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Relative salt tolerance of south Khorasan millets

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Abstract

Millets are important agricultural crops for arid regions due to short life span and their resistance to salinity and drought conditions. In Iran, three main species of millets including proso millet (*Panicum miliaceum)*, foxtail millet (*Setaria italica*) and pearl millet (*Pennisetum glaucum*) are cultivated in Shouthern Khorasan province, eastern Iran. In order to assess inter-specific genetic variation for salt tolerance at vegetative and reproductive stage, an experiment was conducted in split plot based on completely randomized block design. Nine genotypes of these millets collected from four different regions of the Shouthern Khorasan province (Ghaen, Sarayan, Nehbandan, and Birjand) were subjected to three levels of salinity stress (1.5, 5.5, and 9.5 dS/m). Although the yield and other yield related parameters of millets decreased by salinity stress, this reduction was more prominent only at high level of salinity (9.5 dS/m). Remarkable differences among same species from different areas were observed. Growth and yield capacity of three millet species from Birjand were also different. Of three millets, pearl millet from Birjand followed by foxtail millet, showed maximum yield potential under both salt stress and normal conditions. Of genotypes of foxtail millets, genotype from Sarayan exhibited maximum growth and yield potential under saline conditions. In contrast in proso-millets, genotype from Ghaen showed higher salt tolerance. Thus, salt tolerance varies in three millets from different regions, which could be further explored in future research.

Keywords: Salinity; Millets; Proso; Foxtail; Pearl millets

1. Introduction

The world cultivable land available is constantly shrinking because of human encroachment and the available lands are also being spoiled to the greater extent by accumulation of salts in high concentration especially in arid and semiarid regions with irrigation systems for crop production. As soil salinity is one of the main important constraints for agricultural production, better understanding of the mechanisms that enable plants to adapt to salt stress is necessary for exploiting saline soils/water (Ashraf and McNeilly, 1987; Blastensperger, *et al.*, 2000; Yensen, 1995 and Zhu, 2001).

Salt stress can lead to changes in growth, development, and productivity and severe stress may threaten plant survival. Salt stress caused changes in various biochemical and physiological processes of crop plants. However, salt induced osmotic stress, nutritional imbalance, specific ion toxicity, hormonal imbalance and reactive oxygen species are major factors reducing crop productivity (Ashraf and Idrees, 1992; Karyudi and Fletcher, 1999; and Katerji *et al.,* 2000). In view of these circumstances, there is need to develop plants, which could withstand salt stress

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and retain an acceptable level of productivity. During the course of evolution, different plants have developed adaptive characters against salt stress (Ashraf, 1994; Ulery *et al.*, 1998; Yensen 1995).

Of various crops, cereal crops (i.e. wheat, barley, rice and millets) cover almost 70% of the cultivated land, while wheat alone covers nearly 52% in Iran (Lal, *et al.,* 1990; Limon-Ortega, *et al.*, 1998). Millets are cultivated in some areas where other cereals are not able to produce satisfactory yield (Oelke *et al.*, 1990; Ulery *et al.*, 1998), because among cereals these species are best adapted crops to environmental adversaries including drought, salinity and extreme temperature, due to having C_4 photosynthetic pathways and short span of life cycle. Owing to these characters, after many centuries' millets are a permanent member of cropping pattern in dry and saline areas such as Iran, India, Algeria and Pakistan (Ashraf *et al.*, 2003; Blastensperger *et al.*, 2000 and Blatensperger, 2002). Based on FAO documents the area under cultivation of millets in Iran is 10000 ha, while the area was 17000 ha 30 years ago(FAO, 2003). South Khorasan is one of the main centers for millet production and all three types of millets, (proso, foxtail, pearl millet) are cultivated there and good amount of variation among landraces could be found. In this arid region, majority of millet fields are irrigating by brakish waters and still more saline water is available that could be applied for millet production.

The majority of research projects on millets were carried out in artificial growing conditions, which in many cases are not applicable to field conditions. Therefore, there is a necessity to arrange field experiments beside the controlled environment experiments. Most of papers published about response of millets to salinity concentrated on pearl millets. Ashraf and Idrees (1992) reported that all growth stages of pearl millets affected by salinity. Pre treatment of millet seeds by osmotic stress improved salt tolerance of this plant (Ashraf and McNeilly, 1987; Ashraf and Idrees 1992; and Ashraf *et al*., 2003). Some authors reported that if a good market could be found for millets, they could be good alternatives for maize and sorghum (Bidinger *et al.,* 1987; Blatensperger, 2002, Cash *et al.,* 1999, and Oelke *et al.*, 1990).

In this two years experiment, our objectives were to collect seeds of three main millet species from different locations of the province and the response of growth and yield of them was studied under different levels of salinity in irrigation water.

2. Materials and methods

This experiment was conducted in two successive years 2003-2004 in the Field Station of Birjand University in the east of Iran, with 32 ᵒ and 53 ´ North latitude, 59º and 13´ east longitude and 1480 meter altitude. Being adjacent to desert (Kavir) the climate is hot and dry in the summer and dry and cold in the winter. The average annual rainfall is 169 mm in this region and annual average minimum and maximum temperature are 4.6 and 27.5 °C. Average minimum and maximum relative humidity are 23.5 and 59.6%, respectively. The soil chemical characteristics are presented in Table 1.

Table 1. Soil chemical properties of the site of experiment in 0-30 cm layer

Depth Cm	Cl (mg/kg)	SO4 (mg/kg)	Anions (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	Na (mg/kg)	Cations (mg/kg)	SAR	EC dS/m	PH	CO3 (mg/kg)
0-30	13	4.5	21.75	5.3	4.7	11	21	5.25	2.35	8.5	4.25

Seeds were collected from the farmer fields from four main regions of South Khorasan namely, Birjand, Nehbandan, Ghaen and Sarayan, where each region is at least 100 km far from the next one and irrigation water of millet fields is mainly brakish. Pearl millet is cultivating only in Birjand, while proso and foxtail millets are producing in all four regions. Seeds were kept in room temperature conditions and at the time of sowing the germination rate of all seed masses were more than 90%.

Irrigation water used for imposition of salinity stress was pumped from three deep wells. There is a natural salinity gradient in ground water in the site, where three deep wells have three levels of salinity including 1.5, 5.5, and 9.5 dS/m, so, there was no requirement to transfer saline water from long distance or make the saline water treatment by adding salt to fresh water. The experiments were conducted using a split plot on the base of randomized complete block design with salinity level of irrigation water as main plots (1.5, 5.5, and 9.5 dS/m), and nine different millet genotypes (proso and foxtail millet from Ghaen, Sarayan, and Nehbandan, proso, foxtail and pearl millet from Birjand) as sub-plots in three replications.

Seeds of millets were sown in 25th May, 2003 with density of 200 plants per m^2 and 20 cm row space in 8 m^2 plots. The method of irrigation was flooding method and the volume of water to each plot was controlled by a water gauge. Irrigation intervals were different between 7- 10 days based on the growth stage and the rate of evapo-transpiration.

In order to study morphological traits including plant height and number of tillers per plant, five plants from each plot were selected randomly, but for measuring the yield components a complete row from each plot were selected. For measuring the seed weight, 1000 seeds from each plot weighted.

All millet genotypes were ripen by second fortnight of September, after harvesting two m^2 from the middle of each plot, biological, straw and grain yield were measured. Yield was expressed based on 12% moisture content of the grain. Harvest index was calculated by dividing grain yield by sum of grain and straw yield. For statistical analyzing of data MSTATC and Excel computer packages were used, and for mean comparison in 5% probability, least significant differences (LSD) was applied.

3. Results and discussion

3.1. Plant Height

Salinity stress significantly reduced plant height, so that, by increasing salinity level from 1.5, to 9.5 dS/m plant height decreased from 71.7 to 54 cm (Table 2). This result are in accordance with some earlier report in which it was reported that salt stress reduced the plant height in cereal crops by reducing internodal length (Ashraf and McNeilly, 1987; Blastensperger, *et al.*, 2000; Lal, *et al.,* 1990, and Masojidek and Trivedi 1991). In this experiment also the plant height reduced 2.2 cm by adding one dS/m of salinity in irrigation water in the average of two year. Different millet species also showed different plant height. Generally, foxtail and pearl millets were taller than proso millets. Salinity imposed its maximum effects on height of foxtail and pearl millets (Table 2).

Table 2: Plant height (Cm) of millet species from different areas of South Khorasan at different levels of salinity of irrigation water.

Salinity	Proso				Aver.	Foxtail				Aver.	Pearl	Aver.
dS/m	Ghaen	Sarayan	Nebandan	Birjand		Ghaen	Sarayan	Nebandan	Birjand		Birjand	
1.5	60 (1) efghij	64.3 defgh	54.3 efghijk	58.3 efghijk	46.0	48.7 hijk	99.0 a	80.3 cd	82.7 bc	77.7	98.0 ab	71.7
5.5	52.3 efghijk	50.7 fghijk	45.0 jkl	54.0 efghijk	50.5	42.0 kl	83.3 bc	68.0 cdef	69.0 cde	65.6	82.7 bc	60.78
9.5	45.7 ijkl	49.3 ghijk	49.0 hijk	55.7 efghijk	49.9	31.0 l	66.7 cdefg	62.7 efghi	66.7 cdefg	56.8	59.3 efghijk	54.0

(1) Means with at least one similar letter, are not significantly different (P= 0.05) based on least significant differences (LSD)

3.2. Tillers per Plant

Number of tillers per plant did not reduce significantly under salinity conditions; however, the highest number of tillers was achieved at lowest level of salinity and high level of salinity produced markedly lower tillers (Fig. 1). Different millet species showed significantly different number of tiller per plant. Proso and foxtail millet produced 4.4 and 3.2 tiller per plant in the presence of 9.5 dS/m, respectively. Pearl millet had lower tiller per plant than the other two millets and did not show high capability of tiller production at all levels of salinity (Table 3). It seems likely that due to low accumulation of salt in the soil before application of brakish water in our experiment site, the primary stages of millet development did not significantly affected by salinity (Sing and Sing, 1995; Yensen 1995). In this experiment plant density (200 plants/m2) was not also so high to inhibit tillering by inter plant competition (Blatensperger, 2002). Therefore, at high level of salinity the number of tillers was more than 3.5 per plant (Table, 3).

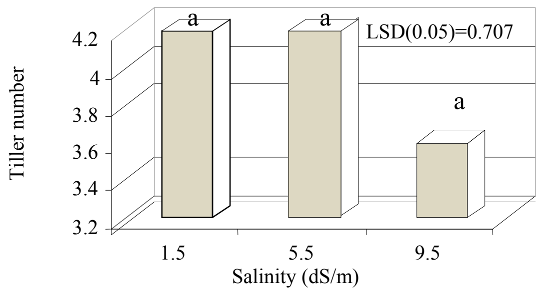

Fig. 1. Number of tillers per plant of millet species at three levels of salinity

Table 3: Number of tiller per plant of millet species from different areas of South Khorasan at different levels of salinity of irrigation water

Salinity	Proso				Aver.	Foxtail				Aver.	Pearl	Aver.
dS/m	Ghaen	Sarayan	Nebandan	Birjand		Ghaen	Sarayan	Nebandan	Birjand		Birjand	
1.5	6.1(1) ab	4.8 bcdef	4.8 bcde	4.5 bcdefg	5.1	4.9 abc	3.3 defghi	2.8 ghi	3.0 fghi	3.5	2.6 hi	4.1
5.5	7.1 a	7.5 bcdefg	3.7 defghi	4.8 bcdef	5.5	7.3	3.2 efghi	2.8 ghi	2.4 hi	3.9	2.3 i	4.4
9.5	5.1 bcd	4.4 bcdefg	4.2 cdefgh	3.9 defghi	4.4	4.5 bcdefg	2.9 ghi	2.7 ghi	2.7 ghi	3.2	2.4 i	3.6

(1) Means with at least one similar letter, are not significantly different (P= 0.05) based on least significant differences (LSD)

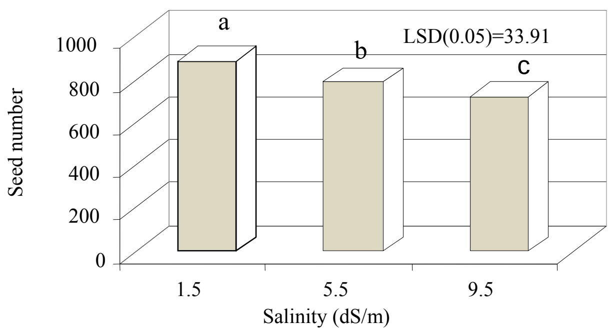

Fig. 2. Number of seeds per panicle of millet species at three levels of salinity

Amongst different millet species pearl millet produced the highest (1879) and proso millet produced the lowest number (411.5) of seed per panicle. Foxtail millet also produced higher number of seeds per panicle (1023) than proso millet (411.5). The main difference between millet species in number of seeds per panicle might be due to difference in florescence type. e.g. proso millet has panicle while foxtail millet has spike type florescence. Moreover, the number of seeds per panicle in the main stem is more than tillers in a particular plant, therefore, proso millet that have more tillers have less seeds per panicle.

At high level of salinity the rate of decrease in number of seeds per panicle were vary among millet species, for example, this number in proso, foxtail and pearl millets 306.2, 915.8, and 734.2, respectively (Table 4). Based on this yield component pearl millet was the most salt tolerant millet species.

Table 4: Number of grain per punicle of millet species from different areas of South Khorasan at different levels of salinity of irrigation water

Salinity dS/m	Proso				Aver.	Foxtail				Aver.	Pearl	Aver.
	Ghaen	Sarayan	Nebandan	Birjand		Ghaen	Sarayan	Nebandan	Birjand		Birjand	
1.5	325.2(1) jklmn	437.9 ij	266.4 igklm	255.8 mnl	321.3	488.3 i	1445.0 de	1547.0 d	1132.0 g	1153	2050.0 a	880.1
5.5	281.9 klmn	383.9 ijkl	313.6 jklmn	227.9 mn	301.8	417.0 ijk	1293.0 f	1470.0 d	850.7 h	1007.7	1868.0 b	789.5
9.5	250.3 lmn	386.8 ijkl	293.0 klmn	294.7 n	306.2	337.2 jklm	1252.0 fg	1323.0 ef	750.9 h	915.8	1721.0 c	734.2

(1) Means with at least one similar letter, are not significantly different (P= 0.05) based on least significant differences (LSD)

3.3. Seed weight

Seed size was also negatively affected by salinity stress. Seed weight of proso millet decreased from 2.95 mg in control to 2.62 mg at 9.5 dS/m salinity, respectively but this reduction was higher in foxtail and pearl millets (table 5). Since during irrigation of crop using brakish water, salts were accumulated in the soil gradually; grain filling stage of plants faced with high level of salt accumulation in the plant root medium and smaller grains might be produced (Ashraf and McNeilly, 1987; Karyudi, and Fletcher. 1999; and Katerji et al., 2000).

Different genotypes showed different seed size at all levels of salinity. The biggest seed size was produced by proso millet (Table 5). The average seed weight of proso and foxtail millets were 2.8, and 2.2mg, respectively. Different seed lots from different environments also had different seed sizes. But pearl millet had the smallest seed size at all circumstances. Seed size is a genetically controlled character which varies among plant species of a plant genus and differences in seed size among three millet species is quit normal (Ashraf and McNeilly, 1987; Blastensperger, *et al.*, 2000; Cash *et al.*, 1999; and Masojidek and Trivedi, 1991).

Table 5: Grain weight (mg) of millet species from different areas of South Khorasan at different levels of salinity of irrigation water

Salinity dS/m	Proso				Aver.	Foxtail				Aver.	Pearl	Aver.
	Ghaen	Sarayan	Nebandan	Birjand		Ghaen	Sarayan	Nebandan	Birjand		Birjand	
1.5	3.6(1) a	2.9 bc	2.5 cdef	2.8 bcd	2.95	2.4 efgh	2.5 cdefg	2.5 defg	2.5 defg	2.48	2.5 cdefg	2.69
5.5	3.4 a	2.7 bcde	2.5 cdefg	3.0 b	2.90	2.3 fgh	2.3 efgh	2.1 ghij	2.2 fghi	2.22	2.5 cdefg	2.55
9.5	3.0 b	2.4 cefgh	2.3 fghi	2.8 bcd	2.62	1.9 ij	1.7 j	2.0 hij	2.0 hij	1.90	2.1 fghij	2.24

(1) Means with at least one similar letter, are not significantly different (P= 0.05) based on least significant differences (LSD)

3.4. Seed yield

In both years, seed yield were affected by salinity, for instance, grain yield was reduced from 956 kg/ha in control to 771 kg/ha in medium and to 635.8 kg/ha in high level of salinity (table 6). But still at 9.5 dS/m salinity, millets produced more than 64% of their yield in no salinity stress conditions. In average, based on our results, by adding one unit of electrical conductivity of irrigation water, 40 kg/ha of millet grain yield will be lost.

The maximum grain yield was obtained from pearl millet with 1398 kg/ha (Table 6). The main yield component of this species that was more than the other two was number of seed per panicle. The average grain yield of foxtail and proso millet at high level of salinity were 671.3, and 454.9 kg/ha, respectively (Table 6). There were one foxtail genotype from Sarayan which produced the highest yield (1410 kg/ha) amongst other foxtail millets, but the best yield performance of proso millet was observed in landrace of ghaen (Table 6). These observations indicate that there is a good intraspecific variation among landraces of millets in different regions of production. Therefore, in south Khorasan the best landrace of proso, foxtail, and pearl millets were found in Ghaen, Sarayan and Birjand, respectively.

Regarding grain yield, the highest yielding millet for cultivation is pearl millet following by foxtail and proso millets, respectively. Interestingly, there is no significant different between the prices of millets in many countries due to using them mostly as bird feeding, therefore it is possible to replace high yielding millet species with the conventional millet species

Table 6: Grain yield (kg/ha) of millet species from different areas of South Khorasan at different levels of salinity of irrigation water

Salinity dS/m	Proso				Aver.	Foxtail				Aver.	Pearl	Aver.
	Ghaen	Sarayan	Nebandan	Birjand		Ghaen	Sarayan	Nebandan	Birjand		Birjand	
1.5	916.0(1) fgh	500.5 mno	858.1 ghij	580.6 klmn	713.8	1136.0 de	863.4 ghij	1410.0 b	728.5 ijk	1034.5	1161.0 a	906.0
5.5	721.9 jk	398.0 o	697.0 jkl	424.3 no	560.3	1000.0 efg	740.5 hijk	1063.0 def	528.6 lmno	833.0	1396.0 bc	774.4
9.5	608.9 klm	358.4 o	489.1 mno	363.0 o	454.9	788.4 hij	539.0 lmno	901.5 fghi	456.1 mno	671.3	1217.0 cd	635.8

(1) Means with at least one similar letter, are not significantly different (P= 0.05) based on least significant differences (LSD)

3.5. Straw Yield

Since straw is also an economic part of the plant in areas with shortage of fodder and forage, those crop genotypes that produce higher straw along with higher yield are more acceptable (Masojidek and Trivedi, 1991). Straw yield was also decreased by increasing salinity. By increasing irrigation water salinity from 1.5 to 9.5 dS/m, straw yield of proso reduced from 3822.3 to 3163.0 kg/ha, while foxtail millet produced the highest straw yield and straw yield this millet at 9.5 dS/m is higher that straw yield of proso in control conditions (Table 7). But there was no significant difference between 1.5 and 5.5 dS/m.

Table 7: Straw yield (kg/ha) of millet species from different areas of South Khorasan at different levels of salinity of irrigation water

Salinity dS/m	Proso				Aver.	Foxtail				Aver.	Pearl	Aver.
	Ghaen	Sarayan	Nebandan	Birjand		Ghaen	Sarayan	Nebandan	Birjand		Birjand	
1.5	4155(1) fghijk	3063 lmno	4141 fghijk	3930 hijkl	3822.3	5038 cdef	6944 a	4880 defgh	4603 defghi	5363.3	6347 ab	4787.7
5.5	4315 efghij	2743 no	3990 ghijkl	2841 mno	3472.3	5280 cde	4785 defgh	4967 defg	4180 fghijk	4803.0	5967 bc	4340.9
9.5	3936 hijkl	2425 o	3442 jklmn	2849 mno	3163.0	3730 ijklm	4462 efghi	3970 ghijkl	3257 klmno	3854.8	5563 bcd	3737.1

(1) Means with at least one similar letter, are not significantly different (P= 0.05) based on least significant differences (LSD)

3.6. Harvest Index

Harvest index is the ratio of grain yield to biological yield. It shows that how plant allocates its assimilates to harvestable organs. In those plants that manage to send more photosynthetates are transferred to economic organs, grain in cereals, harvest index will be higher. This index in conventional cereals like wheat and rice varies between 0.3 and 0.5 (Katerji, *et al*., 2000). Since both main parameters for harvest index calculation are under salinity effect, the outcome might not change significantly under stress, while both grain and biological yield decreased in the presence of salinity (Ashraf and McNeilly, 1987; Blatensperger, 2002; Lal, *et al.,* 1990 and Ulery *et al.*, 1998).

In this experiment salinity stress did not change harvest index, however, this index was affected by genotype. Average harvest index of proso, foxtail and pearl millet were 0.14, 0.15 and 0.19 (Table 8) which is comparatively lower that other cereals like wheat and rice. Even on control conditions the highest harvest index did not exceed 0.21 which was in pearl millet.

Table 8: Harvest Index of millet species from different areas of South Khorasan at different levels of salinity of irrigation water

Salinity dS/m	Proso				Aver.	Foxtail				Aver.	Pearl	Aver.
	Ghaen	Sarayan	Nebandan	Birjand		Ghaen	Sarayan	Nebandan	Birjand		Birjand	
1.5	0.18(1) bc	0.14 fgh	0.18 bc	0.13 hij	0.16	0.18 bc	0.17 bcd	0.15 efg	0.14 ghi	0.16	0.21 a	0.166
5.5	0.14 fgh	0.13 hij	0.15 efg	0.14 ghi	0.14	0.16 def	0.18 bc	0.13 ghij	0.12 j	0.15	0.19 b	0.15
9.5	0.14 ghi	0.14 ghi	0.13 hij	0.12 ij	0.13	0.18 bc	0.17 cde	0.12 ij	0.13 hij	0.15	0.18 bc	0.133

(1) Means with at least one similar letter, are not significantly different (P= 0.05) based on least significant differences (LSD)

In this experiment by increasing salinity of irrigation water from 1.5 to 9.5 dS/m, grian yield of proso, foxtail and pearl millets decreased 35.6, 37.2 and 24.5%, respectively, indicating that pearl millet is also tolerate higher salt compare with two other species. Therefore for areas that the source of irrigation water is brakish, pearl millet is the best millet species for cultivation. These results also confirm other results which indicate that those genotype that produce higher yield in ideal conditions they also produce higher yield in stress conditions.

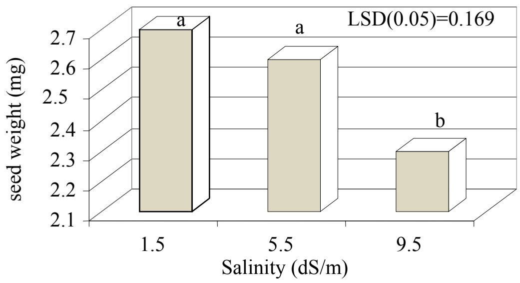

Fig. 3. seed weight (mg) of millet species at three levels of slinity

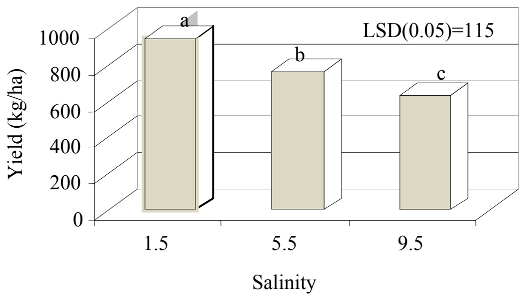

Fig. 4. Grain yield of millet species at three levels of salinity

References

Ashraf, M., A. Kausar and M.Y. Ashraf, 2003. Alleviation of salt stress in pearl millet (*Pennisetum glaucum*) through seed treatments. Agronomie: 23: 227-234.

Ashraf M., and N. Idrees, 1992. Variation in germination of some salt tolerant and salt sensitive accessions of pearl millet (*Pennisetum glaucum* (L.) R. Br.) under drought, salt and temperature stresses. Pak. J. Agric. 1:15-20.

Ashraf M. and T. McNeilly, 1987. Salinity effects on five lines/cultivars of pearl millet. (*Pennisetum americanum* L.). Plant and Soil 103:13–19.

Bidinger, F.R., V. Mahalakshmi, and G.D.P. Rao, 1987. Assessment of drought resistance in pearl millet (*Pennisetum americanum* (L.) Leeke). II.Estimation of genotype response to stress. Aust. J. Agric. Res. 38: 49-59.

Blastensperger, D., D. Lyon, R. Anderson, T. Holman, C. Stymiest, J. Shanahan, L. Nelson, K. De Boer, G. Hein and J. Kall., 2000. Producing and marketing proso millet in the high plains. University of Nebraska Cooperative Extension. PP 1-20.

Blatensperger, D.D., 2002. Program with proso, pearl and other millets. In: J. Janick and A. Whipkey (eds), Trends in New Crop and New Uses. ASHS press, Alexander,USA PP: 100-103.

Cash, D., D. Johnson and D. Wichman. 1999. Growing millet in Montana. Publication and Information. Animal and Range Science, Extension Service. Montana State University.

Food and Agriculture Organization (FAO) of the United Nations Regional Office for Asia and the Pacific. 2003. Selected Indicators of Food and Agriculture Development in Asia-Pacific Region 1992-2002. Bangkok

Karyudi, Ir. and R.J. Fletcher, 2003. Osmoregulation in birdseed millet under conditions of water stressII. Variation in F3 lines of *Setaria italica* and its relationship to plant morphology and yield. Euphytica. 132: 191-197.

Katerji, N., J. W. Van Hoorn, A. Hamdy, and M. Mastrorilli, 2000. Salt tolerance classification of crops according to soil salinity and to water stress day index. Agricultural Water Management. 46: 99-109.

Lal, P., A. Kumar, and S. C. Gupta, 1990. Effect of water stress and recovery on some physiological parameters at various growth stages of pearl millet. Proceeding of the International Congress of Plant Physiology, New Delhi, India. 2: 859- 865.

Limon - Ortega, A., S.C. Manson and A.R. Martin, 1998. Production practices improve grain sorghum and pearl millet competitiveness with weeds. Agron. J., 90: 227-232.

Masojidek, J., and S. Trivedi. 1991. The synergetic effect of drought and light stress in sorghum and pearl millet. Plant Physiol. 96: 198- 207.

Oelke, E. A., E. S. Oplinger, D. H. Putnam, B. R. Durgan, J. D. Doll, and D. J. undersandra. 1990. Millets, from Alternative Field Crops Manual. University of Wisconsin-Madison.

Sing, B.R. and D.P. Sing, 1995. Agronomic and physiological responses of sorghum, maize and pearl millet to irrigation. Field Crops Res. 42 :57-67.

Ulery, A.L., J.A.T. Martinus, Th. Van Genuchten and M.C. Shanon, 1998. Salt data: A database of plant yield response salinity. Agron. J. 90: 556 - 562.

Yensen, N.P., 1995. International symposium on high salinity tolerant plants. Edited by M. A. Khan and I. A. Ungar. University of Karachi, Karachi, Pakistan. PP: 1-12.

Zhu, J.K., 2001. Plant salt tolerance. Trends in Plant Science. PP. 66-71.