + drought at flowering, early planting + flood and late planting+ flood, respectively. LSD- Least Significant Difference.

Distribution of morphological variations

Table 6. Explained that, factor1 axis was highly correlated with plant height and panicle length with the coefficient of 0.86 and 0.81, respectively and the variance was explained by 31.1 % across the management conditions. Tiller angle and number of tillers loaded into factor 2 axis with the coefficient of 0.70 and 0.61, respectively, further factor 2 explained the variance as 24.0 %. PFI and canopy angle loaded into factor 3 axis with the coefficient of 0.71 and 0.74, respectively and variance explained 22.4 %. PFI, plant height, tiller angle, canopy angle, panicle length and number of tillers recorded greater variances, 0.84, 0.84, 0.0.62, 0.81, 0.81 and 0.72, respectively and 4.10 of total variance. Thus, across the management conditions where flood, drought and heat, panicle length highly correlated with the plant height. Tiller angle highly correlated with number of tillers. PFI highly correlated with the canopy angle. Meanwhile, across the management condition the relationship of plant height on tiller angle and canopy angle was 0.72 and -0.60, respectively.

Table 6. Factor pattern, final communality, Eigen value and percentage of variance of morphological traits across the management conditions

Morphological trait	Factor pattern			Final communality
	Factor 1	Factor 2	Factor 3	
PFI	0.41	-0.41	0.71	0.84
Plant height	0.86	-0.05	-0.33	0.84
Tiller angle	0.30	0.70	0.21	0.62
Canopy angle	0.07	0.51	0.74	0.81
Panicle length	0.81	-0.39	0.05	0.81
Number of tillers	0.46	0.61	-0.37	0.72
Eigen value	1.87	1.45	1.34	
Variance %	31.1	24.0	22.4	

Note: PFI – Pollen Fertility Index

Effect of morphological diversity on transpiration cooling

Soil moisture condition and planting time also have significant impacts on canopy temperature (Silva *et al*., 2016, 2019). However, across the different management conditions such as flood, drought and heat, Factor 1 negatively, and Factor 2 positively impacted on IRT reading and the parameter estimates -0.04 and 0.01, respectively (Table 7). It was suggested that, plant height and panicle length negatively impacted on IRT reading. Increased plant height produce more facilities for transpiration and increased transpiration cools across the tested management conditions. Meanwhile, increase in tiller angle and number of tillers decreased the transpiration cooling.

Table 7. Parameter estimate and significance of factors explained on IRT reading across the management conditions

Variable	Parameter Estimate	Standard error	F Value	***P*** **> f**
Factor1	-0.04	0.01	27.57	<.0001
Factor 2	0.01	0.01	9.33	0.002

Relationship of canopy temperature with filled grain % and yield

Fischer *et al*. (2008) described that, the canopy temperature of rice indicates transpiration cooling of leaves, which is a complex condition of many factors such as vapour pressure deficit, air temperature, wind velocity, soil moisture condition and plant characteristics (canopy size, canopy architecture, and leaf adjustments to water deficit). It is a better indicator for selecting genotypes that are growing under the same condition for drought stress. However, there were linear relationships between the canopy temperature measured as the IRT reading with yield and filled grain % across management conditions of varieties by 0.05 and 0.04 significant levels and 0.06 and 0.009 of r^2, respectively.

Conclusion

Plant height, panicle length, number of tillers and tiller angles are important transpiration cooling related characteristics across the flood, heat and drought management conditions which are important characters for variety selection for drought stress. Bg366, Kalu Henneati and Pachchaperumal have higher transpiration cooling ability.Acknowledgements

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