Effects of Alternate Furrow Irrigation with Supplemental Every-Furrow Irrigation at Different Growth Stages on the Yield of Maize (Zea mays L.)

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Abstract: The effect of water stress caused by alternate furrow irrigation (AFI) on the yield of maize may be alleviated by applying every-furrow irrigation (EFI) at stress sensitive growth stages. This research was conducted in two different areas with deep and shallow water tables to examine the amount of water used, yield, yield components and water use-efficiency of maize under AFI at 7-day intervals supplemented with EFI at different stages. AFI resulted in significant reduction in grain yield and in both Bajgah and the Kooshkak areas with deep and shallow water tables, respectively. This occurred due to probable water stress and reduction in 1000-grain weight. However, under AFI supplemented with EFI once or twice at the tasseling or silking stage grain yields were statistically equal to those obtained in EFI although the amount of water used was about 30% smaller in both Bajgah (deep water table) and Kooshkak areas (shallow water table). In both areas the water-use efficiency for grain yield under these irrigation treatments was 1.04 and 0.97 kg grain per m$^3$ of water, respectively.

Key words: Alternate furrow irrigation, Corn (Zea mays L.), Supplemental every-furrow irrigation, Water-use efficiency.

Crop production in semi-arid area mainly relies on irrigation. This is true for Fars province in southern I.R. of Iran where annual rainfall is less than 400 mm with negligible amount of rain during the growing season of summer crops.

Agricultural water can be conserved in various ways. Several investigators (Samadi and Sepaskhah, 1984; Hodges et al., 1989; Graterol et al., 1993; Stone and Nofziger, 1993; Sepaskhah and Kamgar-Haghighi, 1997; Ghasemi and Sepaskhah, 2003) have used wide-spaced furrow irrigation and alternate furrow irrigation (AFI) as a mean to improve water-use efficiency (WUE). In AFI, some furrows are irrigated while adjacent furrows are not, and water is saved mainly by reduced evaporation from the soil surface, as in the case of drip irrigation.

In general, the use of these irrigation methods are a trade-off: a lower yield for a higher WUE. New (1971) reported a significant yield reduction by AFI (at 7-day interval) in sorghum (Sorghum bicolor L.) and Samadi and Sepaskhah (1984) reported the same in dry bean (Phaseolus vulgaris L.) when using AFI. The reduction of yield was due to the small amount of applied water, apparently imposed soil moisture stress, especially at the reproduction stages of growth. AFI at 10-day intervals resulted in a 18% reduction in sugarbeet yield and a 54% reduction in applied water (Sepaskhah and Kamgar-Haghighi, 1997).

Reduced crop yield in AFI may be alleviated by applying every furrow irrigation (EFI) at specific stages of growth. Samadi and Sepaskhah (1984) reported that in the AFI with supplemental EFI at only the podding and pod filling stages resulted in the higher grain yield with less water use compared with the full season EFI in dry bean. Water stress at the end of vegetative growth period and during the silking stage of maize resulted in 35 and 43% reduction in grain yield, respectively (Miller and Duley, 1925). Robins and Domingo (1953) showed that soil water depletion to permanent wilting point (PWP) for 1-2 days at tasseling or pollination stage resulted in 22% reduction in grain yield of maize, however, this reduction was 50% when the soil water depletion to PWP lasted 6-8 day. Soil water depletion to PWP at growth stage before silking and after silking resulted a 50 and 21% reduction, respectively in grain yield in maize (Denmead and Shaw, 1960).

When the water is scarce in arid and semi-arid regions the value of AFI method may be justified. Furthermore, in these regions such as the Kooshkak area, the water table may be shallow as reported by Sepaskhah and Khajehabdullahi (2005) and Sepaskhah et al. (2003). The shallow groundwater may contribute to the supply of water to the plants and the use of AFI may prove valuable. Studies in California and Texas (USA) have shown that salt-tolerant crops (cotton, alfalfa and barley) are capable of extracting significant quantities of water from a saline water table (reported by Ayars and Schoneman, 1986; Hutmacher et al.,1996; Ayars et al., 1999, 2003). Grismer and Gates (1988)
reported that under arid conditions, groundwater can supply as much as 60-70% of the water required for crop growth. Wallender et al. (1979) found that cotton extracted up to 69% of its evapotranspiration (ET) from a saline (6 dS m\(^{-1}\)) groundwater. Ayars and Schoneman (1986) reported that cotton extracted up to 49% ET from a saline (10 dS m\(^{-1}\)) groundwater depending on the amounts of non-saline water applied. The amount of water extracted from the groundwater depends on the amount of water applied and irrigation schedule (Sepaskhah et al., 2003). The maximum use of saline groundwater was observed when irrigation was applied only once after pre-plant irrigation in cotton as reported by Ayars and Schoneman (1986).

The objectives of this study were to determine the amount of water used, yield, yield components and water-use efficiency of maize under AFI with supplemental EFI at different stages of growth in two different areas with deep and shallow water table.

### Materials and Methods

#### 1. Experiment at Bajgah

The experiment on a clay loam soil (Fine, mixed, mesic, Typic Calcixererts) with deep water table was conducted at the Bajgah Agriculture Experiment Station of Shiraz University located 16 km north of Shiraz with latitude of 29°, 36' N, longitude of 52°, 32', E and a mean sea level (MSL) elevation of 1810 m. Some physical properties of the soil were reported by Sepaskhah and Khajehabdullahi (2005). Volumetric soil-water contents at the field capacity and permanent wilting point in depth of 0-30 cm were 0.34 and 0.17 cm\(^3\) cm\(^{-3}\), respectively. These values at the soil depth of 30-90 cm were 0.39 and 0.16 cm\(^3\) cm\(^{-3}\), respectively. The mean temperature during the growth period was 20.2°C. Water table level in this area was deeper than 25 m. The experiment was conducted with a randomized complete block design with four replications and consisted of 11 irrigation treatments (plots, each with net area of 45.0 m\(^2\)). The irrigation treatments are described in Table 1. The irrigation interval for AFI and EFI is seven days. Stages of growth were determined according to the recommendation of Doorenbos and Kassam (1979). Irrigation water with an electrical conductivity (EC) of 0.5 dS m\(^{-1}\) was obtained from a well.

Each plot consisted of six rows of maize (Zea mays L.) and V-shaped furrows of 10 m long at 0.75 m spacing. The slope of furrows was about 0.002 m m\(^{-1}\) and they were diked to prevent runoff. Nitrogen and phosphorous at 116 and 42 kg ha\(^{-1}\), respectively, were applied prior to planting and thoroughly mixed into the soil to a depth of 10-15 cm. Forty-six kg ha\(^{-1}\) nitrogen was applied five weeks after sowing when the plants reached a height of 50-60 cm. Seeds of a local cultivar (SC 704) were planted on May 16, 1995 in rows at a spacing of 25 cm. The plant population was 53000 plants ha\(^{-1}\).

After sowing, the plots were irrigated by EFI once a week for four weeks (with a total of five irrigations) as pre-treatment irrigation. The total amount of pre-treatment irrigation water was 227 mm. There was no rainfall during the growing season. The experimental treatments were started on June 13, 1995 with weekly irrigation intervals.

Siphon tubes (25 mm, ID) from an equalizing ditch supplied the water for irrigation treatments. They were also used to measure the amount of irrigation water for each irrigation treatments. The amount of water consumed by the crop in each irrigation treatments was estimated by the amount of water required to bring the root zone profile back to the field capacity, based on before-irrigation soil moisture. The soil-water content in the root zone at 1.05 m depth was measured by neutron probe before each irrigation. The neutron

| Treatment | Treatment description |
|-----------|-----------------------|
| EFI       | Every furrow irrigation at 7-day interval |
| VAFI      | Variable alternate furrow irrigation in which water was applied at 7-day intervals to furrows which were dry in the previous irrigation cycle |
| FAFI      | Fixed alternate furrow irrigation in which water was applied to alternate furrows throughout the growing season with 7-day interval |
| VAFI-T    | Similar to VAFI but EFI was applied once at tasseling stage |
| FAFI-T    | Similar to FAFI but EFI was applied once at tasseling stage |
| VAFI-S    | Similar to VAFI but EFI was applied twice at silking stage |
| FAFI-S    | Similar to FAFI but EFI was applied twice at silking stage |
| VAFI-F    | Similar to VAFI but EFI was applied three times at grain filling stage |
| FAFI-F    | Similar to FAFI but EFI was applied three times at grain filling stage |
| VAFI-R    | Similar to VAFI but EFI was applied twice at ripening stage |
| FAFI-R    | Similar to FAFI but EFI was applied twice at ripening stage |
tubes were placed in the middle of each plot in two replications. In EFI one neutron access tube was placed in the middle of each plot between the furrow and the top of the bed, and in AFI, two neutron tubes were installed, one at the bottom of furrow and the other on the top of the bed. Neutron probe readings were made at the depths of 0.15, 0.45, 0.75 and 1.05 m. For each treatment plot, the difference between the water content of soil measured in the root zone before each irrigation and the water content of field capacity was regarded as irrigation water. The volume of irrigation water for each furrow was the multiplication of irrigation water depth and the area of each irrigated furrow (furrow width × furrow length). The field was irrigated 19 times in all the treatments.

The crop evapotranspiration during each irrigation interval (ET, mm) was estimated from the following equation (Jensen, 1973): 

\[ ET = I + P - D + \sum_{i=1}^{n} (\theta_{i} - \theta_{o}) \Delta S_{i} \]  

where \( I \) is the amount of irrigation water (mm), \( P \) is precipitation (mm), \( D \) is deep percolation (mm) from the bottom of root zone, \( n \) is the number of soil layers, \( \Delta S \) is the thickness of each soil layer (mm) and \( \theta_{i} \) and \( \theta_{o} \) are volumetric soil-water contents (cm\(^3\) cm\(^{-3}\)) of each soil layer before two consecutive irrigations. The value of \( D \) was estimated from soil unsaturated hydraulic conductivity (K) of soil at the bottom of the root zone. \( K(\theta) \) equation was determined by the internal drainage method by measuring soil-water content at a depth of 0-70 cm at a representative point inside the field (Hillel et al., 1972; Kashefi pour and Sepaskhah, 1995). The equation of \( K(\theta) \) for the field soils are \( K(\theta)=2.72 \times 10^{-16}\exp(110 \theta) \).

The maize was harvested from the middle portion of the treatment plots (7.5 m\(^2\)) on October 5 and grain yield (at 15.5% moisture content) and top dry yield were weighed. The number of grain in each cob and the 1000-grain weight were determined in sub-samples from each plot.

2. Experiment at Kooshkak

The experiment in the field with shallow water table 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 an elevation of 1609 m (MSL). Volumetric soil water contents at field capacity and permanent wilting point at 0-30 cm depth were 0.39 and 0.21 cm\(^3\) cm\(^{-3}\), respectively. These values at the depth of 30-90 cm were 0.42 and 0.28 cm\(^3\) cm\(^{-3}\), respectively. The mean temperature during the growing period was 22.2 °C. There was no rainfall during the growing season. The depth of water table in this area varied between 1.4 m at the sowing time and 1.18 m at the end of irrigation treatments.

The water evapotranspiration from the crop during irrigation intervals under the presence of groundwater which contributed to the water use of the plant was estimated from the soil water balance equation at a given interval as described by Sepaskhah et al. (2003) and Sepaskhah and Khajehabdullahi (2005). The contribution of groundwater to the water use of the plant was computed from the potential capillary rise according to the depth of the water table, which was corrected by the soil water depletion to below the critical soil water content in the root zone (Sepaskhah et al., 2003; Sepaskhah and Khajehabdullahi, 2005). The root depth during the growing season was determined by the equation proposed by Borg and Grimes (1986).

The experimental procedure was similar to that for the Bajgah area, except that the planting date was May 22, 1995 and harvest date was October 3, 1995. The total amount of pre-treatment irrigation water was 273 mm. The experimental treatment started on June 20. Electrical conductivity of irrigation water was 0.6 dS m\(^{-1}\).

Statistical analysis

The analysis of variance and Duncan multiple range test (DMRT) used to analyze the data. Although, the experiments have been conducted only for one year (no significant rainfall during the growing season), the results of multiple sites were statistically analyzed.

Results and Discussion

1. Yield

The effects of irrigation treatments on the stover yield in Bajgah and Kooshkak areas were not significantly different (data are not shown). The average of stover yields under EFI and AFI (mean value of VAFI and FAFI) were 9.15 and 8.06 t ha\(^{-1}\) respectively, in the Bajgah area and 8.18 and 7.59 t ha\(^{-1}\) respectively, in the Kooshkak area. The absence of a statistical significant difference between stover yields under EFI and AFI indicated that AFI does not reduce the vegetative growth significantly. This finding is in accordance with the results obtained by Sepaskhah and Kamgar-Haghhighi (1997) for sugarbeet yield. However, the lower stover yield in the Kooshkak area might probably be due to nitrogen leaching that might have occurred in condition of shallow water table in this area.

The relative effects of different irrigation treatments on the maize grain yield in the Bajgah area were similar to those in the Kooshkak area (Tables 2 and 3). The effect of irrigation treatment on the grain yield (15.5% moisture content) in both areas was statistically significant at the 5% level (Tables 2 and 3). In both experimental sites, grain yield under AFI with supplemental EFI at flowering stages (tasseling and silking) were not statistically different from that under
Similar results were reported with dry beans by Samadi and Sepaskhah (1984). However, the grain yields under AFI and AFI with supplemental EFI at the other growth stages (AFI-F and AFI-R) was significantly lower than that under EFI (Tables 2 and 3).

2. Yield component

The effect of irrigation treatment on the number of grains per cob in both experimental areas was not significantly different. However, the number was lower under AFI-F and AFI-R than under AFI-T and AFI-S (data are not shown). The average number of grain per cob under EFI and AFI was 590 and 551, respectively, in the Bajgah area and 583 and 513, respectively, in the Kooshkak area. The effect of irrigation treatments on the 1000-grain weight in Bajgah and Kooshkak areas was statistically significant at the 5% level (Tables 2 and 3). In these experimental areas, the 1000-grain weight under AFI-T and AFI-S was not statistically different from that obtained for EFI (Tables 2 and 3). However, the 1000-grain weight under AFI-F and AFI-R was significantly lighter than that obtained under EFI (Tables 2 and 3). Therefore, it may be concluded that reduced grain yield in some of the irrigation treatments was mainly caused by reduction in 1000-grain weight. A small reduction in the number of grains per cob under AFI-F and AFI-R compared with that under AFI-T and AFI-S was intensified by the significant reduction in 1000-grain weight under AFI-F and AFI-R.

| Irrigation treatment | Grain yield t ha⁻¹ | 1000-grain weight g | Applied water mm | Water use efficiency kg m⁻³ |
|----------------------|---------------------|---------------------|------------------|-----------------------------|
| EFI (Every furrow)   | 8.30 a*             | 292 a               | 1053             | 0.785                       |
| VAFI (Variable alternate furrow) | 5.92 def          | 258 d               | 747              | 0.793                       |
| FAFI (Fixed alternate furrow) | 6.49 cdef        | 265 cd              | 742              | 0.875                       |
| VAFI-FI at tasseling (VAFI-T) | 7.86 ab           | 284 ab              | 754              | 1.042                       |
| FAFI-FI at tasseling (FAFI-T) | 7.33 abcd         | 284 ab              | 783              | 0.936                       |
| VAFI-FI at silking (VAFI-S) | 7.29 abcd         | 283 ab              | 776              | 0.940                       |
| FAFI-FI at silking (FAFI-S) | 7.37 abc           | 282 ab              | 781              | 0.944                       |
| VAFI-EFI at grain filling (VAFI-F) | 5.75 f            | 279 abc             | 842              | 0.682                       |
| FAFI-EFI at grain filling (FAFI-F) | 5.92 def          | 268 bcd             | 864              | 0.685                       |
| VAFI-EFI at ripening (VAFI-R) | 5.88 ef            | 273 bcd             | 807              | 0.729                       |
| FAFI-EFI at ripening (FAFI-R) | 6.02 cdef          | 272 bcd             | 806              | 0.747                       |

*: Means followed by the same letter in each column are not different significantly at 5% level of probability by Duncan’s multiple range test.

| Irrigation treatment | Grain yield t ha⁻¹ | 1000-grain weight g | Applied water mm | Water use efficiency kg m⁻³ |
|----------------------|---------------------|---------------------|------------------|-----------------------------|
| EFI (Every furrow)   | 8.41 a*             | 317 a               | 1139             | 0.738                       |
| VAFI (Variable alternate furrow) | 6.58 b            | 301 b               | 747              | 0.880                       |
| FAFI (Fixed alternate furrow) | 6.38 b            | 297 b               | 717              | 0.891                       |
| VAFI-FI at tasseling (VAFI-T) | 7.29 ab           | 309 ab              | 767              | 0.950                       |
| FAFI-FI at tasseling (FAFI-T) | 6.98 ab           | 305 ab              | 783              | 0.891                       |
| VAFI-FI at silking (VAFI-S) | 7.52 ab           | 310 ab              | 769              | 0.978                       |
| FAFI-FI at silking (FAFI-S) | 7.77 ab           | 304 ab              | 799              | 0.973                       |
| VAFI-EFI at grain filling (VAFI-F) | 6.33 b            | 304 ab              | 837              | 0.756                       |
| FAFI-EFI at grain filling (FAFI-F) | 6.56 b            | 302 ab              | 803              | 0.817                       |
| VAFI-EFI at ripening (VAFI-R) | 6.38 b            | 303 ab              | 851              | 0.750                       |
| FAFI-EFI at ripening (FAFI-R) | 6.26 b            | 303 ab              | 814              | 0.769                       |

*: Means followed by the same letter in each column are not different significantly at 5% level of probability by Duncan’s multiple range test.
weight in the former and resulted in significant
reduction in grain yield in the former.

Grain protein and oil contents of grain were not
significantly influenced by irrigation treatments (data
are not shown). The grain protein contents of grains
under EFI and AFI were identical (8.9%) and the oil
contents were 2.92 and 3.38% under EFI and AFI,
respectively.

3. Water use

Tables 2 and 3 show the amount of applied water in
different treatments in the Bajgha and Kooshkak. The
amount of water used was smaller in AFI than in EFI
because half of the number of furrows was irrigated in
this treatment.

Table 4 shows the relative reduction in grain yields
and water use in the Bajgha and Kooshkak areas.
In general, the amount of water used for AFI in the
Bajgha and Kooshkak was 29.7 and 35.8%, respectively,
less than that used for EFI, respectively. This difference
might be due to the contribution of groundwater
in the Kooshkak area with shallow water table. VAFI
with one supplemental EFI at tasseling in the Bajgha
area resulted in 5.4% reduction in grain yield and
28.8% reduction in water use. However, FAFI-S in the
Kooshkak area resulted in 7.6% reduction in grain
yield and 29.8% reduction in water use.

4. Evapotranspiration (ET)

In general, ET under AFI and AFI complemented
by EFI at various stages of growth decreased (Table 5). The values of ET were similar in both Kooshkak and

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### Table 4. Relative grain yield and reduction of water use under different irrigation treatments compared to every furrow irrigation (EFI) in Bajgha and Kooshkak areas.

| Irrigation treatment                  | Bajgha Water use reduction % | Grain yield reduction % | Kooshkak Water use reduction % | Grain yield reduction % |
|---------------------------------------|------------------------------|-------------------------|--------------------------------|-------------------------|
| Variable alternate furrow (VAFI)      | 29.5                         | 28.7                    | 34.4                           | 21.8                    |
| Fixed alternate furrow (FAFI)         | 29.5                         | 21.8                    | 37.1                           | 24.1                    |
| VAFI-EFI at tasseling (VAFI-T)        | 28.8                         | 5.4                     | 32.7                           | 13.4                    |
| FAFI-EFI at tasseling (FAFI-T)        | 26.1                         | 11.8                    | 31.2                           | 17.0                    |
| VAFI-EFI at silking (VAFI-S)          | 26.7                         | 12.2                    | 32.5                           | 10.6                    |
| FAFI-EFI at silking (FAFI-S)          | 26.2                         | 11.2                    | 29.8                           | 7.6                     |
| VAFI-EFI at grain filling (VAFI-F)    | 20.4                         | 30.8                    | 26.5                           | 24.8                    |
| FAFI-EFI at grain filling (FAFI-F)    | 18.4                         | 28.7                    | 29.5                           | 22.0                    |
| VAFI-EFI at ripening (VAFI-R)         | 23.8                         | 29.2                    | 25.3                           | 24.1                    |
| FAFI-EFI at ripening (FAFI-R)         | 23.9                         | 27.5                    | 28.6                           | 25.6                    |

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### Table 5. Seasonal evapotranspiration (ET, mm), deep percolation (D_r, mm), capillary rise (G_c, mm) and relative groundwater contribution to seasonal evapotranspiration (G_c/ET, %) under different irrigation treatments and experimental locations.

| Irrigation treatment                  | Bajgha ET | D_r | Kooshkak ET | D_r | G_c | G_c/ET |
|---------------------------------------|-----------|-----|-------------|-----|-----|--------|
| Every furrow (EFI)                    | 1023       | 43.9| 996         | 188.0 | 9.5 | 1.0    |
| Variable alternate furrow (VAFI)      | 747        | 28.3| 736         | 23.0  | 12.3| 2.0    |
| Fixed alternate furrow (FAFI)         | 738        | 21.4| 714         | 23.8  | 21.4| 3.5    |
| VAFI-EFI at tasseling (VAFI-T)        | 758        | 16.7| 762         | 23.6  | 14.7| 2.3    |
| FAFI-EFI at tasseling (FAFI-T)        | 779        | 17.5| 760         | 26.0  | 12.2| 1.9    |
| VAFI-EFI at silking (VAFI-S)          | 772        | 30.1| 759         | 23.7  | 12.7| 1.9    |
| FAFI-EFI at silking (FAFI-S)          | 762        | 39.2| 786         | 26.5  | 12.5| 1.9    |
| VAFI-EFI at grain filling (VAFI-F)    | 835        | 22.8| 820         | 25.8  | 8.7 | 1.2    |
| FAFI-EFI at grain filling (FAFI-F)    | 858        | 27.7| 787         | 26.7  | 10.4| 1.5    |
| VAFI-EFI at ripening (VAFI-R)         | 813        | 22.0| 839         | 26.2  | 14.6| 2.0    |
| FAFI-EFI at ripening (FAFI-R)         | 789        | 24.6| 805         | 27.0  | 18.3| 2.6    |
Bajgha locations.

5. Actual capillary rise
The actual capillary rise ($G_c$) for each irrigation treatment in the Kooshkak area was estimated and they were summed up to determine the seasonal $G_c$ using the formulation presented by Sepaskhah et al. (2003) and Sepaskhah and Khajehabadollahi (2005). The ratio of $G_c$ to ET was also calculated. The results are presented in Table 5. The values of $G_c$ and $G_c/ET$ were negligible for different irrigation treatments due to the fact that irrigation interval of seven days was not long and the soil water content before irrigation was not below the critical soil water content (Sepaskhah et al., 2003). These values were obtained where water depths in the study area varied between 1.40 m at sowing time and 1.18 m at the end of irrigation treatments. In the previous study with nearly similar water table depth and greater irrigation intervals, the contribution of groundwater to the water use by plant may be greater (Sepaskhah et al., 2003; Sepaskhah and Khajehabadollahi, 2005).

6. Deep percolation
In general, deep percolation was reduced by AFI drastically. This may be due to the more lateral movement of water in soil under AFI (Table 5). Further, deep percolation under EFI at the Kooshkak location was greater than that at the Bajgha location due to higher water table and drainage installation. In general, AFI reduced the deep percolation by 43.1% and 86.6% at the Bajgha and Kooshkak locations, respectively. The ratio of deep percolation to ET was very low (4% or less) except that under EFI at the Kooshkak location which was about 19% due to higher water table. These results are similar to those reported by Sepaskhah and Khajehabadollahi (2005).

7. Water-use efficiency
Water-use efficiency (WUE) was calculated as the harvested grain weight per unit of applied irrigation water. The amount of water applied was smaller in AFI than in EFI (Tables 2 and 3). The amounts of applied water in AFI with supplemental EFI at flowering stages (774 and 780 mm in the Bajgha and Kooshkak areas, respectively) were larger than those used in EFI (745 and 732 mm in the Bajgha and Kooshkak areas, respectively) but were much smaller than those applied in EFI (1054 and 1139 mm in the Bajgha and Kooshkak areas, respectively). The highest values of WUE were 1.04 and 0.97 kg grain per m$^2$ of water in AFI with supplemental EFI at flowering stages (AFI-T and AFI-S) in both experimental areas (Tables 2 and 3).

Conclusions
The results obtained at different sites with a 65 km distance were analyzed and similar findings were obtained in two sites with different soil conditions and different mean air temperatures during the growing season. Alternate furrow irrigation (AFI) resulted in significant reduction of maize grain yield compared with every furrow irrigation (EFI) in both Bajgha and the Kooshkak areas with deep and shallow water table. This occurred probably due to water stress and reduction in 1000-grain weight. However, AFI with one or two EFI at flowering stages (tasseling and silking) resulted in a grain yield statistically equal to those obtained in EFI but with near 30% reductions in water use in both Bajgha (with deep water table) and the Kooshkak (with shallow water table). These irrigation treatments may be useful in both areas to improve the water-use efficiency.

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