Performance of rice varieties under aerobic conditions in Hungary

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Abstract: Drought tolerance is an important trait of rice breeding because mainly in rainfed systems, plants must cope with water scarcity from time to time. But it can also be important in the temperate zone. In Hungary, an aerobic rice growing system was developed and the breeding of aerobic rice varieties was started in the 1990's. Successful rice growing under aerobic conditions requires drought tolerant varieties, uniform sowing, weed management and irrigation set to the crop water requirements. Yield and quality of the paddy rice in aerobic systems can be the same as in conventional production. In our experiment, performance of 15 aerobic rice genotypes from the International Rice Research Institute was compared to the Hungarian bred varieties in the Lysimeter Research Station of the NAIK ÖVKI as part of the IRRI INGER nursery program. However, some of the physiological parameters (RWC) of international drought-tolerant varieties were measured superior to the temperate varieties, photoperiodic sensitivity, duration and cold sensitivity limit the direct adaptation under the temperate climate.

Keywords: aerobic rice, Oryza sativa L., drought tolerance, temperate climate

Introduction

In Hungary, first steps of scientific research on aerobic rice cultivation were begun in the 1940s. The pioneer experiments were carried out to find appropriate varieties for the sandy soils of the Great Hungarian Plain and not to develop water saving technologies. The second phase of aerobic rice research was started in 1984 and a new water-saving rice growing method (Sanoryza) was patented in 1992 (Simon-Kiss 2001). With that method, in favourable years irrigation can be decreased even up to 78 %, but the average amount of saving is also 45-70% compared to the conventional rice production by using of special aerobic genotypes in Hungary (Jancsó 2011). Nowadays, water for agriculture is becoming increasingly scarce and rice is one of the major consumers of irrigation water. The 79 million ha of irrigated rice worldwide is estimated to receive 34-43 % of the total world's irrigation water (Bouman *et al.* 2007). Therefore, water is an important factor for rice production. When water deficit occurs in sensitive periods of plant development, like near the flowering, rice yield is dramatically reduced. Primarily, increased spikelet sterility is a main symptom (Lafitte 2002). However, relative water content (RWC) is an easy way to determine the physiological status of rice plants exposed to different levels of drought; the correlation is strongly influenced by genetic differences in yield potential and maturity (Lafitte 2002). Selection for drought tolerance, especially under the temperate climate is very complex (Courtois *et al*. 2012), because plants are usually exposed to multiple stressors (drought, salinity, low temperature, mechanical damage, etc.) (Sulmon *et al.* 2015). Among all, leaf rolling, leaf drying, harvest index, biomass yield, relative water content, panicle length, grains per panicle, grain yield, root/shoot ratio and root length offer high scope for improvement for drought tolerance by way of simple selection technique (Manickavelu *et al.* 2006). Hungary is one of the northernmost countries for rice growing in Europe; therefore optimal sowing date and cold tolerance are important factors of successful rice production in the relatively short growing season (Gombos and

Simon-Kiss 2008). To develop better selection methods and models, duration of periods from sowing to emergence at different temperature values and base temperatures were determined and a thermal time model was established (Gombos and Simon-Kiss 2005). However, Hungarian varieties e.g. HSC-55 has high tolerance to cold (Ye *et al* 2009), further improvement of the genotypes and testing of international breeding lines are important to maintain rice production under the temperate climate (Simon-Kiss 2001).

Materials and methods

The experiments on aerobic rice production were set up at the Lysimeter Research Station of the National Agricultural Research and Innovation Centre, which is located in Szarvas (south-east Hungary, latitude 46°86'N, longitude 20°52'E). The Station was built in the year of 1971 when 320 non-weighable backfilled gravitation lysimeters were set up on a 1 hectare experimental field. For the aerobic production, plots between lysimeter blocks were used in 2016. A modified version of Sanorzya aerobic rice production system (Simon-Kiss et al. 1992) was applied for the field management. From the seedling stage, drip irrigation was set up. Source of irrigation water was the oxbow of Körös-river. Meteorological data was automatically collected at the meteorological station of the Szarvas Campus of Szent István University and by a WS-GP1 Compact Weather Station (Delta-T Devices, UK) during the growing season (Table 1). However, rainfall was low in April, May and September. In the period of intensive vegetative growth (from June to the beginning of August), quantity and distribution of natural precipitation was close to the optimal.

Table 1. Monthly rainfall (mm), air temperature (°C) and soil temperature at 5 cm (°C) in the cropping season in Szarvas in 2016, average temperature data and total precipitation for the season are also shown.

	April	May	June	July	Aug	Sept	Oct	AV	Total
Mean min temp., °C	7.4	10.1	15.6	16.4	15.0	12.3	6.1	11.8	-
Mean max temp. , °C	19.8	23.6	27.5	29.1	27.9	26.0	14.6	24.1	-
Average mean temp. , °C	13.4	16.6	21.3	22.5	21.1	18.3	9.8	17.6	-
Precipitation, mm	12.3	18.8	124.4	124.4	50.5	9.8	72.7	-	412.9
Mean soil temp. at 5cm, °C	13.8	17.4	22.6	24.0	23.2	20.0	12.4	19.0	-

New breeding lines and standard varieties (15) for aerobic rice cultivation (Table 2) from the International Rice Research Institute (IRRI, Manila, The Philippines) were compared to the Hungarian bred varieties as part of the IRRI International Network for Genetic Evaluation of Rice (INGER) nursery program (Forty-Second International Upland Rice Observational Nursery, IURON). The experiment was started with the direct dry sowing that was done on the 5th of May 2016. After a preemergent herbicide treatment, first irrigation was started on the 6th of May (20 mm) to accelerate germination. Due to the cold periods in May date of emergence was observed on 20th of May and 25-26th of May for the Hungarian check and the IURON lines, respectively.

The symptoms of cold and drought stress were evaluated after the international standard evaluation system (IRRI 2013). In our experiment (Table 2), tolerant (SES score 2-3 –

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tip of leaves slightly dried, folded and light green), moderately tolerant (SES score 4-5 – some seedlings moderately folded and wilted, 30-50% seedlings dried, pale green to yellowish leaves) and sensitive (SES score 6-7 – seedlings severely rolled and dried; reddish-brown leaves) reactions to low temperature were observed after a cold period in May. Relative water content (RWC) of the varieties was measured and calculated as Lafitte (2002) described.

The variation of soil moisture content and soil temperature at 15 cm (Sensor1, Temp1) and at 30 cm (Sensor2, Temp2) below the surface were logged in every 10 minutes of the season (Figure 1) by using of SM300 soil moisture sensors connected to a GP1 data logger (Delta-T Devices, UK). Soil moisture and drought symptoms were regularly checked and irrigation was applied as the crop needs (sensitive checks Beside the agronomic parameters (yield, grain weight, thousand grain weight, plant height) changes in chlorophyll content using SPAD-502 hand-held chlorophyll meter (Minolta Co. Ltd., Osaka, Japan) were also detected.

Results and discussion

The rice growing season in 2016 was divisive in Hungary, after a cold period in May (Table 1) the quantity and distribution of natural precipitation was close to the optimal.

Table 2 Scoring of cold tolerance (after IRRI 2013) and the recovery of the plants described by SPAD values (Szarvas, Hungary, 2016)

Breeding line	SES Score of cold tolerance	SPAD readings, 16.06.2016	Average yield per parcel, g/m^2
IR14L594	4-5	27.1±3.8	n.p.
IR14L176	4-5	25.3±1.7	144.5
IR14L226	2-3	27.3±1.2	4.0
IR14L231	2-3	26.9±1.8	25.0
IR14L537	6-7	28.4±1.2	n.p.
IR14L540	4-5	34.0±2.9	n.p.
IR14L546	4-5	30.2±2.0	n.p.
IR14L560	4-5	31.8±3.1	n.p.
IR14L562	6-7	29.7±1.3	n.p.
IR14L572	6-7	28.2±1.8	n.p.
IR64	4-5	28.5±2.0	n.p.
IRRI 132	4-5	22.3±1.7	n.p.
IRRI 148	4-5	23.1±1.3	n.p.
UPL RI 7	4-5	20.7±1.9	n.p.
VANDANA	4-5	29.8±2.1	sterile spikelets
JANKA*	2-3	30.4±1.4	592.8

* Local check, Nucleoryza DH somaclone; n.p. – no heading stage

In the fourth pentad of May, effective temperature was calculated only as 14.8 °C with the minimum temperature of 3.0 °C. However, it has a negative effect on the cold sensitive plants (e.g. rice, sorghum), from the experimental view, on-field cold tolerance could be easily scored. On most of the tested breeding lines, symptoms of moderate tolerance were observed as it was determined in the SES (IRRI 2013). However, 'IR14L537', 'IR14L562' and 'IR14L572' genotypes were set as sensitive lines where seedlings were severely rolled and dried and the leaves had reddish-brown colour right after the cold period. However, the effects of low temperature were observable even after a two-week period of optimal growth temperature on 16th of June (Table 1). The SPAD readings were shown that varieties what were scored as moderately tolerant ('IRRI 132', 'IRRI 148' and 'UPL RI 7') could have long-term damages.

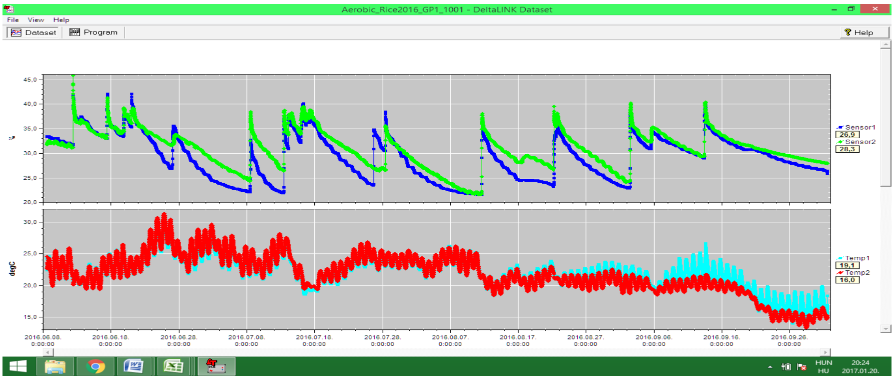

Figure 1 Variation of soil moisture content and soil temperature at 15 cm (Sensor1, Temp1) and at 30 cm (Sensor2, Temp2) below the surface. (Szarvas, Hungary, 2016)

Soil moisture content was determined during the season. Irrigation was applied only 5 times as an average of 20 mm (Figure 1). The overall season was favourable for the plants' development (Figure 1). Compared to our previous results (Jancsó 2011), water saving was significant (85%) compared to the paddy fields. Middle of September was the end of the season when soil temperature went below 10 °C.

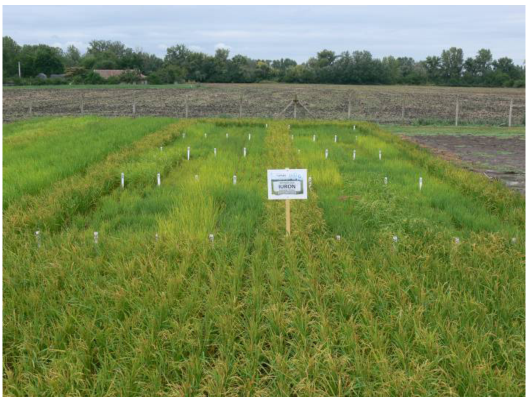

Figure 2 Aerobic rice experiment after the flowering of 'Janka' on 11th August (Szarvas, Hungary, 2016)

As part of the experiment, standard varieties were also tested for drought tolerance. Symptoms of drought were observable first on the sensitive plants ('Marilla'). Leaf rolling was significant when soil moisture went below 25-30 % depending on the developmental stage of plants and the air temperature (Figure 1). RWC was determined multiple times during the season. RWC at well-irrigated (29.06) and water-limited (07.07) conditions are also presented (Table 3).

Compared to the results of Lafitte (2002), moderate stress environment was maintained in our nursery field. Sensitive genotypes as the 'Marilla' (87.8±3.5) had lower RWC values, while drought tolerant varieties as 'IRAT 109' (91.2±0.6) and 'Ábel' (91.8±1.0) maintained RWC close to the optimum.

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Table 3 Relative water content (RWC) of Hungarian rice varieties under well-irrigated (29th of June) and under drought prone (7th of July) conditions (Szarvas, Hungary, 2016)

Name of varieties	RWC on 29th of June	RWC on 7th of July
Ábel	92.4±0.7	91.8±1.0
Janka	94.1±0.5	87.5±3.7
Bioryza H	93.0±0.5	89.3±1.7
IRAT 109	93.6±1.3	91.2±0.6
Marilla	93.9±0.8	87.8±3.5

Plots were harvested manually when grains were fully matured. Hungarian varieties were collected at the beginning and middle of September to avoid damage of rodents. International genotypes were harvested when development of plants was stopped due to the low temperature at the end of September. Beside 'Janka', only 'IR14L176', 'IR14L226' and 'IR14L231' produced yield that was very low (Table 2). Our results verified as it was reported by multiple authors (Bouman *et al.* 2007, Courtois *et al.* 2012, Sulmon *et al.* 2015) that in the temperate zone, short growing season (May to September), the long days during most of the growing season, and the low temperatures are also limiting factors. Aerobic rice cultivars need to integrate good tolerance to diverse stressors.

Conclusions

Drought tolerance is an important trait of rice breeding because mainly in rainfed systems, plants must cope with water scarcity from time to time. But it can also be important under the temperate zone. In our experiment, performance of 15 aerobic rice genotypes from the International Rice Research Institute was compared to the Hungarian bred varieties at the Lysimeter Research Station of the NAIK ÖVKI. Even moderate stress environment could lower the yield performance. Cold resistance is important because in Hungary, low temperature can be occurred in May and in August. In 2016, effective temperature was calculated only as 14.8 °C with the minimum temperature of 3.0 °C in the fourth pentad of May. Therefore, symptoms of cold stress were observable on young plantlets. Moreover, RWC is a good and relative fast method to measure reaction of different plants to drought. However, selection for drought tolerance, especially under the temperate climate is very complex. Photoperiodic sensitivity, duration and cold sensitivity limit the direct adaptation of tropical aerobic varieties under the temperate climate.

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