Comparison of Physiological Responses among Four Contrast Rice Cultivars under Drought Stress Conditions

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Abstract**—**In order to investigating the physiological aspects of different rice cultivars under drought stress conditions, an experiment was conducted at the Rice Research Institute of Iran – Deputy of Mazandaran (Amol) in glasshouse condition during 2006. The experiment carried out in factorial based on complete randomized block design with four replications. Drought stress in four levels (continuous irrigation or no water stress as a control, drought stress in vegetative, flowering and grain filling stages) and cultivars in four levels (Tarom, Khazar, Fajr and Nemat) were the treatments. Results showed that drought stress in vegetative growth stage, increase days to flowering and leaf rolling in different cultivars. Drought stress in different growth stages, increased proline content and those cultivars with higher proline content had higher grain yield in drought stress. Drought stress decreased chlorophyll content and relative water content (RWC) in different cultivars. There were significant and positive correlation between chlorophyll content, proline content, and relative water content and also between these traits and grain yield. Drought stress in different growth stages decreased F_v, F_m, F_v/F_m and increased $t_{1/2}$ in different cultivars. There were positive and significant correlation between F_v, F_m and F_v/F_m with grain yield and negative and significant correlation between $t_{1/2}$ and grain yield.

Keywords**—**Rice, drought stress, relative water content, praline, yield.

I. INTRODUCTION

RICE (*Oryza sativa* L.) is the important primary cereal crop in the world. It is the staple food for more than two-third of the world's population (Dowling *et al*, 1998).Although rice ranks second to wheat as the most extensively grown crop in the world, it is the most important food crop and largest irrigated crop in the world (Roel et al., 1999). More than 75% of the world's rice supply comes from 79 million ha of irrigated land in Asia. Thus, the present and future food security of Asia depends largely on the irrigated rice production system. This system is a major user of fresh water (Tabal et al., 2002). The available amount of water for irrigation, however, is increasingly getting scarce. Environmental factors that impose water-deficit stress, such as drought, salinity and temperature extremes, place major limits on plant productivity (Boyer, 1982). Meanwhile, rice is often considered as one of the most drought sensitive cultivated species, however, water deficit commonly occurs during the growing season, and the intensity of stress depends on the duration and frequency of water deficit. In Iran, drought is a serious constraint on the productivity of main crops such as wheat and rice. It is known that drought can affects chlorophyll content, inhibits root growth, dry matter production and severely reduces the yield and yield components. In previous research has indicated that Proline accumulation in plant cells exposed to salt or water stress is a widespread phenomenon (Lin and Kao, 1996). This study was designed to determine, aside from growth phenology, the effect of drought stress on some physiological responses such as praline content, relative water content and chlorophyll florescence parameters in some commonly traditional and modern rice varieties exhibiting differences in drought tolerance in northern of Iran.

II. METHODS

The study was conducted during 2006 growing seasons in a greenhouse at the Rice Research Institute of Iran-Deputy of Mazandaran (Amol), Iran. The experiment was factorial in a completely randomized design with three replications. Each treatment had three pots as repetitions. Main-plots were four water stress regimes (water stress imposed during vegetative stage, water stress imposed during flowering stage, water stress imposed during grain filling stage and control or no water stress). Control was irrigated as required to ensure a high level of standing water throughout crop growth. Four rice cultivars; Tarom (as a traditional variety), Khazar, Fajr and Nemat (as improved cultivars), were selected for this study. Plants in water stress treatments were grown under favorable water conditions with supplementary surface irrigation throughout the crop cycle while irrigation was interrupted to induce drought stress at around vegetative, flowering and grain filling stages. Sub-plots were four contrasting cultivars. Seedlings (25-day-old) were transplanted to plastic pots filled with puddle soil having pH 7.1. The pots were kept in the well-ventilated glasshouse during the whole growing season. The air temperature and relative humidity in the glasshouse was in the range from 22 to 32°C and 60–80%, respectively.

Days to flowering was measured as the time taken from transplanting to 50% of plants in each pot to flower (anthers visible).Relative leaf water content (RLWC) and proline of the young expanded leaves (according to Bates, 1973) were

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measured. Grain yield/pot also measured from the collected five plants for each replication. Photosynthetic parameters were measured at the fourth youngest leaf with a photosynthesis analyzer (LI-6400, Licor, Lincoln, USA). The maximum quantum efficiency of PSII primary photochemistry (Fv/Fm) and dark respiration was determined after 30 min of dark adaptation. The maximum fluorescence (Fm) yield was recorded during the application of a 0.8-s saturation flash (>8000 mmol m^{-2}. s^{-1}). The maximum quantum efficiency of PSII primary photochemistry (Fv/Fm) was calculated as (Fm - Fo)/Fm. Data were subjected to ANOVA using the SAS statistical software package (SAS Institute, 2000) and means were compared by Duncan test (P< 0.05).

III. RESULTS

The significance level for the measured parameters, including grain yield, proline content, SPAD, F_v, F_m, F_v / F_m , t $_{½}$ is summarized in Table I. Genotypes varied for all studied traits except F_v / $F_{m.}$ Interaction variations of W*C were not significant for SPAD, RWC, F_v, F_v / F_m, whereas W*C were significant for praline content, F_m and t $_{½}$. The cultivars used in this study had different genetic backgrounds and were dissimilar in plant height, phenological development and yield potential. RWC of Fajr and Nemat were higher than Tarom and Khazar (Table I). Table I shows that the amounts of free proline in different water stress treatments were within a range of 19–30 µmol.g leaf dry weight. Remarkably, when the drought condition was extended to 20 days, free proline amount was increased. Bohnert and Jensen (1996) suggested that proline accumulation may serve as a means of osmotic adjustment and storing carbon and nitrogen when stress leads to slower growth. Nemat cultivar had both higher grain yield and proline than Fajr and Kazar and Tarom had the lowest grain yield and proline content. Water treatment differences were significant on grain yield. Table I show the reduction by 25, 45 and 61% in the W1, W2 and W3 treatment, respectively relative to control treatment which was fully watered. Drought stress also affected the chlorophyll content in leaves. Chlorophyll fluorescence parameters of well-watered plants were compared to those of drought-treated plants (Table I). Interestingly, as drought period was extended to 20 days at each growth stages, F_v , F_m , and t $_{½}$ contents decreased proportionally in the leaves.

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TABLE I

GRAIN YIELD AND PLANT PARAMETERS OF FOUR RICE CULTIVARS GROWN UNDER FOUR WATER STRESS TREATMENTS

Treatments††	Grain yield(g)	SPAD	Proline (µmol.g)	RWC (%)	F_v	F_m	F_v/F_m	$t_{1/2}$
Water Stress (W)								
W0	66.43a	40.87a	19.00c	87.67a	0.16a	0.28a	0.52a	281.3a
W1	49.18b	36.54b	28.37a	72.04b	0.13a	0.24b	0.44ab	242.5c
W2	36.1c	33.12c	30.08a	73.12b	0.08b	0.21c	0.53a	272.1b
W3	25.87d	30.42d	26.58b	73.16b	0.05b	0.19d	0.33b	229.3d
Cultivar (C)								
Tarom	24.49d	33.37c	19.20d	71.54c	0.07c	0.17d	0.37b	332.2a
Khazar	31.89c	37.37a	25.92c	75.76b	0.08bc	0.23c	0.46ab	257.0b
Fajr	58.29b	35.16b	28.87b	79.04a	0.13ab	0.25b	0.48a	223.5c
Nemat	62.90a	35.04b	30.04a	79.66a	0.14a	0.27a	0.51a	221.5d
Significance†††								
W	**	**	**	**	**	**	*	**
C	**	**	**	**	*	**	NS	**
W*C	**	NS	**	NS	NS	**	NS	**
CV	12.1	9.6	5.8	3.29	10.9	3.8	29.3	4.6

†Means followed by different lowercase letters in the same column differ significantly at P=0.05.

†† W0, control; W1, water stress at vegetative stage; W2, water stress at flowering stage; W3, water stress at grain filling stage.

†††Levels of significant:* P< %5, ** P<%1