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Full Length Research Paper

Response of high yielding rice varieties to NaCl salinity in greenhouse circumstances

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Salinity is one the biggest constraint to obtain crop potential yield throughout paddy fields in some part of the coastal line of rice cultivated area in Iran. In order to find resistant varieties and study the reaction of some newly released high yielding varieties to different levels of salinity of irrigation water an experiment was conducted at the Rice Research Institute of Iran-Amol station in a greenhouse. Eight varieties, cultivated in pots, were tested with three levels of salinity (2, 4 and 6 dS m^{-1}: S1, S2 and S3, respectively) along with control (S0: EC = 0.8 dS m^{-1}) with 3 replications. The results showed that salinity adversely affected yield, number of tillers per pot, filled and unfilled spikes, fertility and 100 grain weight, but increased number of unfilled tillers. The average of rice yield loss threshold was calculated 1.3 dS m^{-1}. On average, number of panicle and number of filled spikes accounted for 80 and 59% of total variation of grain yield, but it decreased by increasing in salinity level. There was a high correlation between yield and number of panicle and grain weight per panicle.

Key words: Salinity, NaCl, rice, yield, greenhouse.

INTRODUCTION

Salinity causes a wild range of problems throughout large areas of the world farmlands (Kijne, 2006). This problem is also existent in Mazandaran Province where over 200 thousand hectares are under rice cultivation and is considered a major center for rice cultivation in Iran. The main sources of irrigation water of rice paddies (rice fields) in this province are rivers, springs, wells and local embankments and in some cases irrigation is done by means of dams and canals. However, large areas of such lands are agriculturally unproductive and they suffer from salinity because of various factors including the proximity to sea. These areas with the land surface of over 30 thousand hectares come to 14% of the total surface of rice paddies in Mazandaran.

Although some physiological mechanisms responding to salinity are not fully clear (Beatriz et al., 2001), reports show that osmotic pressure due to the presence of water ions regardless of its source (Castillo et al., 2007) leads to reduction of leaf area, evapotranspiration (Shahdi, 1994) and plants inefficient water consumption. Furthermore the direct presence of some poisonous ions and their high frequency seriously upset the existent balance among the soil elements and eventually as the soil salinity and osmotic pressure increase, this process leads to less water and nutrient absorb including nitrogen and potassium by plants (Beatriz et al., 2001) hence the plants growth will get stunted (Homaei, 2002). Although keeping a balance among the ions found around and on the roots, that is, the photosphere may support the plants to resist against the salinity (George, 1967). Some reports claim that salinity may affect the accumulation of ammonium and reduction of the amount of chlorophyll in leaves (Hoai et al., 2005). On the other hand other reports state that although salinity causes the accumulation of salt in plant tissues, because of the reduction of total biomass, nitrogen absorption decreases in return (Shahdi, 1994).

Moreover, the conclusion of some reports indicated that as a result of nitrogen escape (loss) and hence unavailability of such an element to the plant, salinity causes less absorption of nitrogen by plants. Consequently, in order

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to tackle the low concentration of this vital element, it is suggested that in such circumstances by introducing some nutrients including more nitrogen and zink, inefficient growth is exceedingly compensated (Shahdi, 1994; Verma and Neue, 1984).

Before the appearance of panicle, salinity affects the number of tillers and it also influence the number of spikes and panicle weight from the period of three leaves to booting (Zeng et al., 2003). However, it does not affect the percentage of fertility, stem weight and white grain weight (Kavousi, 1995). In addition Castillo et al. (2007) reported that osmosis effect on the percentage of the fertility of the panicle, the weight of hundred grains and consequently its performance during reproductive stage would be extremely higher than that of its vegetative period. Water or soil salinity causes plant's unction (production), the number of panicle per square meter, the weight of thousand grains, the number of grains within panicles and also harvest index (Shahdi, 1994; Kavousi, 1995; Kiani et al., 2006; Aslam et al., 1989) but it increases the number of tillers (Beatriz et al., 2001).

Regardless of the season and the year, salinity in any stage of the growth reduces plant's production, the number of spikes, the weight of hundred grains and also increases infertility of panicle in various kinds of rice. However, this effect is more observable during panicle initiation (Aschl and Wopereis, 2001). Mass and Hoffman (1997) reported that yield reduction is zero up the threshold of yield loss. However, the equation of relative yield falling in accordance with rising salinity or electrical conduction of saturated essence in rhizosphere would be simple. Eventually, since rice is a highly sensitive plant to the salinity of water and soil (Shahdi, 1994; Aslam et al., 1989; Mass and Hoffman, 1997) even the application of fresh water of good quality may also reduce the water content in xylems, consequently leads to yield reduction (Casanova et al., 1999).

So far lots of experiments have been conducted on order to tackle such difficulties. The results of which indicate that rice of local varieties in this province are more resistant than those genetically modified (Saadati, 1987). Razavipour (1999) stated that certain varieties like Hassani and Domsiah are more resistant to salinity variations.

However, no study has been done to find out the reaction of high yield rice in various levels of salinity. The present study, however; aims to test the reaction of such varieties to various level of salinity in order to find out highly resistant varieties for any level of salinity. One Significant implication of this study to scientists is to use such varieties as parents in their future genetic modifications.

METHODOLOGY

This experiment was conducted in a complete randomized design (CRD) by the use of various kinds of rice including eight genetically modified varieties to determine the effect of different levels of salinity in the year 2004 in a greenhouse at the Rice Research Institute of Iran-Amol Station. Levels of water salinity include controlled pads with electrical conduction equals to 0.8 dS m^{-1} and experimental pad (S1, S2, and S3) with electrical conduction of 2, 4, and 6 dS m^{-1}, respectively. The genetically modified variation of high yield used in the experiment include: Dasht, Khazar, Kadous, Nemat, Neda, Fajr, Shafagh and Sahel. To obtain the accurate result and exclude any unwanted and interfering variable in the environment and to minimize their effects, the experiment was conducted in a highly controlled greenhouse. The greenhouse made of plastic and wood is located in an area within the station 10 km along Amol, Babol road. To avoid destructive effects of high temperature inside the greenhouse on rice, several holes were made on the framework of the greenhouse and the plastic was raised in sunny weather, so that the temperature would be controlled. Three rice seedlings planted normally in pots stuffed (filled) with local soil. Within 10 days from planting, the seedlings were irrigated by normal water. Then supporting operation started in flooding water covering the whole surface all the time in a depth of 5 cm. All agricultural operations were done normally, commonly and local procedures were followed as well. Having been ripened, the yields were measured in term of the number of tillers, plant height, and performance of any pot with 14% moisture. The percentage of filled and unfilled panicles, their length and 100 grain weight were also determined. The yield was analyzed by using SAS and SPSS Software. The Duncan’s multiple range tests (DMRT) was used to compare the means at 1% of significant.

RESULTS AND DISCUSSION

Results and observations in great detail (Tables 1 and 2) show that as the salinity of water increases and as a result of osmosis stress up to EC = 2 dS m^{-1}, there is no change in the height of rice. However, the more the water is saline, the shorter the height is as it declines from 123 to 107 cm in controlled S3 (Figure 1). The results also show that dryness stress and lack of Nitrogen cause the rice to be shorter (Aragon and De Datta, 1982; Manzoor et al., 2006). It can be assumed that the reduction of rice height in proportion to the increase of water salinity is due to the effect of osmosis stress in reduction of water and nutrient absorption including nitrogen which is necessary for plant growth (Shahdi, 1994; Homaei, 2002; George, 1967).

Due to the effect of salinity on height reduction and its significant effect on the number of tillers as well, it was expected that as the salinity increased, the number of tillers will decrease accordingly. However, the results showed the reverse effect, that is, salinity have had the additive effect regarding this characteristic. At first as salinity increased, the number of tillers increased as well (Figure 1) then rising salinity caused more tiller after a pause. Controlled pot with 28 tillers was the least in number. The higher the salinity level, the more the number of tillers grew, so much as the number of tillers reached 38 with the highest salinity level. The outcome was in agreement with Kavousi's report (Kavousi, 1995). Hence, it can be said that if planting density decrease in order to produce less tillers and less percentage of infertility, there would be an increase in performance, that is, more yield is obtained (Zeng and Shannon, 2000a).

Table 1. ANOVA results for characteristic as independent variable.

Error source	df	Yield	Height	Number of tiller per plot	Weightof 100 grain	Number of grain per plot			Filled (%)	Length of spike	Weight of spike	Number of spike	Unfilled tiller
						Filled	Unfilled	Total					
Variety	7	999**	1442**	572**	0.29**	255**	1112**	4027**	460 **	70.7**	1.09 ^{ns}	292 **	383 ^{ns}
Salinity	3	24659**	1789**	334**	0.415 **	21080**	908*	26437**	1167**	75.5 **	15.4 **	1103**	151**
S × variety	21	307*	37**	31 ^{ns}	0.086 ^{ns}	602 ^{ns}	171 ^{ns}	721 ^{ns}	43 ^{ns}	8.8 ^{ns}	0.5 ^{ns}	58 ^{ns}	285 ^{ns}
Error	64	174	82	53	0.06	748	225	524	154	5.7	0.516	40	313

** and * respectively significant in 1 and 5% area; ns: non significant.

Table 2. Results for means compare of characteristic in different treatment means with similar letters are not significant at the 0.01 level of significant based Duncan's.

Expt	Yield (g/pot)	Height (cm)	Number of tiller per plot	Weightof 100 grain (g)	Number of grain per plot			Filled (%)	Length of spike (cm)	Weight of spike (g)	Number of spike	Unfilled tiller (%)
					Filled	Unfilled	Total					
Control	83.9 a	123 a	29.9 b	2.5 a	122 a	37 a	159 a	76 a	24.9 a	a 3.08	26 a	12 d
S1	63.1 b	126 a	35 ab	2.39 ab	122 a	33 ab	155 a	79 a	25 a	2.93 a	23 a	36 c
S2	29.8 c	113 b	37 ab	2.29 b	98 b	29 ab	b121	80 a	23.4 a	2.16 b	14b	56 d
S3	12.9 d	107 b	38.4 a	2.2 b	61 c	24 b	85 c	65 b	21.2 b	1.34 c	11 b	70a

Within each column, treatments that carry the same superscript letter are not significantly different at $P < 0.01$ (DMRT).

Like height variation under the influence of irrigation with saline water, 100 grain weight decreased. This feature had a great role in determining the effect of salinity on land production. Moreover, the number of grain per panicle is more important in rice production than that of fertility percentage (Mass and Hoffman, 1997).

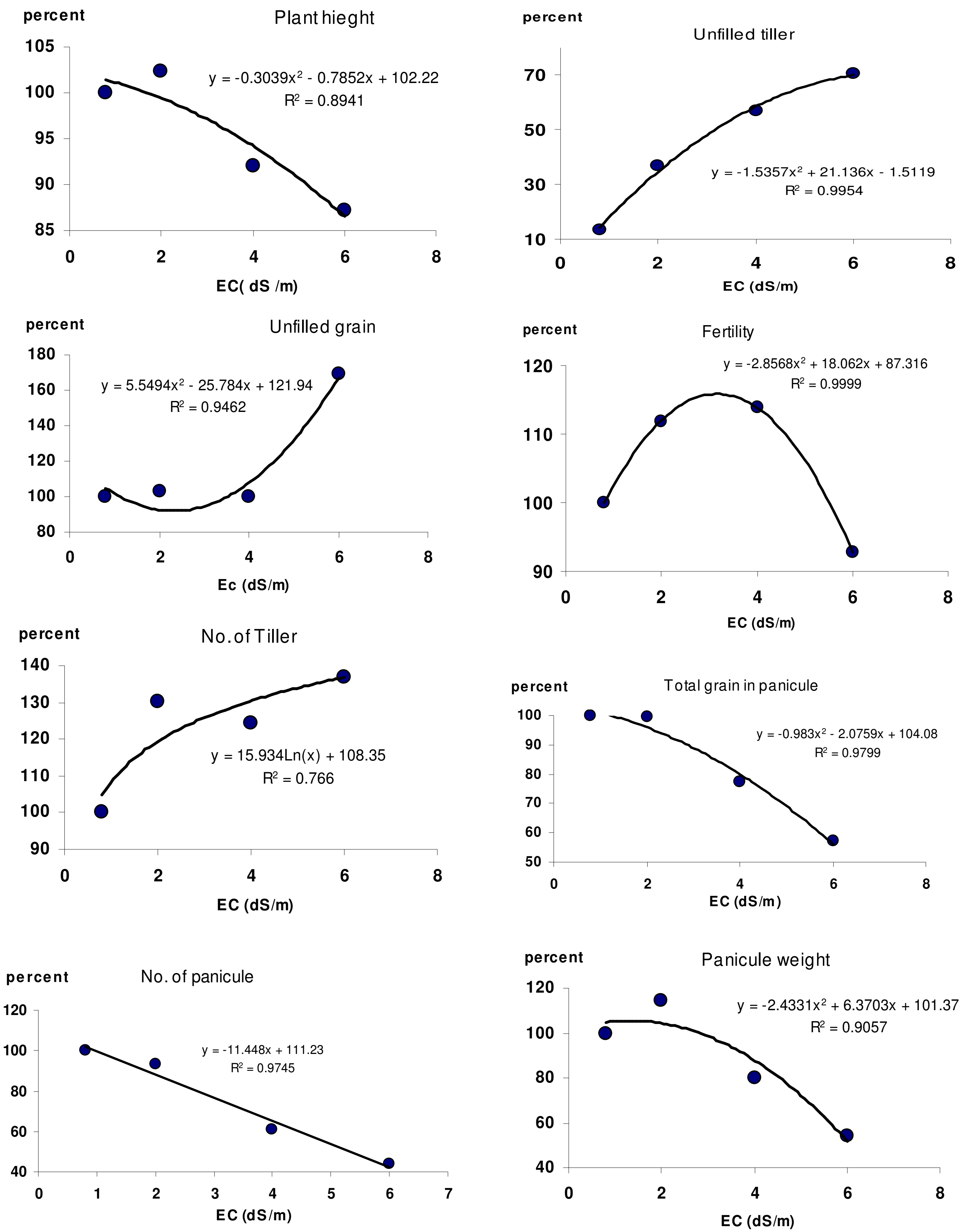
This study showed that the loss of filled grain per panicle was so observable that in accordance with salinity variation from controlled to experiment pot the number of grains decreased repeatedly up to the half of the first plantation.

Figure 1 shows that filled, unfilled, and total grain features and numbers per spike which constitute the number of filled grains to total grains will alter drastically because of salinity. This table interestingly shows that both filled and unfilled grains and even the total number of grains in the pot decrease in accordance with salinity increase.

However, the number of filled and total grains decreased drastically in such a way that the number of grains in pot S3 (experimental) was half as many as the number of grains in controlled one.

The data also show that the amount of fertility percentage which is actually the ratio of the healthy grains to the total numbers remains almost stable up to 4 dS m^{-1}. However this ratio decreases drastically afterward. Similar to variations in other features (traits), the stress created by saline water causes decrease in panicle length. Yet such variations are negligible and maximally reach to 14% of fully grown grains. Although salinity stress causes the total number of tillers to be increased, data show that this rise does not lead to the increase or stability of panicles, instead the number of panicles decreased extremely. In other words the ratio of infertile tillers to the total ones increased. Therefore, among the characteristics measured, the numbers of spike lets per panicle are the most sensitive whereas the characteristic of 100 grain weight, the percentage of fertility and plant height are the least sensitive to the salinity of water supply irrigation (Figure 2).

In Table 1, variance analysis shows that the effect of osmotic stress caused by saline water on plant production and characteristics measured are significant. Table 2 was used to analyze the effect of salinity stress on these characteristics by using multi grain Dunken test per one percent area. According to this table, the maximum production


percent
Plant hieght
y = -0.3039x² - 0.7852x + 102.22
R² = 0.8941
EC(dS /m)
percent
Unfilled tiller
y = -1.5357x² + 21.136x - 1.5119
R² = 0.9954
EC (dS/m)
percent
Unfilled grain
y = 5.5494x² - 25.784x + 121.94
R² = 0.9462
Ec (dS/m)
percent
Fertility
y = -2.8568x² + 18.062x + 87.316
R² = 0.9999
EC (dS/m)
percent
No.of Tiller
y = 15.934Ln(x) + 108.35
R² = 0.766
EC (dS/m)
percent
Total grain in panicule
y = -0.983x² - 2.0759x + 104.08
R² = 0.9799
EC (dS/m)
percent
No. of panicule
y = -11.448x + 111.23
R² = 0.9745
EC (dS/m)
percent
Panicule weight
y = -2.4331x² + 6.3703x + 101.37
R² = 0.9057
EC (dS/m)

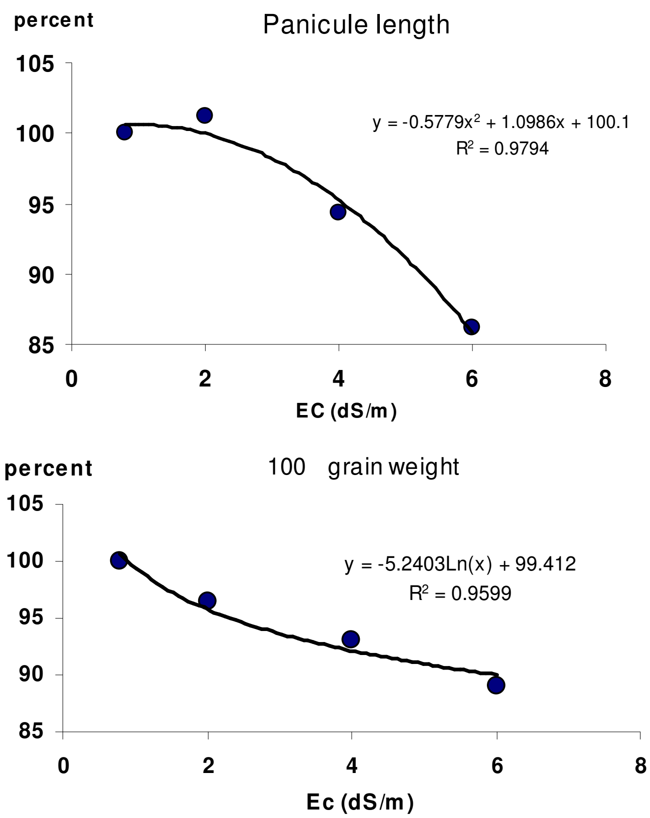


Figure 1. Fluctuation in average of measured traits in different salinity.

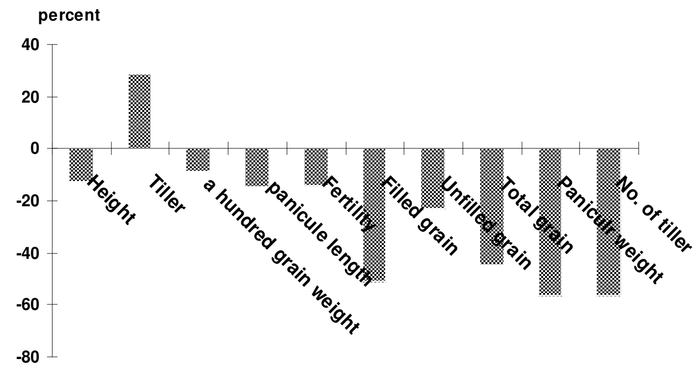


Figure 2. Maxium flactuation in measured traits.

was obtained in controlled pot up to 83.9 g per pot, however, as the amount of salinity of water increased, the amount of production in controlled pot (S3; salinity of 6 dS m^{-1}) reached the minimum level. This process can be due to slight and partial salinity (Saadat et al., 2005). To consider the 90% of production (Kavousi, 1995), the threshold of decreasing would be 1.3 dS m^{-1} in water salinity. However, the amount of production loss to one unit of salinity rise would be different in various salinity levels (Figures 3).

At first production loss increased regarding to salinity variation but it slowed down gradually. Since the identical equation of line shows that high yield varieties are more sensitive to osmosis stress, their production slows down in salinity level up to 4 dS m^{-1} limit (Kavousi, 1995). If this equation is analyzed more deeply, it will become clear that the productivity of high yield varieties reaches the minimum level in salinity of 8 dS m^{-1} which is the lowest amount.

Data analysis in Table 2 shows that varieties perform differently according to salinity. Hence, varieties can be categorized in two different classes. The first class consists of varieties including Neda, Sahel, Nemat, and Kadous are more resistant than other varieties and their production loss is lower in salinity level up to 2 dS m^{-1}. If salinity increases, their production loss increases drastically as well. The second class consists of varieties including Khazar, Dasht, and Fajr are seriously sensitive to salinity level and they extremely lose their productivity if there is s slight alteration in salinity level. However, the trend of unproductivity declines after the salinity of 4 dS m^{-1} in such varieties. Shafagh is more distinguishable variety among all the others since sloping line in productivity loss in such a variety remains almost stable. From the very beginning to the end, its productivity loss equation would be a linear and simple one. Consequently the most resistant varieties are Neda, Sahel, Nemat, and Kadous, and accordingly they will be give priority in plantation. On the other hand, varieties like Dasht, Khazar and Fajr are considered the most sensitive ones.
According to Table 3 an estimated correlation coefficient exists between production and measured variables by using step to step method (one to one) including number of panicles, panicles weight, proportion of tiller infertility and unfilled grains and excluding other variables like height would be (r^2 = 0.871). Analyzing yield components is a way to analyze the yield (Zeng and Shannon, 2000b). Accordingly, grain production can be obtained in any part if the number of healthy grain per panicle and 100 grain weight are estimated. So Table 3 shows that just the above mentioned variables would suffice to estimate productivity in various salinity levels (r^2 = 0.85).

If the correlation matrix in Table 4 is analyzed, the relationship between salinity and other variables measured shows variation in productivity in panicle numbers, panicle weight, and number of grains per panicle, panicle infertility percentage and filled grains plus fertility. The result of the study is in conformity with the findings of other researchers (Zeng and Shannon, 2000b).

In Table 5 coefficient matrix between production and its components in various salinity level shows that in controlled pad with normal water the maximum or perfect coefficient exists between production and panicle numbers, weight of one panicle, and 100 grain weight respectively. Since at this salinity level (control), the proportion of tiller infertility as at minimum level, it can be concluded that the production of this pad is mainly under

Table 3. Step-wise results for yield as dependent variable and other characters as independent variables.

Yield component	Equation	R^2
Spike numbers : PD	Y = 2.608PD - 1.446	0.630
Spike numbers + spike weight SWE	Y = 2.202PD + 15.138SWE - 29.821	0.846
Spike number + unfilled tiller N + spike weight	Y = 1.628D + 13.946SWE - 0.267N - 4.4	0.86
Spike number + unfilled tiller N + spike weight + unfilled grain P	Y = 1.706D + 14.367SWE - 0.229N + 0.164P - 15.58	0.87

Table 4. Phenotype correlation between characteristics of independent variable.

	Unfilled of tiller	Number of spike	Weight of Spike (g)	Grain per spike	Unfilled grain	Filled grain	Filled (%)	Length of spike (cm)	Weight of 100 grain (g)	Number of tiller	Height (cm)	Yield
Yield	-0.79 **	0.80 **	0.63 **	0.59 **	0.068 ns	0.59 **	0.26 **	0.47 **	0.33 **	-0.003 ns	0.32 **	1
Height	-0.20 *	-0.21 ns	0.55 ns	0.56 **	0.01 ns	0.54 **	0.29 **	-0.055 ns	0.19 ns	-0.42 **	1	
Number of tiller	-0.30 **	0.27*	-0.23 *	-0.26 *	-0.11 ns	-0.22 *	-0.07 ns	0.22 *	-0.06 ns	1		
Weight of 100 grain	-0.18 ns	0.15 ns	0.41 **	0.11 ns	0.005 ns	0.11 ns	0.05 ns	0.10 ns	1			
Length of spile	-0.38 **	0.48 **	0.28 **	0.28 **	0.10 ns	0.25 *	0.12 ns	1				
Filled (%)	-0.17 ns	0.19 ns	0.60 **	0.30 **	-0.75 **	0.66 **	1					
Filled grain	-0.32 **	0.22 *	0.95 **	0.91 **	-0.11 ns	1						
Unfilled grain	-0.11 ns	-0.006 ns	-0.08 ns	0.32 **	1							
Grain per spike	-0.35 **	0.21 **	0.87 **	1								
Weight of spike (g)	-0.36 **	0.26 *	1									
Number of spike	-0.80 **	1										
Unfilled of tiller	1											

** and * respectively significant in 1 and 5% area; ns: none significant

Table 5. Correlation coefficient between yield and other characters as independent variable in different salinity.

Ec	Unfilled tiller	Number of spike	Weight of spike (g)	Number of grain per spike			Filled (%)	Length of spike (cm)	Weight of 100 grain (g)	Number of tiller	Height (cm)
				Total	Unfilled	Filled					
0.8	-0.004 ns	0.75 **	0.45 **	0.25 ns	-0.20 ns	0.35 ns					
2	-0.54 *	0.83 **	-0.18 ns	-0.41*	-0.33 ns	0.33 ns	0.33 ns	0.53 **	0.19 ns	0.49 *	-0.42 *
4	-0.60 **	0.73 **	0.31 ns	0.17 ns	-0.52 **	0.37 ns	0.61 **	0.31 ns	-0.09 ns	0.44 *	0.08 ns
6	-0.35 ns	0.24 ns	0.46 **	0.46 *	-0.27 ns	0.56 **	0.52 **	0.06 ns	-0.04 ns	-0.05 ns	0.15 ns

** and * respectively significant in 1% and 5% area; ns: none significant.

Table 6. Correlation equation using step by step test.

EC	Equation	r^2
0.8	Y=1.874PD + 8.595SWE + 33.567	0.70
2	Y=1.893PD + 1.671PL + 7.351SWE – 42.604	0.80
4	Y=1.221PD + 10.342SWE – 0.136N – 3.004	0.91
6	Y= 0.17SS – 0.233N + 18.517	0.51

SS: percent of filled grain; PL: length of panicle; P: number of unfilled grain; N: filled ratio of unfilled tiller; SWE: weight of spike; PD: number of panicle.

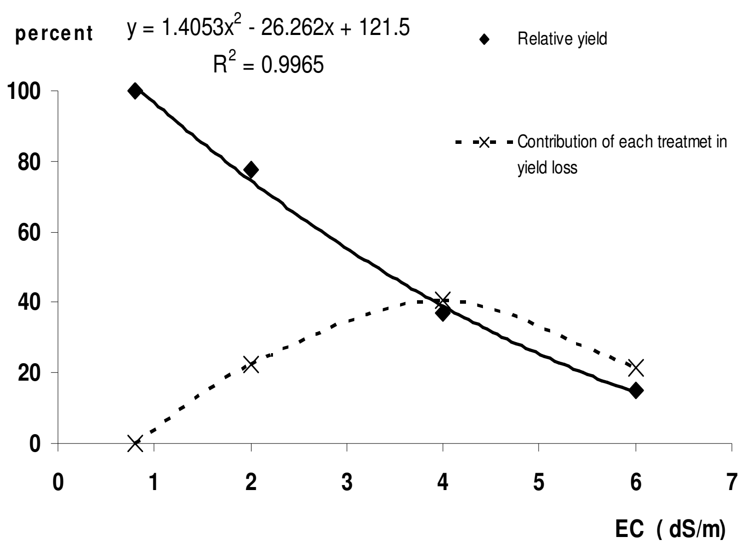


Figure 3. Relative rice yield (Y/Y max).

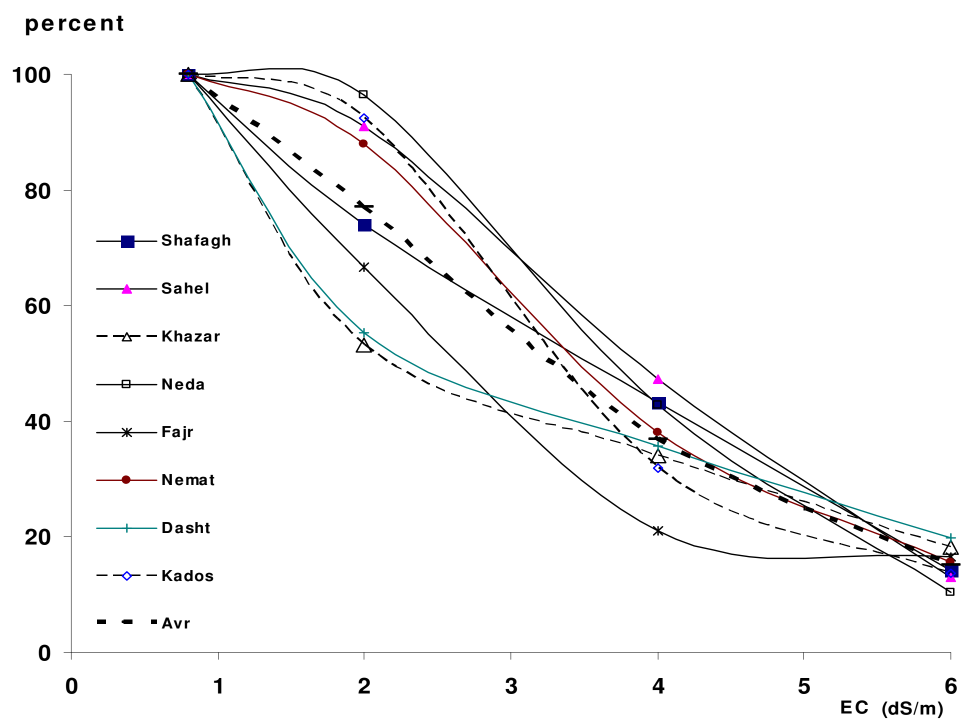


Figure 4. Relative rice yield (Y/Y max).

the effect of panicle weight and its numbers as well. In Table 6 these two characteristics (variable) are shown through multi level regression (Figure 4).

In salinity level of 2 dS m^{-1}, there is a significant correlation between production and panicle number, proportion of tiller, panicle length and tiller numbers. It should be mentioned that in multi level regression, variables like panicle numbers, panicle length and panicle weight have been considered. At salinity level of 4 dS m^{-1}, variable like panicle numbers and percentage of grain fertility have a positive correlation while there is a more negative correlation between the ratios of panicle infertility to the rest of variables. The final point is that although in multi level regression, panicle numbers, panicle weight and ratio of tiller infertility were calculated, it was demonstrated that in salinity level of 6 dS m^{-1} the most significant correlation exists between the number of filled panicle which overlaps with grain productivity and panicle weight.

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