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EFFECTS OF ALTERNATE FURROW IRRIGATION ON YIELD AND WATER USE EFFICIECNY OF DRY BEANS[1]

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ABSTRACT

A field experiment was conducted to study the effect of ordinary furrow, variable alternate and fixed alternate furrow irrigation with water salinities of 0.6 and 1.2 mmhos cm^{-1} on yield and water use efficiency of a local cultivar of dry bean (*Phaseolus vulgaris* L.). In addition, effects of the previous irrigation treatments alone and combined with supplementary ordinary furrow irrigation at the flowering, podding and pod filling stages were evaluated. The experiments were conducted on a clay loam soil. Bean yield, yield components, bean protein content, number of weeds in the field and water use efficiency were measured. Alternate furrow irrigation decreased yield. These reductions were more pronounced at water salinity of 1.2 mmhos cm^{-1} and fixed alternate furrow irrigation. The reduction of yield was due to the smaller amount of applied water and apparent imposed moisture stress, specially at the reproductive stages of growth. Supplementary ordinary furrow irrigation at the pod filling stage produced the highest bean yield with smaller amount of water used compared to the ordinary furrow irrigation. Supplementary ordinary furrow irrigation at the podding stage is requied to obtain the highest water use efficiency. The effects of irrigation treatments on the yield components, yield quality and weed population are also discussed.

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اثرات آبیاری شیاری یک درمیان برروی عملکرد وراندمان مصرف آب لوبیا

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خلاصه

اثرات آبیاری شیاری معمولی، یک درمیان دائم و یک درمیان متغیر با دو کیفیت آب آبیاری (۰/۶ و ۱/۲ میلی موز بر سانتی متر در ۲۵ درجه سانتی گراد) بر روی عملکرد و راندمان مصرف آب یک رقم لوبیای محلی در مزرعه مورد بررسی قرار گرفت. علاوه بر تیمارهای فوق اثرات آبیاری شیاری یک درمیان دائم و متغیر و آبیاری شیاری معمولی در دوره‌های گلدهی، غلاف دهی و دانه بستن نیز بر روی عملکرد و راندمان مصرف آب همان رقم لوبیا مطالعه گردید. این مطالعات در خاک لوم رسی در کوشکک را مجرد انجام گرفت و در آنها عملکرد دانه، شاخ و برگ، اجزاء عملکرد، میزان پروتئین دانه، تعداد بوته‌های علف هرز در مزرعه و راندمان مصرف آب اندازه‌گیری شد. آبیاری شیاری یک درمیان دائم و متغیر سبب کاهش محصول دانه لوبیا شد و مخصوصاً "این کاهش در آب آبیاری با شوری ۱/۲ میلی موز بر سانتی متر در ۲۵ درجه سانتیگراد و آبیاری شیاری یک درمیان دائم بیشتر بود. در آبیاری شیاری یک درمیان بعلت کمی مقدار آب آبیاری بکار رفته، خشکی نسبی در رطوبت خاک موجب کاهش عملکرد گردید. آبیاری شیاری معمولی تکمیلی در دوران دانه بستن، در مقایسه با آبیاری شیاری معمولی در تمامی دوران رشد، با آب آبیاری کمتر، بیشترین عملکرد را تولید نمود. آبیاری شیاری معمولی تکمیلی در مرحله غلاف دهی بالاترین راندمان مصرف آب را بدست داد. اثرات آبیاری شیاری معمولی تکمیلی در مراحل مختلف رشد نیز بر روی اجزاء عملکرد، کیفیت محصول و تعداد بوته‌های علف هرز مورد بحث قرار گرفته است.

INTRODUCTION

Shortage of water in arid and semi-arid regions of Iran is an important limiting factor in crop production. Adopting improved irrigation methods promote irrigation efficiency and prevents loss of water.

Fischbach and Mulliner (6) showed that alternate furrow irrigation of corn (*Zea mays* L.) decreased the average amount of irrigation water on a silty clay loam by 29% with a non-significant reduction of grain yield of 4.7%. Similar results were reported by Box *et al.* (3) and Grimes *et al.* (7) for potatoes (*Solanum tuberosum* L.) and cotton (*Gossypium hirsutum* L.), respectively. However, New (11) demonstrated that irrigated grain shorghum (*Sorghum bicolor* L.) on a loam and a fine sandy loam soil resulted in 1973 kg ha^{-1} less grain in alternate furrow using 25 cm of water, than in the ordinary furrow which used 37.5 cm of water.

There is limited information regarding the effects of alternate furrow irrigation on dry bean (*Phaseolus vulgaris* L.) yield and water use efficiency. Furthermore, the effect of low quality irrigation water in alternate furrow irrigation is not known. On the other hand, supplementary ordinary irrigation during certain stages of growth may prevent the yield decrease due to alternate furrow irrigation. Therefore, this study was designed to evaluate the effects of alternate with fixed and variable cases and ordinary furrow irrigation using two levels of irrigation water salinity (0.6 and 1.2 mmhos cm^{-1}) on the yield and yield components of white dry beans and on weed performance. The study was further extended to evaluate the effects of fixed and variable cases of alternate furrow supplemented with ordinay furrow irrigation at different stages of growth.

MATERIALS AND METHODS

First Year Experiment

The experiment was conducted on a clay loam soil at the Agricultural Experiment Station of Shiraz University located 65 km north of Shiraz. Some physical and chemical properties of the soil and irrigation water are shown in Table 1. The irrigation treatments used in this experiment were as follows: (i) fixed alternate furrow (FAF) irrigation in which water was applied only to one side of each row throughout the growing season, (ii) variable alternate furrow (VAF) irrigation which was similar to the fixed alternate, but water was applied to the furrow which remained dry in the previous irrigation cycle and (iii) ordinary furrow irrigation in which water was always applied to every furrow. Irrigation water with electrical conductivities of 0.6 and 1.2 mmhos cm^{-1} was used from a shallow well and from a canal of Doroodzan Irrigation District, respectively.

The design of the experiment was a randomized split plot with four replications and consisted of two main plots (irrigation water qualities) and three sub-plots (irrigation treatments). Each sub-plot consisted of eight rows of plants and v-shape furrows 15 m long and with 50 cm spacing. Nitrogen and P at the rates of 35 and 42 kg ha^{-1}, respectively, were applied prior to planting and thoroughly mixed into the soil.

Table 1. Some physical and chemical characteristics of the experimental soil and irrigation water.

Physical properties of soil	Depth of soil, cm	
	0-30	30-80
Field capacity (% dry weight)	27.50	29.00
Permanent wilting point (% dry weight)	15.00	19.00
Bulk density, g cm^{-3}	1.42	1.48
Saturation percentage	48.10	48.10
Texture	Clay loam	Clay loam
Sand, %	28	22
Silt, %	40	40
Clay, %	32	37
Chemical properties of soil		
pH of saturated paste	7.70	
Available phosphorus, ppm	23	
Available potassium, ppm	348	
Organic matter, %	2.14	
Chemical properties of water	Source of water	
	Doroodzan irrigation district	Ground water (Kooshkak well)
Electrical conductivity, mmhos cm^{-1}	0.60	1.20
pH	8.28	8.27
Sum of anion, meq L^{-1}	5.85	11.97
Sum of cation, meq L^{-1}	5.06	10.86
Sodium adsorption ratio	1.58	2.25
Salinity type	Chloride-carbonate	Chloride carbonate

At maturity, plants on the ordinary and alternate furrow sub-plots were harvested on Septermber 6 and October 7, 1976, respectively. The beans were separated and seed and plant yields were obtained. Number of pods per plant, number of seeds per pod, and the weight of 1000-seed were also measured. Sub-samples of seed from each treatments were analyzed for protein content by the Kjeldahl method (4).

Second Year Experiment

In this experiment the effects of ordinary, fixed and variable alternate furrow irrigations (as in the first year experiment) and other irrigation treatments were studied as follows: (1) fixed alternate furrow irrigation during all stages of growth except the flowering stage in which ordinary furrow irrigation was adopted (FAFL) (2) variable alternate furrow irrigation during all stages of growth except at the flowering stage during which ordinary furrow irrigation was adopted (VAFL) (3) fixed alternate furrow irrigation during all stages of the growth exceptat the podding stage during which ordinary irrigation was adopted (FAPO), (4) variable alternate furrow irrigation during all stages of growth except at the podding stage during which ordinary furrow irrigation was adopted (VAPO) (5) fixed alternate furrow irrigation during all stages of growth except the filling stage during which ordinary furrow irrigation was adopted (FAVFI), (6) variable alternate furrow irrigation during all stages of growth except at the filling stage during which ordinary furrow irrigation was adopted (VAFI).

This experiment was carried out at a site next to the previous experiment. The experimental design was a complete randomized block with four replicates. Each plot was made of six rows and 10-m long furrows with 50 cm sapcing Fertilizer application and seeding rates were similar to the first year experiment. The beans were planted on May 4, 1977 and the Doroodzan Irrigation District was the only source of irrigation water.

Urea and $(NH_4)_2HPO_4$ were used as N and P sources, respectively. White dry bean seeds were planted on single rows at the rates of 120 kg ha^{-1} on June 4, 1976. The average maximum and minimum daily temperatures, relative humidity and daily pan evaporation during the growing season were 35.1°C, 12.6°C, 58% and 10.3 mm, respectively.

After sowing, the plots were irrigated twice at 7-day intervals with 9.7 and 7.1 cm of water with respective qualities for uniform seed germination and seedling emergence. Then the experimental treatments of irrigation were imposed to each sub-plot. Irrigation was conducted by siphon tubes from an equalizing ditch. The ditch was lined with a plastic sheet to prevent salt build up and water loss. The amount of water for each irrigation treatment was determined by measuring the soil water content in the root zone (up to 90 cm) by gravimetric method before irrigation and raising it to field capacity. Soil samples were taken from the middle section of each sub-plot from all four replicates. The sampling sites on each sub-plot were the two adjacent furrows and the ridge between them. Water contents of the samples were determined gravimetrically and averaged over three sites of each sub-plot and four replicates. An irrigation application efficiency of 70% for all irrigation treatments and an area factor of 50% for alternate furrow irrigations were used in calculation of needed volume of irrigation water. The volume of irrigation water for each sub-plot was applied by a 7.5-cm Parshall flume. The number of plants was reduced to one plant in every 10 cm on the row on July 14, 1976 for all treatments.

Number of weeds ha^{-1} on all the sub-plots was determined on July 20, 1976. These measurements were made by counting the number of weeds on randomly selected areas by throwing a standard square frame (25x25 cm) on both sides of each ridge on each sub-plot. The weeding operation was performed after completion of these measurements.

The average daily maximum and minimum temperatures, relative humidity and pan evaporation were 33.1°C, 11.4°C, 59% and 9.3 mm, respectively.

The time of flowering, podding and filling was chosen when nearly 50% of plants in each plot had reached flowering, podding and filling stages, respectively. The rest of the experimental procedure was similar to the first year experiment. Plots of ordinary furrow and supplementary irrigation at the podding stage were harvested on August 31, 1977. The plots with supplementary irrigation at the flowering stage were harvested on September 7, 1977. The plots with alternate furrow and supplementary irrigation at the pod filling stage were harvested on September 14, 1977.

RESULTS AND DISCUSSION

First Year Experiment

Yield. The plants irrigated with alternate and ordinary furrow matured after 125 and 94 days, respectively. Bean and vine yield obtained from the various irrigation methods and irrigation water qualities are shown in Table 2. The interaction of irrigation methods and water qualities on bean and plant yields was significant. Alternate furrow irrigation significantly decreased the bean yield at both irrigation water qualities. The amount of applied water was reduced by 27 and 20% for the variable and fixed alternate furrows, respectively. At water salinity of 1.2 mmhos cm^{-1} fixed alternate furrow irrigation further reduced the bean yield compared to the variable alternate furrow irrigation. This might be due to salt accumulation in soil at the non-irrigated furrows. Bean yield was not influenced by the quality of irrigation water for the ordinary furrow or variable alternate furrow irrigation methods whereas plant yields were reduced significantly by fixed alternate furrow at the irrigation water salinity of 1.2 mmhos cm^{-1}. In general, the low magnitude of the yield might be due to late planting, low

Table 2. Effects of irrigation methods and salinity levels of irrigation water on seed and plant yields and water use efficiency of dry beans (experiment I).

Salinity level of irrigation water (mmhos cm^{-1})	Irrigation methods	Bean yield (kg ha^{-1})	Plant yield (kg ha^{-1})	Irrigation water quantity (cm)	Water use efficiency (kg ha^{-1} cm^{-1})
0.6	Ordinary furrow (OF)	1288a*	1492a	117.00	11.01a
	Variable alternate furrow (VAF)	759b	1275a	85.49	8.88a
	Fixed alternate furrow (FAF)	647b	1214a	94.11	6.88ab
1.2	Ordinary furrow (OF)	1234a	1438a	117.00	10.54a
	Variable alterante furrow (VAF)	659b	1274a	83.49	7.71ab
	Fixed alternate furrow (FAF)	353c	1055b	94.11	3.75b

*Means followed by the same letters in each column are not significantly different at the 5% level by Duncan's Multiple Range Test.

fertility of soil or low yield potential of the local bean cultivar. The results are in agreement with those of sugarbeets (10), grain sorghum (11) and cotton (12). The yield reduction was a result of lower amount of water used. The salinity of irrigation water further reduced the yield in the plots with fixed alternate furrow irrigation.

Yield components. The results of yield components of bean are shown in Table 3. The number of pods per plant tended to decrease in the fixed alternate furrow (FAF) with the water salinity of 0.6 mmhos cm^{-1}. A significant reduction in the number of pods per plant occurred in the alternate furrow irrigation at the water salinity of 1.2 mm hos cm^{-1} salinity level. The number of beans per pod and the weight of 1000-bean decreased only at the fixed alternate furrow with water salinity of 1.2 mm hos cm^{-1}. These results indicate that pod formation was inhibited strongly by alternate furrow irrigation with water salinity of 1.2 mmhos cm^{-1} due to lower amount of applied water. Consequently bean yield was reduced (Table 2). Bean formation and pod filling were also retarded by the fixed alternate furrow method with water salinity of 1.2 mmhos cm^{-1}; resulting in a decrease in the bean yield. Apparently plants with alternate furrow irrigation might have been under water stress due to lower amounts of applied water (14). As a result, a significant reduction in the number of pods was obtained. A similar result was reported by El-Nadi (5) for haricot beans. Although alternate furrow irrigation with the water salinity of 0.6 mmhos cm^{-1} caused non-significant reduction in the yield components (Table 3), these non significant reduction in the number of pods per plant together with number of beans per pod, might have resulted in the bean yield reduction (Table 2).

Protein content. The protein contents of beans increased significantly with the alternate furrow irrigation at both levels of salinity (Table 4). Regardless of the higher protein content, the total protein yields significantly

Table 3. Effects of irrigation methods and salinity levels of irrigation water on the yield components of dry beans (experiment I).

Salinity level of irrigation water (mmhos cm^{-1})	Irrigation methods	Number of pod per plant	Number of seed per pod	Weight of 1000-seed (g)
0.6	Ornidnary furrow (OF)	14.1a*	2.8a	206.5a
	Variable alternate furrow (VAF)	13.0a	2.4a	208.7a
	Fixed alternate furrow (FAF)	10.2ab	2.4a	198.0a
1.2	Ordinary furrow (OF)	13.1a	2.4a	211.2a
	Variable alternate furrow (VAF)	7.5b	2.2ab	208.3a
	Fixed alternate furrow (FAF)	6.2b	1.5b	184.7b

* Means followed by the same letters in each column are not significantly different at the 5% level by Duncan's Multiple Range Test.

Table 4. Effect of irrigation methods and salinity levels of irrigation water on seed protein content and total protein yield of beans (experiment I).

Salinity level of irrigation water (mmhos cm^{-1})	Irrigation methods	Protein content of seed (%)	Total protein yield (kg ha^{-1})
0.6	Ordinary furrow (OF)	22.3b*	288.6a
	Variable alternate furrow (VAF)	26.6a	198.9ab
	Fixed alternate furrow (FAF)	27.0a	174.2b
1.2	Ordinary furrow (OF)	23.7b	292.9a
	Variable alternate furrow (VAF)	28.3a	185.2b
	Fixed alternate furrow (FAF)	28.2a	99.2b

* Means followed by the same letters in each column are not significantly different at the 5% level by Duncan's Multiple Range Test.

decreased with the fixed alternate furrow at the water salinity of 0.6 mmhos cm^{-1} and with the alternate furrow irrigation with the water salinity of 1.2 mmhos cm^{-1}. Lower amount of water increased the protein content. These results are in agreement with those for field peas as reported by Sosulski *et al.* (16).

Water Use Efficiency

The depth of irrigation water and water use efficiency for different methods of irrigation and salinity levels of irrigation water are shown in Table 2. The amounts of water used in the variable and fixed alternate furrows were reduced 27 and 20%, respectively, as compared to the ordinary furrow irrigation. The water use efficiency was calculated based on the bean yield. The values of water use efficiency were not statistically different for different irrigation methods with lower water salinity. However, these values were reduced significantly with the fixed alternate furrow and water salinity of 1.2 mmhos cm^{-1}. This was a result of a drastic reduction of bean yield at this particular irrigation treatment. These results are not in agreement with those for corn, cotton and sorghum as reported by other investigators (6, 7, 11, 12). This discrepancy between beans and other crops might have been due to their higher sensitivity to the water stress (17) and salt stress (2) of the latter.

Weed control. The number of weeds for the alternate furrow irrigation decreased significantly (Table 5). The number of weeds in the variable and fixed alternate furrow irrigation were 54 and 60% of those with the ordinary furrow irrigation, respectively. This decrease was a result of a lower number of weeds in the non-irrigated furrows. Half of the soil surface or furrows in the fixed alternate furrow irrigation remained dry throughout the growing season and thus the weed seeds could not germinate effectively. Furthermore, the wetting intervals in the furrows of variable alternate furrow

Table 5. Effect of irrigation methods on the number of weeds per ha.

Irrigation method	Number of weeds per ha X10[4]		
	Odd furrow	Even furrow	Plot
Ordinary furrow (OF)	38.4a*	38.4a	38.4a
Variable alternate furrow (VAF)	14.4b	27.2a	20.8b
Fixed alternate furrow (FAF)†	25.6a	20.8a	23.2b

†Only odd furrows were irrigated.

*Means followed by the same letters in each column are not significantly different at the 5% level by Duncan's Multiple Range Test.

irrigation were long enough (2 weeks) to cause a soil water shortage for good germination of the weed seeds.

Second Year Experiment

Yield. Bean and plant yields of the second year experiment are shown in Table 6. The bean yield was highest for the alternate furrow irrigations with supplementary ordinary furrow irrigation at every stages of growth , and lowest for alternate furrow irrigation throughout the growing period. Bean yield was significantly reduced by the variable alternate furrow irrigation comapred to the ordinary furrow irrigation. These results confirmed those obtained in the first year experiment (Table 2). In contrast to the first year experiment, the plant yield for the ordianry furrow irrigation was significantly higher than those for the alternate furrow irrigations (Table 6). This might be due to the interaction between better growth conditions and adequate water supply during the second year growing season.

Table 6. Effects of different irrigation treatments on seed and plant yields of dry beans (Experiment II).

Irrigation treatments	Bean yield (kg ha^{-1})	Vine yield (kg ha^{-1})
Ordinary furrow (OF)	1823ab*	3162a
Variable alternate furrow (VAF)	1133c	2761ab
Fixed alternate furrow (FAF)	1396bc	2572b
VAF, but ordinary furrow during the flowering stage (VAFL)	1665abc	2578b
FAF, but ordinary furrow during the flowering stage (FAFL)	1641abc	2661ab
VAF, but ordinary furrow during the podding stage (VAPO)	1674abc	2754ab
FAF, but ordinary furrow during the podding stage (FAPO)	1836ab	2401b
VAF, but ordinary furrow during the filling stage (VAFI)	2056a	2861ab
FAF, but ordinary furrow during the filling stage (FAFI)	2010a	2553b

*Means followed by the same letters in each column are not significantly different at the 5% level by Duncan's Multiple Range Test.

Yield components. The number of pods per plant, number of beans per pod and the weight of 1000 beans are shown in Table 7. The number of beans per pod was not increased statistically by applying supplementary ordinary furrow irrigation at any growth stage. Supplementary ordinary furrow irrigation at the flowering stage (VAFL and FAFL) and ordinary furrow irrigation produced statistically similar number of pods per plant. These treatments also increased the number of pods per plant compared to the alternate furrow irrigation. The supplementary ordinary furrow irrigation at the other stages of growth did not statistically affect the number of pods per plant. Supplementary ordinary irrigation at the podding stage (VAPO and FAPO) statistically increased the weight of 1000-bean which might be due to the increased flow of synthesized material to the beans (8). The time of application of the supplementary ordinary furrow irrigation at the pod filling stage (VAFI and FAFI) probably was somewhat late to affect the weight of 1000-bean. However, the apparent disagreement between bean yield and yield components at the VAFI and FAFI treatments (Tables 6 and 7) might be a result of random chance or variation in the plant population. Application of ordinary irrigation at the flowering stage might have prevented the abortion of flowers and consequently increased the number of pods per plant. This result is in agreement with those for soybean (*Glycine max* (L.) Merr.) as reported by Singh and Tripathi (15).

Protein content. The protein content and total protein yield of beans are shown in Table 8. All the treatments except FAF resulted in statistically lower protein content than the variable alternate furrow irrigation. Treatments with supplementary irrigation resulted in similar protein content as ordinary furrow irrigation. The only significant decrease in total protein yield occurred with the variable alternate furrow. The highest significant protein content of

Table 7. Effect of different irrigation treatments on the yield components of dry beans (Experiment II).

Irrigation treatments	Number of pods per plant	Number of seeds per pod	Weight of 1000-seed (g)
Ordinary furrow (OF)	18.6a*	2.2a	234.1a
Variable alternate furrow (VAF)	8.8d	2.3a	185.4b
Fixed alternate furrow (FAF)	9.2cd	2.3a	200.7b
VAF, but ordinary furrow during the flowering stage (VAFL)	16.9ab	2.4a	202.3b
FAF, but ordinary furrow during the flowering stage (FAFL)	14.3abc	2.4a	208.3b
VAF, but ordianry furrow during the podding stage (VAPO)	12.6bcd	2.2a	239.6a
FAF, but ordinary furrow during the podding stage (FAPO)	13.3bcd	2.3a	240.2a
VAF but ordinary furrow during the filling stage (VAFI)	13.6bcd	2.4a	206.6b
FAF, but ordinary furrow during the filling stage (FAFI)	11.9bcd	2.6a	203.3b

*Means followed by the same letters in each column are not significantly different at the 5% level by Duncan's Multiple Range Test.

Table 8. Effect of different irrigation treatments on seed protein content and total protein yield of dry beans.

Irrigation treatments	Protein content (%)	Total protein yield (kg ha^{-1})
Ordinary furrow (OF)	25.93c*	427.18a
Variable alternate furrow (VAF)	28.63a	320.41b
Fixed alternate furrow (FAF)	27.74ab	384.71a
VAF, but ordinary furrow during the flowering stage (VAFL)	26.45bc	346.93a
FAF, but ordianry furrow during the flowering stage (FAFL)	26.89bc	441.92a
VAF, but ordianry furrow during the podding stage (VAPO)	25.34c	442.80a
FAF, but ordinary furrow during the podding stage (FAPO)	25.42c	436.96a
VAF, but ordinary furrow during the filling stage (VAFI)	25.33c	522.51a
FAF, but ordinary furrow during the filling stage (FAFI)	25.77c	513.92a

*Means followed by the same letters in each column are not significantly different at the 5% level by Duncan's Multiple Range Test.

beans which were subjected to water shortage throughout the growing season belonged to the alternate furrow irrigation. On the other hand, the lowest significant protein content was obtained by the variable alternate furrow irrigation. These results were similar to those of the firt year experiment and those reported by Alikhan (1).

Water use efficiency. The number of irrigations total amount of water applied and the water use efficiency are shown in Table 9. Water use efficiencies were calculated as the amount of beans produced per unit amount of water applied. The maturation of beans in the FAF, VAF, FAFI and VAFI treatments was delayed up to two weeks. This could be a result of inadequate water supply during the vegetative and reproductive stages. Similar results has been reported for dry beans (13). Among the supplementary irrigation treatments, the FAPO treatment utilized the smallest amount of water and produced a relatively higher yield (Table 6). VAPO treatment resuled in a statistically higher water use efficiency. Furthermore, the water use efficiency with the FAPO treatment was statistically greater than that of the ordinary irrigation. The podding stage was found to be a critical period. Similar results were reported by Hiler *et al.* (9) who showed that water stress during early pod formation was more detrimental to seed yield and water use efficiency of dry peas.

CONCLUSION

Alternate furrow irrigation decreased the bean yields significantly. This reduction was more pronounced with water salinity of 1.2 mmhos cm^{-1} and with fixed alternate furrow irrigation. The yield reduction was due to the smaller amount of water applied, especially at the reproductive stages. Therefore, supplementary ordinary furrow irrigation at either the podding or pod filling stages produced the highest bean yield with lower amount of water used compared to the ordinary furrow irrigation. This resulted in higher

Table 9. Effect of different irrigation treatments on the number of irrigation, irrigation water quantity, and water use efficiency.

Irrigation treatments	Number of irrigations	Irrigation water quantity (cm)	Water use efficiency (kg ha^{-1}-cm^{-1})
Ordinary furrow (OF)	15	115.5	15.8bc*
Variable alternate furrow (VAF)	18	90.0	12.6c
Fixed alternate furrow (FAF)	18	76.4	18.3bc
VAF, but ordinary furrow during the flowering stage (VAFL)	17	87.6	19.0abc
FAF, but ordinary furrow during the flowering stage (FAFL)	17	79.3	20.7ab
VAF, but ordinary furrow during the podding stage (VAPO)	15	82.0	20.3ab
FAF, but ordinary furrow during the podding stage (FAPO)	15	76.8	23.9a
VAF, but ordinary furrow during the filling stage (VAFI)	18	112.4	18.3ab
FAF, but ordinary furrow during the filling stage (FAFI)	18	100.3	20.0abc

*Means followed by the same letters in each column are not significantly different at the 5% level by Duncan's Multiple Range Test.

water use efficiency.

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