Emir. J. Agric. Sci. (1993), 5 : 59-81

Pearl Millet Response to Different Irrigation Water Levels : 1. Yield, Yield Components, and Crude Protein.

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ABSTRACT :

The effects of decreasing irrigation water levels on yield, yield components and percent crude protein of pearl millet (Pennisetum americanum (L.) K. Schum) were studied for two parents and their hybrid at Tucson, Arizona, in 1983 and 1984. These parameters were evaluated as possible indices for drought tolerance in millet. A line source sprinkler irrigation gradient was used to create the treatments (water levels).

Water stress significantly affected all parameters measured and the stress effects were more pronounced in 1983. Yield and yield components were reduced significantly by stress in both seasons and that was reflected in the reduced harvest index. Relative yield of dry matter was higher for the male in both seasons. The hybrid had the highest drought tolerance index in 1983, while the female had the highest drought tolerance index in 1984.

In 1983, when the stress was pronounced, yield was positively correlated with grain size, number of seeds per head, length of head, number of productive tillers, harvest index and drought tolerance index. The percent crude protein of seeds (weight basis) was increased significantly by stress by 38, 43, and 28%, in 1983, and by 47, 33, and 46% in 1984 for female, male, and hybrid, respectively.

Key words : Gradient, Drought index, Relative yield.

INTRODUCTION

Pearl millet (Pennisetum americanum (L.) K. Schum) is considered one of the most important crops in the Indian sub-continent and in Africa. Millet is an important grain crop on some 31 million ha of the world, where semi-arid conditions prevail (Burton et al., 1980). No crop seems better able to supply the major food requirements for man in the dry, infertile lands of the tropics. Despite the importance, there is little work in millet performance under such conditions.

In cereals, grain yield can be expressed by the equation, grain yield = growth rate x growth duration x harvest index (Bramel-Cox et al., 1984). Yield gains to date have been obtained almost entirely from increase in harvest index, but little possibility exists for further improvement in this trait. Studies by Okono and Vanderlip (1980) have shown a close positive relationship between seed size, vigor and grain yield. With the introduction of high yielding millet hybrids, it became essential to work out the agronomic requirements under different agro-climates (Kaushik and Gautam, 1980). As indicated by Praeger et al. (1980), the highest yielding millet hybrids were comparable to hybrid grain sorghum (Sorghum bicolor L. Moench) of the same maturity.

Millet has a higher protein content (8.8 to 20.9 %) than other cereals grown under similar conditions (Burton et al., 1972). However, the reason for the higher protein content is not clear (Pomeranz et al., 1980). Results of Nwasike et al. (1979) and Pomeranz et al. (1980) indicated that millet protein was similar to corn (Sea mays L.) rather than that of grain sorghum in the distribution and laysine content of the protein fractions. In general, millet is low in lysine, tryptophan, threonsione, and sulfur containing amino acids, as are other cereals (Pomeranz et al., 1980).

The effects of water deficits at different stages of development on crop growth and yield have been studied extensively and early work in this area has been summarized for cereals by Salter and Goode (1967) and Begg and Turner (1976). Passioura (1976) stated that if water was limited, grain yield of cereals depended on the amount of water which the plant used between anthesis and maturity. Gregory and Squire (1979) reported that yield of the irrigated millet crop was higher than that of the dry crop mainly because more tillers survived to produce grain.

Yield and yield components were found to be very useful indicators for drought resistance in many crops (Rosielli and Hamblin, 1981; Vidal and Arnoux, 1981; Stewart et al., 1983; Garrity et al., 1984; Mechel et al., 1984; and Pandey et al., 1984). Rosielli and Hamblin (1981) defined tolerance to stress as the difference in yield between stress and non-stress environments, while mean productivity was the average yield in stress and non-stress environments.

Drought tolerance index was considered by Vidal and Arnoux (1981) as a good basis for which to define new selection criteria for drought tolerance in soybean (Glycine max L.). They regarded the drought tolerance index as independent of earliness and the productivity of cultivars. Panicle exsertion was found by O'Toole and Namuco (1983) to decrease in rice (Orza sativa L.) by water stress. According to Singh and Kanemasu (1980), millet genotypes having high yield reduction had high reduction in number of heads under no irrigation. Thus, head number might be an index of drought tolerance.

The primary objectives of this research were, a) to study the effects of decreasing water levels on yield parameters and protein content of millet, and b) to point out possible useful indices for drought tolerance for grain yield.

MATERIALS AND METHODS

The experiment was carried out in 1983 and 1984 at Tucson, Arizona, to study the performance of three millet entries at different water levels. Millet entries were provided by W.D. Stegmeier, Kansas State University. The entries; namely, 81-1014 female (a male sterile early maturing genotype); Senegal-Bulk male, (a selection from a bulk drought tolerant population); and their hybrid, were planted on 26 April, 1983 and 1984, in east-west rows, 100 cm apart on a Brazito sandy loam soil.

The experiment was a split-plot in a randomized complete block design with four replications. The entries were assigned to the main plots, which consisted of 14 rows each side of the water source line and 4.5 m wide, with water levels as sub-plots. Sub-plots were taken as high water level for the seventh and eighth rows, and low water level for the last two rows away from the water source line.

The field was planted at a rate of 120 seeds per 4.5 m plot (20 kg/ha) in 1983, and 180 seeds per 3.0 m plot (40 kg/ha) in 1984. The seed rate was doubled in 1984 as the germination percentage of seeds was lower. In both seasons, the field was furrow-irrigated to field capacity immediately after planting. After emergence, the field was thinned to a uniform stand (approximately 10 to 15 cm between plants).

At the five leaf stage of growth, the sprinkler line was set-up. The system consisted of a single line of sprinklers which was located at the center of the plots and parallel to the crop row direction. Catch cans were located between the entries in the row of each replication at 200 cm intervals. Water was measured from the catch cans throughout the season after each irrigation or rainfall. Irrigation was applied for an average of 1 hour in the early morning when wind speed was low. Wind speed in 1983 resulted in decreased water application, which placed severe stress on the plants. In 1983, the treatments received a total of 61.2, 26.4, and 9.4 cm of water, while in 1984, they received 67.3, 29.0, and 15.6 cm of water for high, medium and low water levels, respectively. Water levels were different due to wind speed effects and differences in rainfall (24 mm in 1983, and 129 mm in 1984).

At anthesis, heads were bagged in both seasons to prevent severe problems caused by birds eating the grain and to obtain estimates of yield. Two plants from each plot were randomly sampled, and the number of seeds was counted for the main head, using the electronic seed counter Model 850-3 (manufactured by Old Mill Company, Savage, Maryland). The same plants were used in the determination of both numbers of total and productive tillers. Length of head and head exsertion, as the distance between the colar of the flag leaf and the bottom of the head, were measured. One-hundred random seeds were weighed from each sample and the weight was then adjusted to 1000-seed weight.

Yields and dry weights were used to calculate harvest index, relative yield, and drought tolerance index, as follows :

Harvest index (O'Neill, 1982) =

$$\frac{\text{Weight of grains per plant x 100}}{\text{Total shoot dry weight per plant}}$$

Relative yield of dry matter (Vidal and Arnoux, 1981)=

$$\frac{\text{Shoot dry weight at low water level x 100}}{\text{Shoot dry weight at high water level}},$$

Drought tolerance index (Vidal and Arnoux, 1981) =

$$\frac{\text{Weight of grains at low water level x 100}}{\text{Weight of grains at high water level}},$$

Seeds were taken to the laboratory for crude protein determination and were analyzed by a modified Kjelkahl digestion method (Summerfield, et al., 1977). Samples were weighed (about 0.5 g) and put into 25 x 200 mm pyrex test tubes with 1.0 g K_2SO_4, 0.1 g Na_2SeO_3, and 10 ml concentrated H_2SO_4. Samples were then digested at approximately 400 C on a block digester until they turned to a clear amber color. The tubes were removed and placed in test tube racks to cool. The digestate was then quantitatively transferred to a 100 ml volumetric flask along with 3g K_2SO_4. The sample was diluted to the mark with de-ionized water and transferred to polyethylene bottles.

Aliquat of the digest (0.4 m) was injected into a Technicon Auto analyzer (manufactured by Technicon Industrial System, Terrytown, New York), which quantitatively detected ammonia by indophenol-blue formation in the presence of sodium phenate and sodium hypochlorite. Different peaks for different samples were drawn and ppm of nitrogen were found from the peaks in reference to standards. Percent nitrogen was calculated by the equation :

$$\% N = \frac{(PPM)\ (100)(10)\ 100}{\text{Sample weight}}$$

Percent crude protein was obtained by multiplying the percent nitrogen by 6.25 based on the assumption that about 16%of protein is nitrogen (Chapman and Pratt, 1961).

RESULTS AND DISCUSSION

Grain Characters

Grain yield of all entries was significantly higher at the high than at the low water levels in both seasons (Tables 1 and 2). This was attributed to the increase in sterility of spikelets under water stress (O'Toole and Namuco, 1983). In 1983, when stress was pronounced, the female had a significantly lower yield at both high and low water levels due to male sterility (Table 1). However, in 1984, there were no

Table 1. Yield and yield components for three millet entries grown under a sprinkler gradient line in 1983.

Entries	Water treatments	Total tillers (Number)	Productive tillers (Number)	Head exsertion (cm)	Head length (cm)	grains $head^{-1}$ (Number)	Grain yield ($t\ ha^{-1}$)	1000-grain wt. (g)
Female 81-1014	High	7.13a†	6.00a	3.89a	16.40c	338.13c	1.92b	11.06a
	Medium	5.50a	3.75a	1.44b	17.12c	109.38d	-	6.26b
	Low	4.50a	0.25c	0.24c	8.11d	12.17e	0.48d	1.21b
Male Senegal Bulk	High	6.38a	2.50b	1.64b	32.84a	1584.13a	2.16a	9.48b
	Medium	6.25a	1.13b	0.84b	31.65a	291.63c	-	7.87b
	Low	5.75a	0.08c	0.04c	10.18d	32.63e	0.96c	2.27b
Hybrid 81-1014 x Senegal Bulk	High	7.13a	4.63a	3.39a	27.91b	831.63b	2.21a	12.18a
	Medium	6.50a	2.25b	0.85b	23.96b	341.31c	-	8.51b
	Low	6.50a	0.50c	0.20c	10.25d	113.75d	1.16c	9.73b

†Means followed by the same letter within each column are not significantly different at the 5% level according to the SNK Method.

Table 2. Yield and yield components for three millet entries grown under a sprinkler gradient line in 1984.

Entries	Water treatments	Total tillers (Number)	Productive tillers (Number)	Head exsertion (cm)	Head length (cm)	Grains $head^{-1}$ (Number)	Grain yield ($t\ ha^{-1}$)	1000-grain wt. (g)
Female 81-1014	High	6 25a[†]	1.25a	4.95a	29.21a	1698.75a	3.24a	8.50a
	Medium	6.13a	1.38a	3.44a	29.60a	1231.63b	-	6.88a
	Low	7.75a	1.38a	1.05b	19.39b	221.00c	1.54b	4.88b
Male Senegal Bulk	High	8.63a	1.75a	3.37a	31.39a	1563.25a	3.15a	8.50a
	Medium	6.25a	0.88a	3.09a	24.49a	1242.38b	-	6.13a
	Low	10.00a	0.31a	0.50b	20.75b	135.25c	1.30b	4.63b
Hybrid 81-1014 x Senegal Bulk	High	6.25a	1.38a	5.16a	29.90a	1598.63a	2.96a	9.88a
	Medium	6.25a	1.00a	1.83a	26.68a	926.25b	-	8.63a
	Low	6.63a	0.88a	1.45b	20.24b	153.75c	1.23b	3.38b

[†]Means followed by the same letter within each column are not significantly different at the 5% level according to the SNK Method.

significant differences among entries at high or low water levels, but the male-sterile female had a relatively higher yield (Table 2). Increased bee activity or the greater amount of water available to stressed plants at anthesis may have accounted for the higher yield in 1984.

Grain weight was significantly reduced by stress (Tables 1 and 2). However, in 1983, there were no significant differences in the male parent at all water levels (Table 1). The grains were heavier at high water level in 1983 than in 1984. However, at low water level, the grains were heavier in 1984, except for the hybrid which had heavier grain in 1983 (Tables 1 and 2). Under stress, grains were the heaviest for the hybrid in 1983 and for the female parent in 1984.

Tillering Capacity :

There were no significant differences among entries or water levels in total tiller number in both seasons (Tables 1 and 2). The number of productive tillers showed no significant differences among entries or water levels in 1984 (Table 2) and a significant differences among water levels in 1983 (Table 1). Severe stress in 1983, as compared to 1984, resulted in a significant decrease of productive tillers. The number of productive tillers at high or medium water levels was greater in 1983 than in 1984. However, at low water level, all entries showed higher productive tillers in 1984.

Head Characters :

Head exsertion was reduced significantly by water stress in both seasons (Tables 1 and 2). The degree of exsertion being a visible response to waterstress has also been reported in rice (Cruz and O'Toole, 1984). Under low water level, the female had the greatest exsertion in 1983, while the hybrid had the highest degree of exsertion in 1984. Exsertion of all entries, at all water levels, was found to be greater in 1984 than in 1983 (Tables 1 and 2).

There was a significant reduction in head length by stress in 1983 (Table 1) and in 1984 (Table 2). At high and medium water levels, there was a significant difference among entries in 1983 (Table 1), while there was no significant difference among entries at low water level in each season. Due to higher amounts of water in 1984, head length was greater at all water levels. There was a significant reduction in number of grains per head with water stress at both seasons. The number of grains per head was fewer in 1983 than in 1984 at both high and low water levels due to the reduced amount of water received in 1983.

Calculated Parameters :

There were no significant differences among entries at low water level for harvest index in both seasons (Table 3). However, at high water level, the female parent had a significantly lower harvest index than the other two entries in 1983, while there was no difference in 1984 (Table 3). Water stress reduced the harvest index significantly for all entries in both seasons. The reduction in harvest index was caused

Table 3. Calculated yield parameters for three millet entries grown under a sprinkler gradient line in 1983 and 1984.

	1983				1984			
	Water-treatment High	Water-treatment Low	Relative yield	Drought tolerance index	Water-treatment High	Water-treatment Low	Relative yield	Drought tolerance index
Entries	Harvest index	Harvest index	Dry matter	Grain	Harvest index	Harvest index	Dry matter	Grain
Female 81-1014	0.05 b*^	0.0003 a*	0.29	0.002	0.21 a*	0.01 a*	0.47	0.03
Male Senegal Bulk	0.24 a*	0.0020 a*	0.45	0.003	0.21 a*	0.01 a*	0.54	0.02
Hybrid 81-1014 x Senegal Bulk	0.19 a*	0.0200 a*	0.44	0.040	0.19 a*	0.01 a*	0.51	0.02

^ Means followed by the same letter within each column are not significantly different at the 5% level according to the SNK Method.

* Treatment means indicated horizontally are significantly different each year at the 5% level according to the SNK Method.

by the reduction in grain yield which was more sensitive to water stress than total plant yield (Biomass or biological yield), as stated by Pandey et. al., (1984). Harvest index, in general, was higher for both high and low water levels in 1984 than in 1983 for all entries due to increased grain yield resulting from the high total amount of water applied. Under stress, the hybrid had the highest harvest index in 1983 though not significant, while in 1984, all entries had the same harvest index (Table3).

The relative yield of dry matter was higher for the male (0.45, 0.54) and hybrid (0.44, 0.51) than for the female (o.29, 0.47) in 1983 and 1984, respectively (Table 3). The hybrid had the highest drought tolerance index in 1983, followed by the male and female parents (Table 3). In 1984, the hybrid and the male parent had lower drought tolerance index than the female parent. Drought tolerance index and relative yield were independent of earliness and Productivity of entries as reported before by Vidal and Arnoux (1981) and Singh and Kanemasu (1980), who used the term, grain-yield stability, instead of drought tolerance index and relative yield.

Protein :

The crude protein percentage on a weight basis, was significantly increased by stress (Tables 4 and 5). The crude protein percentage was greater in 1983 for all entries at high water level and for female and male at low water level than in 1984 (Fig. 1).

The increase in crude protein due to water stress was 38, 43, and 28 %, in 1983, and 47, 33, and

Table 4. Observed F-values of percent crude protein of seeds for three millet entries grown under a sprinkler gradient line in 1983

Source	Degrees of Freedom	Sum of Squares	Mean of Squares	F-value	Significance 0.05	0.01	
Subplot	35	291.97	8.34	..	..	..	..
Main plot	11	81.20	7.38	..	..	..	..
Blocks (B)	3	21.53	7.18	..	..	..	..
Entries (E)	2	7.03	3.52	0.40	5.14	10.92	NS
Main plot error	6	52.64	8.77	..	..	..	..
Treatment (t) (Water levels)	2	127.38	63.69	15.65	5.14	10.92	**
Interaction (EXT)	4	4.52	1.13	0.25	32.6	5.41	NS
Subplot error	18	78.87	4.38	..	..	..	..
Blocks x treatment (BT)	6	24.44	4.07	..	..	..	..
Blocks x treatment x entries (B x T x E)	12	45.43	4.54	..	..	..	..

NS = Not significant at 0.05 level
** = Highly significant (0.01)

Table 5. Observed F-values of percent crude protein of seeds for three millet entries grown under a sprinkler gradient line in 1984

Source	Degrees of Freedom	Sum of Squares	Mean of Squares	F-value	Significance 0.05	0.01	
Subplot	35	447.97	12.80	..	..	..	..
Main plot	11	28.36	2.58	..	..	..	..
Blocks (B)	3	3.61	1.20	..	..	..	..
Entries (E)	2	17.78	8.89	7.66	5.14	10.92	*
Main plot error	6	6.97	1.16	..	..	..	..
Treatment (t) (Water levels)	2	348.31	174.16	39.67	5.14	10.92	**
Interaction (EXT)	4	11.94	2.99	1.00	3.26	5.41	NS
Subplot error	18	59.36	3.30	..	..	..	..
Blocks x treatment (BT)	6	26.34	4.39	..	..	..	..
Blocks x treatment x entries (B x T x E)	12	33.02	2.75	..	..	..	..

NS = Not significant at 0.05 level
** = Highly significant (0.01)
* = Significant at 0.05 level

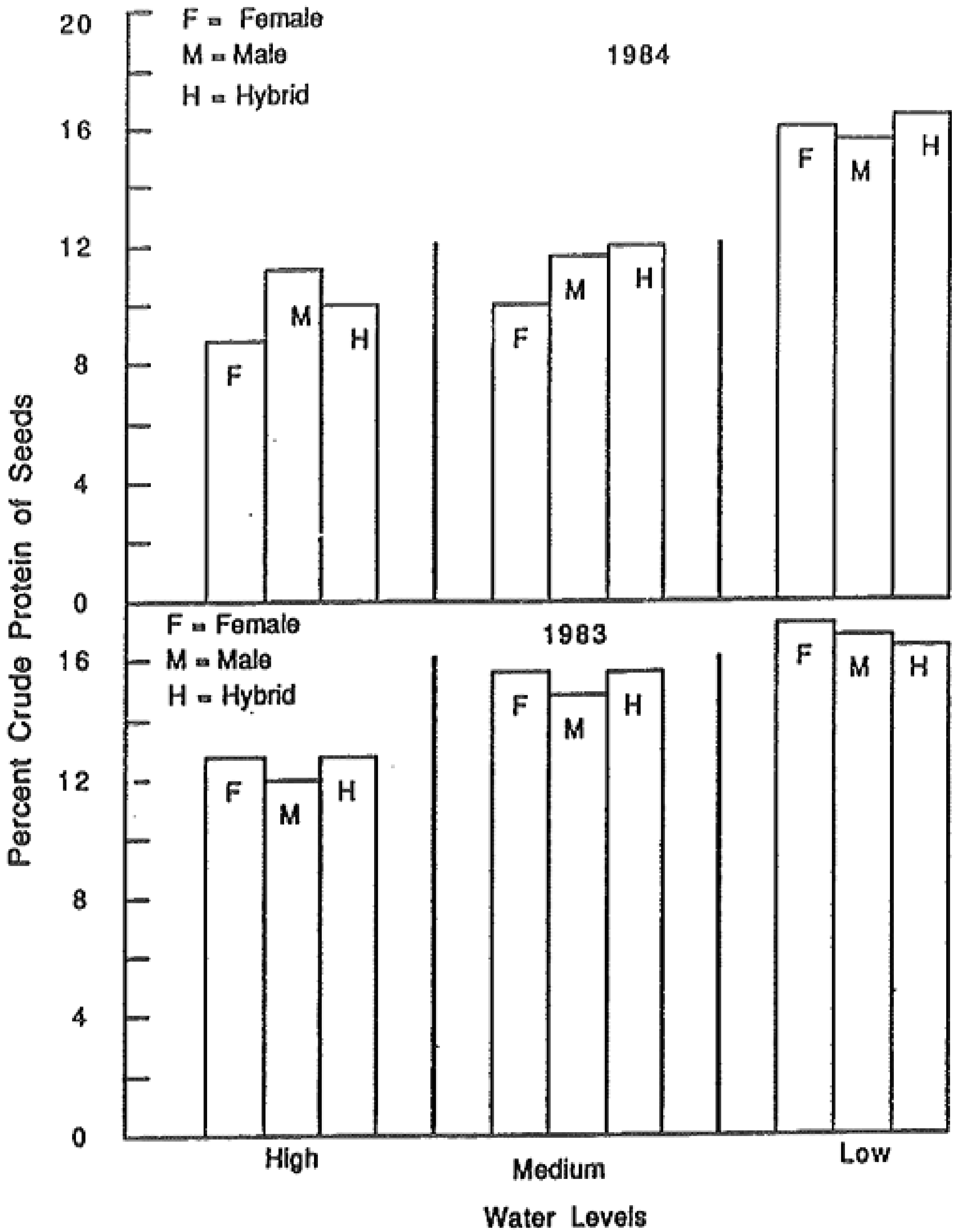

Fig. 1. Percent crude protein of grains (weight bases) of three millet entries grown under a sprinkler gradient line in 1983 and 1984.

46 % in 1984 for female, male, and hybrid, respectively. Similar results have been reported by Campbell et al. (1981) who found an increase in protein of spring wheat under high moisture stress during boot stage. In contrast, Carter and Sheaffer (1983) found that the crude protein of alfalfa was not affected by plant water status.

Indices of Drought :

Under severe stress, the hybrid was the best yielder in 1983 (Table 1). The hybrid yield was directly related to number of grains per head, length of head, number of total tilers, number of productive tilers, grain size, harvest index, and drought tolerance index as stated previously (Ibrahim et al. 1986). These parameters can be used as yield indices under severe drought conditions. On the other hand, head exsertion was not related to yield. In 1984, the female yield was the highest under water stress and was directly correlated to number of seeds per head, grain size, number of procutive tillers, and drought tolerance index (Table 2). However, length of head, exsertion, and number of tillers were not correlated to yield as shown in a previous study by correlation coefficients (Ibrahim et al., 1986).

Results of this study showed that not all the indices used correlated well with yield, but as stated by O'Toole et al. (1984) "these parameters represent processes of production that can be markedly affected by water stress." Due to these complexities, Aragon and DeData (1982) suggested that drought tolerance should not be equated solely with grain yield.

CONCLUSIONS :

From the investigation reported above, the following can be concluded : a) Water stress significantly affected all parameters measured in both seasons; b) When such stress was pronounced in 1983, the hybrid outyielded both parents; c) Relative yield and tiller number appeared to be good indices for forage production; d) Stress increased the percent crude protein of seeds; e) Not all indices used correlated with yield in this study; f) Identification of stable and drought tolerant genotypes was difficult due to seasonal and varietal differences with the different indices used.

REFERENCES

Aragon, E.L. and S.K. DeDatta. 1982. Drought response of rice at different nitrogen levels using line source sprinkler system. Irrig. Sci. 3:63-73.

Begg, J.E. and N.C. Turner. 1976. Crop water deficits. Adv. in Agron. 28:161-217.

Bramel-Cox, P.J., D.J. Andrews, F.R. Bidinger, and K.J. Frey. 1984. A rapid method of evaluating growth rate in pearl millet and its weedy and wild relatives. Crop Sci. 24 : 1187-1192.

Burton, G.W., A.T. Wallace, and K.O. Rachie. 1972. Chemical composition and nutritive value of pearl millet (Pennisetum typhoides) (Burn) Stapt and E.C. Hubbard) Grain. Crop Sci. 12:187-188.

...., R. Rabson, and H. Axman. 1980. Immediate effect of male and female gametes on five pearl millet grain characteristics. Crop Sci. 20 : 7-9.

Campbell, C.A., H.R. Davison, and G.E. Winkleman. 1981. Effect of nitrogen, temperature, growth stage and duration of moisture stress on yield components and protein content of Manitou spring wheat. Can. J. Plant Sci. 61: 549-563.

Carter, P.R. and C.C. Sheaffer. 1983. Alfalfa response to soil water deficits. I. Growth, forage quality, yield, water use, and water use efficiency. Crop Sci. 23:669-675.

Chapman, H.D. and P.E. Pratt. 1961. Methods of analysis for soils, plants and waters. Univ. of Calif. Divi. of Agric. Sci. Chap. 17:150-160.

Cruz, R.T. and J.C. O'Toole. 1984. Dryland rice response to an irrigation gradient at flowering stage. Agron. J. 76:178-183.

Garrity, D.P., C.Y. Sullivan and D.G. Watts. 1984. Changes in grain sorghum stomatal and photosynthetic response to moisture stress across growth stages. Crop Sci. 24:441-446.

Gregory, P.J. and G.R. Squire. 1979. Irrigation effects on roots and shoots of pearl millet (Pennisetum typhoides). Expl. Agric. 15 : 161-168.

Ibrahim, Y.H., V. Marcarian and A.K. Dobrenz. 1986. Drought tolerance aspects in pearlmillet. J. Agron. ad Crop Sci. 156:110-116.

Kaushik, S.K. and R.C. Gautam. 1980. Response of pearl millet hybrids to nitrogen levels under dryland conditions. Indian J. Agric. Sci. 50(7):577-580.

Mechel, L., D.B. Egli, E.R. Philips, D. Radcliffe, and J.E. Leggett. 1984. Effect of moisture stress on seed growth in soybeans. Agron. J. 76:647-650.

Nwasike, C.C., E.T. Mertz, R.C. Pickett, D.V. Glover, B.A.K. Chibber and S.W. Van Scoyoc. 1979. Lysine level in solvent fractions of pearl millet. J. Agric. Food Chem. 27:1329-1331.

Okono, J. and R.L. Vanderlip. 1980. Effect of crop management on seed quality, subsequent seedling establishment and grain yield of pearl millet. Third annual report : Improvement of pearl millet. Manhattan, KS. 66506. p. 71-74.

O'Neill, M.K. 1982. The development and water use of moisture stressed and non-stressed sorghum (Sorghum bicolor L, Moench). Ph.D. Disertation. Univ. of Arizona, Tucson, AZ. 85721.

O'Toole, J.C. and O.S. Namuco. 1983. Role of panicle exsertion in water stress induced sterility. Crop Sci. 23:1093-1097.

...., N.C. Turner, O.P. Namuco, M. Dingkuhn and K.A. Gomez. 1984. Comparison of some crop water stress measurement methods. Crop. Sci. 24(6):1121-1129.

Pandey, R.K., W.A.T. Herrera and J.W. Pendleton. 1984. Drought response of grain legumes under irrigation gradient. I. Yield and yield components. Agron. J. 76:549-553.

Passioura, J.B. 1976. Physiology of grain yield in wheat growing on stored water. Aust. J. Plant Physiol. 3:559-565.

Pomeranz, Y., R.C. Hoseney, E. Varriano-Marston and D.A.V. Dendy. 1980. Sorghum and millets. Chapter for advances in cereal science and technology. Third annual report. Improvement of pearl millet. Manhattan, KS. 66506. p. 208-319.

Praeger, H.A. Jr., R.L. Vanderlip and W.D. Stagmeier. 1980. Yield evaluations of pearl millet (Pennisetum americanum L. Leeke). Third annual report. Improvement of pearl millet. Manhattan, KS. 66506. p. 66-69.

Rosielli, A.A. and J. Hamblin. 1981. Theoretical aspects of selection for yield in stress and nonstress environments. Crop Sci. 21:943-946.

Salter, P.J. and J.E. Goode. 1967. Crop responses to water at different stages of growth. Common W. Agric. Bur. Farrham Royal, Bucks, England.

Singh, P. and E.T. Kanemasu. 1980. Soil water, plant water, and temperature relation of millet (Pennisetum americanum L. Leeke) and their relationship to crop yields. Third annual report.

Improvement of pearl millet. Manhattan, KS. 66506. p. 75-93.

Stewart, B.A., J.T. Musick and D.A. Dusek. 1983. Yield and water use efficiency of grain sorghum in a limited irrigation dryland farming. Agron. J. 75:629-643.

Summerfield, R.J., P.J. Dart, P.A. Huxley, A.R.J. Eaglesham, F.R. Minichin, and J.M. Day. 1977. Nitrogen nutrition of cowpea (Vigna unguiculata). I. Effects of applied nitrogen and symbiotic nitrogen fixation on growth and seed yield. Expt. Agric. 13 : 129-142.

Vidal, A. and M. Arnoux. 1981. Drought tolerance proceses in soybeans. Biologia plantarum 23(6): 434-441.

إستجابة محصول الدخن لمستويات مختلفة من مياه الري

١- الإنتاج ومكوناته والبروتين الخام

يس محمد إبراهيم[١] وفيكتوريا ماركريان[٢] و أ.ك. دوبرنز[٢]

درس تأثير إضافة كميات متناقصة من مياه الري على إنتاج محصول الدخن ومكوناته ونسبة البروتين الخام في الحبوب على أبوين وهجينهما بمدينة توسان بولاية أريزونا الأمريكية عامي ١٩٨٣ و ١٩٨٤ وقيمت تلك الصفات كمعاملات ممكنة لقياس التحمل للجفاف في الدخن وقد أستعملت طريقة الري بالرش لإعطاء كميات مياه مختلفة .

وقد تأثرت معنوياً كل الصفات المقاسة بنقصان الماء وقد كان التأثير أكثر وضوحاً عام ١٩٨٣، وإنخفض الإنتاج ومكوناته إنخفاضاً جوهرياً في الموسمين بإنخفاض مستوى الماء وقد إنعكس ذلك في معامل الحصاد ، وكان الإنتاج النسبي للمادة الجافة عالياً بالنسبة للأب المذكر في الموسمين وقد أعطى الهجين أعلى معامل لتحمل الجفاف في عام ١٩٨٣ بينما أعطى الأب المؤنث أعلى معامل في عام ١٩٨٤ .

وفي موسم ١٩٨٣ حيث كان الجفاف أكثر وضوحاً كانت علاقة الإنتاج إيجابية مع حجم الحبوب وعدد الحبوب بالنورة وطول النورة وعدد الخلف المنتجة ومعامل الحصاد ومعامل التحمل للجفاف . وقد إزدادت نسبة البروتين الخامس بالحبوب زيادة معنوية مع زيادة الجفاف بنسب ٣٨٪، ٤٣٪ ، و ٢٨٪ وبنسبة ٤٧٪ ، ٣٣٪ و ٤٦٪ لموسمي ١٩٨٣ و ١٩٨٤ في كل من الأم والأب والهجين على التوالي .

كلمات مفتاحية : التدرج ، معامل الجفاف ، الإنتاج النسبي

١- كلية العلوم الزراعية .. العين .. ص .ب . ١٧٥٥٥ - دولة الإمارات العربية المتحدة .

٢- شعبة الإنتاج النباتي - كلية الزراعة .. جامعة أريزونا .. توسان ٨٥٧٢١ .. أريزونا .. الولايات المتحدة الامريكية .