Australian Journal of Crop Science AJCS
AJCS 5(12):1595-1602 (2011) ISSN:1835-2707

Effect of salinity and irrigation regimes on the internode physical variations of rice stem

Mohammad Reza Alizadeh*[1], Ali Dabbaghi[1], Fatemeh Rahimi-Ajdadi[1], Mojtaba Rezaei[1] and Mohammad Hashem Rahmati[2]

[1]Department of Agricultural Engineering, Rice Research Institute of Iran (RRII), Postal code: 41996-13475, Rasht, Guilan, Iran
[2]Gorgan University of Agricultural Sciences and Natural Resources, Iran

[*]Corresponding author: alizadeh_mohammadreza@yahoo.com

Abstract

In this study, the effects of five levels of water salinity (S_0: EC ≤ 1 dSm^{-1}, S_1: EC=2 dSm^{-1}, S_2: EC=4 dSm^{-1}, S_3: EC=6 dSm^{-1} and S_4: EC=8 dSm^{-1}) and five levels of irrigation regimes (I_0: Continuous flooding, I_1: Alternative wetting and drying, I_2: Intermittent irrigation at 100% of field capacity, I_3: Intermittent irrigation at 90% field capacity and I_4: Intermittent irrigation at 80% field capacity) on some physical variations of rice stem were examined. A common local rice variety, namely Hashemi was chosen for the experiment. Results indicated that the internode length was decreased from 36.85 to 22.33 cm, 24.65 to 17.41 cm, 17.58 to 11.88 cm and 8.36 to 5.18 cm at the first**,** second**,** third and fourth internode positions, respectively as the water salinity increased from S_0 to S_4. Compared to unstressed control (I_0S_0), the treatment of I_4S_4 created to a decrease of about 48% in the length of stem. At each level of water salinity, lower internode length was measured at higher water stress. A significant decreasing trend in stem major and minor diameters was observed with increasing salinity and water stress with high coefficient of determinations. At each internode position, the stem wall cross-sectional area decreased significantly (P<0.01) as the salinity and water stress increased. The highest wall cross-sectional area of 4.64 mm^2 was recorded in I_0 and S_0, while the lowest value of 1.48 mm^2 was measured in I_4 and S_4. The bending force of rice stem was decreased significantly (P<0.01) with increasing salinity and water stress at each internode position.

Key words: Rice stem, internode position, water salinity, irrigation regime, stem properties.

Abbriviations:

S_0	Salinity level (EC≤1 dSm^{-1})	I_4	Intermittent irrigation at 80% field capacity
S_1	Salinity level (EC=2 dSm^{-1})	IN_1	First internode position
S_2	Salinity level (EC=4 dSm^{-1})	IN_2	Second internode position
S_3	Salinity level (EC=6 dSm^{-1})	IN_3	Third internode position
S_4	Salinity level (EC=8 dSm^{-1})	IN_4	Fourth internode position
I_0	Continuous flooding	A_c	Stem cross-sectional area (mm^2)
I_1	Alternative wetting and drying	D	Stem major diameter (mm)
I_2	Intermittent irrigation at 100% of field capacity	d	Stem minor diameter (mm)
I_3	Intermittent irrigation at 90% field capacity	t	Stem wall thickness (mm)
L	internode length (cm)		

Introduction

Water sources limitation and world population growth demand the drastic attention to optimizing, managing and prioritizing of water utilization in different economical parts including agriculture. Agriculture is one of the high water consumers especially in cultivation of some grain crops as rice. Rice is considered as one of the major food crops in the world requires higher water consumption respect to other grain crops during growth stages. Such that producing each 1 kg of rice grain, consuming 2-3 times of water more than others (Belder et al., 2004). Thereupon it is necessary particular regard to manage of irrigation for this crop. Applying water with lower quality as relatively saline water which has lower value to human consumption and also irrigation interval is of the viewpoints in this field. However, it should be noted that the excessive water salinity itself leads to a major environmental stress affecting rice productivity. It was reported that nutritional imbalance caused by such ions leads to reduction in photosynthetic efficiency and other physiological disorders (Yoe and Flowers, 1983; Yoe et al., 1990) as ionic toxicity. Indeed, ionic toxicity is caused by an excessive amount of salt entering the transpiration stream, which eventually injures cells in the transpiring leaves and may further reduce growth (Munns et al., 2006). Thus, before irrigating with saline water, survey and evaluation of the effects of salinity levels on productivity indices will be necessary. It should be mentioned that the risk of salinity in the rice field with flooded and irrigated system is more serious. Because the salt levels increased in the soil texture due to frequently irrigation practices. Several researchers investigated the effect of salinity on yield attributes and physical properties of rice; for instance, Gain et al. (2004) investigated the effect of salinity levels between 0 and 31.25

dS m-1 on plant height, number of tillers and the biomass of the plant. The similar study was carried out by Islam et al. (2007), Zeng and Shannon (2000) and Hasamuzzaman et al. (2009). Moreover, other researches were conducted to found the effect of salt stress on germination and seedling growth of rice (Djanaguiraman et al. 2003; Hakim et al., 2010; Khan et al., 1997; Lutts et al., 1996).

In general, the result of these researches indicated that for each yield component can be detected an optimum value of salinity level which doesn't significant effect on each yield component. As mentioned, in addition to using lower quality water (saline water), increase in water interval is one of the other management tools in water saving. But in this case should be considered to crop yield and productivity indices, too. Because the occurrence of excessive moisture stress affects many physiological process such as photosynthesis and transpiration resulted in reduced growth and poor filling (Samonte et al. 2001). On this basis, the effects of water stress on physical properties of rice grain were investigated by several researchers group (Fofana et al. 2010; Mostajeran and Rahimi-Eichi, 2009). The results showed that it is not necessary that rice plant in all stages of growth be continuous submerge (Amiri et al., 2009). Study on the response of rice to both salinity and water stress and their interactive effects may be efficacious in breeding program of salt and drought tolerant cultivars by identifying physiological features and physical properties of rice stem. Therefore, the objective of this study was to investigate the effects of saline water and irrigation regimes on internode dimensional properties of rice stem, such as internode length, stem major and minor diameters and stem wall cross-sectional area as well as stem bending force.

Results

Internode length

The effects of water salinity on the internode length of the rice stem at the different internode positions are presented in Fig. 2a. It was observed that at each internode position, the internode length of rice stem decreased significantly ($P<0.01$) as the water salinity increased. It was decreased from 36.85 to 22.33 cm, 24.65 to 17.41 cm, 17.58 to 11.88 cm and 8.36 to 5.18 cm at internode positions of IN_1, IN_2, IN_3 and IN_4, respectively as the water salinity increased from S_0 to S_4. Results also indicated that at each level of water salinity, lower internode length was measured at higher water stress (Fig. 2b). The internode length decreased from 32.64 to 24.76 cm and 8.62 to 5.69 cm in I_0 and I_4, respectively as the water salinity increased form S_0 to S_4. Furthermore, higher internode length was measured at upper stem position. The regression equations describing the effects of salinity on the internode length of rice stem at different internode positions and irrigation regimes are given in Table 1. As observed, at each level of irrigation regime and internode position, there was a highly correlation between the internode length and salinity.

Major and minor diameters

Effects of water salinity on the stem major and minor diameters at different internode positions are presented in Fig. 3a and 3b. It was found that at each internode position, the major and minor diameters showed a significant decreasing trend ($P<0.01$) with increasing salinity. The results also showed that at each of salinity level, the highest major and minor diameters were obtained at IN_4 and the lowest were registered at IN_1. Similar results were obtained for the interaction effects of water salinity and irrigation regime on the major and minor diameters (Fig. 4a and 4b). The stem major diameter increased from 1.53 to 4.26 mm in I_0 as internode positions varied from the first to forth, while it changed from 1.25 to 3.49 mm in I_4 at the same internode positions. Table 2 shows the equations representing the correlation of salinity on the major and minor diameters of rice stem at different internode positions and irrigation regimes. A significant correlation was observed between salinity and major and minor diameters at each internode position and irrigation regime with highly coefficient of determinations.

Stem wall cross-sectional area

The effect of water salinity on the stem wall cross-sectional area was presented in Fig. 5a. At each internode position, the stem wall cross-sectional area decreased significantly ($P<0.01$) as the salinity level increased from S_0 to S_4. In addition, at each salinity level, the highest wall cross-sectional area was measured at IN_4 and the lowest value was found at IN_1. At all the internodes positions, the stem wall cross-sectional area significantly decreased as the irrigation regime varied from I_0 to I_4 (Fig. 5b.). The highest wall cross-sectional area of 4.64 mm^2 was obtained in I_0 and S_0 and the lowest value of 1.48 mm^2 was measured in I_4 and S_4. Equations representing the correlation of water salinity on stem cross-sectional area at different internode positions and irrigation regimes are given in Table 3. There was a significant correlation between the salinity and wall cross sectional area at all internode positions and irrigation regimes levels with high coefficient of determinations.

Bending force

Fig. 6 shows the effect of salinity level on the average bending force of the rice stem. As observed, with increasing water salinity from S_0 to S_4, the bending force decreased significantly ($P<0.01$). The highest bending force was achieved in S_0 with the mean value of 1.803 N. The corresponding values were 1.434, 1.272, 1.094 and 0.927 N for S_1, S_2, S_3 and S_4, respectively. The effect of irrigation regime on the bending force of rice stem was illustrated in Fig. 7. It can be seen that with increasing the irrigation regime form I_0 to I_4, the diagram represented a descent tendency. The average value of the bending force at the level of I_0 had the highest value of 1.787 N. Further, results indicated that the effect of each irrigation regime on the bending force was significant at 0.01 of probability confidence. Moreover, results showed that the bending force had the lowest value at the first internode (Fig. 8) and it was found to be increased with coming close to the ground (forth internode). The values of bending force at the internodes of IN_1, IN_2, IN_3 and IN_4 were 0.180, 0.539, 1.630 and 2.874 N, respectively. There was significant variation between internodes in terms of the value of bending force ($P<0.01$).

Discussion

Decreasing internode length with increasing water salinity and water stress led to the reduction in stem height and other physiological and morphological characteristics of plant. Such decreases in plant height with increasing salinity are typical effects of the accumulation of toxic ions in cells, which adversely affect cell division and expansion (Munns,

Table 1. Equations representing the relationship between water salinity (S) and stem internode length (L) at different internode positions (IN) and water stress (I)

Internode position	Internode length	R^2
IN_1	$L = 0.3437S^2 - 5.0136S + 40.746$	$R^2 = 0.9830$
IN_2	$L = 0.2054S^2 - 2.8834S + 27.421$	$R^2 = 0.9924$
IN_3	$L = -0.0391S^2 - 0.3885S + 17.729$	$R^2 = 0.9611$
IN_4	$L = 0.0096S^2 - 0.5312S + 8.8739$	$R^2 = 0.9888$
Irrigation regime	Internode length	R^2
I_0	$L = 0.0564S^2 - 1.6563S + 25.859$	$R^2 = 0.9968$
I_1	$L = 0.1367S^2 - 2.439S + 25.556$	$R^2 = 0.9837$
I_2	$L = 0.1641S^2 - 2.551S + 24.234$	$R^2 = 0.959$
I_3	$L = 0.1538S^2 - 2.3065S + 22.189$	$R^2 = 0.9795$
I_4	L = 0.1385S2 - 2.0681S + 20.625	R2 = 0.9758

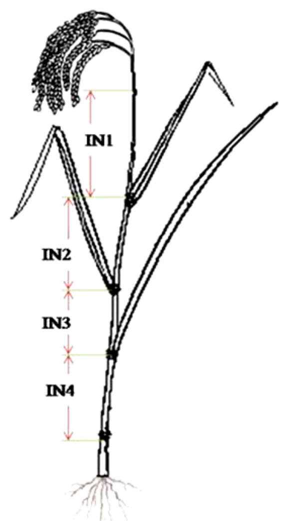
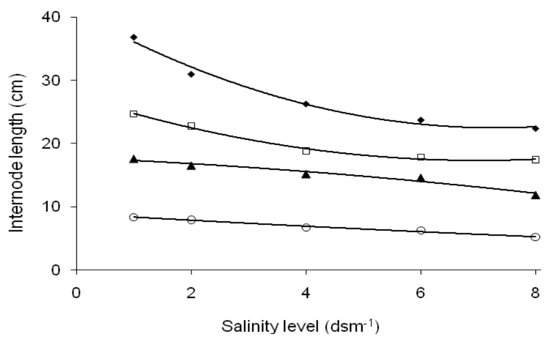


Fig 1. Schematic diagram of rice stem representing different internode positions (IN1, I N2, IN3 and IN4 are first, second, third and fourth internodes, respectively).

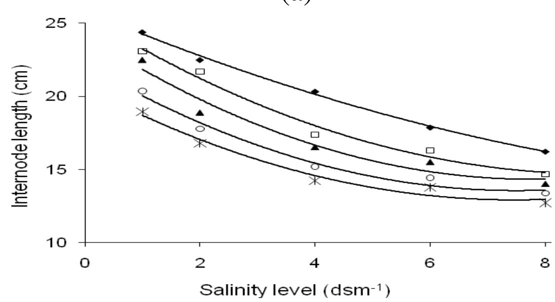
1993). Compared to control treatment (I_0S_0), the treatment of I_4S_4 which was undertaken the highest salinity and water stresses created to a decrease of about 48% in the length of stem. In other word, under the intermittent irrigation at 80% field capacity and EC=8 dSm^{-1} the length of rice stem can be approximately reduce to half its value. The similar results were also reported by other researchers (Saxena and Pandey, 1981; Gain et al., 2004; Razzaque et al., 2009; Hasamuzzaman et al., 2009; Amiri et al., 2009; Çavuşoğlu et al., 2008). Decreasing percentage of major diameter due to increasing in salinity level were 35.0, 33.2, 25.6 and 25.0% for the internodes IN_1, IN_2, IN_3 and IN_4, respectively. This value for minor diameter was 34.2, 34.7, 29.6 and 24.5%, respectively. This occurs because of the destructive effects of toxic ions accumulation. As revealed, the decrease percentage of diameter for IN_3 and IN_4 were lower than IN_1 and IN_2. It means that the lower internodes were less affected by salinity stresses compared to upper ones. Comparing between the effects of salinity and irrigation regimes on the stem major and minor diameters of rice can be inferred that the salinity stress plays the higher role on decreasing the means of these physical properties (with the percentage of 30 against 20%, respectively). The treatment of I_4S_4 compared to control treatment (I_0S_0) had a decreasing influence of 40.0 and 40.7% on major and minor diameters, respectively. The values of major and minor diameters are important on the mechanism of crop lodging and analysis of mechanical characteristics of stem as bending, tensile and shearing stresses. Hoshikawa and Wang (1990) reported that the major and minor axes, which reflect the width of internodes, had lower values in lodged culms. Considering the high effect of salinity and draught stresses on the rice stem diameter, particularly in the high levels (about 40%), it is proposed that the lodging was considered as serious limited factors in selecting the saline water or periodic programming irrigation. Stem wall cross-sectional area could be attributed to lager major and minor diameters at the lower portions of the paddy stem, which affectively influences the other physical and mechanical properties of plant stem (Tavakoli et al., 2010; Nazari Galedar et al., 2008). Considering the obtained results, a mean reduction of 52.4% and 42.1% in wall cross-sectional area was obtained as the salinity and irrigation regime varied from S_0 to S_4 and I_0 to I_4, respectively. It can be said that salinity had more impact on wall cross-sectional area of rice stem than irrigation regimes, which is similar to the result obtained for major and minor diameters. The present experiments revealed a decrease in bending force, under water and salinity stress conditions such that increasing salinity level from S_0 to S_4 caused to decrease the percentage of 48.6% in bending force. In addition, in the case of water stress, there was a decrease of 48.3% in stem bending force. Hence, this finding suggested that in saline and draught stress conditions, the harvesting operation is performed towards lower internode than common condition.

Table 2. Equations representing the correlation of water salinity on stem major (D) and minor (d) diameters at different internode positions (IN) and irrigation regimes (I)

Internode position	Major diameter	R^2	Minor diameter	R^2
IN_1	$D = 0.0129S^2 - 0.195S + 1.8853$	0.9556	$d = 0.0138S^2 - 0.1888S + 1.6697$	0.9247
IN_2	$D = 0.0235S^2 - 0.3429S + 3.3076$	0.9639	$d = 0.0263S^2 - 0.352S + 2.9814$	0.8916
IN_3	$D = 0.033S^2 - 0.4119S + 3.9613$	0.8784	$d = 0.029S^2 - 0.377S + 3.5964$	0.8587
IN_4	$D = 0.0334S^2 - 0.4352S + 4.8368$	0.8919	$d = 0.0219S^2 - 0.3101S + 4.0526$	0.8888
Irrigation regime	Major diameter	R^2	Minor diameter	R^2
I_0	$D = 0.0266S^2 - 0.3809S+ 3.9108$	0.9599	$d = 0.0189S^2 - 0.3045S + 3.3957$	0.9102
I_1	$D = 0.0224S^2 - 0.3306S+ 3.6629$	0.9318	$d = 0.0293S^2 - 0.3725S + 3.284$	0.8421
I_2	$D = 0.0255S^2 - 0.3604S+ 3.5454$	0.8468	$d = 0.0259S^2 - 0.3459S + 3.1601$	0.8494
I_3	$D = 0.0275S^2 - 0.3413S+ 3.3221$	0.8904	$d = 0.0227S^2 - 0.289S + 2.9259$	0.8815
I_4	$D = 0.0266S^2 - 0.318S + 3.0475$	0.9451	$d = 0.0169S^2 - 0.2228S + 2.6093$	0.9218



(a)



(b)

Fig 2. The effect of salinity levels on internode length of the paddy stem at a) different internode positions (♦ IN_1, □ IN_2, ▲ IN_3, ○ IN_4) and b) Irrigation regimes (♦ I_0, □ I_1, ▲ I_2, ○ I_3, * I_4)

Materials and Methods

Plant material

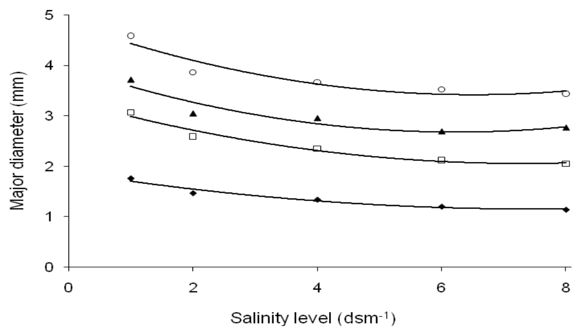
This study was conducted at the Department of Agricultural Engineering, Rice Research Institute (RRII), Rasht, Guilan, Iran. A common local rice variety, namely Hashemi was used in the experiment. The paddy soil was prepared and dried in the ambient air temperature and then crushed with a soil crusher. Required quantity of chemical fertilizers (N-P-K) mixed with the soil. The soil was poured into plastic pots and irrigated with fresh water. In each pot, three seedlings were transplanted. The seedlings were irrigated with fresh water for one week. After that, the experimental treatments were applied on the pots placed under shelter condition.

Treatment conditions

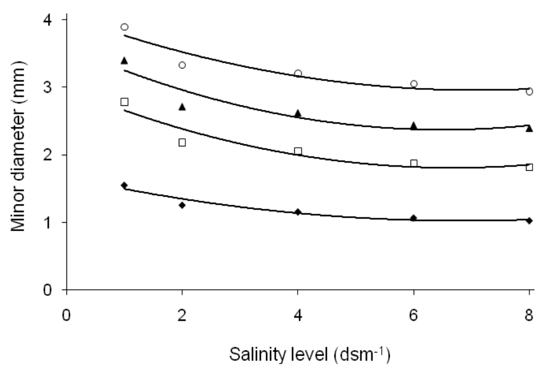
In this experiment the effect of five levels of water salinity (S_0: EC ≤ 1 dSm^{-1}, S_1: EC= 2 dSm^{-1}, S_2: EC= 4 dSm^{-1}, S_3: EC= 6 dSm^{-1} and S_4: EC= 8 dSm^{-1}), five levels of irrigation regimes (I_0: Continuous flooding, I_1: Alternative wetting and drying, I_2: Intermittent irrigation at 100% of field capacity, I_3: Intermittent irrigation at 90% field capacity and I_4: Intermittent irrigation at 80% field capacity) on some dimensional properties of rice stem at four internode positions of IN_1, IN_2, IN_3 and IN4 (from the panicle neck node toward the plant base) were examined. The water salinity levels were simulated based on canal water analysis using NaCl and $CaSo_4$ (2:1). Schematic representation of internode positions of paddy stem is shown in Fig. 1.

Table 3. Equations representing the correlation of water salinity (S) on stem cross-sectional area (A_c) at different internode positions (IN) and irrigation regimes (I)

Internode position	Stem wall cross-sectional area	R^2
IN_1	$A_c = 0.0109S^2 - 0.1519S + 0.8479$	$R^2 = 0.9224$
IN_2	$A_c = 0.0287S^2 - 0.4156S + 2.6123$	$R^2 = 0.9270$
IN_3	$A_c = 0.0507S^2 - 0.7296S + 4.9545$	$R^2 = 0.8961$
IN_4	$A_c = 0.0506S^2 - 0.8545S + 7.5328$	$R^2 = 0.9234$
Irrigation regime	Stem wall cross-sectional area	R^2
I_0	$A_c = 0.028S^2 - 0.5572S + 4.87$	$R^2 = 0.8983$
I_1	$A_c = 0.043S^2 - 0.6405S + 4.5066$	$R^2 = 0.9452$
I_2	$A_c = 0.0406S^2 - 0.5845S + 4.0282$	$R^2 = 0.8700$
I_3	$A_c = 0.0352S^2 - 0.4876S + 3.5263$	$R^2 = 0.9130$
I_4	$A_c = 0.0293S^2 - 0.4197S + 3.0033$	$R^2 = 0.9549$



(a)



(b)

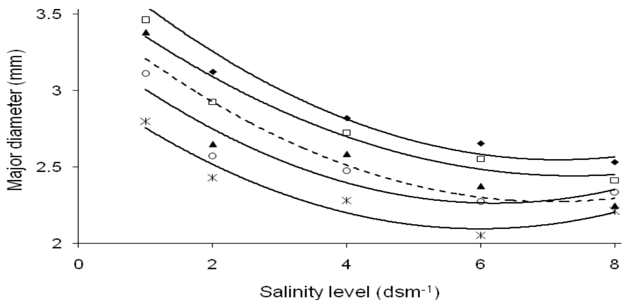
Fig 3. The effect of salinity levels on a) major diameter and b) minor diameters of the rice stem at different internode positions (♦ IN_1, □ IN_2, ▲ IN_3, ○ IN_4)

Experimental methods

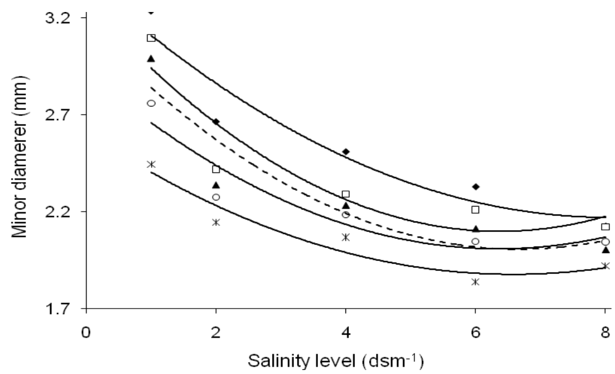
All required practices during plant growing stages were applied. At maturity, the paddy stem were cut from the base and sealed in polyethylene bags, transferred to the laboratory for the main experiments. In order to determine the dimensional properties of rice stem, 10 stems were randomly taken out from the bag in each treatment. Leaf blades and sheaths were removed prior to any measurement. The internodes of each stem were separated out according to their position down from the ear (Annoussamy et al., 2000). The internode length was determined with a ruler reading to 0.1 cm. To determine the average size of the rice stem, the majorand minor diameters and wall thickness were measured with a digital caliper (Mitutoya, Japan) reading to 0.01 mm. The cross-sectional area (A_c) in mm^2 considering oval shape for rice stems was calculated through the following equation (Alizadeh et al., 2011):

$$A_c = \frac{\pi . t}{2}\left[D + d - 2t)\right] \quad (1)$$

Where D, d and t are major diameter, minor diameter and stem wall thickness in mm, irrigation regime, respectively.In order to determine the bending force of rice stem, a digital

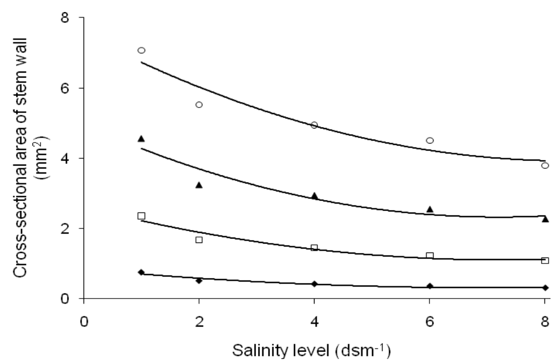


(a)

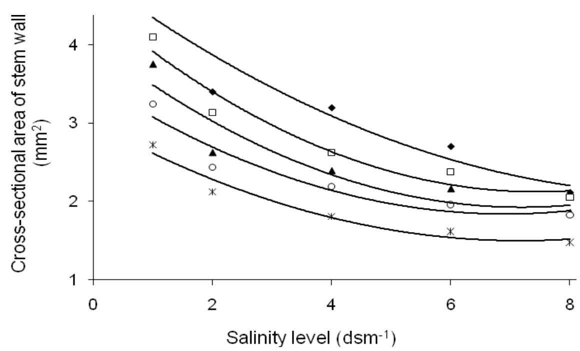


(b)

Fig 4. The effect of water salinity on a) major stem diameter and b) minor stem diameters at different Irrigation regimes (♦ I_0, □ I_1, ▲ I_2, ○ I_3, * I_4)



(a)



(b)

Fig 5. The effect of salinity levels on the cross-sectional area of rice stem at different a) internode positions (♦ IN_1, □ IN_2, ▲ IN_3, ○ IN_4) and b) Irrigation regimes (♦ I_0, □ I_1, ▲ I_2, ○ I_3, * I_4)

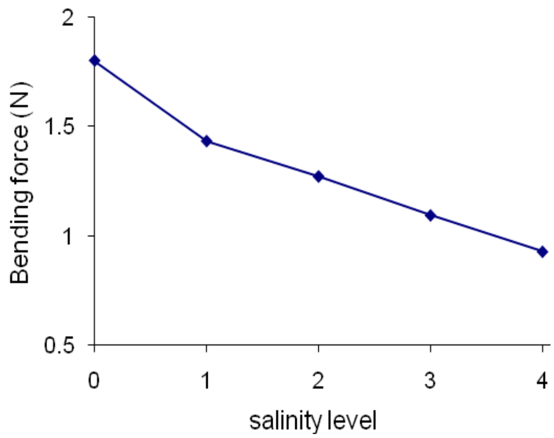


Fig 6. The effect of salinity level on bending force of rice stem

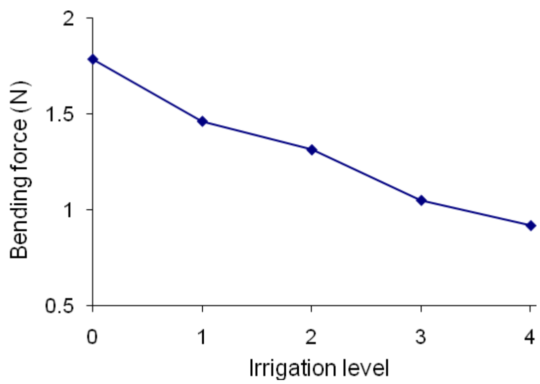


Fig 7. The effect of Irrigation regimes on bending force of rice stem

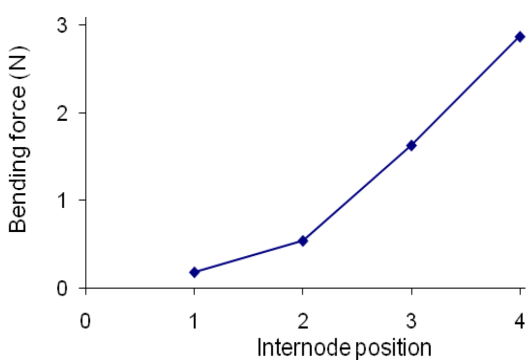


Fig 8. The effect of internode position on bending force of rice stem

force gauge (Lutron FG-5000 A, Taiwan) with accuracy of 0.01N was used. The measuring part is attached to the guide rail. The fragments of tested stem are placed across a pair of vertically pins which are set at a distance of about 50 mm. The testing is carried out by applying pressure gradually against the tested material by moving the force gauge using a suitable form of pointed tools until the tested material breaks as described by Watanabe (1993). The force gauge was moved slowly by a 2 rpm AC electric motor.

Data analysis

The experiment was factorial based on randomized complete blocks design (RCBD) with 10 replications for each treatment. The experimental data was analyzed using analysis of variance (ANOVA) and the means were separated at the 5% probability level applying Duncan's multiple range tests (DMRT). The figures and regression equations were plotted using Microsoft Excel 2003 software.

Conclusions

Some key points for this study can be summarized as follows: 1. The effect of salinity and irrigation regime was significant ($P<0.01$) on the morphological characteristics such as length, major and minor diameters and cross-sectional area as well as the rice bending force. 2. Increasing in salinity (from EC ≤ 1 to EC=8 dSm^{-1}) and water stresses (in the range of continuous flooding and intermittent irrigation at 80% field capacity) simultaneously lead to decrease in the stem length, major and minor diameters by percentage of 48, 30 and 20% respectively. 3. The bending force of the rice stem was decreased with increasing the salinity and water stresses to about 48%. Thereupon, it was proposed to adjust the cutting height of harvesting machine at lower height than usual condition in order to have a clean cutting.

Acknowledgments

Authors are grateful to Rice Research Institute of Iran (RRII) to providing the laboratory facilities and financial support for this project.

References

Alizadeh MR, Rahimi-Ajdadi F, Dabbaghi A (2011) Cutting energy of rice stem as influenced by internodes position and dimensional characteristics of different varieties. Aust J Crop Sci 5(6): 681-687.
Amiri E, Khandan M, Bozorgi HR, Sadeghi SM, Rezaei M (2009) Response of rice varieties to water limit conditions in north Iran. World Appl Sci J 6(9): 1190-1192.
Annoussamy M, Richard G, Recous S, Guerif J (2000) Change in mechanical properties of wheat straw due to decomposition and moisture. Appl Eng Agric, 16(6): 657-664.
Belder P, Bouman BAM, Cabangon R, Lu G, Quilang EJP, Li Y, Spiertz JHJ,Tuong TP (2004) Effect of water-saving irrigation on rice yield and water use in typical lowland conditions in Asia. Agric Water Manage 65(3): 193-210.
Cavuşoğlu K, Kilic S, Kabar K (2008) Effects of some plant growth regulators on stem anatomy of radish seedling grown under saline (NaCl) conditions. Plant Soil Environ 54(10): 428-433.
Djanaguiraman M, Ramadass R, Durga Devi D (2003) Effect of salt stress on germination and seedling growth in rice genotypes. Madras Agric J 90(1-3): 50-53.
Fofana M, Cherif M, Kone B, Futakuchi K, Audebert A (2010) Effect of water deficit at grain repining stage on rice grain quality. J Agric Biotec Sustainable Develop 2(6): 100-107.
Gain P, Mannan MA, Pal PS, Maheb Hossain M, Parvin S (2004) Effect of Salinity on some yield attributes of rice. Pak J Biol Sci 7(5): 760-762.

Hakim MA, Juraimi AS, Begum M, Hanafi MM, Ismail MR, Selamat A (2010) Effect of salt stress on germination and early seedling growth of rice (*Oryza sativa* L.). Afr J Biotech 9(13): 1911-1918.

Hasamuzzaman M, Fujita M, Islam MN, Ahamed KU, Nahar K (2009) Performance of four irrigated rice varieties under different levels of salinity stress. Int J Integrative Bio 6(2): 85-90.

Hoshikawa k, Wang SB (1990) Studies on lodging in rice plants .I. A general observation on lodged rice culms. Jpn J Crop Sci 59(4): 809-814.

Islam MZ, Baset Mia MA, Akter A (2007) Effect of different saline levels on growth and yield attributes of mutant rice. J Soil Nature 1(2): 18-22.

Khan MSA, Hamid A, Karim MA (1997) Effect of sodium chloride on germination and seedling characters of different types of rice (Oryza sativa L.). J Agron Crop Sci 179: 163-169.

Lutts S, Kinet JM, Bouharmont J (1996) NaCl-induced senescence in leaves of rice (Oryza sativa L.) varieties, differing in salinity resistance. Ann Bot-London 78: 389-398.

Mostajeran A, Rahimi-Eichi V (2009) Effects of drought stress on growth and yield of rice (Oryza sativa L.) cultivars and accumulation of proline and soluble in sheath and blades of their different ages leaves. American-Eurasian J Agric Environ Sci 5(2): 264-272.

Munns R (1993) Physiological processes limiting plant growth in saline soils: some dogmas and hypotheses. Plant Cell Environ 16: 5–24.

Munns R, James RA, Lauchli A (2006) Approaches to increasing the salt tolerance of wheat and other cereals. J Exp Bot 57: 47-51.

Nazari Galedar M, Jafari A, Mohtasebi A, Tabatabaeefar A, Sharifi A, O'Dogherty MJ, Rafiee S, Richard G (2008) Effects of moisture content and level in the crop on the engineering properties of alfalfa stems. Biosyst Eng 101: 199-208.

Razzaque MA, Talukder NM, Islam MS, Bhadra AK, Dutta RK (2009) The effect of salinity on morphological characteristics of seven rice (*Oryza sativa.L*) genotypes differing in salt tolerance. Pak J Biol Sci 12(5):406-412.

Samonte S, Wilson LT, McClung AM, Tarpley L (2001) Seasonal dynamics of non-structural carbohydrate in 15 diverse rice genotypes. Crop Sci 41: 902-909.

Saxena MK, Pandey UK (1981) Physiological studies on salt tolerance of tenric varieties growth and yield aspect. Indian J Plant physiol 24: 61-68.

Tavakoli H, Tavakoli H., Azizi MH, Haghayegh, GH (2010) Comparison of mechanical properties between two varieties of rice. Adv J Food Sci Technol 2(1): 50-54.

Watanabe T (1993). A new breaking strength tester BSTW-1. JARQ 26: 277-281.

Yoe AR, Flowers TJ (1983) Varietal differences in toxicity of sodium ions within the shoot of rice varieties differing in salinity resistance. Physiol Plant 56: 343-348.

Yoe AR, Yoe ME, Flowers SA, Flowers TJ (1990) Screening of rice (*Oryza sativa L.*) genotypes for physiological characters contributing to salinity resistance and their relationship to overall performance. Theoretical Appl Gen 79: 377-384.

Zeng L, Shannon MC (2000) Effects of salinity on grain yield and yield component of rice at different seeding densities. Agron J 92: 418-423.