INTERMITTENT IRRIGATION: A PROCEDURE TO USE SALINE WATER IN RICE CULTIVATION

IRRIGATION INTERMITTENTE : PROCEDURE A UTILISER L'EAU SALEE DANS LA RIZICULTURE

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ABSTRACT

Guilan, a well-known rice producing province in Iran, has been facing water shortage and water degradation. In order to study the effects of salinity stress and water stress on rice a pot experiment was conducted at Rice Research Institute of Iran. Five water salinity levels: fresh water (EC=1 dSm^{-1}), 2, 4, 6 and 8 dSm^{-1} and five irrigation regimes: continues flooding, Alternative Wetting and Drying (AWD), intermittent irrigation at 100, 90 and 80 percent of field capacity (FC) were considered as irrigation treatments. The results showed severe effects of water and salinity stresses on rice yield and yield components. Fresh water produced the highest yield, 18.57 g/pot, whereas, the yield in salinity levels of 2, 4, 6 and 8 dSm^{-1} were 13.78, 5.78, 3.61 and 0.74 g/pot, respectively, with corresponding yield losses of 25, 70, 80 and 97 percent. Intermittent irrigation at FC produced the highest yield. The yield increased by 8 and 13 percent in AWD and intermittent irrigation at FC treatments respectively, while it decreased by 8 and 27 percent in intermittent irrigation at 80 and 90% of FC. The highest yield with application of intermittent irrigation at FC was valid only in water salinity less than 4 dSm^{-1}. When water salinity was higher than 4 dSm^{-1} all irrigation methods gave the same yield. This study showed that the best method to use saline water was intermittent irrigation at FC with EC=2 dSm^{-1}. In case of higher salinity, mixing fresh and saline water and intermittent irrigation can mitigate the severe effects of salinity on rice.

Key words: *Saline water, Intermittent irrigation, Salinity-water stress interactions, Guilan province, Iran.*

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RESUME ET CONCLUSIONS

Guilan est une province bien connue dans la production de riz en Iran. Récemment, la pénurie d'eau et la dégradation de sol ont été mise en place des doutes en matière de durabilité de la production rizicole dans la région. Des études antérieures prouvé que l'irrigation intermittente est une stratégie applicable face à la pénurie d'eau. Afin d'étudier les effets de la stresse en eau et aussi la salinité d'eau sur le rendement de riz, une expérimentation en vase a été menée à la centre de recherche sur le riz à Rasht au Nord d'Iran (RRII). L'expérience a été une expérience factorielle dans un plan en blocs aléatoires complets en trois répétitions. Cinq niveaux de salinité de l'eau d'irrigation (l'eau douce: EC=1 dSm^{-1}, 2, 4, 6 et 8 dSm^{-1}) et aussi cinq régimes d'irrigation (inondation permanente, Alternative de mouillage et de séchage (AWD), l'irrigation intermittente à 100, 90 et 80 pourcent des la capacité au champ) ont été considérés comme des traitements. Les résultats ont montré des effets graves de la salinité et de la stresse en eau sur le rendement et les composantes du rendement de riz. L'eau douce comme le traitement témoigne de la salinité a produit le rendement le plus élevé, 18,57 gr/vase, alors que, le rendement des niveaux de salinité de 2, 4, 6 et 8 dSm^{-1} ont été 13,78, 5,78, 3,61 et 0,74 gr/vase, respectivement, avec des pertes de rendement de 25, 70, 80 et 97 pourcent, respectivement par rapport à la témoigne (l'eau douce). Irrigation intermittente à la capacité au champ a produit le rendement le plus élevé. Le rendement a augmenté de 8 et 13 pourcent en AWD et l'irrigation intermittente à la capacité au champ, respectivement, tandis qu'il a diminué de 8 et 27 pourcent dans l'irrigation intermittente à 80 et 90 pourcent de la capacité au champ. Le rendement le plus élevé avec l'application de l'irrigation intermittente à la capacité au champ n'était valable que dans la salinité des eaux de moins de 4 dSm^{-1}. Lorsque la salinité de l'eau était plus élevée que 4 dSm^{-1} tous les régimes d'irrigation ont plus ou moins le même rendement. Cette étude a montré qu'un mélange d'eau salée et d'eau fraîche pour faire une eau de faible salinité (EC=2 dSm^{-1}) et en utilisant l'irrigation intermittente à la capacité au champ peut atténuer les graves conséquences de la salinité d'eau sur le riz.

Mots clés: *Eau salée, irrigation intermittente, interactions entre le stress de l'eau et le stress du sel, province de Guilan, Iran.*

(Traduction française telle que fournie par les auteurs)

1. INTRODUCTION

With 230 thousands hectares of rice cultivated land, Guilan province, in the north of Iran, is one of the most important rice producing regions. Sepidrood dam and its vast irrigation network provide water for this region and support the agricultural activities. Recent dramatic reduction in fresh water resources has been causing concerns about rice production sustainability in Guilan. Climate change, water scarcity and consequently drought (Abbaspour et al. 2009) have raised doubts about the future of agriculture and farmers' income. Previous studies by the authors proved intermittent irrigation as a feasible strategy to overcome the consequences of water stress. This strategy can reduce water consumption and increase water productivity, at no loss of yield (Rezaei and Nahvi 2007; Rezaei et al. 2010 a).

Construction of numerous dams upstream to Sepidrood dam, will further aggravate the situation. Not only the available fresh water will reduce, but water quality also will be degraded due to disposal of drainage water into the river (Rezaei et al. 2010, b). Rice is a very sensitive crop to salinity (Doberman and Fairhurst 2000; Zeng and Shannon 2000). Researches showed that the threshold electric conductivity of local rice varieties as 1-2dSm^{-1} beyond which there will be loss of rice yield (Yousefi, 2006; Homaee, 2002). However, limitation of fresh water has resulted in the tendency to use saline and brackish water in rice irrigation (Ghadiri et al 2006).

Up to now, several experiments and studies have been carried out for the purpose of better understanding of rice reaction to drought stress and finding new solution for mitigating the effects of drought (Bouman and Tuong, 2001; Belder et al. 2005). Water stress prevents nutrients uptake by the plants (Wopereis et al. 1999), which results in fewer tillerings, lower leaf area, dry matter, filled grains, number of panicle, 100 grains weight and yield. So it is recommend to avoid long drought by adopting alternate strategies (Belder et al. 2005; Rezaei and Nahvi 2007). Reports confirmed rice tolerance to a mild soil water potential decline in root zone resulting from intermittent irrigation up to - 30 kPa (Belder et al. 2005). These studies led to finding different approaches such as raised beds and alternative wetting and drying. The role of these methods in reducing water consumption and increasing water productivity has been proved. Even some evidences of increasing rice yield were found in case of adequate soil moisture control (Tabbal et al., 2002; Belder et al., 2004, 2005, 2007; Tuong et al., 2005; Yang et al., 2007; Zhang et al. 2009 ;Zhang et al., 2008a).

Studies showed the effectiveness of alternate watering and drying in decreasing water consumption and increasing rice water productivity in Iran. Eight days irrigation interval for local and 5 days for hybrid and improved varieties were recommended in Guilan province. The studies suggest that local rice varieties perform well under non-flooding condition. Water stress up to of 80% of saturation or irrigation 3 days after disappearing of water from field surface doesn't reduce crop yield but lower moisture has negative effect on yield (Rezaei and Nahvi 2007; Rezaei et al. 2010 a; Amiri 2006). In spite of promising achievements, it is still necessary to have more studies for better understanding of rice reaction to drought stress.

In addition to water scarcity, salinity problem in coastal areas due to decrease of water input into network and entry of low quality waters from upstream have also been under consideration (Rezaei et al 2010, b). Reports indicated that salinity stress caused reduction in leaf water potential, evapotranspiration, stomatal conductance, leaf area and yield (Asch et al. 2000; Castillo et al 2007; Casanova et al. 2000; Zeng et al. 2009; Zeng et al. 2000). However, only limited studies on salinity effects on rice have been conducted in Iran (Kavoosi, 1995; Yosefi, 2006).

Despite the above mentioned researches, not enough attention was paid to synchronous drought and salinity stress in rice cultivation. The change in rice reaction to salinity stress with drought stress has been proved only in Fars province by Yosefi (2006), claiming that in alternate irrigation, the effects of saline water will be alleviated. This was attributed to decrease in evapotranspiration leading to less water absorption and consequently, low accumulation of salt in plant tissues. Plant will usually have low yield in unsuitable conditions due to less photosynthesis. This natural rice reaction could be considered as a strategy for usage of saltwater in rice cultivation in Guilan condition. Unfortunately, there has been no special study in Guilan province where most of the rice cultivation area exists. This research has been carried out in order to study the effects of synchronization of drought and salinity stress on rice in the Guilan province of Iran.

2. MATERIALS AND METHODS

Pot experiment was done in a randomized complete block design (RCBD, with 3 replications) with Hashemi, a local rice variety during cropping season of 2010 at Rice Research Institute of Iran under a five-meter high shelter with plastic sheet coverage surrounded by paddy field. To avoid temperature rise, the sides of the shelter were not covered to let the air flow. Five levels of salinity, S0= fresh water (Ec=1dsm^{-1}), S1, S2, S3 and S4: saline water with 2, 4, 6 and 8 dSm^{-1}, respectively, were used along with five Irrigation methods including: Permanent (continuous) irrigation (PI), Alternative wetting and drying (AWD), Irrigation at field capacity (FC), 90% of FC and 80% of FC. About 9 kg of rice farm soil was put into each plastic pot. After flooding the soil, three 25-day old seedlings were transplanted in each pot. The pots were irrigated by fresh water for a week for stabilization after which the treatments were applied. All P and K and half of N fertilizers from triple super phosphate, potassium and urea was mixed with soil. The remaining N was applied at the maximum tillering. Saline water was prepared from canal water using NaCl and $CaSO_4$ (2:1). In order to prevent salt accumulation in pots, leaching and washing with fresh water in several stages was done. Irrigation was set at specified time as 5 cm depth from the soil surface. All cultural practices were done following the local practices. Grain and straw yield, tiller numbers, fertile and non-fertile panicle were measured. Mean comparison was done after analysis of variance using the Duncan multiple range test (DMRT).

3. RESULTS

The results of soil chemical and physical analysis and Rasht meteorological station data are shown in Table 1, Table 2 and Table 3, respectively.

Table 1. Soil chemical analysis (analyse chimique du sol)

Potassium (ppm)	Phosphorus (ppm)	Total Nitrogen (%)	pH
290	17	0.155	7.4

Table 2. Soil physical analysis (analyse physique du sol)

soil	80% FC	90% FC	FC*	saturation	
Si-CL	40	45	50	65	Water content (volumetric)

*FC at -33 kPa

Table 3. Rasht meteorological station data (données météologiques de la station météological de Rasht)

Ep mm	Sunshine hours	Rainfall mm	RH (%)		Temp.		Month
			Max	Min	Max	Min	
47	114	67	98.8	68.3	16.2	8.3	Apr
72	123	149	98.8	71.5	21	14	May
149	277	2	95.2	59.5	29.8	20.4	Jun
168	371	22	95.1	55.1	32	22.7	July
184	217	23	93.8	51.2	33.9	21.5	Aug
103	200	55	98	57.6	29.9	19.5	Sep

The result (Table 4) showed that salinity of irrigation water had statistically significant effects on all treatments i.e. yield, dry matter, biomass, number of tillerings and filled/unfilled panicles but water stress showed significant effects only on yield and biomass. It seems that salinity had more severe effects on rice in comparison with water stress. No interaction between water and salinity stress was observed. Some reports proved that rice in general and Iranian local variety, Hashemi, particularly to be resistant to intermittent irrigation and non-submerged irrigation (Belder et al., 2005; Amiri, 2006; Rezaei et al. 2010,a).

Table 4. The result of analysis of variance (les résultats de l'analyse de la variance)

Error	Salinity× Irrigation	Irrigation	Salinity	Rep.	S.O.V
48	16	4	4	2	Degree of freedom
43.74	36.16 ns	88.86 ns	350.22 **	77.97	Straw weight (gr/pot)
8.974	16.312 ns	29.079 **	828.705 **	60.600	Yield (gr/pot)
76.462	135.632 ns	124.538 ns	3810.285 **	443.037	Yield / Straw
48.428	30.693 ns	141.572*	1604.035 **	33.182	Biomass
28.341	43.384 ns	42.132 ns	1716.731 **	196.624	Harvest Index
39.396	25.713 ns	7.380 ns	308.713 **	18.493	no. of tillerings
15.668	14.280 ns	12.280 ns	228.247 **	9.640	No. of filled panicle
13.079	22.980 ns	22.913 ns	23.380 ns	2.773	Unfilled filled panicle
20.509	20.805 ns	29.947**	846.574**	19.453	Total panicle
4080.958	3153.82 ns	3697.71 ns	9990.4**	3589.311	filled panicle (%)
4.193	1.846 ns	1.996 ns	17.285**	12.218	Unfilled filled /filled panicle

*, **: represent statistically significant differences at 95 and 99 respectively
ns: represent not statistically significant differences

Salinity stress

The comparison of mean (Table 5) showed that rice is sensitive to irrigation water salinity. Among treatments, control (EC=1 dSm^{-1}) with 18.57 g/pot had the highest yield. Increasing in salinity to 2dSm^{-1} resulted in yield loss to 13.78 g/pot, a loss of about 25%. The same trend was observed with increasing salinity to 4dSm^{-1}, which showed a 70% yield loss with 5.78 g/pot. The yield loss with the salinity of 6 and 8 dSm^{-1} were 80 and 97 per cent, respectively. Some reports showed the high sensitivity of rice to salinity of irrigation water (Kavosi, 1995; Sultana et al. 1999; Yousefi, 2006). It seems relatively high temperature of the year (2010) intensified the effects of saline irrigation water on rice (Asch et al., 2000).

Yield loss was about 97% and the straw loss was about 20%. This showed that in salinity stress, yield loss is higher than the loss in straw. Figure 1 shows that yield loss due to salinity is represented better by a quadratic relation (R^2 = 0.98) as compared to a linear relation (R^2 = 0.91) presented by Mass & Huffman (1997).

Table 5. Analysis of mean comparison (comparaison de moyenne)

	Salinity (dSm^{-1})					
Irrigation	**1**	**2**	**4**	**6**	**8**	**mean**
FI	22.24 A a	11.86 B b	5.85 A bc	2.93 A c	0.83 A c	8.74 AB
AWD	21.93 A a	15.61AB a	5.68 A b	2.92 A b	1.17 A b	9.46 AB
FC	19.36 A a	18.80 A a	6.38 A b	4.15 A b	0.76 A b	9.89 A
90FC	17.99 A a	11.89 B ab	5.70 A bc	4.32 A c	0.25 A c	8.03 AB
80FC	11.34 B a	10.74 B a	5.29 A ab	3.72 A b	0.66 A b	6.35 B
mean	18.57 a	13.78 b	5.78 c	3.61c	0.74 d	

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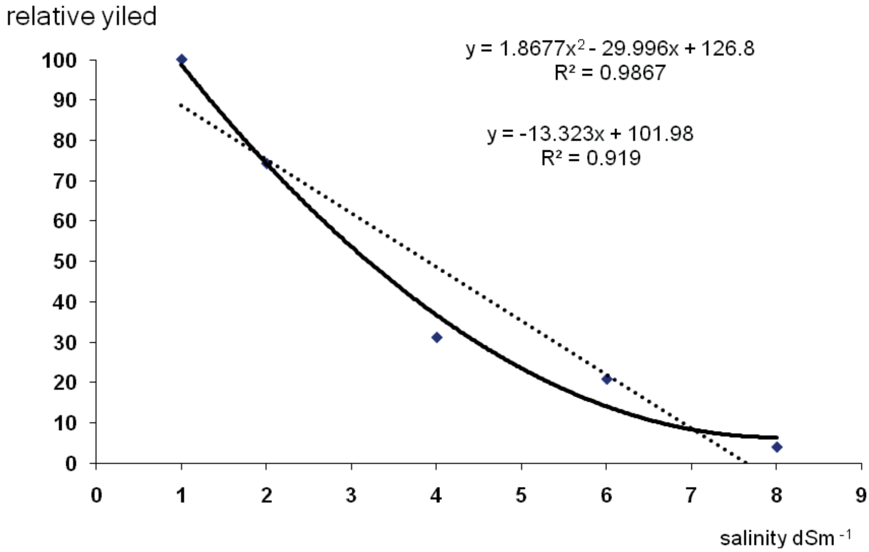

Fig. 1. Relative yield in different salinity levels (le rendement relatif des niveaux de salinité différente)

The harvest index declined from 28.45% when irrigated by fresh water to 1.99% when irrigated by saline water of 8dSm^{-1} (Table 5) due to reduced number of rice tillers. Salinity stress also caused decrease in number of filed panicle and ratio of filed panicle to tillers. Effect of salinity on per cent filled panicles has also been reported by other researchers (Clermont Dauphina, et al. 2010). In fact these traits are the most important factors to reach the maximum yield of rice (Casanova et al. 2000).

Salinity decreased number of tillers per pot, from 34.4 in fresh water to 23.13 in saline water of 8 dSm^{-1}. This was the trend for total number of panicles, numbers of filled panicles and the ratio of the number of filled panicles to the number of tillers. Although majority of measured traits were affected by salinity, the number of unfilled panicles remained unchanged. Contrasting to straw dry weight production, increasing salinity to 4dSm^{-1} had no adverse effect on rice vegetative growth (Fig. 2 and Table 2) but increasing water salinity to 8 dSm^{-1} decreased rice growth and biomass accumulation by 15% and 23%, respectively, compared to fresh water.

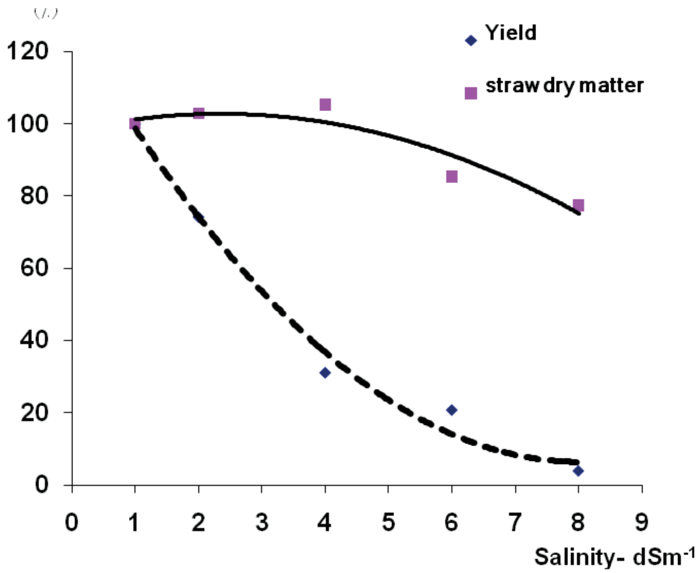

Fig. 2. Rice relative yield and dry matter in different salinity level (les changements relatifs des rendements en grains et en paille affectés par la salinité de l'eau d'irrigation)

Water stress

The Table of mean comparison (Tables 6 & 7) showed that applied irrigation treatments had no statistically significant effects on yield components such as number of tillers, filled and unfilled panicles, ratio of panicle infertility and straw dry weight. But water stress decreased biomass production. Due to negligible change in straw dry matter, this could be attributed to the change in yield. Reviewing yield in different irrigation methods (Table 4) showed that intermittent irrigation not only did not decrease yield but also water stress up to FC caused a yield increase, a finding which had been proved by the authors (Rezaei at all 2006). Irrigation treatment of FC and 80% of FC had the minimum yield. Comparing with PI which had a yield of 8.74 g/pot, applying intermittent irrigation at FC and AWD with 9.89 and 9.46 g/pot showed an increase in yield as much as 13% and 8%, respectively. Two treatments of 80% and 90% of FC with 27% and 8% decrease in yield (comparing with PI) had the least amount of yield, respectively. The roles of intermittent irrigation on increasing rice production have been reported by other researches too. Belder et al. (2004) reported that water tension up to 33 kPa did not cause yield reduction. Using intermittent irrigation to reduce water consumption has been applyed in North farms of Iran for a while. The method is based on wide studies by authors in the Rice Research Institute of Iran (RRII) and was accepted as an applicable method to mitigate water scarcity.

Table 6. Analysis of mean comparison (comparaison de moyenne)

Salinity dSm^{-1}	Straw weight gr/pot	no. of tillering	No. of filled panicle	Filled panicle (%)	Harvest Index (%)
1	39.8 ab	34.40	29.2 a	67.3 a	28.45 a
2	40.9 a	31.40	26.0 a	64.4 a	22.68 b
4	41.8 a	30.20	19.01 b	50.1 ab	10.53 c
6	33.9 bc	25.60	16.6 b	51.6a b	10.19 c
8	30.7 c	23.13	10.3 c	16.6 b	1.99 d

Same lettermeans means no diffrence at 99% by DMRT

Table 7. Comparison of means (comparaison de moyenne)

Irrigation	Straw weight gr/pot	no. of tillering	No. of filled panicle	Filled panicle (%)	Harvest Index (%)
FI	39.3 a	29.6 a	21.8 a	50 a	14.2 a
AWD	40.8 a	28.3 a	21.7 a	51 a	15.1 a
FC	39.6 a	29.7 a	19.3 a	51.8 a	17.2 a
90FC	35.9 a	29 a	19.2 a	49.5 a	14.7 a
80FC	36 a	28.2 a	19.2 a	48.1 a	12.6 a

Same lettermeans means no diffrence at 99% by DMRT

Salinity and water stress interactions

Rice response to salinity stress remained unchanged in all applied irrigation methods in this research; yield decreased when salinity increased (Figs. 1 and 2). The reduction trend in low water stress including PI, AWD and FC was quadratic equation but in other two sever water tension treatments i.e. 80% and 90% of FC, linear equation. According to the Figures 1 and 2, it is concluded that in quadratic equation, yield reduction slope with salinity to $4dSm^{-1}$ is very high and after that the reduction continues with fewer slopes and in harmony with slope of first class linear equations. On the other side with fresh water although applying intermittent irrigation treatments i.e. FI, AWD, FC and 90% of FC did not cause yield differences, using saline water of $2dSm^{-1}$ showed a significant difference. In this circumstance posing water stress up to FC resulted in a trend of yield rise which followed by a falling trend with more severe water stress. Yield in severe salinity stress, more than 4 dSm^{-1}, all irrigation treatments yielded the same, suggesting that in excessive salinity, irrigation management did not have any effect on yield. Yousefi (2006) also reported that alternative irrigation reduce effect of salinity tension and attributed it to less absorption of water and saline solvable in water and as a result to less accumulation of salt in plant tissue.

4. CONCLUSIONS

According to Figure 2 and Table 4, it is concluded that if irrigation water salinity is about 1dSm^{-1}, the best irrigation methods are permanent flooding, alternative irrigation or irrigation at FC, and 90% of FC, but as applying intermittent irrigation (non-submerged) reduces water use, non-submerged is suggested. In this case, in contrast with other treatment, more yield will produce. When water salinity is 2dSm^{-1} Irrigation at FC is suggested, since alternative irrigation decreases salinity effects. When salinity is more than that amount, all methods of irrigation has the same result; in this case irrigation at 90% of FC has a little more yield. In any case in this condition, yield reduction is so high that rice cultivation is not recommended. Generally, we concluded that in some cases, mixing fresh water and saline water to decrease water salinity to an acceptable level of 2dSm^{-1} and using alternative irrigation at FC, prevents yield losses.

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