Possible water saving opportunities in Turkey

Kanber R., Ünlü M., Koç L., Kapur B., Tekin S., Donma S., Yazar S.

in

El Moujabber M. (ed.), Mandi L. (ed.), Trisorio-Liuzzi G. (ed.), Martín I. (ed.), Rabi A. (ed.), Rodríguez R. (ed.).
Technological perspectives for rational use of water resources in the Mediterranean region

Bari : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 88

2009
pages 89-98

Possible water saving opportunities in Turkey

Riza Kanber[1], Mustapha Ünlü[1], Levent Koç[1], Burçak Kapur[1], Servet Tekin[1], Sevgi Donma[2], Servet Yazar[3]

[1] Irrigation and Agricultural Structures Department, Çukurova University, Adana-Turkey
[2] State Hydraulic Works, Adana-Turkey
[3] Kısas Water User Associations, Şanlıurfa-Turkey

Abstract. Water scarcity has been a major concern in Turkey since the 1960's. Agriculture is the major water consuming sector with an average of 70% out of the country's total water consumption. Many studies have been conducted to ensure a more efficient use of water for a sustainable agricultural development through a better management of the irrigation schemes by the local authorities and Water Users Organizations (WUOs). Irrigated agriculture is the most effective means for making rapid increases in crop production. The results from all research activities on irrigation in Turkey have been collected in the last 10-15 years. Statistical aspects of the collected results are presented to provide information and knowledge on irrigation science, to assess the past and current experiences and identify relevant gaps and problems in Turkey. Also, overviews of some scientific results are given on the main irrigation topics such as crop-water-atmosphere relationships, irrigation scheduling techniques, comparison of irrigation methods, and empirical yield response factors for some main crops.

Efforts were carried out to collect the results of all research activities on both irrigation and water saving opportunities to sustain irrigated agriculture in Turkey. However, published data and other activities on all studies could not be obtained due to the deficiencies in the archive system. Therefore, the assessment of all the studies conducted is limited.

Keywords. Water scarcity – Water saving – Water use efficiency – Yield response factors.

Opportunités possibles d'économiser l'eau en Turquie

Résumé. *En Turquie, la pénurie d'eau représente un souci majeur depuis les années 60. L'agriculture est le secteur qui consomme le plus d'eau, avec une moyenne de 70% de la consommation totale à l'échelle nationale. De nombreuses études ont été réalisées afin d'assurer une utilisation plus efficiente de l'eau et favoriser le développement d'une agriculture durable à travers une gestion plus raisonnée des périmètres irrigués par les autorités locales et les organisations d'utilisateurs d'eau. L'agriculture irriguée constitue le moyen le plus efficace pour accroître rapidement la production des cultures. Les résultats de toutes les activités de recherche menées dans le domaine de l'irrigation en Turquie ont été collectés ces 10 à 15 dernières années. L'accent est donc mis sur les aspects statistiques de ces résultats pour donner des informations et promouvoir la connaissance de la science de l'irrigation, évaluer les expériences passées et actuelles et identifier les faiblesses et les problèmes qui se posent à l'échelle nationale. Parallèlement, certains résultats scientifiques sont passés en revue concernant les questions principales de l'irrigation comme, par exemple, la relation plante-eau-atmosphère, les techniques de programmation de l'irrigation, la comparaison des diverses méthodes et les facteurs empiriques de réponse du rendement pour certaines des principales cultures.*

Des efforts ont été déployés pour rassembler les résultats de toutes les activités de recherche portant sur les opportunités de l'irrigation et l'économie d'eau pour soutenir l'agriculture irriguée dans le pays. Cependant, il n'a pas été possible de repérer toutes les données publiées et les informations utiles sur les différentes activités menées à cause des insuffisances dans le système des archives. Par conséquent, l'évaluation des études reste encore limitée.

Mots-clés. *Pénurie d'eau – Économie d'eau – Efficience d'utilisation de l'eau – Facteurs de réponse du rendement.*

I – Introduction

Irrigated agriculture is the most effective means for making rapid increases in crop production. Improvements in irrigation can result in higher levels of living in low income nations because they have approximately 80% of the world's irrigated land. The introduction of irrigation is one of the turning points of the human history in that those men who learned how to use seeds and to sow them in the soil understood that a greater yield could be obtained by irrigation. Water management in agriculture is the process by which water is manipulated and used in the production of food and fiber.

There is no doubt that for developing countries of the Mediterranean region, with erratic rainfall pattern, efficient control and management of water use has to be an essential requirement for this continued development. Without proper water management, autonomy in food and energy will continue to be a mirage for most of these countries. Due to increasing population which leads to growing demand for water resources, and pollution that reduces fresh water yield, most of the Mediterranean Countries have serious water scarcity problems for agricultural production and urban/industrial consumption. Scarcity of water and reliability of its supply are major constraints for agriculture development in those countries.

In the developing countries of the Mediterranean area, the major challenge facing water planners and managers at the end of the 20^{th} century is that while physical availability of water is fixed, its demand will continue to increase steadily in the foreseeable future. Accordingly, the problem is how to balance demand and supply of water under those difficult conditions. In addition, the issue of potential climatic change due to global warming and what its impacts could be on natural resources including water, are basically unknown factors at present (Hamdy and Lacirignola, 1999).

Today, agriculture is the main consumer of freshwater in the Mediterranean countries and the withdrawal for agriculture is about 80% of the total freshwater sources. In the world with an urban/industrial culture today, agriculture still continues to be the biggest consumer of water. For this reason, water saving opportunities should be considered. Water saving in agriculture ranges from genetics to agronomic, engineering, and different management options, including the use of non-conventional water resources.

Irrigation has a vital role for increasing and stabilizing agricultural production in Turkey because of scarcity and unreliability of rainfall conditions prevailing during the growing season in most part of the country. 36.5% of the total land (77.95 Mha) in Turkey is suitable for agriculture (28.05 Mha). Of the total irrigable area (25.85 Mha) 16.6% is being irrigated (4.3 mha) while 65% is not. Only 16% of total water resources are used for irrigation and other purposes. Economically viable irrigation is possible for only 8.5 million hectares.

The annual potential surface runoff from rivers are calculated as 186 billion cubic meters and a certain level of runoff is to be allocated for water requirements of neighbouring countries. The amount of flow that can be used for consumptive purposes is estimated to be around 95 billion cubic meters. Together with 13.66 billion cubic meters of useable ground water resources, the total available water resource of Turkey is around 108.66 billion cubic meters. Today, Turkey can not use soil and water resources effectively, due to coordination, political and economic problems.

However, during the next 20-30 years, Turkey will necessitate to irrigate all the irrigable lands and the population will reach 80 million by 2010 and 90 million in 2025; if 400 kg of grains for one person, the total grain demand will be around 32 million tons by 2010 and 36 million tons by 2030 (Hamdy and Lacirignola, 1998). To meet this demand, the irrigation area should be increased. It should be up to 4.77 million ha by 2010 (a net increase of 0.47 million ha more than the current), and 5.4 million ha by 2025 (a net increase of 1.1 million ha more than the current). This will cause the agricultural water consumption to increase dramatically. Currently in Turkey, about 31

500 km^3 of water is used by agriculture, in which 70 per cent, that is, about 22 050 km^3, is for the grain production (SPO, 2001). As a result, sustainable quantities of freshwater supplies will be diverted from agriculture to industry and households in the country. Irrigated agriculture will face two problems of water shortage and reduced financial resources. Despite these problems, irrigated agriculture has not only to supply the other sectors with their water demands, but has also to provide 70-75% of the additional food grain requirements to the increased population. This will not be possible without the implementation of water demand management in all sectors, and particularly, the agricultural one. There is a great need to find appropriate ways to achieve greater efficiency, better saving in water losses, and an equitable distribution in the irrigation sector. This will require a wider range of alternative approaches to be developed, tested and implemented with greater imagination and flexibility on the part of irrigation policy makers, managers, and planners.

In this report, water scarcity and possible water saving in Turkey are discussed and some scientific results on water saving opportunities taken from some experiments carried out in the different regions and crops.

II – Possible water saving in Turkey

There is a great opportunity for saving significant volumes of water losses through a better use of technical and economic tools as well as the institutional and human resources capacities Turkey already has. It is possible to reduce losses and leaks in drinking water in industry; through recycling, it is possible to reduce water consumption. However, in spite of the water saving that could be achieved in both drinking and industrial sectors, yet, the most beneficial saving in terms of volume would be in the irrigation sector.

In Turkey, where more than 72% of its water resources are allocated to agriculture, major efforts should be directed to increase the efficiency in the field, as the opportunity of water saving is notably higher compared to other water use sectors. For instance, in the irrigation sector, the reduction of conveyance losses and the improvement of irrigation efficiency can result in water saving.

In this section, some summarized results, which showed the water saving approaches and total saved water amount, are given. The results are taken from experiments carried out in the different regions and different topics. These are the new mechanisms which are to protect the resource and allocate diminishing water supplies to increasing and competing uses.

1. Deficit Irrigation

Generally, irrigation and irrigation water requirement of crops were determined without any consideration of likely water limitation of available water supplies. In arid and semi-arid regions, because of increasing allocations of water for municipal and industrial use, major changes came about in water use under irrigated agriculture. New innovations had to be tested and adapted to increase effective use of decreasing water allocations for agricultural use (Hanks, 1983).

Research effort has focused on developing new techniques to receive high returns from restricted supply of water. Among the techniques of increasing effective use of water, deficit evapotranspiration should also be used. Deficit irrigation can be used either through agronomic practices or through changing management schemes to decrease crop evapotranspiration (Kanber *et al.*, 1993). The end result is the so-called "deficit irrigation" (Vaux and Pruitt, 1983). To save irrigation water, crops are exposed to water stress either throughout the whole growth season or at certain growth stages. With this application, water saving is obtained without significant yield decrease and also irrigated area can be increased without additional water supply available (Merriam, 1965). Deficit irrigation is promoted widely and used for some crops in Turkey. Experiments on the deficit irrigation of crops are being considered in different ways: 1) To spread water deficiencies equally through the growing season. For this reason, different approaches are being considered such as using different soil depths for wetting, decreasing irrigation water as control treatment, using different plant-pan coefficients, different irrigation intervals, different furrow spacing in surface, lateral and trickle spacings in drip irrigation systems, and line source sprinkler irrigation technique. In some deficit irrigation experiments, crops are exposed to water stress in different growth stages. This technique is named as omitted irrigation. In all the deficit irrigation experiments, yield response factors (Ky) given by Stewars Equation are elaborated to be calculated. Yield response factors for some main crops are given in the Table 1.

Water saving with deficit irrigation approach is used in different ways in some experiments. For instance, in some studies, different irrigation season lengths are used while in others evapotranspiration losses are prevented by chemical applications.

Different irrigation season lengths were used for cotton under Seyhan Plain conditions (Kanber *et al.*, 1994). In this study, different irrigation intervals, first and last irrigation, are considered. According to the results, different yield reductions and irrigation water savings were obtained depending on irrigation season lengths. When the last irrigation was applied at the ball diameter of 1-2 cm, the maximum water saving measured was 46-62 percent.

Table 1. The Empirical Yield Response Factors for Some Main Crops.

Crops	Ky Values, Growth stage / Irrigation Method	Region	Sources
Cotton	0.76 (flowering-yield formation) 0.99 (seasonal, Furrow) 0.93 (seasonal, furrow) 0.86 (seasonal, drip) 0.72 (sprinkler, sprinkler) 1.22 (sprinkler, Seasonal)	Çukurova Çukurova Harran	Baştuğ, 1987 Yavuz, 1993 Kanber *et al.*, 1991
Pistachio	0.62 (Seasonal, Surface 0.77 (seasonal, drip)	Şanlıurfa Gaziantep	Kanber *et al.*,1993 Aydın, 2004
Maize	0.98 (Seasonal, Furrow) 0.85 (seasonal, sprinkler) 0.69 (Vegetative) 1.03 (Blister) 1.00 (Milk stage) 0.66 (Ripening) 1.14 (Seasonal, surface)	Tarsus Tarsus Thrace	Kanber *et al.*, 1990 Köksal, 1995 Çakır, 1999
Wheat	0.87 (Seasonal, surface) 1.14 (seasonal, sprinkler) 0.76 (Seasonal, surface) 0.32 (seasonal, surface)	Southeast Southeast Central Anatolia East Anatolia	Karaata, 1987 Sezen, 2000 Madanoğlu, 1977 Sevim, 1988
Sunflower	0.62 (Seasonal, surface)	Thrace	Karaata, 1991
Bean	1.3 (Seasonal, Sprinkler)	Central Anatolia	Bahçeci, 1995
Soybean	1.1 (seasonal, sprinkler)	Southeast	Kara, 1995

In some places where the evaporation losses are very high, chemicals were applied to reduce evapotranspiration of cotton. In this study, the effects of irrigation intervals and antitranspirant doses on evapotranspiration, yield, and water use efficiency of cotton were investigated in the plots in Harran Plain for 4 years (Kanber *et al.*, 1992). Different irrigation intervals (I1: 7, I2: 14, and I3:21 days) and four antitranspirant doses (D0: 0; D1: 40 g/ha; D2: 80 g/ha; and D3: 160

g/ha) were tested. The antitranspirant that contains N, N, N-tributtill-3- (trifluoromethyl) benzene methananium chloride as the effective substance was used in the sub-plots of the experiment. The antitranspirant application was made in two times when the reddish colour on the main stem of cotton, 5-7 cm high, reached the top bud (as first application) and on the $5^{th,}$ 7th day of ball formation (as second application) during the growing season. The irrigation programs got started after the first application of antitranspirant and 90 cm soil depth was wetted in irrigation events.

Results show that the frequent irrigation increased evapotranspiration (ET) and net irrigation water requirement (IR). The maximum ET and IR values were found to be 1670 and 1555 mm, respectively in treatment I1 (Table 2). The highest WUE values, although not statistically significant, were obtained from I2 as 2.41 and 2.69; and from D1 as 2.34 and 2.60.

The application of various antitranspirant doses had no significant effect both on seasonal ET and WUE values. The irrigation intervals have significant effect on the yield and quality of cotton. The maximum cotton yield was obtained from frequent irrigations. Frequent irrigation applications increased lint length, whereas infrequent irrigations and antitranspirant doses resulted in shorter and thicker lint.

2. Use of Unconventional Water

Applying deficit irrigation programs including supplemental irrigation and managing irrigation systems according to deficit irrigation approach can be considered as the best solution. However, this solution is very expensive and requires new approaches.

Table 2. Results from the experiment on antitranspirant doses and irrigation program.

Treat.	No of ırr.	IR mm	ET mm	IWUE	TWUE	Average Values					
						Yield* kg/da	No of irr.	IR	ET	IWUE	TWUE
I1D_0	13	1555	1670	2.45	2.28	384a	8 (D_0)	1201 (D_0)	1322 (D_0)	2.51 (D_0)	2.26 (D_0)
I1D_1	13	1555	1670	2.55	2.36	394a	8 (D_1)	1182 (D_1)	1310 (D_1)	2.60 (D_1)	2.34 (D_1)
I1D_2	13	1555	1670	2.39	2.23	361a	8 (D2)	1172 (D_2)	1290 (D_2)	2.54 (D_2)	2.29 (D_2)
I1D_3	13	1555	1670	2.35	2.18	376a	8 (D_3)	1196 (D_3)	1312 (D3)	2.49 (D3)	2.25 (D3)
I2D_0	7	1113	1234	2.62	2.34	295b					
I2D_1	7	1113	1234	2.76	2.48	302b					
I2D_2	7	1113	1234	2.65	2.36	298b					
I2D_3	7	1113	1234	2.74	2.46	304b					
I3D_0	5	894	1019	2.45	2.15	223c					
I3D_1	5	894	1019	2.48	2.18	224c					
I3D_2	5	894	1019	2.57	2.27	227c					
I3D_3	5	894	1019	2.38	2.11	209c					

*$S\bar{x}$ =20.94 and 9.77; the yield groups were statistically obtained by the orthogonal comparison methods

On the other hand, to find new water resources for different purposes including irrigation is another possibility to solve the problems related with insufficient water resources. Using unconventional water such as brackish water (treated waste water, drainage water, and ground water table), shallow ground water and saline water supplied from different resources is considered to be one of the best solutions. Table 3 shows the waste water amount in Turkey from urban and industrial consumption in 2001.

Table 3. Waste water amount from urban and industrial consumption in 2001 (DIE, 1995)[1].

Resources	Amount, km3
Urban waste water	3.700
Industrial waste water	3.000

[1]The values of 1995 are updated for 2004.

The use of drainage and saline water for irrigation seems to be an attractive alternative for solving water scarcity problem. Saline water is a potential source for irrigation. The use of saline water for irrigation increases the quantity of water available for agricultural production if the sustainable management strategies for their utilization have evolved. Such water occurs extensively in the arid and semi arid parts of the Mediterranean, Central and Southeast Anatolia regions and are being used for irrigating some summer crops which are tolerant to salinity. Sometimes saline water is blended with fresh water with different quantity and used to irrigate the salt sensitive crops. There is enough evidence taken from several studies carried out either in Turkey or in other countries to show the potentiality of using water with salinity up to 6 dS/m for major cereal crops (Hamdy, 2002). Unconventional water use for irrigation gradually increases in a lot of countries where irrigation is evitable but water resources are scarce.

3. Use of waste water

In spite of the standards which are prepared in Turkey, waste water is not widely used in irrigation except in a pilot project in the GAP areas and in a few small industries. Enough water is being supplied for irrigated areas; therefore, the total irrigated areas did not reach the marginal limit value for the water resources. Frankly, farmers can still find enough water for irrigation. The experiments on the use of waste water for irrigation purposes persist (Sarikaya, 1994). A study using urban waste water treated by Çiğli treatment plant for irrigating Menemen plain (Eagen Region) has been carried out for a long period. On the other side, in the GAP areas two experiments on the use of waste water and drainage water for irrigation were carried out (Altınbilek and Akçakoca, 1997).

Bilgin *et al.* (1997) carried out studies to determine the effects of Ankara stream-water which is polluted by urban and industrial wastes on soil, plants (lettuce and broccoli) and environment. Moreover, they examined the chemical composition of stream water i.e. heavy metals, microbiological pollution, etc, in the sites where the samples were collected. The experiment was conducted in the open areas and greenhouse conditions. According to the results, heavy metal concentrations of Ankara stream were found to be not hazardous to plants and soils. However, microbiological pollution of the water turned to be too high. Irrigations caused to the yield decreases due to the detergent content of the stream flow.

4. Use of drainage water

Yarpuzlu (1999) studied the response of cotton and wheat grown in a clay soil in a sequence of drainage water applications with different leaching fractions (5 treatments in 1991-1995; in 1996-1997), three different irrigation water sources (drainage canal water, collector water and Seyhan canal water with different leaching fractions were utilized); the salinity build-up in the soil profile was evaluated during each growing season in Tarsus plain. The results of the study showed that the effect of irrigation with different leaching fractions were not statistically important on the yield of wheat crop; the effect of different leaching fractions on cotton yield was statistically significant at 99 signification level. Drainage water applications in the wheat sowing periods did not cause salt accumulations in the soil; however, in the cotton sowing periods it did cause salt accumulations.

Bahçeci (1991) examined the effect of groundwater used in irrigation, the accumulation of salts, sodium and boron in the Konya-Yarma district soils for wheat and sugar beet crops. The trial was designed in randomized block with three replications. According to the results, the salt accumulation wasn't significant but both the boron amount in the soil increased and the increasing amount of exchangeable sodium was statistically significant. The exchangeable sodium accumulation was taken into consideration as a trend function and YB= 0.193+0.309X relationship obtained. This relationship showed that only 20 years later the amount of ESP with a 90 percent probability would be reached to 23 - 47 percents limits.

Bahçeci (1993) studied the quality and the suitability of the main drainage channel waters for irrigation of Konya. In the research, the drainage water of Alakova and Arapçayiri branches of the main drainage channel were tested. The results showed that drainage waters may cause salt and boron accumulations in the soil. Besides the study also determined that Keçeli branch of the main drainage channel in the region was polluted from urban areas and reuse of this drainage water may cause environmental problems.

5. Use of saline water

There are various studies regarding the use of saline water for irrigation purpose. In these studies, surface and pressurized irrigation methods are used with saline water which is diluted at different levels. Diluted-saline water is used with various irrigation systems such as drip, sprinkler and surface methods. In surface irrigation methods, different amount of irrigation water with different saline levels are directly applied to plots whereas in pressurized systems, different salinity levels of irrigation water were used with line source sprinkler and drip which had different line and trickle head spacing (Sönmez and Yurtseven, 1995). Line source sprinkler system and drip system which has different trickle intervals can be shown as examples (Kanber and Bahçeci, 1995; Ödemiş, 2001). The results on saline irrigation of some crops in Turkey are given in Table 4 (Yurtseven *et al.*, 1999a and b; Yurtseven *et al.*, 1996; Yurtseven and Bozkurt, 1997; Çizikçi, 1998; Yurtseven and Baran, 2000; Yurtseven *et al.*, 2001a and b; Yurtseven and Öztürk, 2001; Yurtseven *et al.*, 2002). This table contains both threshold and zero yield values of crops.

Table 4. The Results of Saline Irrigation for Various Crops.

Crops	Threshold Value, dS/m	Zero Yield Value, dS/m
Maize	0.81	4.0
Tomato	2.7	11.0
Pepper	1.8	7.0
Lettuce	1.5	7.0
Broccoli	3.5	9.0
Radish	1.5	7.0
Rape	2.3	9.0
Spinach	3.5	
Cotton	5.7	

The values in Table 4 are close to values given in some papers; however, some little differences may be inferred based on irrigation programs, soil properties and other factors.

III – Conclusions

As the demand for the limited water resources continues to rise, the irrigation comes to be caught in the middle: on one side, with the development of the industry and agriculture and acceleration of the urbanization process, agriculture will have to give way for the industry and urban living; on the other side, in order to feed the increasing population, the new irrigation area must be expanded while maintaining the current irrigated area and guarantee rate, and more water will be needed. This is why for a sustained development, Turkey's agriculture must stick to economy and efficiency.

As the irrigation water-using efficiency in Turkey is much lower than that in western countries, if the water-saving irrigation techniques are practiced generally, the potential to save water will be very prospective. Adopting canal lining or water pipes will increase the water delivery efficiency in a canal system; furrow and border irrigation for dry farmlands will improve the usage of field water; the sprinkling irrigation and micro irrigation will improve the usage of water at its delivery section and in the field, and improve the evapotranspiration environment and reduce evapotranspiration.

As a technical measure, the water-saving irrigation method is employed to make full use of irrigation water resources, to improve water usage efficiency, and achieve high yield and efficiency in grain production. It is an integrated technical system, combining water-saving techniques concerning water resources, engineering, agriculture, management and other links. With it, the overall using rate of irrigation water resources will be improved, the grain production at unit area or total area will be heightened, and the sustained development of agriculture can be guaranteed.

Agriculture is the basis of the national economy, providing necessary agricultural products and industrial raw materials for the living of 72 million people. Because of the special topographic characteristics and climate of Turkey, its agriculture production mostly depends on irrigation, and appropriate irrigation measures will result in a stable and high yield. Due to the serious lack of water resources, the traditional irrigation methods cannot catch up. Hence, water saving is a prerequisite for the sustained development of the national agriculture and national economy.

References

Altınbilek, D., Akçakoca. H., 1997. Innovative approaches in water resources development in the Southeastern Anatolia Project (GAP). *Water Resources Development* 13(4): 485-503.

Aydın, Y., 2004. Antepfıstığında farklı su ve azot düzeylerinin verim ve periyodiziteye üzerine etkileri. Ç.Ü. Fen Bilimleri Enst. Tar. Yap. ve Sul. Anabilim Dalı, Doktora Tezi, Adana, 145 pp.

Bahçeci, I., 1991. Konya Yarma TOPRAKSU Kooperatif alanındaki yeraltı suylarının sulamada kullanılma olanakları. Köy Hizmetleri Araştırma Enstitüsü Yayınları. Genel No. 139, Rapor Seri No. 113, Konya, 46 pp.

Bahçeci, I., 1993. Konya Ovası ana tahliye kanalı suyunun kalitesi ve sulamada kullanılma olanakları. Köy Hizmetleri Araştırma Enstitüsü Yayınları. Genel No. 159, Rapor Seri No. 132, Konya, 44 pp.

Bahçeci I., 1995. Tarla Fasulyesinde Tuz-Su ve Verim İlişkilerinin İrdelenmesi., Doktora, 109 pp.

Baştuğ, R., 1987. A Study on the Defining the Water Production Function of Cotton Plant Under Çukurova Conditions. Unv. Of Çukurova Enst. Of Sci. Irr. And Drain. Dept. Ph. Thesis, Adana, 120 p.(In Turkish).

Bilgin, H. Üstün, İ. Gedikoğlu, G., Dızdar, S., Günal, M., 1997. Evsel ve endüstriyel atıklarla kirlenen Ankara Çayı ile sulamanın toprak ve bitkiye olan etkileri ile mikrobiyolojik kirliliğin belirlenmesi. K.H. Ankara Araştırma Enstitüsü Genel Yayın No.102, Ankara.

Çakır, R., 1999. Trakya Koşullarında Yetiştirilen Hibrit Mısırın Su-Verim İlişkileri. Toprak ve Su Kaynakları Araştırma Yıllığı. APK Dairesi Başkanlığı Yayınları; Toprak ve Su Kaynakları Araştırma Şube Müdürlüğü, Yıyın No:108, Ankara, 293-311.

Çizikçi, S., 1998. Değişik tuzluluk, SAR ve Ca/Mg oranlarına sahip sulama sularının ıspanağın çimlenme ve verimine olan etkileri. Toprak ve Gübre Araştırma Enstitüsü Genel yayın No.106, Ankara

DİE., 1995. Environmental statistics: River basin statistics. Pub. No. 2152, Ankara, 120 pp.

Hamdy, A., 2002. Saline Irrigation Management for Sustainable Use. In Advances in soil salinity and drainage management to save water and protect the environment. Oct. 15-27, 2002. Ministry of Agriculture-Alger, Algeria. p.253-304

Hamdy, A., Lacirignola, C., 1998. Water resources in the Mediterranean region: Development and Management, Non-Conventional Water Resources Practices and Management: An Overview of water resources in the Mediterranean countries. CIHEAM_B, Italy.

Hamdy, A., Licirignola, C., 1999. *Mediterranean Water Resources: Major Challenges Towards The 21st Century.* Mediterranean Agronomic Institute of Bari, 570 pp

Hanks, R. J., 1983. *Yield and Water Use Relationships: On Overview. " Limitation to Efficient Use in Crop Production*. Edit, H.M. Taylor *et al.*," ASEA, Madison, Wisconsin, S.393-410

Kanber , R., Tekinel, O., Baytorun, N., Önder, S., 1991. The Possibilities of Free Water surface Evaporation for Using Irrigation Program and Evapotranspiration of Cotton under Harran Plain Conditions. Prime Minister of Turkish Republic, Chairmanship of South-eastern Anatolia Project Authority, Pub.44, Adana, 38 pp

Kanber, R., Bahçeci, I., 1995. Response of field beans (*Phaseolus vulgaris*) to saline irrigation water. In Workshop "On farm sustainable use of saline water in irrigation: Mediterranean experiences" 5-8 Oct., 1995, Hammamet, Tunisia, p. 205-220

Kanber, R., Eylen, M., Tok, A., 1990. Relationship between Evapotranspiration and Evaporation for Cotton Grown under Çukurova Conditions. Soil and Water Research Institute. Tarsus, Unpublished Data.

Kanber, R., Tekinel, O., Önder, S., Köksal, H., 1993. Comparison of Irrigation Length of Cotton Under Çukurova Climatic Conditions. *Tr. J. of Agric. And Forest*. 18:81-86.

Kanber, R., Yazar, A., Diker, K., Ünlü, M., Sözen, M., 1994. Bitki Üretim Fonksiyonlarının Eldesinde Çizgi Kaynaklı Yağmurlama Sistemlerinin Kullanılması. *Ç.Ü. Z. F. Dergisi.* 9, (1) : 133-148

Kanber, R., Yazar, A., Köksal, H., Oğuzer, V., 1992. Evapotranspiration of Grapefruit In the Eastern Mediterranean Region of Turkey. *Scientia Hort.*, 52:53-62

Kara, C., 1995. Bitki-Su Üretim Fonksiyonlarının Eldesinde Kullanılan Nokta ve Çizgi Kaynaklı Yağmurlama Tekniklerinin Karşılaştırılması. Yüksek Lisans, 117 pp.

Karaata, H., 1987. Harran Ovasında Buğdayın Su Tüketimi. Bölge Topraksu Arş. Enst. Yay. 42(28), Şanlı Urfa, 34 pp.

Karaata, H., 1991. Kırklareli Koşullarında Ayçiçeği Bitkisinin Su-Üretim Fonksiyonlarının Belirlenmesi. Doktora, 90 pp.

Köksal, H., 1995. Çukurova Koşullarında ikinci ürün mısırın su-verim ilişkileri ve Ceres-Maize bitki büyüme modelinin yöreye uyumluluğunun saptanması. Ç.Ü.Fen bilimleri Enst. Doktora tezi, Adana, 199 p

Madanoğlu, K., 1977. Orta Anadolu Koşullarında Buğday (Yektay 406) Su Tüketimi. Merkez Topraksu Araşt. Enst. Yay., 52(19), Ankara, 67p

Merriam, J.L., 1965. A Management Control Concept For Determining The Economical Frequency Of Irrigation. AASE Annual Meeting, Paper No.65-206:1-10.

Ödemiş, B., 2001. Farklı Nitelikteki Sulama Sularının ve Yıkama Oranlarının Pamuk Bitkisinin Değişik Gelişme Dönemlerindeki Etkilerinin İrdelenmesi. Ç.Ü. Fen Bilimleri Enstitüsü, Tar. Yap. ve Sul. Anabilim Dalı Doktora Tezi, Adana, 211pp.

Sarıkaya, Z., 1994. Arıtılmış atıksuların sulamada kullanımı. 40'ıncı kuruluş yılı su ve toprak kaynaklarının geliştirilmesi konferansı bildirileri, ed. DSİ Genel Müdürlüğü, 477-494, Ankara.

Sezen, S.M., 2000. Çukurova ve Harran Ovası Koşullarında Buğdayda Azot-Su-Verim İlişkilerinin Belirlenmesi ve Ceres-Wheat V3 Modelinin Test Edilmesi. Doktora, 211 pp.

Sevim, Z., 1988. Erzurum Koşullarında Buğdayın Su Tüketimi. Köy Hizm. Araşt. Enst., Erzurum. 49p

Sönmez, B. and Yurtseven, E., 1995. Değişik Tuzluluk ve SAR değerlerine sahip suların toprak tuzluluğu ve sodyumluluğu ile domates bitkisinin gelişimine ve verimine olan etkileri. KHGM Toprak ve Gübre Araşt. Enst. Md. Genel Yayın No.202, Ankara

SPO, 2001. 8th Five-Year Development Plan, for the year of 2001, Report by the Special Commission on Water Basins and Management, *SPO*, Ankara.

Vaux, Jr.H.J., Pruitt,W.O., 1983. *Crop-Water Production Functions. "Advances In Irrigation*, Edit. By D. Hillel." Academic Press, Vol.2, .61-93.

Yarpuzlu, A., 1999. Tarsus ovası drenaj kanal sularının niteliği ve sulamada kullanılma olanakları. Ç,Ü. Fen Bilimleri Enstitüsü, Tar. Yap. ve Sul. Anabilim Dalı, Doktora tezi, Adana, 128 pp.

Yavuz, M.Y., 1993. Farklı Sulama Yöntemlerinin Pamukta Verim ve Su Kullanımına Etkileri. Ç.Ü. Fen Bilimleri Enst. Tar. Yap.ve Sul. Anabilim Dalı Doktora Tezi, Adana, 196 p.

Yurtseven, E., Öztürk, A., Kadayıfçı, A., Ayan, B., 1996. Sulama suyu tuzluluğunun Biberde *(Capsicum annuum)* farklı gelişme dönemlerinde bazı verim parametrelerine etkisi. *Ankara Üniv. Ziraat Fak. Tarım Bilimleri Dergisi.* 2(2):5-9.

Yurtseven, E., Bozkurt, D. O., 1997. Sulama suyu kalitesi ve toprak nem düzeyinin marulda verim ve kaliteye etkisi. *Ankara Üniv. Ziraat Fak. Tarım Bilimleri Dergisi.* 3(2):44-51.

Yurtseven, E., Halloran, N.D., Demir, K., Kütük, C., Kasım, M.U., 1999a. Farklı gelişme dönemlerindeki tuzluluk koşullarının domateste vejetatif gelişme ve verime etkisi. VII.Kültürteknik Kongresi Bildirileri, 11-14 Kasım 1999, Kapadokya, p.188-198.

Yurtseven, E., Parlak, M., Demir, K., Öztürk A., Kütük, C., 1999b. Turp *(Raphanus sativus, L.)* bitkisinde farklı sulama suyu tuzluluğu ve Ca/Mg oranı uygulamaları. I. Bazı verim parametrelerine etkisi. *Ankara Üniv. Ziraat Fak. Tarım Bilimleri Dergisi.* 5(3):28-34.

Yurtseven, E., Baran, H.Y., 2000. Sulama suyu tuzluluğu ve su miktarının Brokkolide *(Brassica oleracea botrytis)* verim ve mineral madde içeriğine etkisi. *DOĞA Tr. J. Agric. For.* 24:185-190.

Yurtseven, E., and Öztürk, H.S., 2001. Sulama suyu tuzluluğnun tınlı toprakta profil tuzluluğuna etkisi. A.Ü. Ziraat Fak., Tarım Bilimleri Dergisi, 7(3):1-8.

Yurtseven, E., Ünlükara, A., Top, A., Tek, A., 2001a. Tuzluluğun ve sulama aralığının kolzada *(Brassica napus oleifera)* verime ve gelişmeye etkisi. I. Ulusal Sulama Kongresi Bildirileri Kitabı, 8-11 Kasım 2001, Antalya, Belek, p.215-219.

Yurtseven, E., Ünlükara, A., Demir, K., Kesmez, G.D., 2001b. Sebze tarımında tuzlu suların kullanım olanakları. 1. Ulusal Sulama Kongresi Bildiriler Kitabı, 8-11 Kasım 2001, Antalya/Belek, p. 208-214.

Yurtseven, E., Kütük, C., Ünlükara, A., Kezmez, G.D., 2002. The effect of salinity and nitrogen fertilization on bean yield and quality. 13th International Semp. of international scientific center of fertilizer (CIEC). 10-13 June 2002, Tokat-Turkey, Proc. Of the 13th international semp of CIEC.