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RESPONSES OF SRI LANKAN TRADITIONAL RICE TO PHOTOPERIOD AT EARLY VEGETATIVE STAGE

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Abstract

Rice is a photoperiod sensitive plant for flowering initiation. Effect of photoperiod can be important in vegetative growth and yield determination in rice. The objective of the research was to determine the effect of photoperiod on the vegetative responses of Sri Lankan traditional rice germplasm (SLTRG). Forty five traditional rice accessions (TRA), 5 improved rice varieties (IR), Sri Lankan wild rice (*Oryza nivara* and *Oryza rufipogan*) and *Oryza japonica* accessions 6782 and 6752 were grown in short day (SD), day neutral (DN) and long day (LD) conditions. Days to reach the fifth leaf stage (DFL), plant height (PH) and tiller number (TN) at the fifth leaf stage were recorded. Twenty three genotypes including 21 TRA, *Oryza japonica* 6752 and *Oryza nivara* did not respond to photoperiod having non-significant values for DFL, PH and TN among photoperiods. The DFL was affected in 25 genotypes; among them both DFL and PH were affected in 7 genotypes. DFL was significantly increased during LD in 4 TRA while DFL was significantly reduced in all 5 IR and 5 TRA. DFL was significantly increased in *Oryza japonica* 6782 and 5 TRA under SD. In 4 TRA, DFL was reduced under SD. The TN was affected in *Oryza japonica* 6782 only under SD with increased DFL. The DFL was significantly increased under DN in *Oryza rufipogan*, 5 TRA and 2 IR. Both SD and LD photoperiods differently affected the interaction between DFL and PH in TRA while only LD affected that of IR. DN had an effect on the interaction between DFL and PH only in wild rice *Oryza rufipogon*. Variation of vegetative growth response to photoperiod may depict the wide genetic basis of SLTRG.

Key words: Days to fifth leaf, Photoperiod sensitivity, Sri Lankan rice, Vegetative growth.

Introduction

Rice is the most important cereal crop over 33 countries worldwide including Asia, Pacific region, Africa, Latin America and Caribbean where *Oryza sativa* and *Oryza glaberrima* species are grown (Bambaradeniya & Amerasinghe, 2004). It is the predominant crop in Sri Lanka as 12 % of lands under rice which approximately accounts for 4.62 million metric tons of rice production (Anon., 2013). Rice contributes to more than 40% of daily calorie requirement (Bambaradeniya & Amerasinghe, 2004). Though Sri Lanka is a self-sufficient country with rice production, there is a necessity to increase rice production to meet the need of increasing population. Availability of wide genetic diversity would be more useful to breed new varieties to face future challenges of climate change.There are around 2000 accessions of Sri Lankan traditional rice germplasm, which is conserved at Plant Genetic Resources Center (PGRC), Sri Lanka. The photoperiod sensitivity of Sri Lankan traditional rice had not been intensively studied except for a few attempts (Chandrarathna, 1964; Geekiyanage *et al*., 2012).

We developed a mini-core collection of Sri Lankan traditional rice germplasm (*Oryza indica*) based on a part of the germplasm upon morphological characterization (Rathnathunga *et al*., 2016). The mini-core collection was used in the present study together with improved Sri Lankan rice, Sri Lankan wild rice and *Oryza japonica*. *Oryza rufipogon* and *Oryza nivara* are among the ancestors of *Oryza sativa* (Khush, 1997).

Rice is a short day plant that initiates flowering early under short day condition (Vergara & Chang, 1985; Yano *et al*., 2001). Despite the genetic factors, there are several environmental factors that control rice plant growth and flowering (Hayama & Coupland, 2004; Yano *et al.,* 2001). Photoperiod is a major factor among them.Vegetative growth phase, reproductive phase and ripening phase are the 3 main phases of rice growth (Roberts & Summerfield, 1987; Vergara & Chang, 1985; Yoshida, 1981). There are 2 sub-phases as basic vegetative phase (BVP), which is the photoperiod insensitive juvenile period and photoperiod sensitive phase (PSP) during vegetative growth phase. The rice plant must attain a certain amount of growth of BVP before it reaches the PSP, which shows its response to the photoperiodic stimulus for flowering (Vergara & Chang, 1985). The first few leaves are considered to be insensitive to photoperiod (Roberts & Summerfield, 1987; Vergara & Chang, 1985). Effect of photoperiod on days to flowering had been previously observed in a few Sri Lankan traditional rice accessions as well (Geekiyanage *et al.,* 2012). Most of Sri Lankan traditional rice accessions tested in our experiments are sensitive to short day condition and do not initiate flowering under long day condition (Unpublished data). There are reports on rice remaining in vegetative phase for several years under non inductive photoperiod (Vergara & Chang, 1985). According to Moldenhauer & Slaton (2001), fifth leaf stage is considered as the turn of plant structure from seedling stage to mature plant. In this study we assumed that differences of plant morphology at the fifth leaf stage would indicate the different vegetative growth responses.

The sensitivity for the photoperiod can be a useful characteristic to grow rice under different environments and for the various rice growing seasons while insensitivity can be a suitable characteristic for the multiple cropping systems. Therefore, photoperiod sensitivity at early vegetative growth could be useful in identification of rice genotypes for breeding programs. The objective of this experiment was to determine the effect of photoperiod on the vegetative growth responses of different rice genotypes (*Oryza indica*) of Sri Lankan rice including traditional rice, improved rice and wild rice.

Materials and Methods

Rice accessions: Fifty four Sri Lankan rice accessions were selected for the experiment based on a mini-core collection developed from our initial field collection (Rathnathunga *et al.*, 2016); (*Kottyaran* 4285, 5513, *Kalu heenati* 4536, 5485, 7082, 4089, *Kuru ma wee* 3865, 3828, 4102, *Mada al* 3854,4436, *Sulai* 6287, 6346, 3968, 4365, 3494, *Kalu wee* 5492, *Dahanala* 2049, *Sudu heenati* 3355, *Sudu wee* 3858, 4195, 4594, 3462, *Murungakayan* 5610, 3495, *Kurulu wee* 3601, *Suduru samba* 3594, 3572, *Rathu heenati* 2080, *Hondarawala* 4070, 6428, 3521, 3528, *Pachchaperumal* 5546, 5550, *Mudukiriyal* 4144, 3970, *Wanni heenati* 3401, *Duru wee* 4626, *Kaharamana* 4260); (*Ma wee* 6702, 4561, 6699, 3683 and *Maha ma wee* 8696) respectively. Five improved rice varieties (At 308, Ld 368, Bg 352, Bg 250, Bg 379/2), two rice accessions of (*Hei chiaochui li hiangkenj* 6782, *Hirayama* 6752) and 2 wild rice (*Oryza nivara and Oryza rufipogon*) were selected.

Greenhouse experiment and management practices: Rice accessions were grown under greenhouse condition at the University of Ruhuna, Matara, Sri Lanka (in WL2: Low country Wet zone, agro ecological zone) in a Completely Randomized Design (CRD) with 3 replicates. Experiment was carried out under three photoperiod conditions during 2014 to 2015: Eight hours of light and 16 hours of darkness (short day: SD), 12 hours of light and darkness (day neutral: DN) and 14 hours of light and 10 hours of darkness (long day: LD). The seeds were sown in separate cups and the seedlings were transplanted on pots of 20 cm of diameter by 21 days. Basal fertilizer and top dressing application were done according to the recommendation of the Department of Agriculture, Sri Lanka for the agro-ecological zone.

Measurements in fifth leaf stage of rice plant: Measurements were based on descriptors of rice (Team of NRC research project 12-129, 2014). Three quantitative morphological characters were recorded as follows; days to fifth leaf stage (DFS), seedling height at fifth leaf stage (PH) and Culm number at fifth leaf stage (CN). DFS was calculated by counting days from seed germination to the full emergence of the fifth leaf.

Statistical analysis

Data was analyzed by Principal Component Analysis (PCA) and hierarchical cluster analysis through SPSS software (version 20), IBM, USA. Core collection selection within the clusters was done using the random sampling method (Studnicki *et al.*, 2013). ANOVA statistical analysis was conducted using the SAS (9.1 version) statistical software and $p < 0.05$ was used to determine significance. Treatments means were separated using Duncan Multiple range test (DMRT) test. A number of statistics such as the mean, and error standard deviation were used to describe the distribution of all data.

Results and Discussion

Interaction between accessions and photoperiod during vegetative growth: There was a significant interaction between accessions and different photoperiods on DFL (Table 1). In this study we assumed that fifth leaf stage would be suitable to measure the differences of the vegetative growth responses as the first tiller emerges around 5th leaf stage usually making a morphological difference in rice plant. Differences in the length of the vegetative growth stage among accessions can be due to the differences in genetic factors responding to photoperiod. The duration of the BVP is widely variable among accessions (Vergara & Chang, 1985). *Oryza nivara* and *Duru wee* 4626 showed significantly highest DFL in SD condition, while *Hondarawala* 4070 and *Oryza rufipogon* in DN and *Mudukiriyal* 4144, *Rathu heenati* 2080 and *Hondarawala* 6428 in LD condition. *Hondarawala* 4070, *Kuru ma wee* 3828 *Sudu wee* 4195 and *Mada al* 3854 accessions showed significantly lowest DFL in SD. *Kalu heenati* 7802, *Kaharamana* 4260, *Wanni heenati* 3401, *Sudu wee* 4195 and *Mudukiriyal* 3970 in DN and *Sudu wee* 3462, *Sulai* 6346, *Mudukiriyal* 3970, improved varieties (Bg 352, Ld 368, Bg 250) and *Oryza japonica* varieties (6782, 6752) in LD. DFL of genotypes (varied from 33 – 56 in SD, 33 – 59 in DN and 32 – 59 in LD), *Ma wee* 6702 and *Sulai* 3494 showed significantly highest PH in SD conditions, while *Ma wee* 6699, *Hondarawala* 6428 in DN and *Ma wee* 3683 and 6699 in LD conditions resulting in enhancement of vegetative growth. Improved varieties (Ld 368, Bg 352, Bg 379/2, Bg 250, At 308) and *Sudu wee* 4594 in LD showed significantly lowest PH. PH varied from 27 – 60 in SD, 23 – 60 in DN and 23–57 in LD).

Our observations of variations in DFL and relationships between DFL and PH among different photoperiodic conditions at fifth leaf stage indicate that photoperiod inductive phase determines not only flowering time, but also PH in some genotypes. According to Collinson *et al*. (1992) photoperiod-sensitive inductive phase increased under LD. Twenty three genotypes (21 traditional rice accessions *Kottyaran* 4285, 5513, *Kalu heenati* 4536, 5485, 7082, 4089, *Kuru ma wee* 3865, 3828, 4102, *Mada al* 3854, *Sulai* 6287, 6346, 3968, *Kalu wee* 5492, *Dahanala* 2049, *Sudu heenati* 3355, *Sudu wee* 3858, 4195, *Murungakayan* 5610, *Kurulu wee* 3601 and *Suduru samba* 3594, *Oryza japonica* 6752 and *Oryza nivara*) did not respond to photoperiod having non-significant values for DFL, PH and CN among 3 photoperiods. Thirty one varieties, which responded in different photoperiods comprised of *Rathu heenati* 2080, *Sulai* 4365, 3494, *Hondarawala* 4070, 6428, 3521, 3528, *Mada al* 4436, *Pachchaperumal* 5546, 5550, *Mudukiriyal* 4144, 3970, *Sudu wee* 4594, 3462, *Wanni heenati* 3401, *Murungakayan* 3495, *Duru wee* 4626, *Kaharamana* 4260, *Suduru samba* 3572, *Ma wee* 6702, 4561, 6699, 3683, *Maha ma wee* 8696, improved varieties, At 308, Ld 368, Bg 352, Bg 250, Bg

379/2, *Oryza japonica* 6782 and *Oryza rufipogon*. DFL and either PH or CN were affected in 25 genotypes; among them only DFL was affected in 17 accessions including *Sulai* 4365, 3494, *Hondarawala* 4070, 3528, *Pachchaperumal* 5550, *Mudukiriyal* 4144, 3970, *Sudu wee* 3462, *Murungakayan* 3495, *Kaharamana* 4260, *Ma wee* 4561, 6699, *Maha ma wee* 8696, improved varieties, At 308, Bg 352, Bg 250, Bg 379/2. Both DFL and PH were affected in 7 genotypes: *Hondarawala* 6428, *Sudu wee* 4594, *Wanni heenati* 3401, *Duru wee* 4626, *Ma wee* 6702, improved variety Ld 368 and *Oryza rufipogon*. PH was significantly affected by photoperiod in *Rathu heenati* 2080, *Hondarawala* 3521, *Mada al* 4436, *Pachchaperumal* 5546, *Suduru samba* 3572 and *Ma wee* 3683 while DFL was not affected by photoperiod. Both DFL and CN were significantly affected only in *Oryza japonica* 6782.

Effect of photoperiod on days to fifth leaf: DFL was significantly increased during LD in 4 traditional rice genotypes; *Sulai* 4365, *Hondarawala* 6428, *Mudukiriyal* 4144, *Kaharamana* 4260. The DFL was significantly reduced in all 5 improved rice and 5 traditional rice; *Pachchaperumal* 5550, *Duru wee* 4626, *Sudu wee* 3462, *Ma wee* 6702 and *Maha ma wee* 8696. DFL was significantly increased in *Oryza japonica* 6782 and 5 traditional rice *Wanni heenati* 3401, *Sudu wee* 3462, *Mudukiriyal* 3970, *Sulai* 3494 and *Ma wee* 6702 under SD condition. In 4 traditional rice genotypes, *Sudu wee* 4594, *Murungakayan* 3495 and *Ma wee* 4561, 6699. DFL was reduced under SD. DFL was significantly increased under DN condition in *Oryza rufipogan*, 6 traditional rice *Hondarawala* 4070, *Sudu wee* 4594, *Pachchaperumal* 5550, *Ma wee* 4561, 6699, *Maha ma wee* 8696 and 2 improved rice, At 308 and Bg 352.

Effect of photoperiod on plant height at fifth leaf stage: *Suduru samba* 3572, *Ma wee* 3683 and Ld 368 showed significantly high PH in LD conditions while *Hondarawala* 6428, *Wanni heenati* 3401 and *Duru wee* 4626 showed significantly low PH. PH was significantly high in *Pachchaperumal* 5546, *Hondarawala* 3521, *Sudu wee* 4594, *Wanni heenati* 3401, *Duru wee* 4626, *Suduru samba* 3572 under SD condition. In *Mada al* 4436, *Suduru samba* 3572 and *Oryza rufipogon*, DFL was reduced under SD. Only *Oryza rufipogon* indicated significantly high PH in DN condition while *Rathu heenati* 2080, *Pachchaperumal* 5546 and *Ma wee* 3683 indicated significantly reduced PH in DN.

Table 1. Average values with standard errors of Days to reach fifth leaf, Seedling height and Culm number of the mini core collection of Sri Lankan rice.

	Variety and accession number	Days to reach fifth leaf (Average)			Seedling height (Average)			Culm number (Average)		
Day length condition		SD	DN	LD	SD	DN	LD	SD	DN	LD
1.	*Rath heenati* 2080	44±4.67	44±5.78	58±1.76	49.3±3.03^{x}	34.3±0.33^{y}	46.3±2.85^{x}	1.0±0.00	1.0±0.00	1.0±0.00
2.	*Sulai* 4365	44±3.00^{ab}	36±2.33^{b}	48±2.85^{a}	55.2±4.57	45.7±1.20	45.3±2.67	1.0±0.00	1.0±0.00	1.0±0.00
3.	*Hondarawala* 4070	35±0.58^{b}	59±3.84^{a}	39±0.58^{b}	50.3±5.46	54.2±0.73	54.7±0.33	1.0±0.00	1.0±0.00	1.0±0.00
4.	*Mada al* 4436	44±1.33	46±0.33	45±2.00	32.7±7.31^{y}	49.8±1.88^{x}	52.5±2.36^{x}	1.0±0.00	1.0±0.00	1.0±0.00
5.	*Pachchaperumal* 5546	44±2.08	46±1.86	45±2.40	58.7±1.33^{x}	49.3±2.68^{y}	51.0±2.84^{xy}	1.0±0.00	1.0±0.00	1.0±0.00
6.	*Hondarawala* 6428	42±0.67^{b}	43±3.21^{b}	54±2.60^{a}	54.3±3.48^{x}	55.8±2.42^{x}	42.0±2.08^{y}	1.0±0.00	1.0±0.00	1.0±0.00
7.	*Mudukiriyal* 4144	41±0.33^{b}	37±2.19^{b}	59±2.33^{a}	46.0±3.06	51.8±3.37	49.0±3.21	1.0±0.00	1.0±0.00	1.0±0.00
8.	*Hondarawala* 3521	46±0.58	42±3.93	49±4.98	51.0±0.87^{x}	41.7±0.73^{y}	45.7±2.40^{y}	1.0±0.00	1.0±0.00	1.0±0.00
9.	*Sudu wee* 4594	39±0.58^{c}	54±0.67^{a}	43±1.86^{b}	30.5±0.29^{x}	24.7±1.17^{y}	23.0±2.36^{y}	1.0±0.00	1.0±0.00	1.0±0.00
10.	*Wanni heenati* 3401	41±2.40^{a}	34±0.33^{b}	34±0.00^{b}	45.0±2.00^{x}	41.0±1.53^{xy}	36.8±2.46^{y}	1.0±0.00	1.0±0.00	1.0±0.00
11.	*Murungakayan* 3495	40±0.33^{b}	46±0.88^{a}	46±0.58^{a}	42.7±1.76	47.2±1.30	51.0±4.93	1.0±0.00	1.0±0.00	1.0±0.00
12.	*Pachchaperumal* 5550	40±5.00^{ab}	51±4.08^{a}	34±0.33^{b}	39.7±5.70	39.5±3.67	47.2±0.93	1.0±0.00	1.0±0.00	1.0±0.00
13.	*Duru wee* 4626	50±3.38^{a}	50±3.53^{a}	34±0.00^{b}	53.7±2.03^{x}	49.2±0.44^{xy}	44.7±1.17^{y}	1.3±0.33	1.0±0.00	1.0±0.00
14.	*Sudu wee* 3462	43±2.52^{a}	35±2.85^{ab}	32±1.20^{b}	46.0±3.79	39.5±1.80	45.3±1.45	1.0±0.00	1.0±0.00	1.0±0.00
15.	*Mudukiriyal* 3970	39±0.00^{a}	33±0.58^{b}	32±0.33^{b}	39.5±3.75	42.0±1.04	41.8±0.60	1.0±0.00	1.0±0.00	1.0±0.00
16.	*Kaharamana* 4260	41±0.67^{b}	34±0.00^{c}	47±1.67^{a}	55.5±3.12	51.2±1.30	47.3±2.03	1.0±0.00	1.0±0.00	1.0±0.00
17.	*Suduru samba* 3572	45±2.19	41±1.00	41±2.96	39.8±0.93^{y}	44.0±2.65^{xy}	46.3±1.20^{x}	1.0±0.00	1.0±0.00	1.0±0.00
18.	*Hondarawala* 3528	45±2.33^{a}	38±2.08^{b}	48±0.67^{a}	44.7±0.88	46.7±2.03	52.0±5.13	1.0±0.00	1.0±0.00	1.0±0.00
19.	*Sulai* 3494	45±0.00^{a}	42±3.53^{b}	46±0.88^{b}	59.0±1.00	52.2±1.17	54.0±1.76	1.0±0.00	1.0±0.00	1.0±0.00
20.	*Ma wee* 6702	39±1.20^{a}	36±1.76^{ab}	35±0.33^{b}	59.7±0.33^{x}	48.8±4.21^{y}	46.0±3.21^{y}	1.0±0.00	1.0±0.00	1.0±0.00
21.	*Ma wee* 4561	38±2.40^{b}	54±3.53^{a}	52±6.01^{ab}	45.7±2.60	47.7±2.91	49.7±4.91	1.3±0.33	1.0±0.00	1.0±0.00
22.	*Ma wee* 6699	38±3.33^{b}	53±1.45^{a}	44±3.06^{ab}	54.3±1.86	59.7±3.38	56.8±2.05	1.0±0.00	1.0±0.00	1.0±0.00
23.	*Ma wee* 3683	40±3.21	53±5.03	44±4.73	52.5±3.25^{xy}	45.3±3.76^{y}	57.3±1.76^{x}	1.0±0.00	1.0±0.00	1.0±0.00
24.	*Ma wee* 8696	41±0.67^{ab}	51±5.36^{a}	36±0.58^{b}	55.3±2.40	45.5±4.09	53.7±3.28	1.0±0.00	1.0±0.00	1.0±0.00
25.	At 308	45±3.06^{ab}	53±6.17^{a}	36±2.00^{b}	27.3±0.88	27.8±2.46	29.2±1.17	1.0±0.00	1.0±0.00	1.0±0.00
26.	Ld 368	41±4.06^{a}	45±1.86^{a}	32±0.00^{b}	26.7±1.76^{y}	23.2±1.09^{y}	32.7±1.76^{x}	1.0±0.00	1.0±0.00	1.0±0.00
27.	Bg 352	40±0.88^{ab}	43±3.00^{a}	33±1.20^{b}	32.3±1.92	30.5±3.50	30.5±0.50	1.0±0.00	1.0±0.00	1.0±0.00
28.	Bg 250	43±3.00^{a}	41±1.15^{a}	32±0.00^{b}	28.3±1.88	28.0±3.21	30.3±0.88	1.3±0.33	1.0±0.00	1.0±0.00
29.	Bg 379/2	44±0.67^{a}	43±1.45^{a}	35±2.00^{b}	29.3±0.88	28.8±2.24	30.5±1.76	1.0±0.00	1.0±0.00	1.0±0.00
30.	*Oryza japonica* 6782	47±0.88^{a}	36±2.91^{b}	33±0.67^{b}	38.0±3.25	41.8±4.32	49.0±3.04	2.0±0.0^{p}	1.0±0.00^{q}	1.0±0.00^{q}
31.	*Oryza rufipogon*	46±2.40^{b}	58±4.51^{a}	46±1.76^{b}	39.8±3.11^{y}	49.0±0.29^{x}	43.0±3.06^{xy}	1.3±0.33	1.7±0.33	1.3±0.33

Significantly different values of each character are given in different letters

Effect of photoperiod on interaction between days to fifth leaf and plant height: Under SD condition, DFL affected PH affected in two ways: In *Wanni heenati* 3401 and *Ma wee* 6702, increased DFL led to increase PH while in *Sudu wee* 4594 decreased DFL lead to increased PH. Under LD condition, significantly reduced DFL resulted in reduced PH in *Duru wee* 4626 while increased PH in LD 368. Increased DFL affected reduced PH in *Hondarawala* 6428. Under DN condition, there was an interaction between DFL and PH only in wild rice *Oryza rufipogon*: Increased DFL lead to increased PH.

Effect of photoperiod on Sri Lankan traditional rice: Our results suggest that the fifth leaf stage in Sri Lankan traditional rice can be a determinant in vegetative growth responses to photoperiod as 4 *Honadarawala*, 2 *Mudukiriyal*, 2 *Pachchaperumal*, 4 *Ma wee* and 1 *Maha ma wee* accessions responded to photoperiod for DFL and/or PH indicating that those genotypes reached the PSP at fifth leaf stage. Known photoperiod insensitive variety *Kalu heenati* did not show a photoperiodic response at fifth leaf indicating the fact that genetic factors, which are responsible for photoperiod for flowering also may affect vegetative growth responses. The sensitivity for the photoperiod can be a useful character to grow rice under different environments and for the two rice growing seasons of the year while insensitivity can be a suitable character for the multiple cropping systems.

Conclusions

There is a variation on response to photoperiod at fifth leaf stage among STR accessions: All 4 *Honadarawala*, 2 *Mudukiriyal*, 2 *Pachchaperumal*, 4 *Ma wee*, 1 *Maha ma wee* and 5 improved rice accessions responded to photoperiod for DFL and/or PH.

All 4 *Kalu heenati*, 3 *Kuru ma wee*, and 2 *Kotteyaran* accessions did not respond to photoperiod without having any difference in DFL and/or PH.

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