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EVALUATION OF RICE CULTIVARS IN DIFFERENT IRRIGATION TREATMENTS BASED ON SENSITIVE AND TOLERANCE INDICES

SUMMARY

In order to evaluation rice cultivars in different irrigation treatments based on sensitive and tolerance indices, an experiment was conducted as two-factor factorial in a randomized complete block design with three replications at Rice Research Station of Tonekabon, northern Iran, in 2011. Seven drought resistance indices include susceptible stress index (SSI), tolerance index (TOL), stress mean productivity (MP), geometric mean productivity (GMP), stress tolerance index (STI), yield index (YI) and yield stability index (YSI) were applied on the basis of seed yield in non stress and drought stress conditions. Based on different drought indices, Shiroudi cultivar had the best rank with low standard deviation. The results indicated that it has stable yield performance. Bi-plot display cleared superiority of this genotype. Results showed MP, GMP, YI and STI indices were more effective in identifying high yielding cultivars in diverse water scarcity. Selection of the best Iranian rice variety and determination of best irrigation management based on yield can use these tolerant and sensitive indices in different irrigation position.

Keywords: Rice (*Oryza sativa* L.), drought stress, seed yield, tolerant and sensitive indices, biplot

INTRODUCTION

Drought is the most important limiting factor for crop production and it is becoming an increasingly severe problem in many regions of the world (Passioura, 2007). According to statistics, the percentage of drought affected land areas more than doubled from the 1970s to the early 2000s in the world (Isendahl and Schmidt, 2006). By 2025, 15 out of 75 million hectare of Asia's flood-irrigated rice crop will experience water shortage (Tuong and Bouman, 2003). Alternatives to the conventional flooded rice cultivation were developed worldwide to reduce water consumption and produce more rice with less water. Food security depends on the ability to increase production with decreasing

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availability of water to grow crops. Rice, as a submerged crop, is a prime target for water conservation because it is the most widely grown of all crops under irrigation. To produce 1 kg of grain, farmers have to supply 2–3 times more water in rice fields than other cereals (Barker *et al*., 1998; Farooq *et al*., 2006). Rapidly depleting water resources threaten the sustainability of the irrigated rice and hence the food security and livelihood of rice producers and consumers (Tuong *et al*., 2004).

There is also much evidence that water scarcity already prevails in rice-growing areas, where rice farmers need technologies to cope with water shortage and ways must be sought to grow rice with lesser amount of available water (Tuong and Bouman, 2003). Former requires a possible shift from the traditional system of flooded rice to growing rice aerobically and the latter needs the development of high yielding varieties that thrive under aerobic conditions (Castaneda *et al*., 2003).

To improve crop productivity, it is necessary to understand the mechanism of plant responses to conditions with the ultimate goal of improving crop performance in the vast areas of the world where rainfall is limiting or unreliable. In addition to the complexity of drought itself (Passioura, 2007), plant's behavior responses to drought are complex and different mechanisms are adopted by plants when they encounter drought (Jones, 2004).

Considering the scarcity of water, the economic management of water has become essential and attempts are underway to reduce huge volume of irrigation water required for rice crop production, intermittent irrigation for rice crop instead of flooding is aimed mainly at saving water. It has been reported that application of water 1-5 days after the disappearance of applied standing water saved 25-50% of irrigation water as compared to the continuous submergence of fields without any adverse affect on rice yield (Peng *et al*., 1994; Tajima, 1995). In some under-saturated soil moisture conditions dry matter production and grain yield decreased significantly (Lu *et al*., 2000; Ali *et al*., 2005). Keeping in view the shortage of water, the present research was planned to estimate the optimum water requirement of rice crop and the effect of water stress on production of its economical yield.

Achieving a genetic increase in yield under these environments has been recognized to be a difficult chal-lenge for plant breeders while progress in yield grain has been much higher in favorable environments (Richards *et al*., 2002). Thus, drought indices which provide a measure of drought based on yield loss under drought conditions in comparison to normal conditions have been used for screening drought tolerant genotypes (Mitra, 2001).

Fernandez (1992) classified plants according to their performance in stressful and stress free environments to four groups: genotypes with similar good performance in both environments (group A), genotypes with good performance only in non-stress environments (group B) or stressful environments (group C), and genotypes with weak performance in both environments (group D). Rosielle and Hamblin (1981) defined stress tolerance (TOL) as the differences in yield between the stress (Ys) and non-stress (Yp) environments and mean productivity (MP) as the average yield of Ys and Yp. Fischer and Maurer (1978) proposed a stress susceptibility index (SSI) of the cultivar. Fernandez (1992) defined a new advanced index (STI = stress tolerance index), which can be used to identify genotypes that produce high yield under both stress and non-stress conditions. Geometric mean productivity (GMP) and stress tolerance index (STI) (Fernandez, 1992) have been employed under various conditions. Fischer and Maurer (1978) explained that genotypes with an SSI of less than a unit are drought resistant, since their yield reduction in drought conditions is smaller than the mean yield reduction of all genotypes (Bruckner and Frohberg, 1987). Other yield based estimates of drought resistance are harmonic mean (HM) (Dehdari, 2003; Yousefi, 2004), yield index (YI) (Gavuzzi *et al*., 1997), yield stability index (YSI) (Bouslama and Schapaugh, 1984) and % reduction (Choukan *et al*., 2006). Katouzi1 *et al*. (2008) reported that under moderate stress, HM, MP, GMP and STI were more effective in identifying high yielding cultivars in both drought-stressed and irrigated conditions (group A cultivars). The suitability of indicators seems to depend on the timing and severity of stress in drought prone environments.

The objective of this experiment was to determine best cultivar based on influences of water stress on yield of rice in Tonekabon, Iran, a main rice growing area in Iran. The present study was conducted to determine how drought affects grain yield in three cultivars of rice and also to test this hypothesis in order to identify the most suitable indices/cultivars for each environment.

MATERIAL AND METHODS

The experiment was conducted outdoors in plastic pots at Rice Research Station in Tonekabon (36° 54' N, 40° 50' E; -21 m above sea level), north of Iran, from June to September in 2011. The experiment was arranged as a two-factor factorial in a randomized complete block design with three replications. The two factors included three native rice cultivars (Shiroudi, Hashemi and Deylamani) and five irrigation levels (flooded irrigation (normal treatment), two, four and six interval irrigation (stress treatments)).

Pots (35 cm average diameter by 30 cm deep) were arranged in a rectangular grid pattern with approximately 40 cm between edges of adjacent pots. Pots were filled to a depth of 25 cm with clay loam soil from the Tonekabon Rice Research station Farm. Soil properties were 2.2% organic matter content, 37% clay, 44% silt, 19% sand, 6.8 pH, 29.9 cation exchange capacity (CEC) (meg 100 g). Consistent with the lowland paddy field practices for normal treatment in north of Iran, a permanent flood 5 cm deep was maintained. Rice seeds were disinfected with thiophanate-methyl pesticide 70 WP (2 g L^{-1} H_2o) and subsequently were sown in the nursery on 6 April, 2011.

Recommended rate of nitrogen (100 kg ha-1), phosphorous (100 kg ha-1) and Potassium (150 kg ha-1) were applied. One-third amount of nitrogen and whole phosphorous and Potassium were applied as a basal dose at transplanting stage. The Remaining two-thirds of nitrogen were utilized in two split doses, 30 days after transplanting (tiller stage) and panicle initiation stage. Weeds were controlled by hand weeded during growth season.

The seed yield was measured by hand-cutting of each pod at crop maturity. Drought resistance indices were calculated using the following relationships:

(1) $Stress\ susceptibility\ index\ (SSI) = \frac{1-(Ys/Yp)}{1-(\bar{Y}s/\bar{Y}p)}$ (Fischer and Maurer, 1978),

Where Ys is the yield of cultivar under stress, Yp the yield of cultivar under irrigated condition, $\bar{Y}s$ and $\bar{Y}p$ are the mean yields of all cultivars under stress and non-stress conditions, respectively, and $1-(\bar{Y}s/\bar{Y}p)$ is the stress intensity. The irrigated experiment was considered to be a non-stress condition in order to have a better estimation of optimum environment.

(2) $Mean\ productivity\ index\ (MP) = \frac{Yp+Ys}{2}$ (Hossain *et al*., 1990).

(3) $Tolerance\ (TOL) = Yp - Ys$ (Hossain *et al*., 1990).

(4) $Stress\ tolerance\ index\ (STI) = \frac{Yp \times Ys}{(\bar{Y}p)^2}$ (Fernandez, 1992).

(5) $Geometric\ mean\ productivity\ (GMP) = \sqrt{Yp \times Ys}$ (Fernandez, 1992).

(6) $Yield\ index\ (YI) = \frac{Ys}{\bar{Y}s}$ (Gavuzzi *et al*., 1997).

(7) $Yield\ stability\ index\ (YSI) = \frac{Ys}{Yp}$ (Bouslama and Schapaugh, 1984).

(8) $\%\ Reduction = \frac{Yp-Ys}{Yp} \times 100$ (Choukan *et al*., 2006).

All data were subjected to analysis of variance (ANOVA), and means were separated using Duncan's multiple range test (at the 0.05 probability level). All statistical analyses were conducted by using SAS (SAS Institute, Inc, 2002). The biplot display was also used to identify tolerant and high yielding genotypes using StatGraphics software, based on principal component analysis.

RESULTS AND DISCUSSION

Selection based on a combination of indices may provide a more useful criterion for improving drought resistance of rice but study of correlation coefficients is useful in finding the degree of overall linear association between any two attributes. As shown in Tables 1, the greater value TOL has, the larger yield reduction under stress and the higher drought sensitivity are. Negative correlations between TOL and SSI with yield under stress (Ys) (Table 2) suggest that selection based on TOL and SSI will result in reduced yield under water stress conditions. Similar results were reported by Sio-Se Mardeh *et al*. (2006) and Shirani Rad and Abbasian (2011) for canola.

Based on ranking of MP, GMP and STI indices, Shiroudi had the best performance and showed the highest value. Also, the lowest value of SSI and TOL assigned to Shiroudi. In consideration to all indices, Shiroudi showed the best mean rank and low standard deviation of ranks. On the other hand, Shiroudi had stable yield under different intensity of drought stresses (Tables 1). Shiroudi cultivar which has been cultivating by farmers since eight past years, had the first rank with medium standard deviation (Tables 1).

Grain yield under normal irrigation showed positive significant correlation with the yield in dry conditions. The correlation between yield under dry condition and normal irrigation with SSI index was negative. Whereas, MP, GMP, STI and YI indices had positive significant correlation at 1% probability level with each other and grain yield in both conditions in (Tables 2). The MP can be related to yield under stress only when stress is not too severe and the difference between yield under stress and non stress conditions is not too big (Sio-Se Mardeh *et al*., 2006). Hossain *et al*. (1990) used MP as a resistance criterion for wheat cultivars in moderate stress conditions. Ahmad Zadeh (1997) introduced MP as appropriate criterion for selection of high yield and drought tolerance in corn. Regarding the results of bi-plot, Shiroudi, in the vicinity of drought tolerance indices was identified as stable high yielding genotypes. It was mainly due to yield potential and drought tolerance region (Fig. 1). Genotype Deylamani (Fig. 1) was identified as drought sensitive genotypes, due to location in sensitive to drought stress and low yield region (Fig. 1; top left). This genotype, in terms of yield in normal irrigation and dry conditions was superior compared to other genotypes, according to MP, GMP, YI and STI indices. This genotype (Deylamani) was separately classified in the stress susceptible region, according to bi-plot analysis.

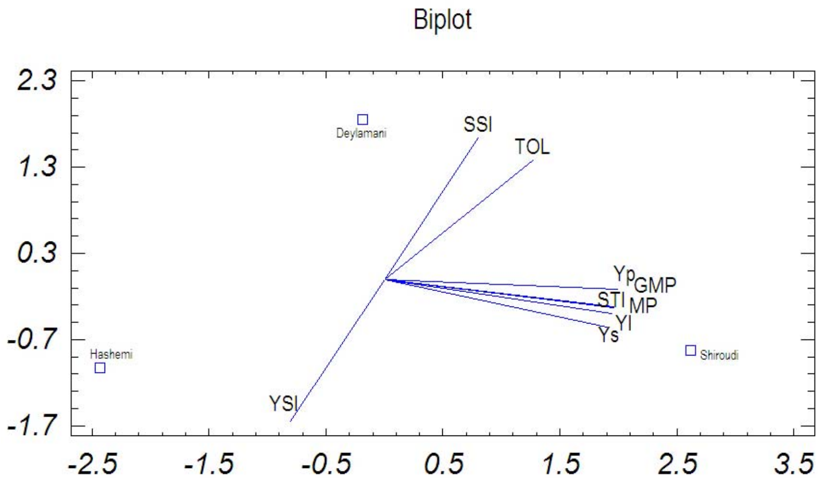

Figure 1. Drawing bi-plot based on first and second components for three rice genotypes and different indices.

Table 1. Resistance indices of 3 rice genotypes under stress and non-stress environments for seed yield in 2011.

Cultivar	Yp	Ys	SSI	TOL	MP	GMP	STI	YI	YSI	% reduction
Irrigation after two day interval										
Shiroudi	33.62 a	30.79 ab	0.96	2.83	32.21	32.18	1.27	1.18	0.92	8.43
Deylamani	27.84 bcd	24.28 cde	1.45	3.56	26.06	25.99	0.83	0.93	0.87	12.77
Hashemi	24.2 cde	23.06 def	0.54	1.14	23.63	23.62	0.68	0.89	0.95	4.73
			Irrigation after four day interval							
Shiroudi	33.62 a	28.1 bc	0.79	5.52	30.86	30.74	1.16	1.24	0.84	16.42
Deylamani	27.84 bcd	20.43 efg	1.29	7.4	24.14	23.85	0.69	0.9	0.73	26.59
Hashemi	24.2 cde	19.44 efg	0.95	4.76	21.82	21.69	0.58	0.86	0.8	19.67
Irrigation after six day interval										
Shiroudi	33.62 a	27.64 bcd	0.68	5.98	30.63	30.49	1.14	1.31	0.82	17.79
Deylamani	27.84 bcd	18.62 fg	1.27	9.22	23.23	22.77	0.64	0.88	0.67	33.11
Hashemi	24.2 cde	17.09 g	1.13	7.11	20.65	20.34	0.51	0.81	0.71	29.38

Note. Ys: yield of cultivar under stress, Yp: yield of cultivar under irrigated condition, SSI: stress susceptibility index, TOL: tolerance, MP: mean productivity, GMP: geometric mean productivity, STI: stress tolerance index, YI: yield index, YSI: yield stability index.

Table 2. Simple correlation coefficients of stress indices with seed yield of 3 rice cultivars

Cultiv	Ys kg ha^{-1}	SSI	TOL	MP	GMP	STI	YI	YSI	% reduction
Yp	0.85**	-0.19ns	0.019ns	0.96**	0.95**	0.95**	0.94**	0.24ns	-0.22ns
Ys	1	-0.42**	-0.51ns	0.97**	0.97**	0.97**	0.89**	0.71*	-0.69*
SSI		1	0.48ns	-0.33ns	-0.34ns	-0.35ns	-0.47ns	-0.54ns	0.54ns
TOL			1	-0.27ns	-0.27ns	-0.29ns	-0.15ns	-0.96**	0.96**
MP				1	0.99**	0.99**	0.95**	0.51ns	-0.49ns
GMP					1	0.99**	0.94**	0.53ns	-0.52ns
STI						1	0.95**	0.52ns	-0.51ns
YI							1	0.39ns	-0.38ns
YSI								1	-0.99**

Note. Ys: yield of cultivar under stress, Yp: yield of cultivar under irrigated condition, SSI: stress susceptibility index, TOL: tolerance, MP: mean productivity, GMP: geometric mean productivity, STI: stress tolerance index, YI: yield index, YSI: yield stability index. ns: not significant; *: P < 0.05, **: P < 0.01.

CONCLUSIONS

In addition, results of investigation on seed yield in different drought stress and non-stress conditions with drought tolerance indices showed that MP, GMP, YI and STI are best indices for selecting and specifying of rice tolerant cultivars in arid areas. These results completely agreed with Katouzi *et al*. (2008) that aforementioned indices for having positive and significant correlation with seed yield of rice cultivars at drought stress and non-stress conditions were an appropriate criterion for recognition of high yield and drought tolerance genotypes.

REFERENCES

Ahmad Zadeh, A. (1997): Definition of the best drought tolerant index in corn selective lines. M.Sc. thesis (unpublished). College of Agriculture, University of Tehran, Iran, 238 p. (in Farsi)

Ali, Y. Sarwar, G. Aslam, Z. Hussain, F. & Rafique, T. (2005): Evaluation of advanced rice germplasm under water stress environment. International Journal of Environmental Science and Technology., 2(1): 27-33.

Barker, R. Dawe, D. Tuong, T. P. Bhuiyan, S. I. & Guerra L. C. (1998): The outlook for water resources in the year 2020: Challenges for research on water management in rice production. In ‘‘Assessment and Orientation Towards the 21st Century’’, pp. 96-109. Proceedings of 19th Session of the International Rice Commission, Cairo, Egypt, 7–9 September 1998. FAO.

Bouslama, M. & Schapaugh, W.T. (1984): Stress tolerance in soybean. Part 1. Evaluation of three screening techniques for heat and drought tolerance. Crop Science., 24: 933-937.

Bruckner, P. L. & Frohberg, R. C. (1987): Rate and duration of grain fill in spring wheat. Crop Science., 27: 451-455.

Castaneda, A. R. Bouman, B. A. M. Peng, S. & Visperas, R. M. (2003): The potential of aerobic rice to reduce water use in water-scarce irrigated lowlands in the tropics. In ‘‘Water-Wise Rice Production’’ (B.A.M. Bouman, H. Hengsdijk, B. Hardy, P.S. Bindraban, T.P. Tuong, and J.K. Ladha, Eds.). Proceedings of a Thematic Workshop on Water-Wise Rice Production, 8–11 April 2002 at IRRI Headquarters in Los Banos, Philippines. International Rice Research Institute, Los Banos, Philippines

Choukan, R. Taherkhani, T. Ghannadha, M. R. & Khodarahmi, M. (2006): Evaluation of drought tolerance in grain maize inbred lines using drought tolerance indices. Iranian Journal of Agricultural Sciences., 8: 79-89 (in Farsi)

Dehdari, A. (2003): Genetic analysis of salt tolerance in wheat crosses. Ph.D. thesis (unpublished). Isfahan University of Technology, Isfahan, Iran, 141 p. (in Farsi)

Farooq, M. Kobayashi, N. Wahid, A. Ito, O. & Basra, S. M. A. (2009): Strategies for Producing More Rice with Less Water. Advance in Agronomy., 101: 351-387.

Fernandez, G. C. J. (1992): Effective selection criteria for assessing stress tolerance. Proceedings of the International Symposium on Adaptation of Vegetables and Other Food Crops in Temperature and Water Stress Tolerance. Asian Vegetable Research and Development Centre, Taiwan, 257-270 p.

Fischer, R. A. & Maurer, R. (1978): Drought resistance in spring wheat cultivars. I. Grain yield response. Australian Journal of Agricultural Research, 29: 897-907.

Gavuzzi, P. Rizza, F. Palumbo, M. Campanile, R.G. Ricciardi, G. L. & Borghi, B. (1997): Evaluation of field and laboratory predictors of drought and heat tolerance in winter cereals. Canadian Journal of Plant Science., 77: 523-531.

Hossain, A. B. S. Sears, A. G. Cox, T. S. & Paulsen, G. M. (1990): Desiccation tolerance and its relationship to assimilate partitioning in winter wheat. Crop Science., 30: 622-627.

Isendahl, N. & Schmidt, G. (2006): Drought in the Mediterranean-WWF policy proposals. In A, edited by W. Report. Madrid.

Jones, H. (2004): What is Water Use Efficiency? In Water Use Efficiency in Plant Biology, Edited by M.A. Bacon. Oxford: Blackwell.

Katouzi, M. Rahimzadeh khoei, F. & Sabouri, H. (2008): Evaluation of rice cultivars in different irrigation treatment based on sensitive and tolerance indices. Electronic Journal of Crop Physiology., 1(3): 33-47 (in Farsi).

Lu, J. Ookawa, T. & Hirasawa, T. (2000): The effects of irrigation regimes on the water use, dry matter production and physiological responses of paddy rice. Plant and Soil., 223: 207-216.

Mitra, J. (2001): Genetics and genetic improvement of drought resistance in crop plants. Current Science., 80: 758-762.

Passioura, J. B. (2007): The drought environment: physical, biological and agricultural perspectives The Journal of Experimental Botany, 58(2): 113-117.

Peng, S. Li, S. Xu, G. & Wu, Z. (1994): New water consumption pattern of rice under water saving irrigation. Irrigation and drainage., 8: 97-108.

Richards, R. A. Rebetzke, G. J. Condon, A. G. & Herwaarden, A. F. (2002): Breeding opportunities for increasing the efficiency of water use and crop yield in temperate cereals. Crop Science., 42: 111-121.

Rosielle, A. A. & Hamblin, J. (1981): Theoretical aspects of selection for yield in stress and non-stress environment. Crop Science., 21: 943-946.

SAS Institute Inc. (2002): SAS System, Version 9.1. SAS Institute Inc., Cary, NC.

Shirani Rad, A. H. & Abbasian, A. (2011): Evaluation of drought tolerance in winter rapeseed cultivars based on tolerance and sensitivity indices. Žemdirbystė Agriculture., 98: 41-48.

Sio-Se Mardeh, A. Ahmadi, A. Poustini, K. & Mohammadi, V. (2006): Evaluation of drought resistance indices under various environmental conditions. Field Crops Research., 98: 222-229.

Tajima, K. (1995): Occurrence and mechanism of drought change. In: Science of the Rice Plant. 2. Physiology. T. Matsuo, K. Kumazawa, R. Ishii, K. Ishihara and H. Hirate. (Eds). Food and Agriculture Policy Research Center, Tokyo. pp. 838-849.

Tuong, T. P. & Bouman B. A. M. (2003): Rice production in water-scarce environments. Paper Presented at the Water Productivity Workshop, 12–14 November 2001. Colombo, Sri Lanka.

Tuong, T. P. Bouman, B. A. M. & Mortimer, M. (2004): More rice, less water—Integrated approaches for increasing water productivity in irrigated rice-based systems in Asia. ‘‘New Directions for a Diverse Planet.’’ Proceedings of the 4th International Crop Science Congress, 26 September–1 October 2004. Brisbane, Australia (published on CDROM)

Yousefi, M. (2004): Evaluation of selection efficiency for drought tolerant in wheat. M.Sc. Thesis (unpublished). Isfahan University of Technology, Isfahan, Iran, 109 p. (in Farsi)

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EVALUACIJA KULTIVARA PIRINČA U RAZLIČITIM TRETMANIMA NAVODNJAVANJA NA OSNOVU INDEKSA OSJETLJIVOSTI I TOLERANCIJE

SAŽETAK

U cilju evaluacije kultivara pirinča u različitim tretmanima navodnjavanja na osnovu indeksa osjetljivosti i tolerancije, sproveden je ogled, postavljen kao dvofaktorski, po slučajnom blok sistemu sa četiri ponavljanja u Stanici za istraživanja pirinča u Tonekabonu, sjeverni Iran, 2011. godine. Sedam indeksa otpornosti na sušu obuhvatila su: indeks osjetljivosti na stres suše (SSI), indeks tolerantnosti (TOL), prosječnu produktivnost (MP), geometrijsu prosječnu produktivnost (GMP), tolerantnost na stres suše (STI), indeks prinosa (YI) i indeks stabilnosti prinosa (YSI), primjenjenih na osnovu prinosa sjemena u uslovima bez stresa i sa stresom suše. Na osnovu različitih indeksa suše,Shiroudi kultivar bio je najbolje rangiran, sa niskom vrijednošću standardne devijacije. Rezultati su pokazali da ima stabilan prinos. Biplot grafikon pokazao je superiornost ovog genotipa. Rezultati su pokazali da su indeksi MP, GMP, YI i STI uspješniji u identifikovanju visokoprinosnih kultivara pri različitim nivoima nedosatatka vode. U odabiru najbolje iranske sorte pirinča i utvrđivanju najboljeg sistema navodnjavanja na osnovu prinosa mogu se koristiti ovi indeksi tolerancije i osjetljivosti pri različitim tretmanima navodnjavanja.

Ključne riječi: Pirinač (*Oryza sativa* L.), stres suše, prinos sjemena, indeksi tolerancije i osjetljivosti, biplot grafik