

EFFECT OF NETWORK WATER DISTRIBUTION SCHEDULE AND DIFFERENT ON-FARM WATER MANAGEMENT PRACTICES ON SUGARBEET WATER USE EFFICIENCY — CASE STUDY: MAHABAD, I.R. IRAN

Shahab Daneshvar¹
Ali Reza Shokoohi²
Karim Shiati³
Farshid Morshedi⁴

ABSTRACT

Application of different irrigation management practices plays a considerable role in water saving to achieve potential yields. On the other hand, network water distribution schedule is a governing factor in this regard. In current study conducted in Mahabad plain in North West of Iran, four different irrigation managements on sugarbeet cultivation including traditional farmer's management, Furrow Deepening, Reduced Discharge per Deepened Furrow, and Alternate Furrow Irrigation have been studied in real farmers' fields measuring 10.2 hectares. Participatory management approach has been used while working in farmers fields. Soils textures are silty clayey. Results of studies indicate that water used has been reduced considerably while higher root and sugar yields are obtained due to better on-farm water management practices. Water Use Efficiency, in kg of yield per m³ of water used, increased considerably under alternate furrow irrigation management in comparison to what obtained under traditional management. Results show application of alternate furrow irrigation in sugarbeet cultivation not only resulted in lesser water use per hectare, but also it increased both root and sugar yields and, consequently, higher water use efficiency was obtained. Assessments have been made on irrigation schedule imposed by the irrigation network and its effects on actual water requirements. Results show that the delivery schedule practiced in the network is incapable of delivering the actual amount of water requirement for the dominant crop of the scheme. Suggestions are made to the network operator to improve overall network efficiency including revisions on water resources planning and allocation and/or improve network operation system.

INTRODUCTION

The increasing population in the Lake Uromiyeh region places increasing demands on water for drinking, industry and for food production. Out of this total demand, irrigation consumes 95% of all the available water. The water resources are limited. More and more rivers are controlled by dams and reservoirs in order to increase the availability of water. Where no surface water is

¹ Project Manager – Mahab Ghodss Consulting Engineering Company, P.O. Box: 19395-6875, Takharestan st., Dastgerdi st., Tehran, Iran, Zip Code: 1918781185, Email: Daneshvar@MahabGhodss.com

² Assistant Professor – Imam Khomeini International University, Ghazvin, Iran, Email: Shokoohi_ar@ikiu.ac.ir

³ Head of Water Resources Department, Yekom Consulting Engineers, Tehran, Iran, Email: Karim.Shiati@Yekom.com

⁴ Project Manager – Mahab Ghodss Consulting Engineering Company, P.O. Box: 19395-6875, Takharestan st., Dastgerdi st., Tehran, Iran, Zip Code: 1918781185, Email: Morshedi@MahabGhodss.com

available, wells are constructed to conduct the irrigation. In spite of the scarcity of water, the irrigation methods applied in many regions in the Uromiyeh basin are highly inefficient. It is estimated that the average efficiency of irrigation systems is about 35%. The inefficient irrigation methods cause severe damage to the irrigated areas. Also the groundwater tables in many basins are decreasing rapidly as a result of over-pumping, leading to salt water intrusion from the lake and the death of hundreds of hectares of orchards.

Conventional irrigated agriculture enjoyed an abundant availability of water. Since water was not a scarce resource, this led to irrigation methodologies with low water use efficiencies and resulted in overuse of water, seepage, and development of waterlogging and salinity in the downstream areas. The intensification of use of the limited water resources and the intended expansion of irrigated area will lead to a strain on the availability of water on farm level and require improvement of the waterlogging and salinization of the downstream areas, which are now intended to be used for agriculture as well. The increased environmental awareness in Iran does not tolerate a deterioration of the land through waterlogging and salinization either. In order to make it technically possible and socially acceptable to irrigate with less water while obtaining similar or higher yields new methodologies should be developed and demonstrated.

Kang et al. (1998) studied three treatments on furrow irrigation management including fixed, alternate and conventional irrigation in maize cultivation. Results indicated that number of preliminary root, total dry root, and root intensity are higher under alternate furrow irrigation in comparison to the other two irrigation managements. Also, higher water use efficiency was obtained in this method. Kang et al. (2000) reported that incorporating alternate furrow irrigation in maize cultivation has resulted in 35% reduction in water use, while only 6-11% reduction in dry material occurred. Fischback and Mulliner (1972) reported alternate furrow irrigation for maize cultivation has resulted in 29% reduction in water use while only 4.7% reduction in dry material occurred. Studies of Stone et al. (1979) indicated that amount of evapotranspiration in alternate furrow irrigation is less than that of achieved under conventional management. Raine (1999) reports that studies of Bakker et al. (1997) on alternate furrow irrigation have shown that significant water use reduction would be achieved while insignificant reduction in yield occurred. Raine (1999) also reports the studies of Torres et al. (1996) on alternate furrow irrigation in sugarcane cultivation that has shown 40% water use reduction against 38 ton/ha reduction in yield. Box et al. (1963) and Raine (1999) report results of several studies regarding incorporation of alternate furrow irrigation in potato, onion, wheat, maize, sorghum, and cotton cultivations with 50% reduction in water use. Also, due to potential increase in water use efficiency by using this method, it is a highly preferable method to be incorporated in areas with scarce water resources.

METHODS AND MATERIALS

Approach

The practical validity of the methodology of reduced water use has to be proven to, and accepted by the farmers, the ultimate users. To assure that the results are applicable by the farmers, it was decided to conduct the studies in a participatory way by fully integrating the farmers in the

selection of the areas, the development and testing of the methodology and the evaluation of the results.

The concept of the Pilot Water Management Studies (PWMS) is schematically shown in Figure 1. The final objective, reduced on-farm water use, is shown in the top of Figure 1. After a first cycle the same process could be followed again for further improvement and higher technology levels incorporation as indicated by the dotted arrow.

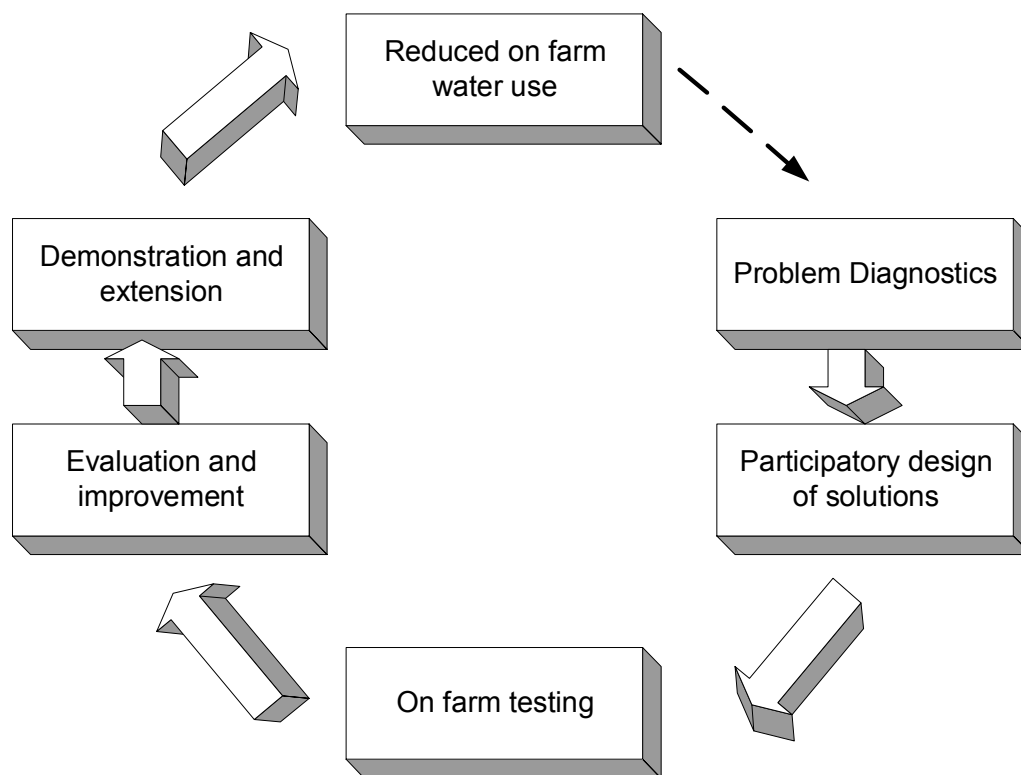


Figure 1. Conceptual Framework of the PWMS

The right-hand side shows the methodology to reach this objective, starting with the problem diagnoses in which main constraints to reach efficient irrigation are identified. The problem diagnostics are used as basis for the participatory design of solutions. The solutions are subsequently implemented for on farm testing, which is followed by an evaluation of the tests. The evaluation are used to improve the design and, if the evaluation is positive, the solutions can be disseminated through demonstration and extension, which will eventually lead to improved irrigation and reduced on-farm water use.

The irrigation techniques practiced in study area were investigated and assessed in general and around the PA more specifically. Interviews were conducted with farmers of the PA and in the Reference Area (RA). The monitoring focused on cropping patterns, yields, irrigation techniques and constraints with respect to irrigation and agricultural production. In several workshops and field sessions, a participatory problem inventory of present irrigation practices and the related

problems was carried out, with farmers, and City Jihad Agricultural Management (CJAM) and Agricultural Service Center (ASC) staff. The diagnostic outcomes formed the basis for the design of the treatments. During the study period, a qualitative understanding of the causes and effects of over-application of irrigation water at farm level for the dominant crop (sugarbeet) has been developed. This understanding is summarized in the problem tree shown in Figure 2.

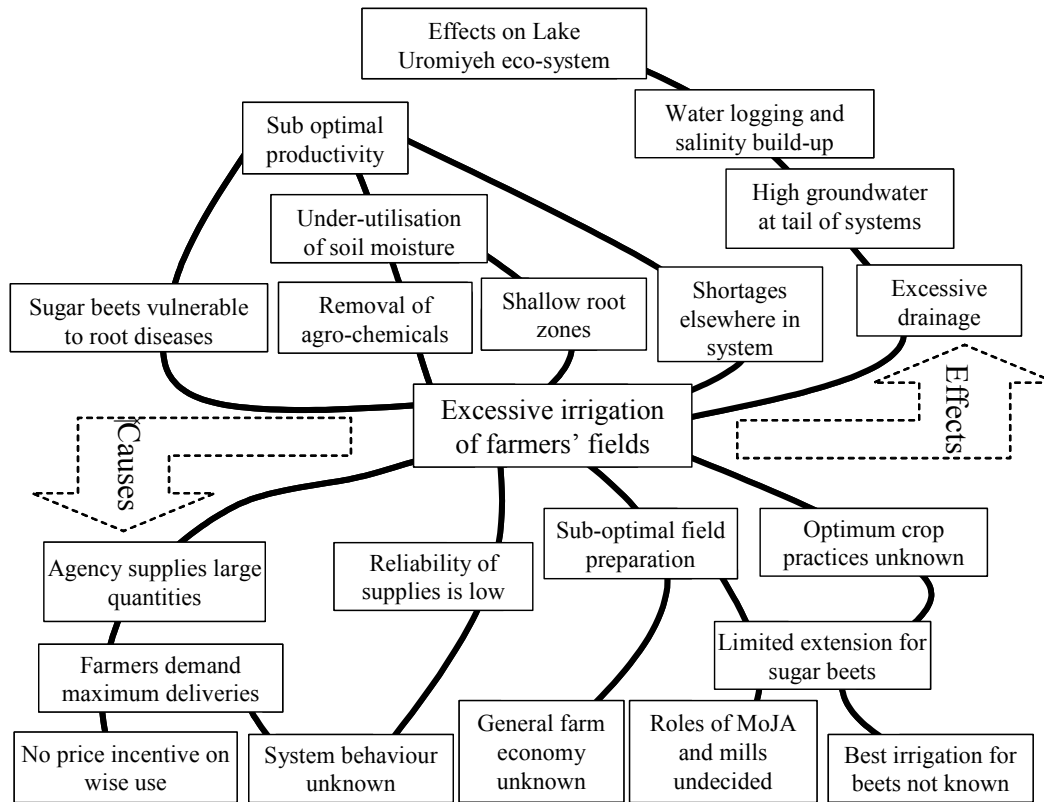


Figure 2. Problem Tree Analysis of Excessive Irrigation of Sugarbeet in Study Area

Pilot and Reference Areas

Mahabad Pilot Area is located in the eastern part of the Mokriyan Irrigation System. The management of the main infrastructure is undertaken by the Water Authority, through an Operation and Maintenance Company (OMC). An alternative pilot site in West Mokriyan was discarded as its less reliable water supply and its smaller plot size could compromise the quality of the tests. The pilot area consists of three farms, and it measures about 7.0 ha. The external reference area selected in this region consists of one farm measuring 2.1 ha. Soils in these farms are silty clayey, fields are between 1.4 and 4.7 ha in size and 85-280 m long. The fields are uneven and they have an irregular micro-topography that jeopardizes proper on-farm irrigation water control and distribution. Sketches of all farms included in pilot and reference areas are shown in Figures 3 to 6.

Treatments

The treatments focused on testing:

- 1) Better irrigation water distribution on field and increasing infiltrating water into the field (DF);
- 2) Reduction of tail-end runoff and increasing infiltrating water into the field and better irrigation water distribution on field, tried out were:
 - Deepening Furrow with Less Discharge per Furrow (DFLD);
 - Alternate Furrow Irrigation (AFI).
- 3) Reference Areas: Neither change nor improvements were made in this treatment. When located in pilot farms, these are considered as *Internal Reference (IRFM)* and when they are located in reference farms, they are considered as *External Reference (Ref.)*.

All treatments have been tried out with three replications each except the external reference area, which consists of one complete farm. Treatment number 1 (IRFM) is an internal reference itself. Results of this treatment and results of the external reference area are averaged and considered as Reference (Control) for assessment of conducted treatments, i.e. treatments 2 to 4 (DF, DFLD, and AFI). Results of these two reference areas are shown separately and statistically compared with other treatments to have an idea of differences between internal and external references, but as mentioned above, averaged results of the two references are used in final comparisons. In all treatments crop was Sugar beet, and irrigation method was Furrow irrigation. Also in all treatment it was decided that one irrigation turn is omitted at the end of growing season. In this respect, during the last 80 days before harvest, there were 3 irrigations applied in all reference plots, whereas only 2 irrigations were applied in all treatment plots. This practice has a twofold purpose: 1) totally less water is used, and 2) sugar content is increased without significant reduction of the root yield.

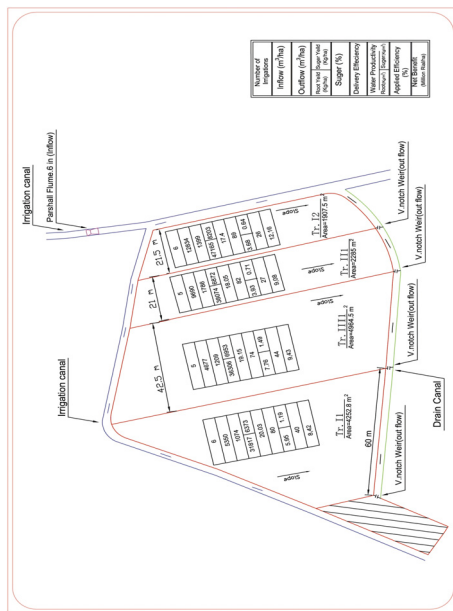


Figure 3. Pilot farm no. 2-1 (1.4 ha)

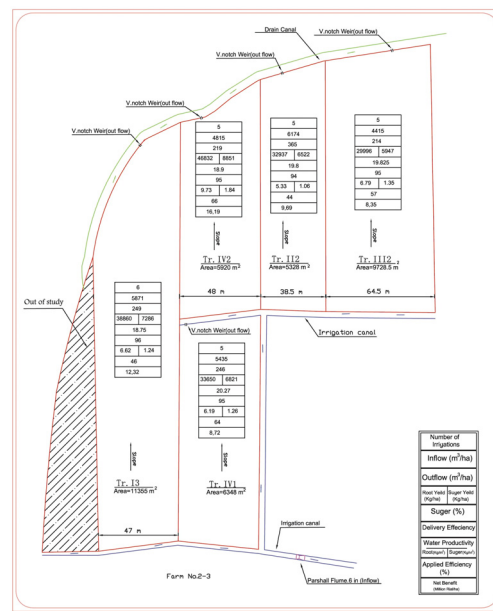


Figure 4. Pilot farm no. 2-3 (4.7 ha)

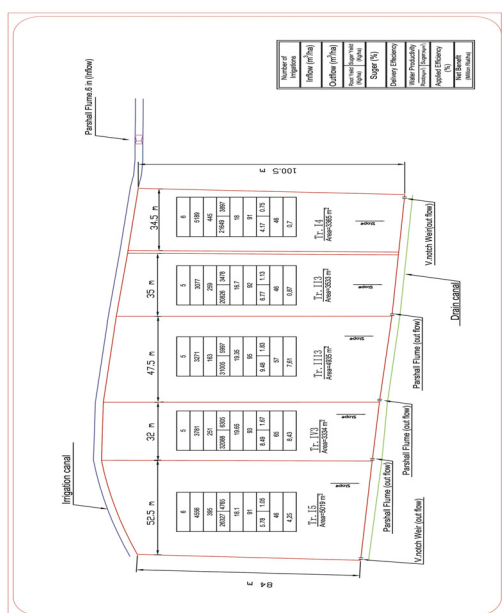


Figure 5. Pilot farm no. 2-4 (2.0 ha)

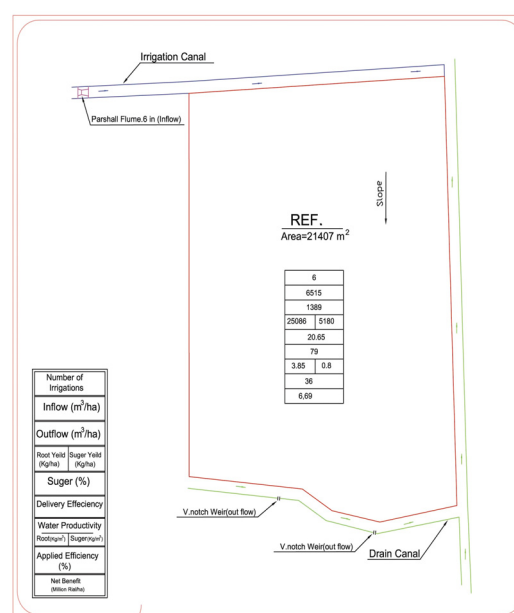


Figure 6. Ext. Ref. farm no. 2-2 (2.1 ha)

RESULTS

The indicators values for the treatments in the pilot area and the reference areas are given in Table 1. The treatment shown in bold represents the best treatment tried out, i.e. alternate furrow irrigation.

Table 1. Summary of Water Use, Yields, Efficiencies and Net Benefits

Treatment	Water use	Yield		Efficiencies				Net Benefit	
		Root	Sugar	Water Use		Delivery	Application		Monetary Water Use
				Root	Sugar				
units	m ³ /ha	kg/ha		kg/m ³		%	%	IRR/m ³	10 ⁶ IRR/ha
DF	6314	30612	5624	5.34	0.97	89	39	1050	6.63
DFLD	4121	32436	6299	8.01	1.56	88	53	2072	8.54
AFI	4677	37523	7326	8.14	1.59	94	65	2393	11.19
Reference	6638	29125	5643	4.55	0.89	84	39	1103	7.33

During the spring season 2004 water use in the entire Pilot Area in Mahabad area was reduced with 24% compared to the reference area while yields, root and sugar, were slightly higher, both similarly about 15%, than in the reference area.

The Alternate Furrow Irrigation (AFI) treatment obtained highest yields (37523 kg/ha root yield and 7326 kg/ha sugar yield) with second lowest total water applications (4677 m³/ha). All other

treatments also resulted in higher yields than the reference, while total water application didn't exceed that of the reference, too. Also, treatment DFDL produced more sugar per ha than the reference, while treatment DF production was lesser.

Average water use and yields for the different treatments and the reference are shown in Figures 7 and 8 for root and sugar yield, respectively. *Water Use Efficiency*, in kg of yield per m³ of total water used, is shown in Figures 9 and 10 for root and sugar production, respectively. *Net benefit*, in 10⁶ Islamic Republic Iran Rials (IRR) per ha, is shown in Figure 11, left bars and left Y axis. *Monetary water use*, in Net Benefit in IRR per m³ of total water used, is shown in Figure 11, right bars and right Y axis. *Application Efficiency*, in %, is shown in Figure 12. In application efficiency calculations an engineering judgment based irrigation water distribution factor is considered for different treatments and reference areas. The considered distribution uniformity factors are 0.5, 0.5, 0.6 and 0.7 for reference areas, DF, DFDL, and AFI treatments, respectively.

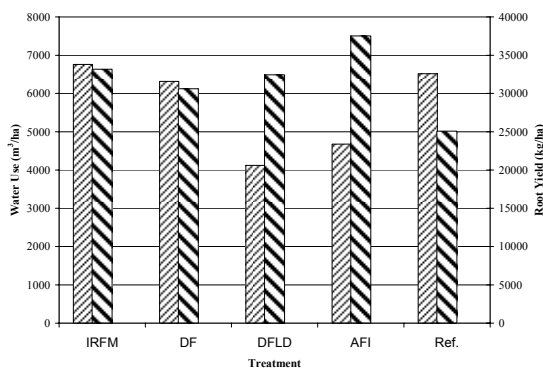


Figure 7. Average water use and root yields

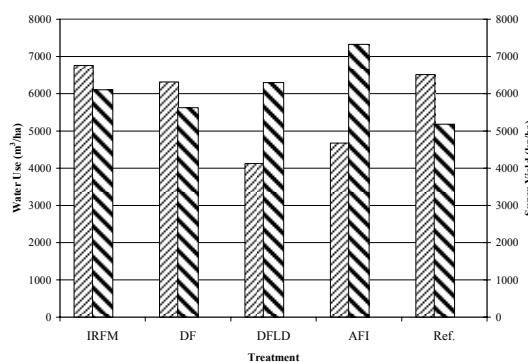


Figure 8. Average water use and sugar yields

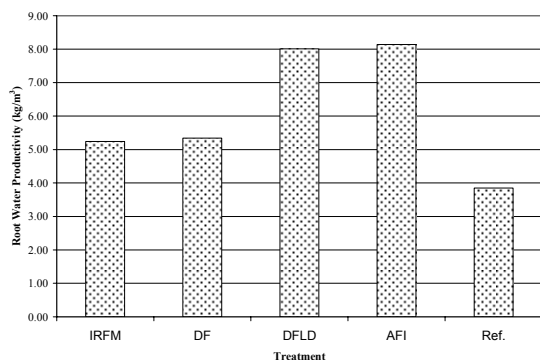


Figure 9. Water use efficiency in root production

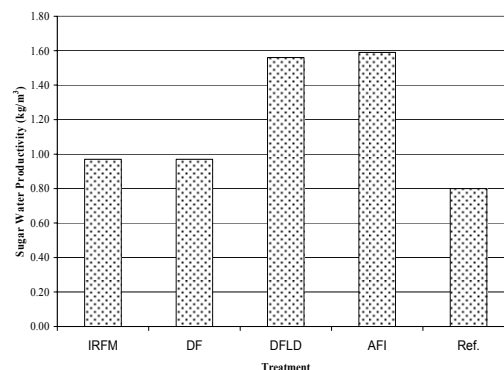


Figure 10. Water use efficiency in sugar production

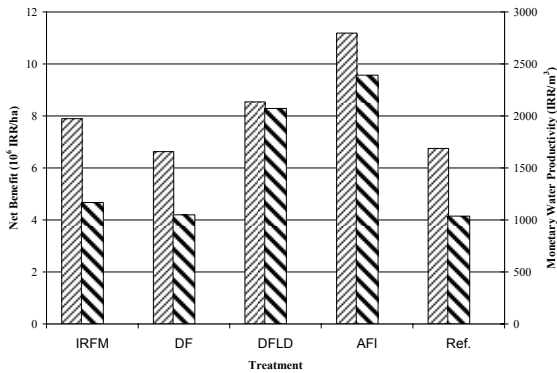


Figure 11. Net Benefit per ha and Monetary water use efficiency

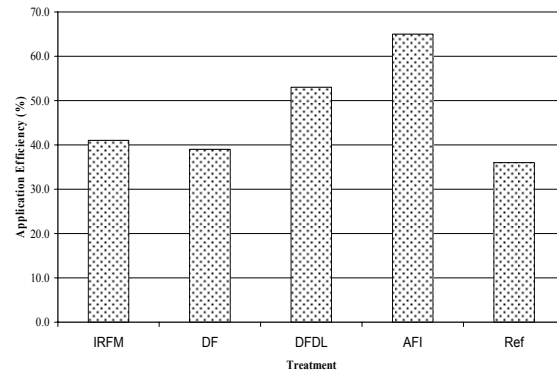


Figure 12. Average application efficiencies

DISCUSSION

Treatments are statistically analyzed and compared using One Factor Randomized Complete Block Design method. It should be noted that, as mentioned previously, with deepening of furrows it was aimed to have a better irrigation water distribution on field and also increase amount of infiltrating water into the field. However, in practice it was found that this solution would not make any considerable change in management. This happened due to uneven micro-relief of farms. Therefore, after the first two irrigations, deepening of furrows discontinued. As a result, treatment DF is actually the same as reference area and treatment DFLD is actually LD, i.e. less discharge per furrow.

Difference of **water use** between AFI and DFLD treatments and DF treatment is statistically significant ($\alpha=10\%$). However, difference between average water use in these two treatments and the reference area is not significant. Difference of **tail-end outflow** between treatment AFI and external reference area is statistically significant ($\alpha=5\%$). Difference of **root yield** between treatment AFI and reference area (both internal and external reference areas) is statistically significant ($\alpha=10\%$). Amounts of root yield produced under other treatments are not statistically different. Moreover, difference of this factor between AFI and DFLD treatments and external reference is significant ($\alpha=5\%$). Difference of **sugar yield** between treatment AFI and reference area (both internal and external reference areas) is statistically significant ($\alpha=5\%$). Moreover, difference of this factor between AFI treatment and external reference is significant ($\alpha=1\%$).

Difference of **root water productivity** between AFI and DFLD treatments and both internal and external references is statistically significant ($\alpha=5\%$). Moreover, difference of this factor between AFI treatment and external reference is significant ($\alpha=1\%$). Difference of **sugar water productivity** between AFI treatment and both internal and external references is statistically significant ($\alpha=1\%$). Difference of **net benefit** between AFI treatment and both internal and external references is statistically significant ($\alpha=5\%$). Difference of **monetary water productivity** between treatment AFI and both internal and external references is statistically significant ($\alpha=5\%$). The **delivery efficiency** (ratio of infiltrated water in the field to the delivered water to

the field) for all treatments is in good range. However, it should be noted that since total inflow has been reduced, therefore, final tail-end outflow has changed considerably; i.e. about only 23% tail-end outflow is produced in AFI treatment comparing to reference area.

The main physical bottlenecks common in Mahabad area could be summarized as follows:

Sub-optimal field preparation

The fields in this area have an uneven micro-relief. Fields are not well-levelled. The passage of water from the irrigation ditch to the furrows and again from the furrows to the tail-end drainage crosses perpendicular on the first rows of sugar beet. As a consequence, the areas up- and downstream of the furrows are watered in a very uneven way. Also due to sub-optimal field preparation, the depth of irrigation is uneven over the fields.

Shallow root zone

The impression exists that the transformation of the alluvial deposits in Mahabad to a deep soil profile, progresses very slowly. A modest moisture stress promotes deep penetration of roots, which in the end helps deepen the soil profile and thereby the storage of water in the root zone.

Irrigation Frequency

As mentioned in application efficiency discussion, according to Mahabad scheme operation program fields would receive only 6 irrigation gifts during spring growing season. This little number of irrigation turns together with shallow root zone in the area result in an uncontrolled deficit irrigation in the area.

High Groundwater Table

It should be noted that there is no potential hazard of soil salinization in Mahabad attributed to irrigation water. However, high groundwater table is a critical problem in most areas in Mahabad plain, especially at tail of irrigation system that would result secondary soil salinization through capillary rise. This phenomenon was not addressed in studies. But it is recommended to conduct specific study to address this issue. The high groundwater table also prevents root development and penetration, which results in poor crop stands and under-utilization of soil moisture.

CONCLUSION

Results show that application of alternate furrow irrigation in sugarbeet cultivation not only resulted in lesser water use per hectare, but also it increased both root and sugar yields and, consequently, higher water use efficiency was obtained.

In Mahabad yields improved and water use was reduced significantly by improved control over the irrigation. Better uniformity of on-field water distribution through irrigating alternate furrows in each irrigation turn and reducing inflow into each single furrow were key factors in improving irrigation efficiencies and crop yields.

Treatments AFI and DFLD resulted in water productivity close to the maximum expectable values reported. The range of water productivity for sugarbeet reported by FAO is between 6 and 9 kg of product per m³ of water used. In this regard, treatments AFI and DFLD resulted in water productivity more than 8 kg per m³ of water used. It should be noted that water productivity in reference area is considerably lower than the minimum value reported by FAO, i.e. 4.55 kg/m³ against reported value of 6 kg/m³. It shows that current sugarbeet production in Mahabad plain is very inefficient.

Total area under cultivation of sugarbeet in Mahabad area during spring season 2004 using surface irrigation was 1530 ha. About 20 percent of soils in Mahabad area have heavy texture. It was effectively shown that adopting alternate furrow irrigation would save up to 1950 m³ per hectare in fields with heavy soils. As a result, application efficiency increased from 65%, which is 26% increase. It should be noted that officially reported application efficiency in Mahabad area is about 45%, which in this case application efficiency is increased by 71% resulting in roughly 1700 m³ water saving per hectare. The studies were conducted on heavy soils and for sugar beet, however, it is possible to find practical solution also for other soil textures and crops to save water and increase application efficiency. Considering a sound value of 1500 m³/ha of water saving as an average for the whole Mahabad area, consisting of 14088 hectares of irrigated lands that utilize surface water resources, it would be concluded that roughly 21.1 MCM water would be saved if better on-farm irrigation water management is practiced in the area.

Best sowing dates for sugar beet cultivation in Mahabad plain in Mahabad sub-basin is recommended to be in late March and early April, and preferably in the third decade of March. In Table 2 recommended dates of irrigations and relevant amount of irrigation gift is given. The figures are for one hectare of land with heavy soils. This table is developed to be considered by OMC of Mahabad irrigation scheme for future operational planning of the system.

Table 2. Irrigation Interval and Application Quantity for Sugar beet in Mahabad Area

Interval	Quantity
days number	m ³ /ha
Day 80	900
Day 95	900
Day 115	960
Day 135	960
Day 160	930
Total	5 irrigations (4650 m ³ /ha)

The number of days given in above table represents number of days after sowing. The figures are flexible in a range of ± 5 days.

REFERENCES

- Box J., Sletten W., Kyle J., Pope A. (1963), "Effects of Soil Moisture, Temperature and Fertility on Yield and Quality of Irrigated Potatoes in Southern Plains", *Agronomy Journal*, 55: 492-494
- FAO, (1979), "Yield Response to Water", Technical Paper No. 33
- Fischback P., Mulliner H. (1972), "Every Other Furrow Irrigation of Corn", ASCE paper, No. 72
- Kang S., Laing Z., Zhang J., (1998), "Water Use Efficiency of Controlled Root-Division Alternate Irrigation on Maize Plants", *Agricultural Water Management*, 38: 69-76
- Kang S, Laing Z., Yinhou P., Peize S., Jianhua Z. (2000), "Alternate Furrow Irrigation for Maize Production in an Arid Area", *Agricultural Water Management*, 45: 267-277
- Raine S., (1999), "Research, Development and Extension in Irrigation and Water Use Efficiency", NCEI production No. 17297/4
- Stone J., Garton E., Webb B, Reeves H., Keflemariam J., (1979), "Irrigation Water Conservation Using Wide Spaced Furrows", *Soil Science Society of American Journal*, 43: 407-411
- Yekom Consulting Engineers, (2005), "Integrated Water Resources Management for Lake Uromiyeh Basin, Iran (PvW-02.048): Module 2- Water for Food: Assessment of Existing Irrigation Condition and Farm Water Management in Naghadeh and Mahabad Plain for Improving the Irrigation Efficiency – Part 2: Water Management on Farm to Increase Water Efficiency", 71 pages