http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 11 (9): 1234-1239, 2008
ISSN 1028-8880

Every-Other-Furrow Irrigation with Different Irrigation Intervals for Grain Sorghum

A.R. Sepaskhah and M.M. Ghasemi
Department of Irrigation, Shiraz University, Shiraz, Islamic Republic of Iran

Abstract: The water stress effects caused by every-other-furrow irrigation on yield may be alleviated by more frequent irrigation intervals. This research was conducted to determine yield and water use efficiency of grain sorghum under fixed and variable every-other-furrow and every furrow irrigations at different irrigation intervals and shallow and deep water table conditions. Water needs of grain sorghum grown on a fine-texture soil may not be met by using Every-Other Furrow Irrigation (EOFI) especially under 15 and 20 day irrigation intervals. The water stress decreased the grain yield mainly through decreasing the number of grains per cluster and in a lesser degree by decrease in 1000-seed weight. The clay soil with a layer of high clay content at depth of 70-100 cm and shallow water table may restrict the root growth and consequently the longer irrigation intervals with greater soil water stress can cause lower grain yield in these conditions. However, more frequent EOFI using 10 day intervals has produced very similar results with only a marginal reduction in crop yield. Furthermore, there was no statistically significant difference in grain yield between fixed and variable every-other -furrow irrigations. In general, at given applied water, the relative grain yield with respect to the maximum grain yield of sorghum at EOFI was higher than those at EFI. At relative applied water of 85% (mild deficit irrigation), EOFI may be recommended to obtain the same grain yield as that of EFI with full irrigation. Furthermore, it may result in 23% more grain yield than that obtained by EFI with the same amount of applied water as deficit irrigation.

Key words: Alternate furrow irrigation, deficit irrigation, water consumption, water use efficiency

INTRODUCTION

Shortage of water in arid and semi-arid regions of IR of Iran is an important limiting factor in crop production. Every-other and wide-spaced furrow irrigations promote irrigation efficiency and reduce loss of water (Sepaskhah and Kamgar-Haghighi, 1997; Sepaskhah and Khajehabdollahi, 2005; Sepaskhah and Parand, 2006). However, the results of Sepaskhah and Parand (2006) for maize (7 day irrigation interval) indicated a significant yield reduction in every-other furrow irrigation. The reduction of yield was due to the smaller amount of applied water and an apparently imposed soil moisture stress, especially at the reproduction stage of growth. Every-other furrow irrigation with exceptional every furrow irrigation at the tasseling and silking stages produced the highest maize yield with a smaller amount of water compared with the every furrow irrigation (Sepaskhah and Parand, 2006).

Using proper irrigation scheduling may increase crop yield. Lyle and Borodovsky (1995) used LEPA (low energy precision application) irrigation with intervals of 3, 6, 9 and 12 days for maize and obtained the highest grain yield at 3 and 6 days intervals.

The water stress effects of every-other furrow irrigation on yield may be alleviated by more frequent irrigation intervals. Root yield of sugarbeet under every-other furrow irrigation at 6 day interval was similar to that of every furrow irrigation at 10 day interval while an average of 23% water was saved (Sepaskhah and Kamgar-Haghighi, 1997).

The objectives of this research were to determine water use, yield, yield components and water use efficiency of sorghum under every-other furrow and every furrow irrigations at different irrigation intervals in two different areas with deep and shallow water table conditions.

MATERIALS AND METHODS

Badjgah experiment: The deep water table experiment was conducted on a clay loam soil (Fine, mixed, mesic, Typic Calcixerepts) at the Badjgah Agricultural Experiment Station of Shiraz University located 16 km north of Shiraz with latitude of 29°, 36'N, longitude of 52°, 32'E and elevation of 1810 m (MSL). Some physical properties of the soils was reported by Sepaskhah and Khajehabdollahi (2005). Soil volumetric water contents at field capacity and permanent wilting point in depth of 0-30 cm were 0.335 and 0.168 cm^3/cm^3, respectively. These values for the soil depths of 30-90 cm were 0.39 and 0.157 cm^3/cm^3, respectively. The mean temperature during the growth

Corresponding Author: A.R. Sepaskhah, Department of Irrigation, Shiraz University, Shiraz, Islamic Republic of Iran

period was 20.2°C. The design of experiment for each site was a randomized split plot with four replications and consisted of three irrigation intervals (10, 15 and 20 day) as main plots (each with net area of 180 m^2) and three furrow irrigation methods (sub-plots, each with net area of 60 m^2). The irrigation methods were: (i) Fixed Every-Other Furrow Irrigation (FEOFI) in which water was applied to alternate furrows throughout the growing season, (ii) Variable Every-Other Furrow Irrigation (VEOFI) which was similar to FEOFI, but water was applied to the furrow which was dry in the previous irrigation cycle and (iii) Every Furrow Irrigation (EFI) in which water was always applied to every furrow. Irrigation water was used from a well with an electrical conductivity (EC) of 0.5 dS m^{-1}. Water table level in this area was deeper than 25 m.

Each sub-plot consisted of 8 rows of sorghum (*Sorghum durra* L.) and V-shaped furrows 10 m long and 0.75 m spacing. The slope of furrows was about 0.002 m m^{-1} and they were diked to prevent runoff. Nitrogen and elemental phosphorous at rates 88 and 42 kg ha^{-1}, respectively, were applied prior to planting and thoroughly mixed into the soil in depth of 10-15 cm. Forty six kilogram per hacter nitrogen was applied when the plants reached a height of 40 cm. Seeds of a local cultivar (Kimia) were planted in the fourth week of May, 1998 in single rows at a spacing of 10 cm. The plant population was 133300 plants ha^{-1}.

After sowing, the plots were irrigated by EFI irrigation once a week for three weeks as pre-treatment irrigation. The total amount of pre-treatment irrigation water was 123 mm. No rainfall occurred during the growing season. The experimental treatments were imposed on June 19, 1998.

Siphon tubes (25 mm, ID) from an equalizing ditch applied the water for irrigation treatments. Furthermore, they were used to measure the required amount of irrigation water for each irrigation treatments. The amount of water consumed by the crop in each irrigation treatment was estimated by the amount of water it took to bring the root zone profile back up to the field capacity, based upon before-irrigation soil moisture measurements. The soil water content in the root zone to 1.2 m depth was measured by neutron probe before irrigation. The neutron tubes were placed in the middle of each sub-plot in two replications. In the middle of each sub-plot in the every furrow irrigation treatment one neutron access tube was placed between the furrow and the top of the bed and for the every-other furrow irrigation treatment, two neutron tubes were installed, one at the bottom of furrow and the other on the top of the bed. Neutron probe readings were taken at depths of 0.15, 0.45, 0.75 and 1.05 m with respect to furrow bottom and top of the bed, respectively.

The evapotranspiration for irrigation intervals (ET, mm) was estimated by the following equation (Jensen, 1973):

$$ET = I+P-D^{+}-(\Sigma_{I=1}^{n}(\theta_1-\theta_2)\,\Delta S_i) \quad (1)$$

Where:

I	=	Irrigation amounts (mm)
P	=	Precipitation (mm)
D	=	Deep percolation (mm) from the bottom of root zone
n	=	Number of soil layers
ΔS	=	Thickness of each soil layer (mm)
θ_1 and θ_2	=	Volumetric soil water contents (cm^3/cm^3) before two consecutive irrigations

The value of D was estimated by soil unsaturated hydraulic conductivity (K) equation through assumption of unit hydraulic gradient at bottom of root zone. The $K(\theta)$ equation was determined by the internal drainage method at a depth of 0-70 cm by measuring soil water content profile on a representative point inside the field (Kashefipour and Sepaskhah, 1995). The equation of K (mm day^{-1}) for the field soils are $K(\theta) = 2.72\times10^{-18}$ Exp (1.1θ) and $K(\theta) = 1.6\times10^{-9}$ Exp $(0.56\,\theta)$ for Badjgah and Kooshkak areas, respectively.

Two plants were selected randomly on each irrigation treatments. The length and width of the plant leaves were measured with a ruler. These measurements were repeated on the same plants in 10 day intervals. The leaf areas of some selected plants throughout the growing season were determined by a leaf areas meter. The linear relationship between a leaf area (A, cm^2) and the corresponding leaf length (L, cm) and width (W, cm) was obtained as follows:

$$A = 0.745(L\times W),\ n = 38,\ R^2 = 0.98,\ p<0.01 \quad (2)$$

The ratio of total leaf area of a plant to the surface area of land devoted to a plant was considered as Leaf Area Index (LAI).

The sorghum was harvested from subplots (20 m^2) on 30-31 October and grain yield (at 14% moisture content) and top dry yield were separated and weighed. The number of branches in each cluster, the 1000-seed weight and the number of seeds per cluster were determined in sub-samples from each sub-plot.

Kooshkak experiment: The shallow water table experiment was conducted on a clay loam soil (Fine, carbonatic, mesic, Aquic Calcixerepts) at the Kooshkak Agricultural Experiment Station of Shiraz University located 75 km North of Shiraz with latitude of 30°, 4'N, longitude of 52°, 35'E and elevation of 1609 m (MSL).

Volumetric soil water contents at field capacity and permanent wilting point in depth of 0-30 cm were 0.39 and 0.213 cm^3/cm^3, respectively. These values for depths of 30-90 cm were 0.42 and 0.282 cm^3/cm^3, respectively. The mean temperature during the growth period was 20.4°C. No rainfall occurred during the growing season. The depth of water table in this area varied between 1.8 m at the sowing time and 1.55 m at the end of irrigation treatments.

The experimental procedure was similar to that for Badjgah area, except the planting and harvest dates were 9 June and 25-27 October, 1998, respectively. The total amount of pre-treatment irrigation water was 137 mm. The experimental treatments were imposed on June 30. Electrical conductivity of irrigation water was 0.6 dS m^{-1}. The analysis of variance and LSD test were used to analyze the data.

RESULTS AND DISCUSSION

Yield

Badjgah experiment: In general, grain and top dry yields (grain plus stover) were higher under 10 day irrigation interval than those obtained under 15 and 20 day intervals and decreased as irrigation interval increased (Table 1, 2). Furthermore, grain and top dry yields under Every Furrow Irrigation (EFI) were significantly higher than those for Every-Other Furrow Irrigation (EOFI) (Table 1, 2). However, grain and top dry yields were not statistically different for variable EOFI (VEOFI) and fixed EOFI (FEOFI). Similar results were reported by Samadi and Sepaskhah (1984) for dry bean. The interaction effects between irrigation intervals and irrigation methods for grain and top dry yields were not significant at 5% level of probability, therefore, the main effects of irrigation methods and intervals were compared statistically.

Kooshkak experiment: The effects of irrigation methods and intervals on grain and top dry yields in Kooshkak experiment were similar to those obtained in Badjgah experiment (Table 1, 2). The interaction effects between irrigation intervals and irrigation methods for grain and top dry yields were statistically significant at 5% level of probability. The grain and top dry yields for fixed and variable EOFI method at irrigation intervals of 10 and 20 days were similar, while they were lower for fixed EOFI method at 15 day interval. In general, the grain and top dry yields in Kooshkak experiment for 10 and 15 day irrigation intervals were higher (about 8% higher for grain and 17% higher for top) than those obtained in Badjgah experiment, while the results were reversed for 20 day irrigation interval (about 14% lower for grain and 13% lower for top at Kooshkak). The clay soil, shallow water table and a layer with high clay content at depth of 70-100 cm in Kooshkak experiment might have restricted the root depth. Therefore, the root ability for water uptake at greater irrigation interval (20 day) was restricted and resulted in lower grain and top dry yields. Furthermore, the clay soil (low hydraulic conductivity) and presence of a layer with high clay content at depth of 70-100 cm may have reduced the upward flow of water from shallow water table at depth of 155-180 cm for plant use. However, more frequent irrigation interval (10 day) in Kooshkak experiment with higher air evaporation potential resulted in higher application of irrigation water and grain and top yields (Table 6). Furthermore, there was no statistically significant difference in grain yield between fixed and variable EOFI methods.

Table 1: Average top dry yield (t ha^{-1}) at different irrigation treatments

		Irrigation interval (days)			
Locations	Irrigation methods	10	15	20	Mean
Badjgah	Every furrow	15.45	12.57	11.48	13.17^{a*}
	Variable every-other	12.53	11.12	9.67	11.10^{b}
	Fixed every-other	12.53	11.38	9.87	11.26^{b}
	Mean	13.50^{A}	11.69^{B}	10.34^{C}	
Kooshkak	Every furrow	17.15^{a}	15.44^{b}	11.06^{c}	**
	Variable every-other	14.63^{b}	13.70^{c}	8.19^{d}	
	Fixed every-other	15.38^{b}	12.26^{c}	7.59^{d}	

*: Means at each location with similar letter(s) in each column and row [capital letter(s)] are not significantly different at the 5% level of probability (LSD). **: The main effects were not compared due to statistically significant interaction

Table 2: Average grain yield (t ha^{-1}) with 14% moisture content (dry basis) at different treatments

		Irrigation interval (days)			
Locations	Irrigation methods	10	15	20	Mean
Badjgah	Every furrow	6.52	5.16	3.40	5.03^{a*}
	Variable every-other	5.28	3.55	2.10	3.64^{b}
	Fixed every-other	5.43	3.76	1.91	3.40^{b}
	Mean	5.74^{A}	4.16^{B}	2.47^{C}	
Kooshkak	Every furrow	7.23^{a}	5.46^{b}	2.90^{c}	**
	Variable every-other	5.67^{b}	4.06^{c}	1.77^{d}	
	Fixed every-other	5.79^{b}	3.74^{c}	1.73^{d}	

*: Means at each location with similar letter(s) in each column [lower case letter(s)] and row [capital letter(s)] are not significantly different at the 5% level of probability. **: The main effects were not compared due to statistically significant interaction

Table 3: Average number of seeds per cluster at different treatments

		Irrigation interval (days)			
Locations	Irrigation methods	10	15	20	Mean
Badjgah	Every furrow	1468^{a}	1234^{b}	681^{d}	1128^{a*}
	Variable every-other	1186^{b}	777^{c}	372^{e}	778^{b}
	Fixed every-other	1191^{b}	697^{d}	355^{e}	748^{b}
	Mean	1282^{A}	903^{B}	469^{C}	
Kooshkak	Every furrow	1534^{a}	1174^{b}	572^{e}	1093^{a}
	Variable every-other	1200^{b}	868^{c}	310^{f}	793^{b}
	Fixed every-other	1242^{b}	750^{d}	286^{f}	759^{b}
	Mean	1325^{A}	930^{B}	389^{C}	

*: Means at each location with similar letter(s) in each column [lower case letter(s)] and row [capital letter(s)] are not significantly different at the 5% level of probability

Table 4: Average 1000-seed weight (g) for different treatments

		Irrigation interval (days)			
Locations	Irrigation methods	10	15	20	Mean
Badjgah	Every furrow	32.7	31.7	31.8	32.0^{a}*
	Variable every-other	32.1	31.9	33.7	32.5^{a}
	Fixed every-other	33.5	33.6	31.8	33.8^{a}
	Mean	32.8^{A}	32.4^{A}	32.4^{A}	
Kooshkak	Every furrow	33.8^{a}	34.2^{a}	31.0^{cd}	33.0^{a}
	Variable every-other	33.7^{ab}	30.8^{cd}	30.3^{d}	31.2^{a}
	Fixed every-other	31.5^{bcd}	31.8^{bc}	31.2^{bcd}	31.5^{a}
	Mean	32.7^{A}	32.2^{A}	30.8^{B}	

*: Means at each location with similar letter(s) in each column [lower case letter(s)] and row [capital letter(s)] are not significant different at the 5% level of probability

Table 5: The maximum leaf area index (LAI_m) for different irrigation treatments and experimental locations

		Irrigation interval (days)		
Locations	Irrigation methods	10	15	20
Badjgah	Every furrow	2.54	2.26	1.99
	Variable every-other	2.24	2.21	1.81
	Fixed every-other	2.28	2.30	1.79
Kooshkak	Every furrow	2.89	2.58	1.96
	Variable every-other	2.48	2.29	1.82
	Fixed every-other	2.58	2.34	1.76

Yield components: The reduction in number of grains per cluster due to the irrigation methods and intervals were similar to those obtained for grain yield reduction (Table 3). Therefore, the main cause of grain reduction is attributed to the decrease in number of grains per cluster (Table 3). The interaction effect between irrigation interval and irrigation method for the number of grains per cluster was not statistically significant.

The 1000-seed weight was also decreased significantly at 20 day irrigation interval and EOFI in Kooshkak experiment (Table 4), but it was not reduced at 20 day irrigation interval in Badjgah experiment. The interaction effect between irrigation interval and irrigation method for the 1000-seed weight was not statistically significant. The reduced 1000-seed weight and lower number of grains per cluster at 20 day irrigation interval in Kooshkak experiment were the main reasons for decreased grain yield in this treatment in Kooshkak experiment. Furthermore, the number of grains per cluster was higher at 10 day irrigation interval in Kooshkak experiment than that of Badjgah experiment which may be the cause of higher grain yield in this treatment in Kooshkak experiment.

Leaf area index: In general the maximum leaf area index (LAI_m) decreased in longer irrigation intervals and in every-other furrow irrigation (Table 5). This decrease was greater in Kooshkak area. LAI is usually a measure of solar radiation absorption and photosynthesis which influences the yield. The relationship between top dry yield (y_t, t ha^{-1}) and LAI_m is as follows:

$$Y_t = 5.70\ LAI_m,\ R^2 = 0.97 \qquad (3)$$

The relationship between grain yield (y, t ha^{-1}) and LAI_m is as follows:

$$Y = 4.60\ (LAI_m - 1.30),\ R^2 = 0.85 \qquad (4)$$

A threshold for LAI_m of 1.30 was obtained which is a least value of LAI_m for grain production initiation. It is interesting to note that in both study locations, every-other furrow irrigation at 10 day interval resulted in LAI_m similar to that obtained for every furrow irrigation at 15 day interval. Therefore, more frequent irrigation of every-other furrow irrigation is equally effective in leaf growth as every furrow irrigation at less frequent irrigation.

Evapotranspiration (ET_c): In general ET_c decreased at longer irrigation intervals and every-other furrow irrigation. ET_c was higher in Kooshkak location due to higher mean seasonal air temperature (Table 6). The ratio of mean ET_c for every-other furrow irrigation at 10 day interval to that for every furrow irrigation at 15 day interval was 0.86 for both locations while the grain yields of these treatments were almost equal (Table 2). This might be due to the reduction of surface evaporation in every-other furrow irrigation where almost half of soil surface is wetted in EOFI compared with EFI.

The relationship between grain yield reduction ($1-y/y_m$) and ET_c reduction ($1-ET_c/ET_{cm}$) is as follows:

$$(1-y/y_m) = 1.27(1-ET_c/ET_{cm}),\ R^2 = 0.92,\ SE = 0.009,\ p<0.001 \qquad (5)$$

Where:

y and y_m = Actual and maximum grain yields
ET_c and ET_{cm} = Actual and maximum evapotranspiration.

The coefficient of this equation (1.27) is much greater than that reported by Doorenbos and Kassam (1979), 0.9, for sorghum.

Deep percolation: In general, deep percolation was reduced in every-other furrow irrigation (Table 6). This might be due to the more lateral movement of water in soil in every-other furrow irrigation. Furthermore, deep percolation was decreased drastically in longer irrigation intervals. This might be due to the drier soil at lower layers in the root zone in irrigation treatments with longer intervals. Furthermore, deep percolation in Kooshkak location is higher than those obtained in Badjgah location due to high water table and drainage installation. However, deep percolation in this location was about 10% of the ET_c or less at the shortest irrigation interval.

Table 6: Seasonal evapotranspiration (ET_c, mm) and deep percolation (D, mm) for different irrigation treatments and experimental locations

		Irrigation interval (days)					
		10		15		20	
Locations	Irrigation methods	ET_c	D	ET_c	D	ET_c	D
Badjgah	Every furrow	742.0	43.2	641.3	25.8	484.0	14.3
	Variable every-other	559.7	11.3	417.2	5.8	355.8	1.7
	Fixed every-other	537.2	12.9	433.7	6.7	369.6	1.0
Kooshkak	Every furrow	805.7	79.7	691.3	63.8	662.7	17.6
	Variable every-other	612.1	64.3	458.3	13.4	467.8	13.0
	Fixed every-other	578.3	51.0	582.4	18.4	422.9	11.0

Table 7: Applied irrigation water for different irrigation treatments (mm)

		Irrigation intervals (days)		
Locations	Irrigation methods	10	15	20
Badjgah	Every furrow	800	677	513
	Variable every-other	581	464	392
	Fixed every-other	601	449	379
Kooshkak	Every furrow	833	675	563
	Variable every-other	617	513	379
	Fixed every-other	643	428	385

Table 8: Water use efficiency (kg m^{-3}) for different irrigation treatments

		Irrigation intervals (days)		
Locations	Irrigation methods	10	15	20
Badjgah	Every furrow	0.81	0.76	0.66
	Variable every-other	0.91	0.77	0.54
	Fixed every-other	0.90	0.84	0.50
Kooshkak	Every furrow	0.87	0.81	0.52
	Variable every-other	0.92	0.79	0.47
	Fixed every-other	0.90	0.88	0.45

Water use efficiency: Water use efficiency was considered as the harvested portion of crop produced (grain) per unit of water consumed. The greatest difference in applied irrigation water between EFI and EOFI treatments occurred under 10 day irrigation intervals (Table 7). This is due to the fact that more frequent irrigation under EFI may result in higher evaporation from soil surface, especially during early growing season with incomplete ground cover. Therefore, it is possible to design an experiment where both irrigation interval and water quantities are variables.

The maximum and minimum water use efficiencies (about 0.92 and 0.45 kg m^{-3}) were obtained for EOFI at 10 day interval and EOFI at 20 day interval, respectively (Table 8). When available water is scarce (about 450 mm) FEOFI at 15 day irrigation interval is more efficient in grain production than EFI at 10 day irrigation interval which required more than 800 mm of applied water and resulted in a similar water use efficiency. However, when available water is about 600 mm, EOFI at 10 day interval is more efficient in grain production than EFI at 10 day interval which required more than 800 mm of applied water and resulted in lower water use efficiency.

The mean soil water profiles before each irrigation under different irrigation methods for Badjgah and Kooshkak, showed that no obvious difference could be detected between soil moisture contents for fixed and variable EOFI (FEOFI, VEOFI) (data are not shown). In general, the mean soil water contents of the profile, especially the lower part for EOFI, were lower than those for EFI, therefore, deep percolation might be less important under EOFI treatments. Furthermore, some of the water under EFI, especially under 10 day interval, was probably lost by evaporation and drainage below the root zone.

Yield and water relationship: The relationships between relative applied water (relative to the applied water for maximum grain yield at EFI with 10 day interval, %), x and relative grain yield (relative to the maximum grain yield, %) y, combined for both sites for EFI and EOFI are as follows:

$$y = 1.55(x-35.2),\ R^2 = 0.94 \text{ for EFI} \quad (6)$$

$$y = 1.77(x-28.8),\ R^2 = 0.93 \text{ for EOFI} \quad (7)$$

Since there was no statistically significant difference between yields in fixed and variable EOFI, therefore, these data were included in Eq. 7. The equation for EOFI (Eq. 7) resulted in a relative grain yield greater than that of EFI due to the higher coefficient (1.77 vs. 1.55). This implied that the yield with a given amount of applied water is higher under EOFI. Equation 6 may be used to analyze the yield expected from a given amount of water.

At a relative applied water of 85% by EOFI, a linear extrapolation similar to that for EFI may result in 100% grain yield or 23% more yield than that by EFI. In other words, water saving of about 15% can be expected using EOFI rather than EFI at yield levels less than maximum yield. The soil water contents of the lower part of the soil water profile are not very different for wet and dry furrows of EOFI (Sepaskhah and Kamgar-Haghighi, 1997). Furthermore, these values are not very different from those of EFI at 10 day interval. These results indicated that the lateral movement of soil water might be as important as downward movement. This suggests that in an irrigation system with similar soil texture (at least the same ability to produce as much lateral movement of water as downward) and environment, a given input of water will produce greater grain yield if water is applied as EOFI rather than as EFI. Similar results were reported by Stone and Nofziger (1993) for wide-spaced furrow irrigation for cotton lint.

The slope of the lines (Eq. 6 and 7) was considered as the efficiency of applied water (Stone and Nofziger, 1993; Sepaskhah and Kamgar-Haghighi, 1997). The ratio of the slopes in the linear Eq. 6 and 7, 1.14, suggests that EOFI is about 14% more efficient than EFI in use of applied water. The results of Stone and Nofziger (1993) indicated that wide-spaced furrow irrigation was about 13% more efficient than EFI in use of applied water which is similar to that obtained in the present study. This similarity may be due to the similarity in crops in which the yields result from the reproduction stage of growth (cotton lint and grain sorghum). However, Sepaskhah and Kamgar-Haghighi (1997) reported a ratio of the slope in linear equations for EOFI and EFI as 1.26 for root yield of sugarbeet which is a vegetative based yield. This increase in ratio is almost twice that for grain sorghum for the present investigation or cotton lint as reported by Stone and Nofziger (1993).

Similar relationships between top dry weight (relative to the maximum top dry weight, %), y and relative applied water (relative to the applied water for maximum top dry weight, %), w, for EFI and EOFI are shown as follows:

$$y = -37.0 + 2.06w - 0.0069w^2,\ R^2 = 0.973,\ \text{for EFI} \quad (8)$$

$$y = -76.1 + 4.06w - 0.026w^2,\ R^2 = 0.683,\ \text{for EOFI} \quad (9)$$

Since there was no statistically significant difference between yields in fixed and variable EOFI, therefore, their data were included in Eq. 9. The equation for EOFI (Eq. 9) showed a greater relative top dry weight than that of EFI for relative applied water of smaller than 78%. The maximum increase in top dry weight due to EOFI (about 40%) was obtained at about 52% of relative applied water.

The results of other investigators suggest that the bulk of the savings is due to reduction of evaporation from the soil surface (Tsegaye *et al*., 1993), as may be the case in the present study.

CONCLUSION

Although, the experiments have been conducted only for one year, but the results of multiple sites were analyzed. The results indicated that water needs of grain sorghum on a fine-texture soil may not be met by irrigating Every-Other Furrow (EOFI) especially under 15 and 20 day irrigation intervals. The water stress decreased the grain yield mainly through decreasing the number of grains per cluster and in a lesser degree by decrease in weight of 1000-seed. Clay soil, shallow water table and a layer with high clay content at depth of 70-100 cm may restrict the root growth and consequently the longer irrigation intervals with greater soil water stress might have caused lower grain yield in these conditions. More frequent EOFI using 10 day interval is a controlled-stress irrigation with little risk of crop yield reduction. In general, at a given applied water the relative grain yield of sorghum at EOFI was higher than those at EFI. At relative applied water of 85% (mild deficit irrigation), EOFI may be recommended to obtain the same grain yield as that of EFI with full irrigation or to obtain 23% more grain yield than that obtained by EFI with the same amount of deficit irrigation.

ACKNOWLEDGMENTS

This research was supported in part by Grant No. 85-GR-AGR-42 of Shiraz University Research Council and Center of Excellence on Farm Water Management.

REFERENCES

Doorenbos, J. and A.H. Kassam, 1979. Yield response to water. Irrigation and Drainage Papers No. 33, FAO, Rome, pp: 193.

Jensen, M.E., 1973. Consumptive use of water and irrigation water requirements. ASCE, pp: 215.

Kashefipour, S.M. and A.R. Sepaskhah, 1995. Determination of unsaturated hydraulic conductivity by internal drainage assuming a uniform soil water profile. Iran Agric. Res., 14 (2): 203-216.

Lyle, W.M. and J.P. Borodovsky, 1995. LEPA corn irrigation with limited water supplies. Trans. ASAE., 38: 455-462.

Samadi, A. and A.R. Sepaskhah, 1984. Effects of alternate furrow irrigation on yield and water use efficiency of dry beans. Iran Agric. Res., 3 (2): 95-115.

Sepaskhah, A.R. and A.A. Kamgar-Haghighi, 1997. Water use and yields of sugarbeet grown under every-other-furrow irrigation with different irrigation intervals. Agric. Water Manage., 34: 71-79.

Sepaskhah, A.R. and M.H. Khajehabdollahi, 2005. Alternate furrow irrigation with different irrigation intervals for maize (*Zea mays* L.). Plant Prod. Sci., 8 (5): 592-600.

Sepaskhah, A.R. and A.R. Parand, 2006. Effects of alternate furrow irrigation with supplemental every-furrow irrigation at different growth stages on the yield of maize (*Zea mays* L.). Plant Prod. Sci., 9 (4): 415-421.

Stone, J.F. and D.L. Nofziger, 1993. Water use and yields of cotton grown under wide-spaced furrow irrigation. Agric. Water Manage., 24: 27-38.

Tsegaye, T., J.F. Stone and H.E. Reeves, 1993. Water use characteristics of wide-spaced furrow irrigation. Soil Sci. Soc. Am. J., 57: 240-245.