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Effect of Different Irrigation Intervals to Drip Irrigated Dent Corn (*Zea mays* L. *indentata*) Water-yield Relationship

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Abstract: This study was conducted to determine appropriate irrigation frequencies and water-yield relationship for corn irrigated by drip irrigation system in a semi-arid region. The research was carried out at the Agricultural Research Station of Harran University in Sanliurfa, Turkey in 1998 and 1999. In the study, water was applied to sweet corn as 100, 90, 80 and 70% of evaporation from a Class A Pan corresponding to 2, 4, 6 and 8 day irrigation frequencies, respectively. Irrigation water applied to crops ranged between 814 and 1116 mm in 1998, while 843 and 1206 mm in 1999. The highest values for Total Water Use Efficiency (TWUE) were found to be 1.15 kg m^{-3} in the 4 day irrigation frequency in both 1998 and 1999. The highest values for irrigation water use efficiency (IWUE) were determined to be 1.43 and 1.22 kg m^{-3} in the 4 day irrigation frequency in both 1998 and 1999. Yield, based on the irrigation frequencies, was found to be statistically significant (**$p<0.01$) in both years. Maximum yield was 14.07 and 13.30 t ha^{-1} with four day irrigation frequency treatment in 1998 and 1999, respectively. The minimum yield was found to be 10.27 and 9.53 t ha^{-1} with eight day irrigation frequency in 1998 and 1999, respectively. Yield was reduced with deficit irrigation in both years. The results of this research indicate that a 4 day irrigation frequency, with 90% ET water application by a drip system, will be optimal for corn grown in semi-arid regions similar to that in Turkey where the research was conducted.

Key words: Corn, deficit irrigation, drip irrigation, irrigation frequency, water-yield relationship

INTRODUCTION

Annual water flow regimes of rivers determine the possibility of transforming from non-fed to irrigated agricultural practices. When the availability of water resources is a limiting factor, however, success in agriculture cannot be expected even though funds are available for agricultural applications. Development of irrigated agriculture depends not only on sufficient water being available but also the appropriate use of that water.

Salinity and alkalinity may occur if the irrigation programs are not applied properly. There has been recent research on water saving methods, such as irrigation of different parts of crop root area (Kang *et al.*, 1997). Drip irrigation is one these methods and its use has been increasing due to water savings and its positive effects on crop yield. Drip irrigation provides the efficient use of limited water with increased water use efficiency. There has not been enough research to determine irrigation intervals with corn crop. It is possible to achieve optimum quality and quantity of crop production per unit area if a proper irrigation method is applied along with other agronomic activities. Thus, it is necessary to determine proper irrigation techniques and irrigation intervals for each microclimate and each crop species.

The goal of this research was to determine deficit irrigation effect on yield and how different irrigation intervals with drip irrigation affected water use-yield relationships in corn crop and to determine most efficient irrigation time intervals.

Corn responds to high annual water and is grown in irrigated areas (Musick *et al.*, 1990). Decrease in production of corn crop depends upon cultivar used, rainfall and evaporation rate and soil hydraulic conductivity. It is reported that limited water application does not cause decrease in yield and water use efficiency is increased (Shaozhong *et al.*, 2000). Kanber *et al.* (1990b) determined that the amount of irrigation did not cause increase in yield and indicated that excessive amount of water was unnecessary.

Lamm *et al.* (1993) reported that grain yield was 780 g m^{-2} when supplemental irrigation of 75 mm to 324 mm rainfall was applied. Four rates of irrigation amount were applied equal to 20, 50, 80 and 110% of evaporation measured by lysimeter, respectively with three different soil series (Pullman, Ulysses and Amarillo) in an arid region. Yields were 389-804, 559-899 and 438-736 g m^{-2} in Pullman, Ulysses and Amarillo series, respectively. Kanber *et al.* (1990a) found that annual water consumption and irrigation water requirement of second crop corn ranged from 474.2 530.9 mm and 290 427.8 mm, respectively. This study also indicated that annual crop response factor (ky) was 0.98 for second crop corn and the crop required irrigation five times at different crop growth stages.

Cetin (1994) reported maximum yield of 10.15 t ha^{-1} for second crop corn with irrigation applied every five days interval. The yield decreased to 7.71 t ha^{-1} with irrigation applied at 10 days interval. The amounts of irrigation water were 1303 and 970 mm, water consumptions were 1371 and 1037 mm and maximum monthly water requirements were in August with irrigation treatments of five days and ten days intervals, respectively.

MATERIALS AND METHODS

This study was conducted during 1998 and 1999 at the Field Research Facility of the Faculty of Agriculture at Harran University, Sanliurfa, Turkey. The experimental field is located in Harran Plain (altitude: 465 m; 37°08' north and 38°46' east) where the climate varies from arid to semi-arid. The texture of the soil of experimental field was clay. Field capacity of the soil was between 32.71 and 33.84% on dry basis (Table 1), permanent wilting point was between 21.18 and 22.55% and bulk density of the soil was between 1.37 and 1.41 g cm^{-3} (Table 1). In the months of June, July and August for both treatment years, the temperatures were all above 40°C while the relative humidity was below 50%. Except August 1999, no rainfall was observed in July and September of the treatment years and the rainfall seen in June is fairly low. During the time period for the treatments, the weather conditions were hot, dry and the relative humidity was very low (Table 2).

In this study, Dracma hybrid corn (*Zea mays* L. *indentata*) was used as the crop material. The experiment was laid out in a randomized block design with three replications. Each plot consisted of four rows of 5 m in length. The plants were grown 70 cm apart between the rows with 20 cm spacing in each row. The seeds were sown on 21.06.1998 (Day Of Year (DOY:172)) in the first year and on 26.06.1999 (DOY:177) in the second year. At sowing, 80 kg ha^{-1} pure N and P (20-20-0 composite) was applied to each plot and this was followed by 160 kg ha^{-1} N as urea when the plant reached to 30-40 cm height. Ears from two rows in the centre of each plot (50 plants) were harvested manually. The data obtained from the experiments were analysed with analysis-of-variance (ANOVA) and least significant difference (LSD) tests (Cochran and Cox, 1957) using MSTATC™ statistical analysis software package.

Irrigation treatments: First irrigation water was applied to all treatments using a sprinkler irrigation system during the experiments in 1998 and 1999 to bring the soil water content in 0-90 cm soil depth up to level of field capacity. Irrigation treatments were started using drip irrigation system when the water content of soil decreased to 50% of available soil water.

Irrigation water was applied as 100% of evaporation of Class A Pan in the 2 day irrigation frequency (ID2 treatment), 90% of evaporation in the 4 day irrigation frequency (ID4 treatment), 80% of evaporation in the 6 day irrigation frequency (ID6 treatment) and 70% of evaporation in the 8 day irrigation frequency (ID8 treatment).

The amount of required irrigation water was determined by Class A Pan evaporation every day (Kanber, 1984). The total evaporation from Class A Pan was measured with a manual limnimeter which has 0.1 mm accuracy. These measurements were checked with the readings from the water flow meters mounted in every plot.

Table 1: Some of chemical and physical properties of experimental field soil

Soil depth (cm)	Field capacity (%)	Wilting point (%)	Bulk density (g cm^{-3})	Total salt (%)	$CaCO_3$ (%)	Organic matter (%)	pH
0-30	33.19	22.14	1.39	0.071	26.8	1.1	7.75
30-60	32.71	21.18	1.41	0.069	29.7	0.8	7.83
60-90	33.84	22.55	1.37	0.073	27.9	0.8	7.36

Table 2: Monthly climate data during the growth period of corn in 1998 and 1999 in Sanliurfa

	Temperature (°C)						Average relative humidity (%)		Total precipitation (mm)	
	Maximum		Minimum		Average					
Months	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
June	41.2	40.0	17.8	18.8	29.4	28.8	46.2	43.6	0.6	1.6
July	45.4	43.2	19.8	21.5	33.0	32.5	43.8	39.7	-	-
August	43.0	43.0	22.6	20.5	33.4	31.5	41.4	44.7	-	26.0
September	39.6	36.6	15.1	17.0	27.0	26.2	53.3	46.8	-	-
October	34.1	35.6	10.2	11.3	21.5	21.0	49.5	51.2	0.1	8.4
November	27.9	25.0	8.8	1.2	16.7	13.5	66.4	50.9	22.7	0.8

†: Data collected from Sanliurfa Meteorological Station

Crop water consumption in the treatments was calculated using Eq. 1 (Garrity *et al.*, 1982; James, 1988):

$$ET = P + 1 - R_f - D_p \pm \Delta S \quad (1)$$

where; ET is crop water consumption (mm), P is rainfall (mm), I is irrigation water (mm), R is surface runoff (mm), D_p is deep percolation (mm), ΔS is soil water content variation in crop root depth (mm).

In this study, deep percolation (D_p) and surface runoff (R_f) in Eq. 1 were assumed to be negligible because the amount of irrigation water was not increased to above the field capacity as a result of drip irrigation and deficit irrigation. It approached field capacity only at the 2 day irrigation frequency.

The amount of irrigation water was calculated using Eq. 2:

$$I = A.E_{pan}.\,K_{cp}.\,CAI \quad (2)$$

where; I is the amount of irrigation water (mm), A is plot area (m^{-2}), E_{pan} is cumulative water depth from Class A Pan based on irrigation frequencies (mm), K_{cp} is crop pan coefficient determined as 100% of total evaporation of Class A Pan in the 2 day irrigation frequency (K_{cp1}), 90% of total evaporation of Class A Pan in the 4 day irrigation frequency (K_{cp2}), 80% of total evaporation of Class A Pan in the 6 day irrigation frequency (K_{cp3}), 70% of total evaporation of Class A Pan in the 8 day irrigation frequency (K_{cp4}) and CAI is canopy area index which was assumed to be 1.

During the experimental period, the variation of soil water content at 0-30, 30-60 and 60-90 cm soil depths in each treatment plot was continuously determined by gravimetric method for calculating the actual evapotranspiration (ET_a).

Total Water Use Efficiency (TWUE), defined as the ratio of grain yield per hectare to seasonal water consumption and Irrigation Water Use Efficiency (IWUE), defined as the ratio of grain yield per hectare to the amount of irrigation water, were calculated using the methodology provided by Tanner and Siclair (1983).

$$TWUE = (Y_a/ET_a)*100$$

$$IWUE = (Y_a/I)*100$$

The water use-yield relationship was determined using the Stewart Model in which dimensionless parameters in relative yield reduction and relative water consumption are used (Doorenbos and Kassam, 1979):

$$\left(1-\frac{Y_a}{Y_m}\right) = k_y\left(1-\frac{ET_a}{ET_m}\right) \quad (3)$$

where, Y_a is actual yield (t ha^{-1}), Y_m is maximum yield (t ha^{-1}), Y_a/Y_m is relative yield, 1-(Y_a/Y_m) is decrease in relative yield, ET_a is actual crop water consumption (mm), ET_m is maximum crop water consumption (mm), ET_a/ET_m is relative crop water consumption, 1- (ET_a/ET_m) is decrease in relative crop water consumption, k_y is yield response factor defined as decrease in yield with respect to per unit decrease in ET.

RESULTS AND DISCUSSION

Water use-yield relationship: Yield, decrease in relative yield and decrease in relative water use, amount of irrigation, water saving rates and yield response factors for corn crop irrigated with drip irrigation system at different irrigation intervals are presented in Table 3. Seasonal water consumption of treatments (ET_a) and the amounts of irrigation water was different in each treatment. Maximum seasonal water consumption (ET_m) was 1292 mm and maximum amount of applied water was 1116 mm in 2 day irrigation treatment (ID2), minimum ET_a was 909 mm and minimum amount of applied water was 814 mm in 8 day irrigation treatment (ID8) during the first year experiments.

In the second year, the values were 1306 mm as maximum Et_m and maximum applied water was 1206 mm in ID2 treatment, minimum ET_a was 923 mm and minimum applied water was 843 in ID8 irrigation treatment. Amount of applied water to other treatments ranged between

Table 3: Relationship between the decrease in relative water use and decrease in relative yield and yield response factor for corn crop irrigated by drip irrigation system

Treatments and years	Ya	Yadj	ETa	ETa/ETm	Yadj/Ym	1-(Yadj/Ym)	1-(ETa/Etm)	Amount of irrgation (I, mm)	Water Savings (%)	ky
ID2-1998	13.54	14.06	1292	1.00	1.00	0.00	0.00	1116	0.00	0.00
ID4-1998	14.07	14.07	1224	0.95	-	-	0.05	986	11.64	-
ID6-1998	11.33	11.33	1027	0.79	0.81	0.19	0.21	917	17.83	0.90
ID8-1998	10.27	10.27	909	0.70	0.73	0.27	0.30	814	27.06	0.90
ID2-1999	12.26	13.02	1306	1.00	1.00	0.00	0.00	1206	0.00	0.00
ID4-1999	13.30	13.30	1160	0.89	-	-	0.11	1092	9.40	-
ID6-1999	11.25	11.25	1098	0.84	0.85	0.15	0.16	936	22.33	0.88
ID8-1999	9.53	9.53	923	0.71	0.72	0.28	0.29	843	30.09	0.93

Table 4: Grain yield[1] irrigated by drip irrigation at different irrigation frequencies and LSD groups

	Fresh ear yield[1] ($t\ ha^{-1}$)		
Irrigation treatments	1998**	1999**	Average**
ID2	13.54b†	12.26b	12.90b
ID4	14.07a	13.30a	13.69b
ID6	11.33c	11.25c	11.29c
ID8	10.27d	9.53d	9.90d
LSD	0.2364	0.3684	0.6391

[1]: Grain yield is calculated at 15% kernel moisture, **: p<0.01, †: There is no statistical differences among same letter at, 0.05 level according LSD test

Table 5: Total Water Use Efficiency (TWUE) and Irrigation Water Use Efficiency (IWUE) values for corn irrigated by a drip system at different frequencies

Treatments	TWUE ($kg\ m^{-3}$)	IWUE ($kg\ m^{-3}$)
ID2-1998	1.05	1.21
ID4-1998	1.15	1.43
ID6-1998	1.10	1.24
ID8-1998	1.13	1.26
ID2-1999	0.94	1.07
ID4-1999	1.15	1.22
ID6-1999	1.02	1.20
ID8-1999	1.03	1.13

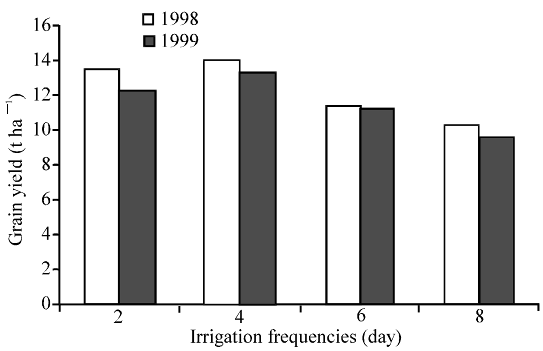

Fig. 1: Grain yield values at different irrigation frequencies in 1998 and 1999

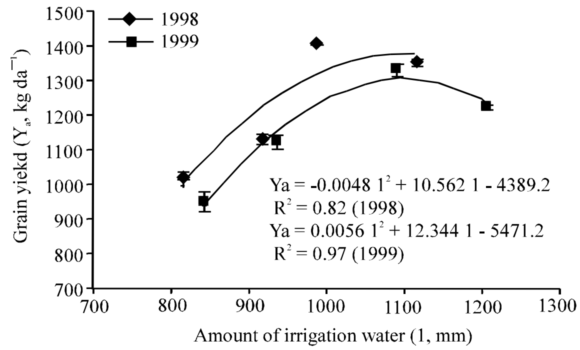

Fig. 2: Irrigation water (I) and fresh ear yield (Y_a) relationship. Vertical bars indicate standard errors of the mean

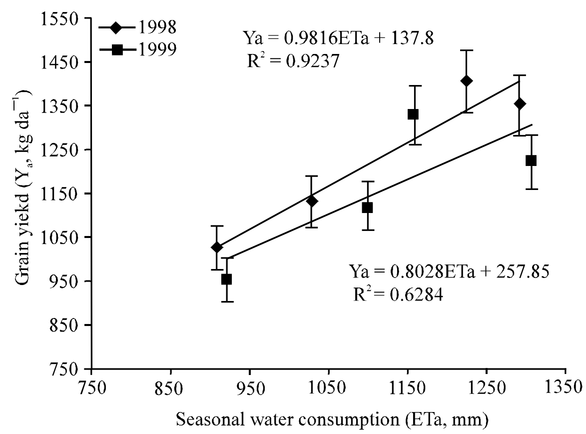

Fig. 3: Fresh ear yield (Y_a) and seasonal water consumption (Et_a). Vertical bars indicate standard errors of the mean

these values. The reason for this was existing water content in the soil before the first irrigation application and the climatical parameters.

The amount of applied water affected grain yield (Table 4). Grain yield increased with the amount of applied water and ET_a increased as seen in ID2 treatment. Findings in the literature were in accord with the results obtained in this study, the rate of decrease in yield was not the same with respect to per unit decrease in water applied (Yaron, 1971).

Decrease in relative yield was 3.77% in 2 day irrigation treatment group in 1998. Maximum yield was found to be 14.07 $t\ ha^{-1}$ in 4 day irrigation treatment group in which the water saving rate was 11.64% (Fig. 1). The rates of the decrease in relative yield were 19.47% and 27.01% in 6 day and 8 days irrigation treatment groups in 1998.

In 1999, the rate if the decrease in relative yield was 7.82% in the 2 day irrigation treatment group in which the amount of water applied was the maximum, 1206 mm. Maximum yield, 13.30 $t\ ha^{-1}$, was obtained from 4 day irrigation treatment group which used 9.4% less water than ID2 treatment. This result was supported by Cetin (1994) who recommended ones irrigation every 5 day time interval for second crop corn. The rates of the decrease in relative yield were 15.41 and 28.35% in ID6 and ID8 treatment groups, respectively. Moreover, the rates of water saving were determined to be 22.33 and 30.09% for 6 day and 8 day irrigation treatment groups, respectively. Zhang and Davis (1990) reported that yield was reduced as the crops were under drought stress for a long time.

Increase water deficit resulted in decrease in crop yield. Crop roots take up nutrients and the water from upper parts of the soil under the conditions of low water stress or non-stress. When the crops experience the water stress, their roots penetrate deep in the soil to withdraw water and crop nutrients (Rhoads and Bennett, 1990). Better aeration in the root zone, better utilization of nutrients and efficient use of soil water by the crops might cause increased yield in ID4 treatment group compared to ID2 treatment group.

Relationship between the amount of irrigation water, seasonal water consumption and grain yield: Second order polynomial relationship was found between the amount of water applied (I) and grain yield (Y_a) in both years from the regression analysis. The equation for the relationship was $Y = -0.0048I^2+10.562I-4389.2$ with $R^2 = 0.82$ in 1998 and the relationship was explained by the equation $Y = -0.0056I^2+12.344I-5471.2$ with $R^2 = 0.97$ in 1999 (Fig. 2).

A linear relationship was found between seasonal water consumption (Et_a) and grain yield (Y_a) in both years. The equations for the relationship were $Y_a = 0.981ET_a+137.8$ ($R^2 = 0.92$) and $Y_a = 0.8028ET_a+257.85$ ($R^2 = 0.63$) for 1998 and 1999 experiments, respectively (Fig. 3). A linear relationship have been reported between crop yield and seasonal water consumption (Mogenson *et al.*, 1985; Musick *et al.*, 1994).

Water use efficiencies: Total Water Use Efficiency (TWUE) and Irrigation Water Use Efficiency (IWUE) were different based on the treatments and years (Table 5). TWUE were 1.05, 1.15, 1.10 and 1.13 kg m^{-3} for the treatments ID2, ID4, ID6 and ID8, respectively in the first year while the values were 0.94, 1.15, 1.02 and 1.03 kg m^{-3} for the treatments ID2, ID4, ID6 and ID8, respectively, in the second year. It was observed that TWUE was increased as the amount of irrigation water increased in both years. IWUE values were ranged between 1.21 and 1.43 kg m^{-3} for the first year and the values were between 1.07 and 1.22 kg m^{-3} in the second year. IWUE values of 1.9 kg m^{-3} (Lyle and Bordovsky, 1995) and 1.25-1.46 kg m^{-3} (Musick and Dusek, 1980) were reported. In a different study conducted in Cukurova regions, IWUE value of 1.38-1.80 kg m^{-3} and TWUE values of 0.87-3.19 kg m^{-3} were stated (Koksal, 1995). In addition, IWUE values of 1.02-2.43 kg m^{-3} and TWUE values of 0.22-1.25 kg m^{-3} were reported in a study conducted in Cukurova region by Gencoglan (1996). Furthermore, IWUE values of 0.57-0.795 kg m^{-3} were found for corn crop in Harran Plain conditions (Cetin, 1994). The findings obtained in this current research are in good agreement to those values reported in the previous literature for corn crop.

Crop response factor (k_y): Crop response factor, k_y, indicates the relationship between the decrease in relative water use and the decrease in relative yield. It shows the sensitivity of yield with respect to the decrease in water use. In other words, it explains the decrease in yield caused by per unit decrease in water use. Adjusted yield (Y_{adj}) was calculated using water consumption and yield relationship when maximum water consumption and maximum yield was not obtained. Adjusted yield values were used to determine relative decrease in yield.

Crop response factor was 0.90 (ID6 and ID8) for the first year and were 0.88 (ID6) and 0.93 (ID8) for the second year in the experiments (Table 3). Based on the research results, 11.64% water savings in irrigation water and 5% less ET_a resulted in maximum 14.07 t ha^{-1} yield in ID4 treatment group in the first year. For the same treatment group in the second year, 9.4% water savings and 11% less ET_a resulted in maximum 13.30 t ha^{-1} yield. These results were in accord with the findings reported in the previous literature. For instance, k_y value of 1.25 (Doorenbos and Kassam, 1979) was reported for total growing season of corn crop. In addition, k_y values of 0.97 (Yildirim *et al.*, 1996), 0.98 (Kanber *et al.*, 1990a) and 0.85 (Koksal, 1995) were found under the application of equal water limiting conditions during the growing season of corn crop.

In conclusion, based on the results obtained from this research, an irrigation time interval of 4 day, with 90% ET water application by a drip system, could be recommended for corn in semi-arid regions similar to that in Turkey where the research was conducted.

REFERENCES

Cetin, O., 1994. Water requirement of second crop corn under Harran Plain conditions. Rural Service Research Institute Publ. No. 90/63, Sanliurfa, Turkey.

Cochran, W. and G. Cox, 1957. Experimental Design. John Wiley and Sons Inc., New York and London.

Doorenbos, D. and A.H. Kassam, 1979. Yield response to water. FAO Irrigation and Drainage Paper No. 33. Food and Agriculture Organization of the United Nations, Rome, 193.

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

Gencoglan, C., 1996. Water-Yield relationships of corn plant, determination of root dispersion and water stress index, CERES-corn growing model. Ph.D Thesis, Cukurova Univ. Adana, Turkey.

James, L.G., 1988. Principles of Farm Irrigation System Design. New York, pp: 543.

Kanber, R., 1984. Watering of main and second crop peanut using Class A Pan evaporation under Cukurova conditions. Soil-water Research Institute Publ. No. 114, Tarsus, Turkey.

Kanber, R., A. Yazar and M. Eylen, 1990a. Water-yield relationship of second crop corn under Cukurova conditions. Soil-water Research Institute Publ. No. 173/108, Tarsus, Turkey.

Kanber, R., R. Bastug, H. Koksal and N. Baytorun, 1990b. Yields and comperative performance of different crop production functions of cotton as influenced by deficit irrigation. Doga Tr. J. Agric. Forest., 14: 533-547.

Kang, S., J. Zhang, Z. Liang, X. Hu and H. Cai, 1997. The controlled alternative irrigation a new appoach for water saving regulation in farmland. Agric. Res. Arid Area, 15: 1-6.

Koksal, H., 1995. Water-production function and determination of different growing models at second crop corn under Cukurova conditions. Ph.D Thesis, Cukurova Univ. Adana Turkey, pp: 199.

Lamm, F.R., M.E. Nelson and D.H. Rogers, 1993. Resource allocation in corn production with water resource constraints. Trans. ASAE., 9: 379-385.

Lyle, W.M. and J.P. Bordovsky, 1995. LEPA Corn with limited water supplies. Transaction of the ASAE., 38: 2455-2462.

Mogenson, V.O., H.E. Jeesen and M.A. Rab, 1985. Grain yield, yield components, drought sensitivity and water use efficiency of spring wheat subjected to water stress at various stages. Irrig. Sci., 6: 131-140.

Musick, L.T. and D.A Dusek, 1980. Irrigated corn yield response to water. Trans. ASAE., 23: 103.

Musick, J.T., F.B. Pringle, W.L. Harman and B.A. Stewart, 1990. Long-term irrigation trends: Texas High Plains. Applied Eng. Agric., 6: 717-724.

Musick, J.T., O.R. Jones, B.A. Stewart and D.A. Dusek, 1994. Water-yield relationship for irrigated and dry land wheat in the U.S. Southern Plains. Agron. J., 86: 980-986.

Rhoads, F.M. and J.M. Bennett, 1990. Corn in irrigation of agricultural crops. ASAE Agron. Monograph, 30: 569-596.

Shaozhong, K., S. Wenjuan and J. Zhang, 2000. An improved water-use efficiency for maize grown under regulated deficit irrigation. Field Crops Res., 67: 207-214.

Tanner, C.B. and T.R. Sinclair, 1983. Efficient Water Use in Crop production: Research in Taylor *et al.* (Eds.) Limitations to Efficient Water Use in Crop Production, ASA, Madison, WI., pp: 1-27.

Yaron, D., 1971. Estimation and use of water prodution funtions in crops. J. Irrig. Drain. Div. Proc. ASCE., pp: 291-302.

Yildirim, O., S. Kodal., F. Selenay, Y.E. Yildirim and A. Ozturk, 1996. Corn yield at sufficient and deficient watering conditions. Turkish J. Agric. For., 20: 283-288.

Zhang, J. and W.J. Davis, 1990. Changes in the concentration of ABA in xylem as a function of changing soil water status will account for changes in leaf conductance. Plant Cell Environ., 13: 277-285.