academicJournals

Vol. 8(20), pp. 2371-2375, 29 May, 2013
DOI: 10.5897/AJAR11.2187
ISSN 1991-637X ©2013 Academic Journals
http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Irrigation withholding time management in four rice varieties at Guilan paddy fields (North Iran)

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Accepted 15 May, 2013

In order to determine the best irrigation withholding time in four varieties of rice, an experiment in factorial statistical format based on complete randomized block design was conducted. This experiment took place in National Rice Research Institute situated in Rasht township (Guilan province, North Iran) in 2008. First factor included four rice varieties (v_1 = Khazar, v_2 = Sepeed Roud, v_3 = Hassani, and v_4 = Binaam). The second factor included three drought periods (d_1 = 1 week after flowering, d_2 = 2 weeks after flowering, and d_3 = 3 weeks after flowering). The statistical analysis results almost in most measured traits showed significant difference at 1% probability level. The highest grain yield of 5635.8 kg/ha was obtained of Sepeed Roud variety. Also, the interaction effect of V_2d_3 with 6000 kg/ha was recorded the maximum grain yield. Since one of the goals for conducting this study was to determine a variety with short-water-necessity period in water deficiency years of cultivation, it is recommended that V_2d_1 level with grain yield of 5325 kg/ha be used even though it has a lower yield.

Key words: Rice varieties, irrigation withholding time, yield, yields components, Iran.

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important cereal crop in the world and it is the primary source of food and calories for about half of mankind (Khush, 2005). More than 75% of the annual rice supply comes from 79 million ha of irrigated paddy land. Thus, the present and future food security of Asia depends largely on the irrigated rice production system. However, rice is a profligate user of water. It takes 3,000 to 5,000 L to produce 1 kg of rice, which is about 2 to 3 times more than the amount needed to produce 1 kg of other cereals such as wheat or maize (Bouman et al., 2002). Irrigation water is an important production factor in rice systems but is no longer available in unlimited rice-growing areas (Bindraban, 2001). In recent years, due to unprecedented growth of demand for water consumption both in domestic and industrial sectors and because lower water content in underground reservoirs due to human consumption, the volume of water for irrigation of paddy fields has significantly declined. According to climate conditions, Iran lies among semi-dry to dry belts of the world. The Guilan province has a high annual rainfall but experiencing water shortage problems in recent years. Rice, a major farming product of Guilan is a lowland crop. Therefore, water shortage means a rapid decline in its growth and yield as an agricultural product. This has several benefits. First, it prohibits addition of excess water to paddy fields after rice physiological water satisfaction. Second, it reduces production expenses and determines those varieties that are drought resistant with high qualitative and quantitative yield for cultivation in years to come. The future of rice production will depend heavily on developing and adopting strategies and practices that will use water efficiently in irrigation system. Numerous studies conducted on the

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Table 1. Soil analysis results of the experimental sites.

Depth (cm)	0-30	SP%	*69.7*
Organic matter (%)	7.1	PH	7.1
Clay (%)	17.81	E.c.d. s/m	6.82
Sand (%)	22	N%	0.18
Silt (%)	60.19	P (ppm)	37.4
Texture	Silty loam	K (ppm)	29.1

manipulation of depth and interval of irrigation to save on water use without any yield loss have demonstrated that continuous submergence is not essential for obtaining high rice yield (Guerra et al., 1998). One method for reducing water consumption in rice cultivation is irrigation withholding at optimum time and blockage of flooding field for all duration of irrigation withholding. Drought stress due to irrigation withholding causes yield decrease and stress in flowering stage cause increase in unfilled grain percentage. According to several researches, there is a significant reduction in tillers and panicles numbers as well as plant height and grain yield due to water stress imposed at tillering stage. On the other hand, moisture stress at late vegetative and reproductive stage results to reduction in number of panicles per plant, percentage of filled grains and 1000-grain weight. Also, the reduction in grain yield was noted when plants were exposed to water stress at panicle initiation stage, while the moisture stress at the milk ripe or dough ripe had significant effects on grain yield (Bahattacharjee et al., 1973; De Datta et al., 1973; Krupp et al., 1971). Nour et al. (1994) reported that exposing rice plant to water stress for 36 days without flush irrigation during both tillering and panicle initiation significantly reduce plant height, number of tillers per plant, total dry matter, crop growth rate and grain yield. Boonjung and Fukai (1996) reported that drought stress during grains filling period results in acceleration of ripening time, causing reduction in growth period duration and filling grains. Abou-Khalifa (2010) in their study with three levels of irrigation withholding time: (w1) irrigation withholding at complete heading, (w2) irrigation withholding after 10 days from complete heading, (w3) irrigation withholding after 20 days from complete heading on two varieties of rice viz: H1 hybrid rice and Giza 177 inbred rice, found that the highest amounts of grain yield (10.59 t/ha), panicle length (18.80 cm) and number of grains per panicle (144) obtained of w3 treatment. This study has been conducted to find the best irrigation withholding time for rice cultivars in Guilan province, Iran.

MATERIALS AND METHODS

In order to study the determination of best irrigation withholding time in four varieties of rice in paddy fields of Guilan province (North Iran), an experiment in factorial statistical format based on complete randomized block design on a land parcel of 1000 m^2 area in National Rice Research Institute situated in Rasht township (Guilan province) with 37˚ 12'5" N latitude and 49˚ 38'30" E longitude in 2008 was conducted. The soil texture was silty loam, PH: 7.1, N: 0.18%, P: 37.4 ppm, K: 29.1 ppm. First factor included four rice varieties namely Khazar (v_1), Sepeed Roud (v_2), Hassani (v_3) and Binaam (v_4). The second factor included three drought periods namely; irrigation withholding 1 week after flowering (d_1), irrigation withholding 2 weeks after flowering (d_2), and irrigation withholding 3 weeks after flowering (d_3). Each replicate was designed from 48 experimental units and each unit with a distance of 30 cm away from one another. These units included 12 treatments and 7 lines with each line having 6 m long and 20 cm apart. Based on soil analysis (Table 1), phosphorous and potash fertilizer were applied for all treatments. Sowing in nursery was done 15, April and transplanted to field 22, May. All options consist of irrigation, weeding, fighting with pests and diseases up to harvest stage have been done. Characteristics to be evaluated are: grain yield, straw yield, harvest index, panicle length, number of grains per panicle, unfilled grain percentage, number of productive tillers, number of non-bearer tillers, 1000 grain weight and plant height. The yield and yield components were analyzed by using SAS software. The Duncan's multiple range tests was used to compare the means at 1% of significant.

RESULTS AND DISCUSSION

Results of variation analysis showed that, in more studied traits, effect of variety and irrigation withholding time has a significant difference at 1% probability level (Table 2). The effect of variety on traits such as grain yield, straw yield, harvest index, panicle length, number of grains per panicle, number of bearer tillers, percentage of unfilled grain per panicle, 1000 grain weight and plant height showed a significant different at 1% probability level. The highest amounts of grain yield, straw yield, harvest index and number of bearer tillers per square meter, respectively were 5635.8 kg/ha, 7870.4 kg/ha, 41.7% and 323/m^2 was obtained of V_2 (Sepeed Roud). The lowest grain yield, straw yield and harvest index was recorded by V_4 (Binaam), respectively were 2609.2 kg/ha, 4506.8 kg/ha and 36.6%. The V_1 (Khazar) with 164 tillers/m^2 was recorded the lowest number of tillers/m^2 (Table 3). Yield is a factor that its importance respectively depend on number of tillers per square meter, panicle length, number of grains per panicle and 1000 grain weight, the Seeped Roud variety due to maximum number of bearer tillers per square meter obtained the highest grain yield, while the Khazar variety due to lowest amounts of mentioned factors showed minimum grain yield. Number of tillers per square meters and plant height are two factors affecting

Table 2. The variance analysis of studied traits in rice varieties under irrigation withholding times.

S.O.V	df	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest Index (%)	Panicle length (cm)	The number of grains per panicle	The number of bearer tillers	percentage of unfilled grains	1000 grain weight (g)	Plant height (cm)
Block	3	39547.2223	59266.25	3.4858	0.027	198.92	1742.25	24.06	0.48	147.74**
Effect of variety	3	18989497.22**	25524936.25**	65.6612**	12.59**	1132.19**	53378.73**	402.48**	147.67**	5364.53**
Effect of irrigation withholding time	2	295581.25	1320700.725**	0.40305	0.195	74.94	516.51	24.37*	8.83**	0.34
Interaction effect	6	1350570.138**	1623841.258**	6.7308	1.92	140.88	865.87	17.25*	0.31	21.09
Error	33	125879.0404	83075.136	4.1092	0.89	73.96	1234.25	5.31	0.39	32.84
CV(%)		8.96	4.69	5.23	3.74	8.83	1234.25	12.25	2.37	4.48

** and * respectively significant in 1 and 5% area.

Table 3. Yield and yield components of four rice varieties under three irrigation withholding time in north of Iran.

Treatment	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest Index (%)	Panicle length (cm)	The number of grain per panicle	The number of bearer tillers	percentage of unfilled grains	1000 grain weight (g)	Plant height (cm)
Variety									
V_1	3977.5^{b}	6688.3^{ab}	37.1^{b}	23.7^{b}	111^{a}	164^{c}	27.3^{a}	23.8^{ab}	123^{ab}
V_2	5635.8^{a}	7870.4^{a}	41.7^{a}	25.2^{ab}	95^{a}	323^{a}	18.1^{ab}	24.1^{ab}	99^{b}
V_3	3622.5^{b}	5492.9^{bc}	39.6^{a}	25.9^{a}	89^{b}	210^{ab}	14.4^{b}	31.4^{a}	143^{a}
V_4	2609.2^{c}	4506.8^{c}	36.6^{ab}	25.7^{a}	92^{a}	222^{ab}	15.4^{b}	26.1^{a}	146^{a}
Irrigation withholding time									
d_1	4043.8^{a}	6310^{a}	38.9^{a}	25.3^{a}	95^{a}	235^{a}	19.9^{a}	25.6^{b}	127.8^{a}
d_2	4035.6^{a}	5808^{ab}	38.8^{a}	25.1^{a}	99^{a}	213^{a}	19.2^{a}	26.3^{b}	127.8^{a}
d_3	3804.4^{a}	6301^{a}	38.6^{a}	25.2^{a}	98^{a}	240^{a}	17.5^{ab}	27.1^{a}	127.5^{a}

Within each column, treatments that carry the same superscript letter are not significantly different at $P < 0.05$.

straw yield, highest straw yield in v_2 treatment was due to the maximum number of tillers per square meter and high size of plant height. Because of higher grain yield and better transfer of photosynthetic materials to grains in v_2 treatment, the highest harvest index was showed in this level. One of the breeding rice varieties characteristics for maximum yield is more tillers production to compare with local rice varieties. This characteristic was observed in Sepeed Roud variety. Only the Khazar was the breeding rice variety that has lowest number of tillers than even the local varieties (Mojtahedi, 1989). With attention to Table 3, the V_3 (Hassani) resulted to highest panicle length with 25.9 cm and 1000 grain weight with 31.4 g. The lowest panicle length and 1000 grain weight was recorded from V_1 (Kazar) with 23.7 cm and 23.8 g, respectively. The grains distance on panicle in Hassani variety genetically is high. As a result, the longest panicle was shown in this treatment. Due to less grain in panicle of Hassani variety, the photosynthetic materials per each grain become more and as a result 1000 grain weight increased. The maximum number of grains per panicle with 111 was recorded from v_1 (Khazar) and the minimum with 89 was recorded from v_3 (Hassani). The highest percentage of unfilled grains per panicle of 27.3% and the lowest percentage of unfilled grains per panicle of 14.4%, respectively were obtained in

v_1 and v_3. It seems that high percentage of unfilled grains per panicle in Khazar variety is due to, first; for genetic problems in this variety and second, further number of grains in this variety. As a result, the proportion of unfilled grains to filled grains in this level is high. In the Hassani variety due to less number of grains, materials transition well division to all grains. In the other side, the proportion of unfilled grains to filled grains was low in this treatment because of less grain. The tallest plant height was recorded from v_4 (Binaam) with 146 cm and the shortest height of 99 cm was recorded from v_2 (Sepeed Roud). One of the clear characteristics of local rice varieties are that the taller plant height trait was shown in Binaam variety. In the other hand, plant height usually is shorter in the breeding varieties.

Rice grain filling and ripening are affected by many environmental factors, including water, temperature, radiation and soil nutritional conditions (Yoshida, 1981). With attention to Table 2, the effect of irrigation withholding time on straw yield and 1000 grain weight significant at 1% probability level and on percentage of unfilled grains per panicle showed a significant difference at 5% probability level. Other traits were not significantly different. Comparison of mean between irrigation withholding times show that (Table 3), the straw yield, harvest index, panicle length, percentage of unfilled grains per panicle and plant height was recorded from d_1 (irrigation withholding 1 week after flowering), respectively were 6310 kg/ha, 38.9%, 25.3 cm, 19.9% and 127.8 cm. d_3 treatment (irrigation withholding 3 weeks after flowering), having the lowest amounts of harvest index, percentage of unfilled grains per panicle and plant height, respectively with 38.6%, 17.5% and 127.5 cm was recorded. The minimum amounts of straw yield and panicle length respectively was 5808 kg/ha and 25.1 cm which was recorded from d_2 (irrigation withholding 2 weeks after flowering). In the first 10 days after flowering, cell division and expansion in the endosperm of most grains ends and starch deposition begins (Hoshikawa, 1967; Egli, 1998). With soon irrigation withholding in d_1 level due to decrease of photosynthesis process and photosynthetic materials production, transition of this materials to grains were reduced causing increase in percentage of unfilled grains in this level, whereas, in d_3 level this case was not shown. Vegetative growth in rice with flowering start become end, therefore not added anymore to plant height and tillering process come to maximum stage. Thus, with irrigation withholding 1 week after flowering (d_1) production of generative organs decreased, the materials resulting from photosynthesis, more transition to vegetative organs and in addition to tillers preservation, leaf area index increased, and as a result the maximum straw yield was obtained. But in d_2, treatment (irrigation withholding 2 weeks after flowering) resulted to more generative organs compared with d_1 level produced; further photosynthetic matters give to grains and in harvest time less straw yield was shown. The highest 1000 grain weight of 27.1 g was obtained in d_3. In the other hand, the lowest 1000 grain weight was found from d_2 with 26.3 g and d_1 with 25.6. The 1000 grain weight is one of the factors in plant that is influenced more by genetic factors with little influence by environment factors. Water is one of the important soil and environmental factors that have a major influence on 1000 grain weight. If water exists sufficiently in all stages of plant growth, nutrients transition to plant and grains filling is well enhanced resulting to increased 1000 grain weight as it was the case from d_3 level. The maximum number of grains per panicle of 99 was found from d_2 and the minimum amount of this trait of 95 grains per panicle was found from d_1. Results of variation analysis showed that, the interaction effect of variety and irrigation withholding time on traits grain yield and straw yield in 1% probability level and on percentage of unfilled grains per panicle in 5% probability level have significant different (Table 2), The highest grain yield of 6000 kg/ha was recorded from v_2d_3 and the lowest one with 2307.5 was in v_4d_2 (Table 4). Since the Sepeed Roud variety genetically had high yield factors in the other hand, irrigation withholding 3 weeks after flowering gave sufficient time to plant for suitable photosynthesis and high photosynthetic materials production causing all flowers inoculation and transition of materials to grains was higher than grains materials receive to maximum amounts that causing high yield in v_2d_3 level compare with v_4d_2. In v_4d_2 treatment, due to lower yield factors and also with irrigation withholding 2 weeks after flowering resulted to insufficient time for transition of photosynthetic materials to all grains resulting to low yield. The maximum yield of straw of 8315 kg/ha was found from v_2d_3 and the minimum of this trait was found from v_4d_2 with 4144 kg/ha (Table 4). Water existence under rice bush is one of the factors that casing to better vegetative growth in this plant. As a result, in Sepeed Roud variety because of more tiller and partly taller plant height and also leaf area duration was increased and the highest straw yield obtained in v_2d_3 level. But in v_4d_2 in addition to low tiller in Binnan variety, irrigation withholding 2 weeks after flowering in this variety caused an increase in generative organs. As a result, more photosynthetic materials were send to generative organs and straw yield in harvest time at this level decreased. V_1d_1 treatment produced the highest percentage of unfilled grains per panicle with 30.1% and the lowest one with 12.2% was found from v_3d_1 (Table 4). Irrigation withholding 1 week after flowering in Khazar variety (v_1d_1) due to high number of grains per panicle in this variety, prevent from filling all grains. As a result, percentage of unfilled grains in this level increased. But in v_3d_1 level (Hassani variety, along with irrigation withholding 1 week after flowering), water withholding had low influence on percentage of unfilled grains because of sufficient photosynthetic materials production for filling the grains per panicle. Although the v_2d_3 treatment with 6000 kg/ha was obtained as the highest grain yield, but since

Table 4. The interaction effects of varieties and irrigation withholding times yield and yield components

Treatment	Grain yield (kg/ha)	Straw yield (kg/ha)	Percentage of unfilled grains
V_1d_1	4492.5^{b}	7293^{b}	30.1^{a}
V_1d_2	3102.5^{cde}	5523^{cd}	25.4^{a}
V_1d_3	4337.5^{b}	7250^{b}	26.2^{a}
V_2d_1	5325^{a}	7763^{ab}	15.9^{bcd}
V_2d_2	5582.5^{a}	7534^{b}	19.6^{b}
V_2d_3	6000^{a}	8315^{a}	18.3^{bc}
V_3d_1	3412.5^{c}	5275^{de}	15.8^{bcd}
V_3d_2	4225^{b}	6030^{c}	16.4^{bdc}
V_3d_3	3230^{cd}	5174^{de}	12.2^{d}
V_4d_1	2945^{cde}	4910^{ef}	17.2^{bc}
V_4d_2	2307.5^{e}	4144^{g}	15.3^{bcd}
V_4d_3	2575^{de}	4467^{fg}	13.5^{cd}

Within each column, treatments that carry the same superscript letter are not significantly different at P<0.

one of the objectives for conducting this study was to determine a variety with short- water-necessity period in water deficiency years for cultivation, it is recommended that v_2d_1 level with grain yield of 5325 kg/ha be used even though for cultivation it has a lower yield.

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