Emir. J. Agric. Sci. 1995. 7: 20-38

Peral Millet Response to Different Irrigation Water Levels : II. Porometer Parameters, Photosynthesis, and Water Use Efficiency

Y. M. Ibrahim[1] , V. Marcarian[2] and A. K. Dobrenz[2]

1 Ministry of Agriculture, P.O. Box 439, Muscat 111, Oman.
2 Dept. Plant Sciences, University of Arizona. Tucson, Az. 85721. U.S.A.

ABSTRACT :

A sprinkler irrigation gradient line was used to evaluate the physiological response of three millet (*Pennisetum americanum* L. K. Schum) entries at Tucso, Arizona in 1983 and 1984. Due to shortage of water in the southwest, drought tolerance indices were evaluated to point out the good indicators of the plant to water shortage. Water stress affected significantly all parameters measured and the effects were more pronounced in 1983.

Transpiration and differential temperature (abmient temperature minus leaf temperature) were reduced siginificantly by stress. Leaf diffusive resistance and leaf temperature were increased by water stress in both seasons. Stability regression analysis provided no adequate differentiation among genotypes. The significant reduction in photosynthesis with water stress was 27, 61, and 47% for female, male, and hybrid, respectively in 1984. Water use efficiency of dry matter and grain yield decreased with stress in both seasons.

Key words : Drought tolerance, Stability, Transpiration, Water use efficiency.

INTRODUCTION

Pear millet (*Pennisetum americanum* L. K. Schum) is one of the most important crops that grow in arid and semiarid areas of the world for both food and forage production. The physiology of the crop is very important under water stress as the crop is considered one of the most drought tolerent.

Various physiological indices have been used to differentiate millet genotypes response to water stress (Singh et al., 1983), and many techniques have been used to indicate water stress intensity. The most commonly used indicators were photosynthesis (Hofmann et al., 1984); transpiration (Hofmann et al., 1984; Ibrahim et al., 1985 and 1986, and Ibrahim 1992); evaportanspiration (Sharrat et al., 1983); diffusive resistance (Hofmann et al., 1984 and Ibrahim 1992); water use efficiency (Squire et al., 1984 and Ibrahim et al. 1985); leaf temperature (Singh and Kanemasu 1983 and Ibrahim 1992); and differential temperature (Singh and Kanemasu 1983 and Ibrahim, 1992)

Diffusive resistance by itself is not always a good indicator of a plant's response to water shortage. Transpiration depends on both diffusive resistance and leaf area, and many species are known to conserve water by losing some of their leaves (Squire et al., 1981). Singh and Kanemasu (1980) found that the relative leaf diffusion resistance, which is further defined as the ratio of cummulative afternoon leaf diffusion resistance under no irigation for a given genotypes to its cummulative afternoon resistance under irrigation, was also directly related to the perentage reduction in grain and total yields under rain-fed treatments. Singh and Kanemasu (1980) also showed that tall genotypes were stressed even under irrigation in the 1980 dry and hot season and concluded that leaf diffusion resistance was correlated to the amount of soil water depletion.

According to Rosielli and Hamblin (1981) the most widely used criteria for selecting for high and stable performance were mean yield, regression response on site mean yield and deviations from regression. This stable performance method was used by Finalay and Wilkinson (1963); Rosielli and Hamblin (1981); and Hofmann, et al. (1984).

Finalay and Wilkinson (1963) proposed that regression coefficients approaching zero indicated stable performance, while Langer, et al. (1979) proposed used of variety ranges (highest mean yield minus lowest mean yield) as a crude measure of stability across variable environments. Rosielli and Hamblin (1981) concluded that lines with high tolerance to stress would be expected to have low regression coefficient stability parameters.

The main objectives of this research were to study some physiological response of pearl millet under various irrigation levels and to evaluate some drought tolerance indices.

MATERIALS AND METHODS

Field experiments were conducted in Tucson, Arizona in 1983 and 1984 under line source sprinkler irrigation system to study the physiological perforamce of three millet entries at different irrigation water levels. The entries, 81-1014 female, a male sterile early maturing genotypes; Senegal-bulk male, a selection from a bulk drought tolerant population; and their hybrid, were planted on 26 April 1983 and 26 April 1984 in east - west rows, 100cm apart on a Brazito sandy loam soil. Type of soil and Meteorology data were described previously (1983 and 1984).

The experiment was a split plot in a systematic complete block strip plots, which consisited of 14 rows each side of the source line and 4.5 m wide with water levels as subplots. Subplots were taken as high irrigation level for the first two rows from the line source, intermediate irigation level for the seventh and eighth rows and low irrigation level for the last two rows away from the line source.

The field was planted at a rate of 120 seeds per 4.5 m plot in 1983, and 180 seeds per 3.0 m plot in 1984. 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 source of sprinkler 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 rows of each replication at 200 cm intervals. Water was measured from the catch cans throughout the season after each irrigation or rainfall. Irrigation treatments were applied for an average of 1 hour in the early morning when wind speeds was low. Wind conditions 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.

Physiological measurements were made at weekly intervals one week after stress was imposed. The repeated measurments included the use of a Li-Cor Model Li - 1600 steady state porometer (manufactured by Li - Cor, Inc., Lincoln, Nebrasks) to measure transpiration (Ug cm-2 S-1), diffusive resistance (Scm-1), leaf and ambient temperatures (C), and relative humidity (%) on the adaxial surface of the two upper exposed leaves of each plant in each water level (6 plants). Eight sampling dates were measured during the growing season in 1983, while seven samples were taken in 1984.

The data for the porometer was analyzed using a regression analysis with a regression method developed by Finalay and Wilkinson (1963) which measures the genotype - environment interactions. To help in identification of stable and drought resistant meterials, the lines with regression coefficients (B) approaching zero indicates stable performance. If two entries have the same regression coefficient (B) : a) the one with the highest mean response is superior, or b) the one with high correlation coefficient R^2) is more stable. The value for transpiration, diffusive resistance, and differential temperature (ambient temperature minus leaf temperature) of an individual entry from each of the weekly measurements were correlated to the mean response from low, medium, and high water level. The seasonal mean response for each entry at the three water levels was graphed.

Apparent photosynthesis was measured only in 1984 with a closed chamber syringe system described by Clegg and Sullivan (1975) and Clegg, et al., (1978). A portion of the uppermost fully expanded leaf of the millet plant was enclosed in a plexiglass chamber for 30 seconds. The Co_2 uptake by the leaf during this time was measured by taking a syringe sample of 5 ml gasat zero time, and with another syringe at 30 seconds later. The two coded syringes from each plant sampled were taken to the laboratory for analysis. The leaf area within the chamber was estimated by measuring the width of the blade on either side of the chamber.

The Co_2 concentration diference in the two syringes was measured using a Beckman Model 865 infrared gas analyzer (manufactured by Beckman Instruments, Inc., Fullerton, California). The photosyntheitc rate was calculated following Hesketh (1980). Yields and dry weights were used to calculate water use efficiency (WUE) (Kg/ha-1 cm) following Singh and Kanemasu (1980).

Analysis of variance and Neumans keuls test were used to determine differences in dry matter and yield per plant and WUE between irrigation treatments within each entry. Linear regression analysis were performed to determine differences between entries for transpiration, diffusive resistance, and differential temperature.

RESULTS AND DICUSSIONS

Porometer measurements :

Transpiration :

Transpiration was reduced 57, 56, and 66% by stress for female, male, and hybrid, respectively in 1983 (Fig. 1). In 1984 the rate of transpiration was higher for all water levels due to increased amounts of water. The reduction due to stress was 45, 53, and 52% for female, male, and hybrid, respectively (Fig. 2). Under stress the female had the highest transpiration rate in both seasons (Figs. 1 & 2).

Deffusive resistance :

Leaf diffusive resistance was increased 7.0, 8.5, and 10.1Scm^{-1} by stress for female, male, and hybrid, respectivley in 1983 (Fig. 1). The rates were lower in 1984, except for the male and hybrid at low water levels. The increase with stress was 7.2, 19.2, and 17.3 Scm^{-1} for hte female, male, and hybrid, respectively (Fig. 2). The female had the lowest diffusive resistance under stress in both seasons (Fig. 1&2).

Leaf temperature :

Stress increased leaf tempertaure in both seasons (Figs. 1&2) due to stomate closure. This may be related to decreased photosynthesis and transpiration rates. Although the difference in leaf temperature was not great, the female was less affected in both seasons.

Defferential temperature :

Temperature differential obtained by subtracting leaf temperature from ambient temperature showed a reduction pattern with stress for both seawsons with the female having the highest differential

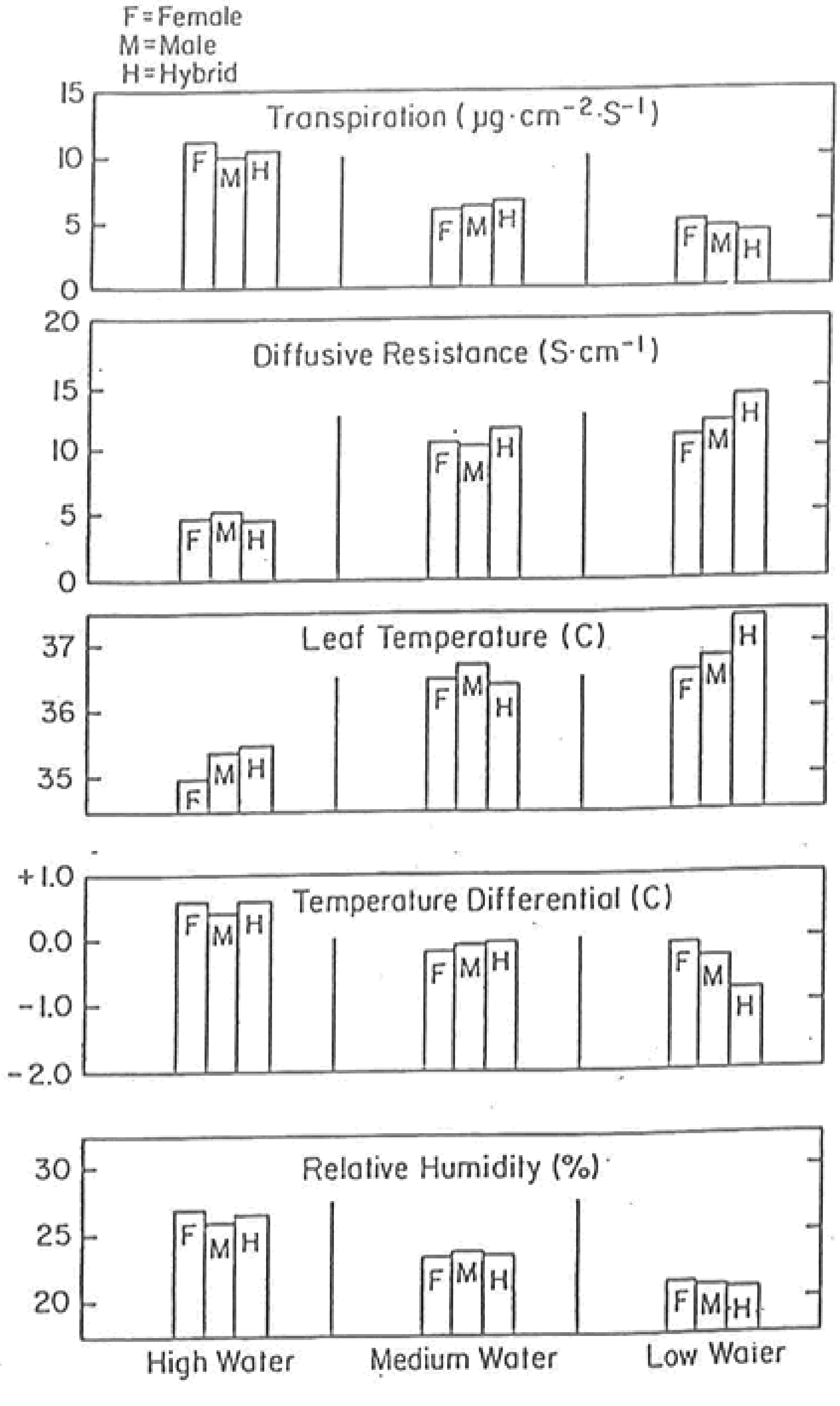

Fig. 1. Mean response for transpiration, diffusive resistance, leaf temperature, differential temperature, and relative humidity for three millet entries grown under a sprinkler gradient line in 1983.

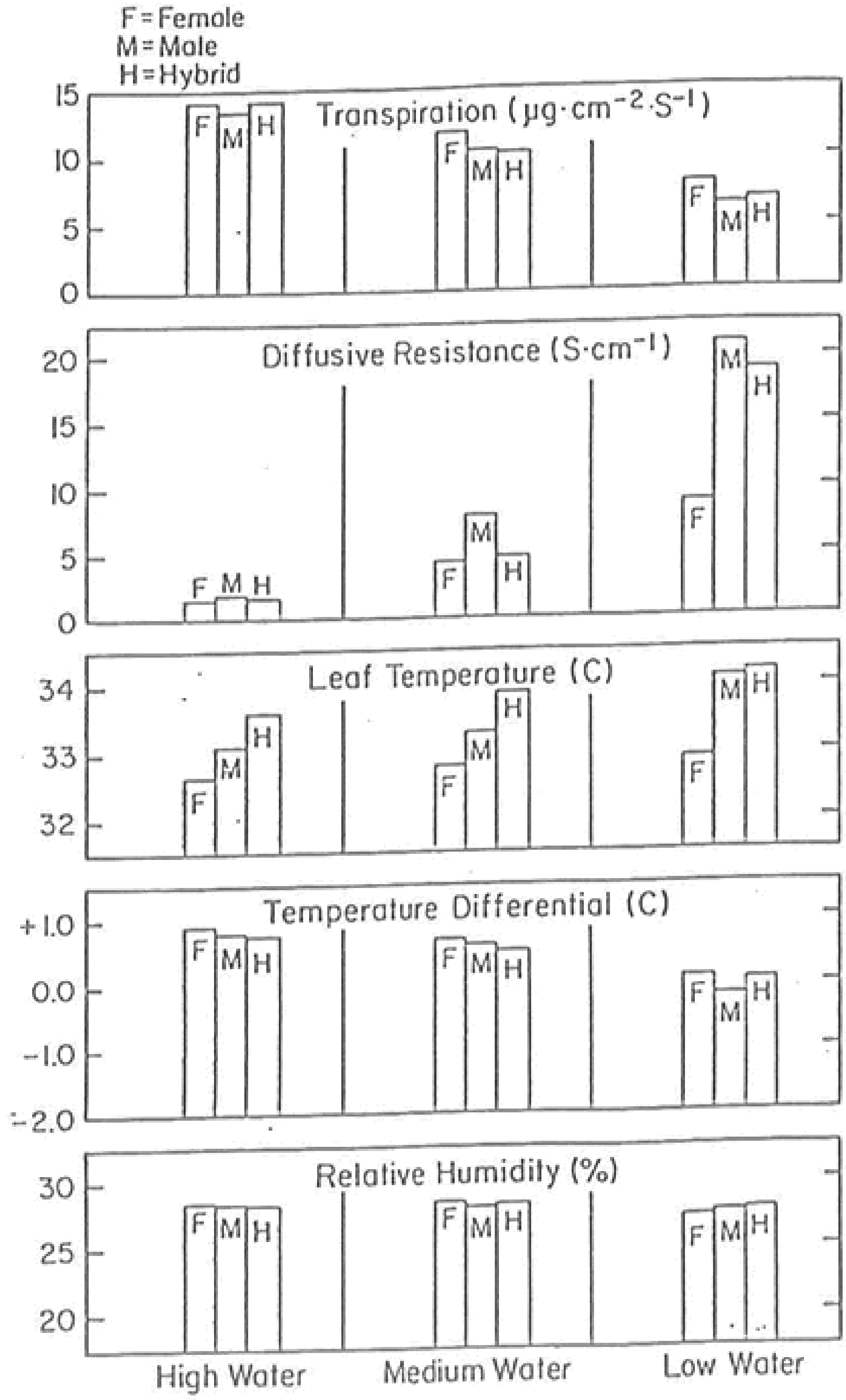

Fig. 2. Mean responses for transpiration, diffusive resistance, leaf temperature, differential temperature, and relative humidity for three millet entries grown under a sprinkler gradient line in 1984.

temperature (Figs. 1 & 2). The results in 1984 (Fig. 2) showed a positive temperature for female and hybridwhich was not the case in 1983 (Fig. 1). Idos, et al. (1977) reported that in hot arid climatic conditions of Phoenix, Arizona, yield would be reduced if the differential temperature (ambient temperature minus leaf temperature) was negative. This was also supported by Ibrahim et al. 1990 and 1992 and Ibrahim, 1992.

Relative humidity :

The relative humidity in the plots was reduced in the stress treatment in both seasons (Figs 1& 2), but the reduction was greater in 1983 (Fig. 1). The reduction in relative humidity was corelated to the increase in diffusive resistance and to the canopy effects. This was in agreement with Squire (1979), who stated that the stomata could open wider on humid days, reducing the diffusive resistance. The difference between entries was very small and not significant in bot seasons. This was reasonable, as relative humidity is a climatic factor and probobly not infoluenced by germplasm.

Stability :

By the regression analysis method of Finlay and Wilkinson (1963)it was possible to evaluatedifferent responses in terms of regression coefficient (b) and mean genotypic response (x), but the results were not consistent. The transpirational reponse observed in Fig. 3 showed the stability of the male parent in 1983 and the hybrid in 1984 because of their relatively lower regression coefficients. Diffusive resistance responses (Fig. 4) favored the female in 1983 and the male in 1984. The male parent was found to be more stable in both years (Fig. 5), with the diferential temperature responses.

Stability regression comparisions provided useful information on the average responses of the individual genotypes, but there was no adequate differentiation among cultivars. However, the results of 1983 were considered more reliable, as the conditions were more variable and the stress was more pronounced.

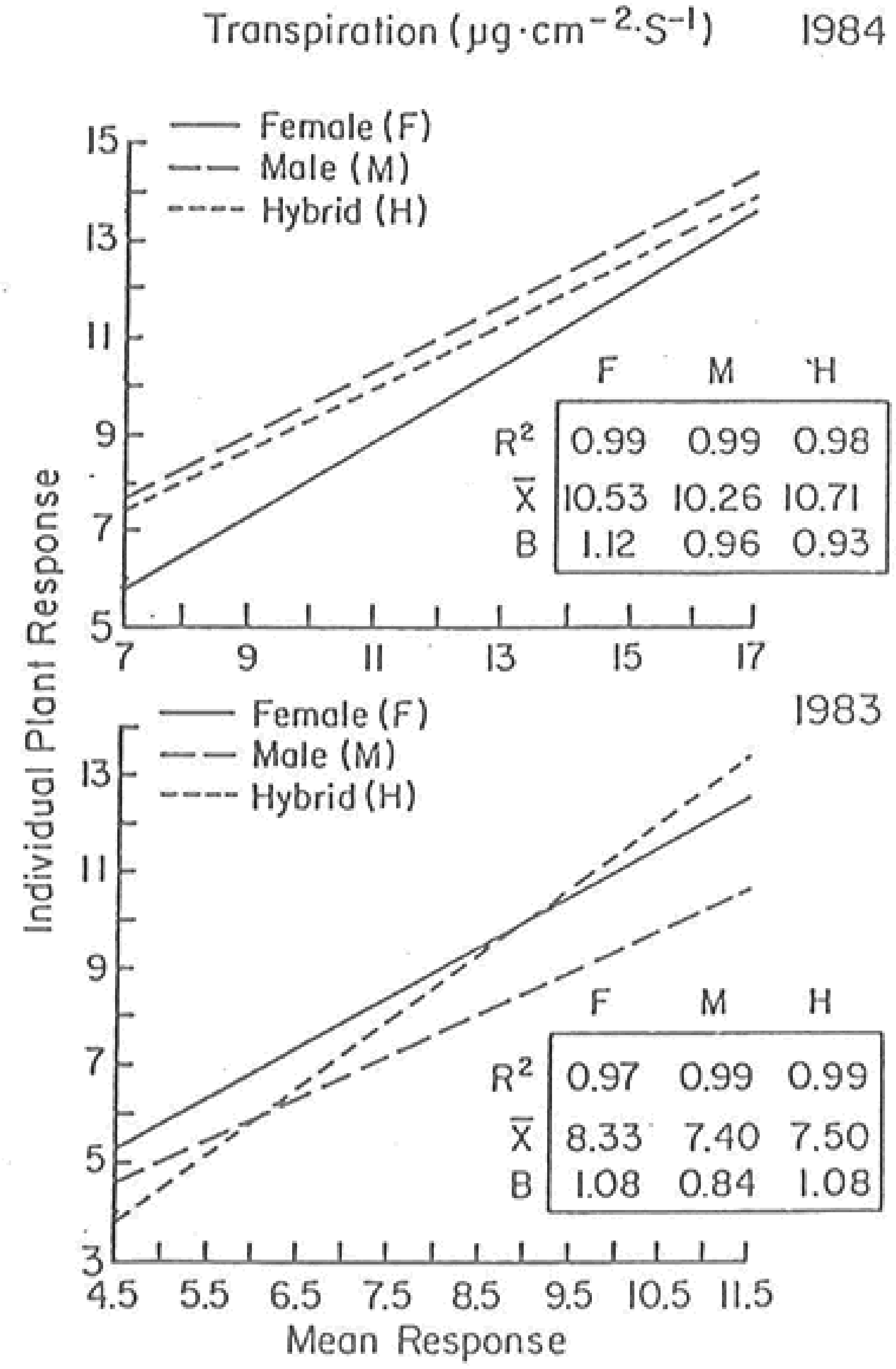

Fig. 3. Finlay and Wilkinson regressions with regression coefficient (r2), mean ($\bar{x}$), and Slope (b) for transpiration of three millet entries grown under a sprinkler gradient line in 1983 and 1984.

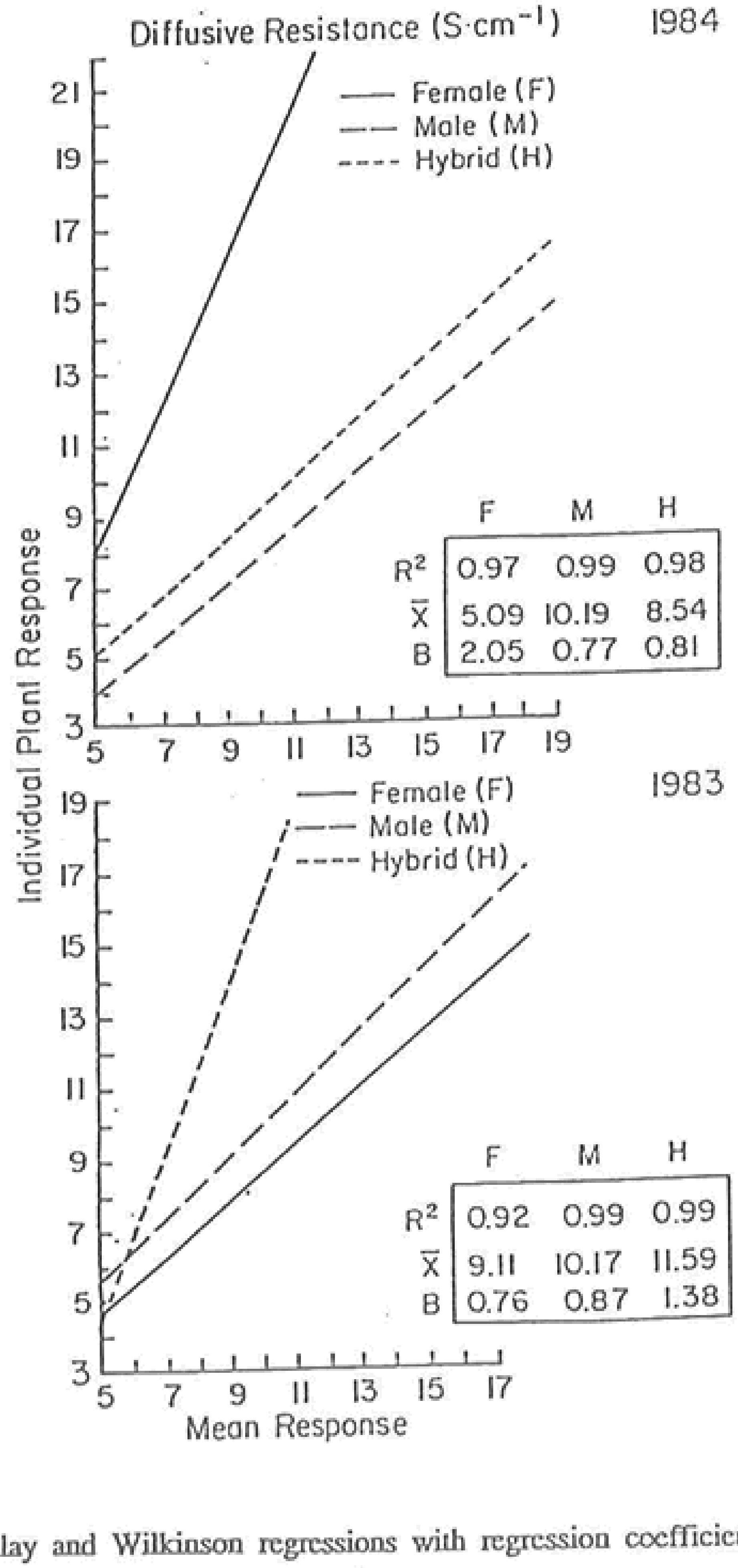

Fig. 4. Finlay and Wilkinson regressions with regression coefficient (r2), mean ($\bar{x}$), and slope (b) for diffusive resistance of three millet entries grown under a sprinkler gradient line in 1983 and 1984.

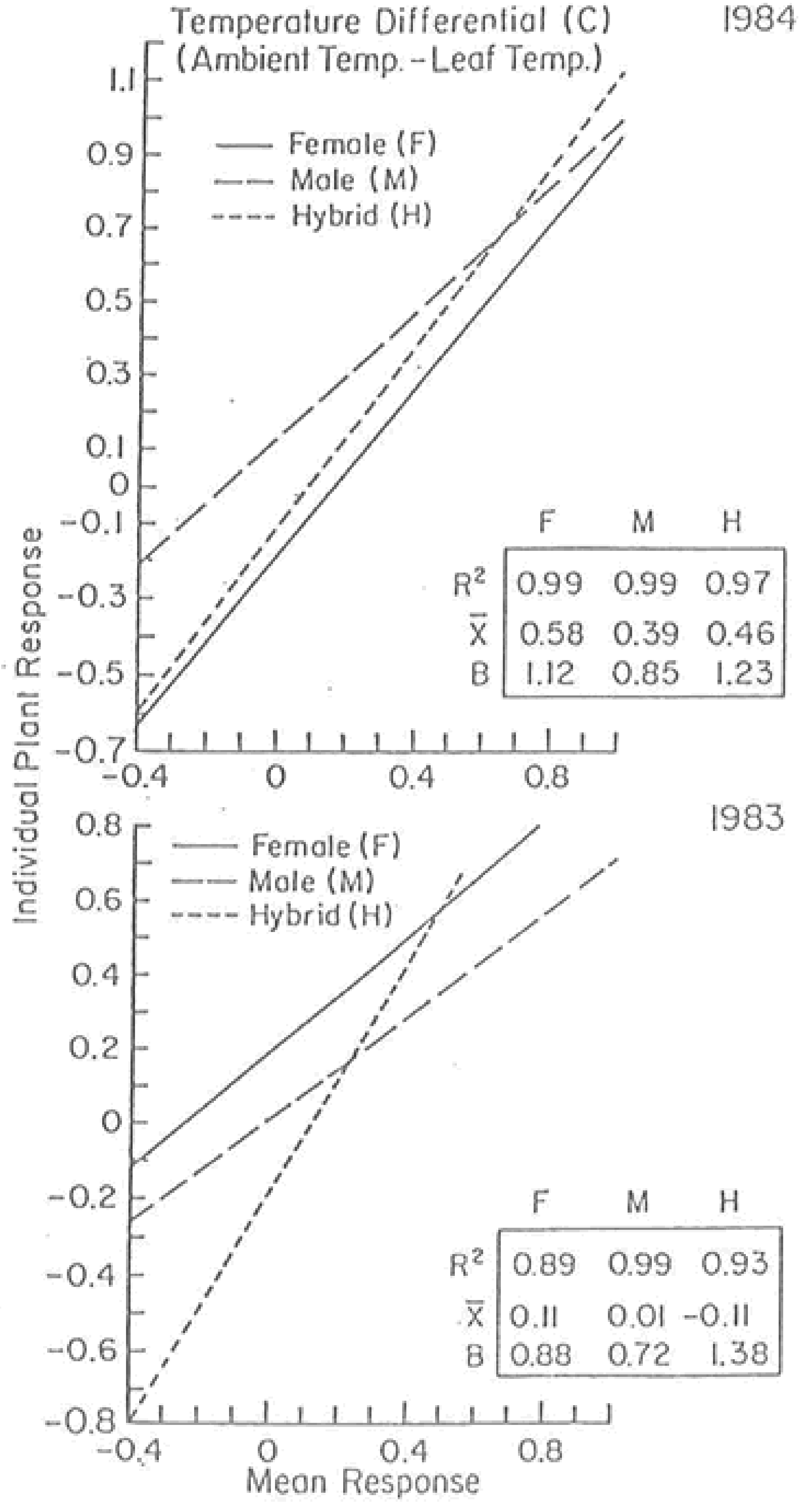

Fig. 5. Finlay and Wilkinson regressions with regression coefficient (r2), mean ($\bar{x}$), and Slope (b) for temperature differential of three millet entries grown under a sprinkler gradient line in 1983 and 1984.

PHOTOSYNTHESIS

Photosynthesis was reduced significantly by decreased water application. Heterosis was expressed by the hybrid at high water level, but under stress the female showed better performance (Fig. 6) followed by the hybrid. The reduction in net photosynthesis was 27, 61, and 47% for female, male and hybrid respectively. The results were consistent with those of Gariety, et al. (1984) who found a reduction of 14 to 26% for canopy apparent photosynthesis of sorghum. This was considered a result of less leaf area in the stressed treatment.

Constable and Hearn (1978) reported in soybean and sorghum that the response of a single leaf may not have been proportional to that of the canopy. While upper leaves respond to water stress, lower leaves may compensate. However, Hofmann, et al. (1984) using the same method used in this study found similar results in sorghum.

WATER USE EFFICIENCY (WUE) :

Water use efficiency for total dry matter and grain yield was decreased with water stress for all entries in 1983 and 1984 (Table 1). The decrease in WUE on yield basis agreed with results of Singh and Kanemasu (1980), who found reduced WUE for grain yield under no irrigation and Garrity, et al. (1982) who found strong negative trends in WUE of Sorghum with water stress. The decrease in WUE for dry matter agreed with Chaudhuri and Kanemasu (1982) findings that increasing the watering level increased the WUE for total dry matter.

WUE was much higher for both water levels of the three entries in 1984 than in 1983 due to increased yield and dry matter (Table 1). In this study, WUE was calculated by the actual amount of water applied after the stress was imposed. Stewart, et al. (1983) calcuated WUE value of sorghum both on the basis of kg grain / m3 evaporation (ET) and kg grain ./ m3 applied irrigation water. The method of the actual applied water was used in this study because water is the main limiting factor to production in this environment, and the emphasis should be geared toward maximum economic Production Per Unit of applied water rather than maximum yield.

Table 1. Water use efficiency (WUE) (kg / ha-1cm) for three millet entries grown under a sprinkler gradient line in 1983 and 1984.

		1983				1984			
				WUE				WUE	
Entries	Irrigation treatment	Final dry matter plant-1 (g)	Grain yield plant-1 (g)	Total dry matter	Grain yield	Final dry matter plant-1 (g)	Grain yield plant-1 (g)	Total dry matter	Grain yield
Female 81-1014	high	113.4b*	5.6b	359.9b	17.7b	174.0a	36.6a	591.3b	89.7a
	medium	99.4d	1.2e	299.3d	3.4e	107.5c	6.2c	246.5d	12.5c
	low	32.9h	0.01g	104.4i	0.03g	81.0d	1.2d	156.0g	2.4e
Male Senegal Bulk	high	106.5c	25.4a	330.1c	80.8a	172.7a	35.5a	586.6b	89.2a
	medium	69.0f	2.4d	227.2f	6.1d	96.6d	5.0c	213.3e	9.8d
	low	48.1g	0.08f	152.8h	0.3f	92.8d	0.6e	174.5f	1.3e
Hybrid 81-1014 x Senegal	high	142.8e	27.1a	435.2a	86.0a	178.6a	33.6a	604.3a	88.1a
	medium	84.9e	4.3c	287.4e	13.7c	131.5b	8.3b	361.7c	15.7b
	low	62.9f	1.1e	199.6g	3.5e	90.3d	0.6e	174.4f	1.2e

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

Water use efficiency at low water level was higher for the hybrid for both yield and dry matter in 1983 (Table 1). In 1984, it was higher for the female and male for yield and dry matter, respectively (Table 1). The findings in 1984 contrasted with those of Singh, et al. (1983), who found that under stress Senegal buldk (male) used the greatest amount of water. Under stress, the hybrid used more water in both seasons, but it was only able to express that in terms of production in 1983 (Table 1) when the stress was more pronounced.

INDICES EVALUATION

Indices of drought used in this study differed considereably in the two seasons of study. In 1983 when the stress was more pronouned, the hybrid had the best transpiration, diffusive resistance, leaf temperaturre and differential temperature (Fig. 1) and that corresponded with higher yields. This was also true for the female in 1984. Under stress the female had the highest photosynthesis (Fig. 6) and also higher yields in 1984. The hybrid and the female had the highest WUE for yield in 1983 and 1984, respectively (Table 1) which corresponded with higher yields. The stability regression analysis did not provide adequate differentiation among cultivars.

CONCLUSIONS

The investigation reported in this study led to the following conclusions :1) Stress significantly affected all parameters measured and the effects were more pronouned in 1983. 2) Under stress, yield was positively correlated with transpiration, diffusive resistance, leaf temperature, and differential temperature. These parameters could be considreed good indices for yield under stres. 3) Photosynthesis correlated positively with grain yield under stress. 4) WUE for grain yield and dry matter correlated with grain yield and dry matter, respectively under stress in both seasons. 5) Stability regression analysis for identification of stable and drought tolerant genotypes provided useful information on the average responses of individual genotypes, but no adequate differentiation among cultivars.

REFERENCES

Chaudhuri, U. An. and E. T. Kanemasu. 1982. Effect of water gradient on Sorghum growth, water relations and yield. Can. J. Plant Sci. 62:599-607

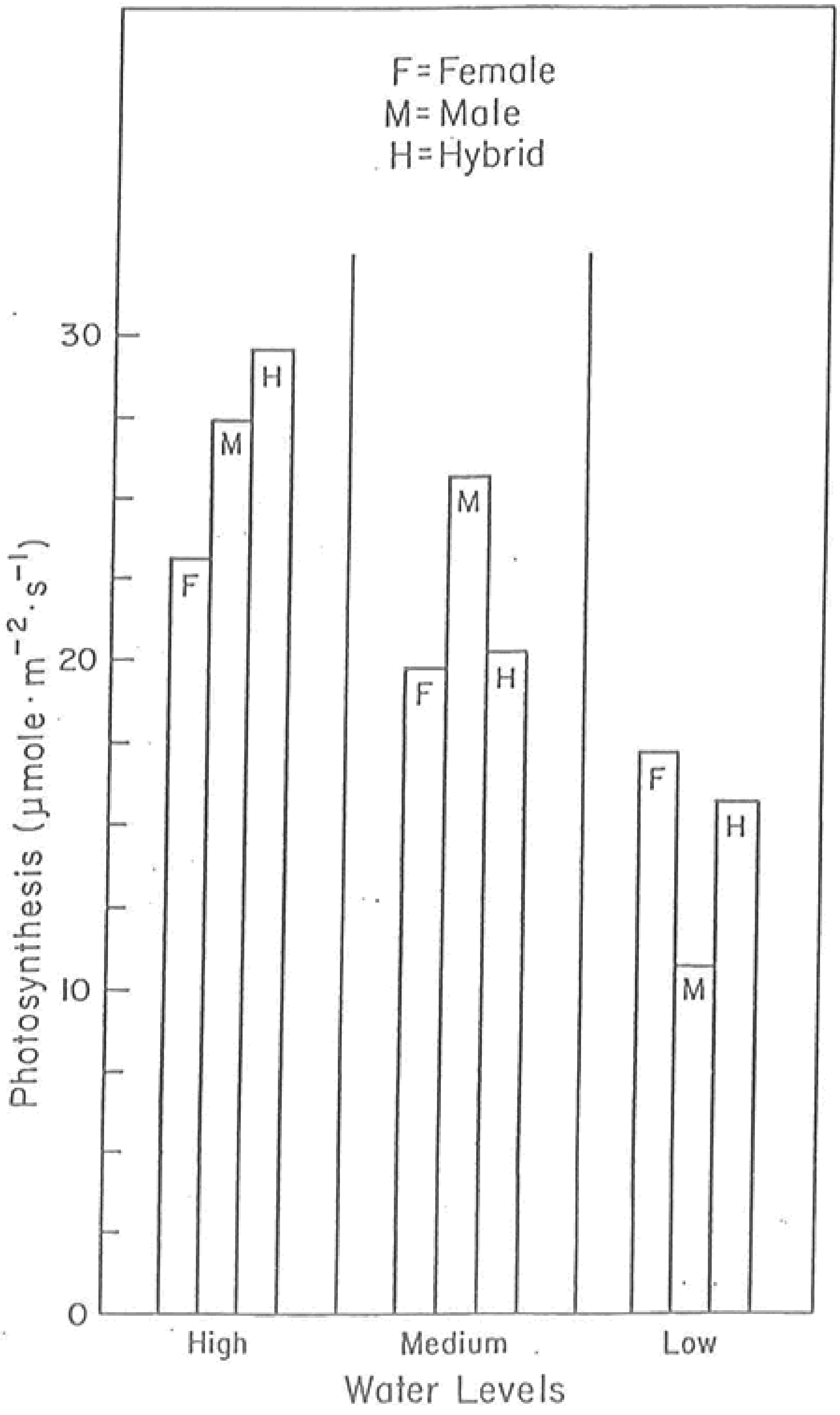

Fig. 6. Apparent photosynthesis of the uppermost fully expanded leaf of three millet entries in 1984.

Clegg, M. D. and C. Y. Sullivan. 1975. A rapid method for measuring carbon dioxide concentrations. Agro. Abstracts p. 70.

------, ------, and J. D. Eastin 1978. A sensitive technique for the rapid meaurment of carbon dioxide concentrations. Plant Physiol. 62:924-926.

Constable, G. A. and A. B. Hearn. 1978. Agronomic and Physiological responses of soybean and sorghum crops to water deficits. I. Growth, development, and yield. Aust. J. Plant Physiol. 5:159-167.

Finlay, K. W. and G. N. Wilkinson. 1963. The analysis of adaptation in aplant breeding program. Aust. J. Agric. Res. 14:742-745.

Garrity, D. P., D. G. Watts, C. Y. Sulivan, and J. R. Gilley. 1982. Moisture deficits and grain sorghum perforamces : Evapotranspiration -yield relationships. Agron. J. 74:815-820.

------, 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.

Hesketh, J. D. 1980. Predicting canopy photosynthesis from gas exchange studies in controlled environments. In J. d. P. 37-50.

Hesketh and J. W. Jones (ed.). Predicting Photosynthesis for Ecosystem Models, Vol. I. CRC Press, Inc. Boca Raton, Florida.

Hofmann, W.C., M. K. O'Neill, and A. K. Dobrenz. 1984. Physiological responses of sorghum hybrids and paretal lines to soil moisture stress. Agron. J. 76P:223-228.

Ibrahim, Y. M., V. Marcarian, and A. K. Doberz. 1985. Evaluation of Drought Tolerence in Pearlimillet (Pennisetum americanum L. (Leekes)). Under sprinkler Irrigation Gradient. Field Crops Res. 11: 232-240.

Ibrahim, Y. M., V. Marcarian, and A. K. Dobrenz. 1986. Drought Tolerence Aspects in Pearl millet. J. of Agron. and Crop. Sci 152(2):110-116.

Ibrahim, Y. M., V. Marcarian, and A. K. Dobrenz. 1990. Effect of Moisture Stress on Millet Growth. Sudan Agric. J. 13:61-81.

Ibrahim, Y. M. 1992. Screening for Drought Tolerence in Pearl millet by Sprinkler Irrigation Gradient. Bull. Fac. of Agric., University of Cairo, Egypt. (In Print).

Ibrahim, Y. M., V. Marcarian, and A. K. Dobrenz. 1992. Pearl millet Response to different water levles. I. Yield, Yield Components, and Crude Protien. Emir.J. Agric. Sci, 5:59-81.

Idso, s. B., R. D. Jackson and R. J. Reginato. 1977. Remote sensing of crop yields. Science. 196:19-25.

Langer, I., K. J. Frey, and T. Bailey. 1979. Associations among pro ductivity, production responses, and stability indexes in oat varieties. Euphytica. 28:17-24.

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

Sharratt, B. S., D. C. Reicosky, S. B. Idso, and D. G. Baker. 1983. Relationship between leaf water potential, canopy temperature, and evapotranspiration in irrigated and non-irrigated alfalfa. Agron. J. 75:891-894.

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 pear/millet. Manhattan, KS 66506. P. 75-93.

------, and -------. 1983. Leaf and canopy temperatures of pearl millet genotypes under irrigated and non-irrigated conditions. Agron. J. 75:497-501.

-------, --------,and P. Singh. 1983. Yield and water relations of pearl millet genotypes under irrigated and non-irrigated conditions. Agron J. 75:886-891.

Squire, G. R. 1979. The response of stomata of pearl millet (Pennisetum typhoides S. and H.) to atmospheric humidity. J. Exp. Bot. 30 (118):925-933.

Squire, G. R., C. R. Black, and P. J. Gregory. 1981. Physical measurements in Crop Physiology. II. Water relations. Expl. Agric. 17:225-242.

Squire, G. R., P. J. Gregory, J. L. Monteith, M. B. Russell and P. Singh. 1984. control of water use by peal millet (Pennistum typhoides) Expl. Agric. 20:135-149.

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. 75:629-634.

مجلة الإمارات للعلوم الزراعية (١٩٩٥) . ٧ : ٢٠ - ٣٨

إستجابة الدخن لمستويات ري مختلفة ٢ - قياسات البارومتر ، التمثيل الضوئي وكفاءة إستعمال الماء .

يسن محمد إبراهيم[١] وفيكتوريا ماكريان[٢] وأ.ك < دوبرنز[٢]

١ وزارة الزراعة ، ص . ب ٤٣٩ ، مسقط ، سلطنة عمان

٢ قسم علوم النبات ، جامعة أريزونا ، توسان ، أريزونا ٨٥٧٢١ ، الولايات المتحدة الأمريكية

إستخدام نظام الرى بالرش المتدرج لتقييم بعض الخواص الفسيولوجية لثلاث أصناف من الدخن بمدينة توسان الأمريكية عامي ١٩٨٣ و ١٩٨٤ . ونظراً لقلة المياه فى جنوب غرب الولايات المتحدة فقد تم تقييم أدلة مقاومة الجفاف وذلك لإختيار أنسب الأصناف لهذا المحصول . وقد أثر نقص الماء على كل القياسات الفسيولوجية حيث كان التأثير أكثر وضوحاً فى موسم ١٩٨٣ . تأثرت كمية النتح وفرق درجات الحرارة تأثراً معنوياً بنقص الماء حيث قلت معدلاتها بينما زادت درجة مقاومة الأوراق ودرجة حرارتها بإزدياد الجفاف خلال موسمى الدراسة .

لم تظهر نتائج التحليل لدرجة الثبات فرقاً واضحاً فى الأصناف وقد كانت نسب النقص فى التمثيل الضوئي مع زيادة الجفاف مقدارها ٢٧٪ ، ٦١٪ ، ٤٧٪ للأم والأب والهجين على الترتيب . كما قلت كفاءة إستخدام الماء للبذور والأعلاف على السواء مع زيادة الجفاف خلال موسمي الدراسة .

كلمات مفتاحية : تحمل الجفاف ، درجة الثبات ، النتح ، كفاءة إستعمال الماء .