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UNCONVENTIONAL IRRIGATION WATER USE IN TURKEY

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ABSTRACT – In Turkey, water is a constraint to agricultural productivity in comparison with the extent of existing irrigable land resources, especially for Mediterranean, Centre and Southeast Anatolia regions, as they are arid and semi-arid regions. Interbasin water transfer is possible, but, would be very expensive and time consuming. For this reason, new water resources are required. Use of non-conventional water is considered to be among the best solutions. In the last decades, the studies were carried out for understanding the principles of such water for agricultural production such as determining the salinity threshold values and the effects of salinity on some properties of crop yield. The results showed that the salinity level of irrigation water decreased yield and qualities of all the crops. It is confirmed that resistance of crops to salinity level of irrigation water is not the same and vegetable crops are more sensitive than other crops.

Key words: Turkey, non-conventional water resources, salinity threshold, crop yield

INTRODUCTION

A considerable part of the world's food and fiber is currently produced by irrigated agriculture which has experienced significant improvements in terms of both production and yield in the last century. Huge resources are devoted to the implementation of irrigation projects around the world in the last few decades. Fresh water from irrigation projects are increasingly being used for domestic, agriculture and industrial purposes. However, agricultural production in arid and semi-arid areas with an extended water deficit largely depends on possibility of finding and using irrigation water (Caliandro *et al.*, 1991). Water, in these environments, is the basic productive factor for obtaining a higher, more stable and differentiated production.

In the Mediterranean area, irrigation represents 72% of the total water withdrawals. In the Southern Mediterranean countries, nearly 90% of the available water resources are allocated for irrigation. The limiting water resources in these countries one hand, and the relatively high rate (3.5%) of population growth on the other hand, will be the major constraint for further agricultural and socio-economic development (Hamdy, 2002).

Overgrowing population is putting a lot of pressure on the water resources. According to the World Bank (1993), the minimum water required to sustain human life is about 25 l day^{-1} (10 m^3 yr^{-1}). A reasonable supply to maintain health may be 100-200 l day^{-1} per capita (40-80 m^3yr^{-1}); in developed countries domestic use can exceed 300-400 l day^{-1} per capita (up to 150 m^3yr^{-1} or more).

Therefore, to overcome the shortage in water and food demands and to reach satisfactory level of food production, the utilization of other water resources, besides fresh water, is actually a must. It can be expected for several reasons that in the future, saline water will be increasingly used for irrigation. More water of good quality must be reserved for human consumption and industrial use. So, the increasing demand for irrigation water can only be met by using water of lower quality. Moreover, the disposal of drainage water from urban areas is posing serious environmental problems, which will undoubtedly lead to reuse of the sea waters (Westcot, 1985).

At present, the water exploitation index taken as percentage of renewable annual water resources for Tunisia is 83%, Egypt is 92%, Israel is 140%, Gaza is 169%, Libya is 644% (because 84% come from non-renewable fossil water from beneath the Sahara), Syria is nearly 50%, Lebanon is about 25%, Algeria is 20%, and Morocco is nearly 40% (Pearce, 1996, from Ragab, 2002).

Great efforts are now being directed to the development and use of unconventional water sources notably artesian, drainage and brackish water for irrigation. In fact, much marginal water is not used for irrigation at present because it is deemed of too poor quality (Hamdy, 1991). Three general management strategies seem to be practical for their safe reuse: (1) to control salinity within permissible level, (2) to change conditions to improve crop response, and (3) to change management to maintain yield at the field level when salinity causes damages to plant. If general strategies are not being used effectively, serious problems will appear. In fact, the unconventional water causes a yield reduction as compared with fresh water because of the reduced water availability to crops, a lower soil permeability, and the toxicity effect of some elements, such as Na, Bo, Cl, etc., to the crops.

The problems related to unconventional waters for irrigation were faced long time ago by developing, through empirical criteria first and on scientific basis later, irrigation strategies aiming at preventing, through leaching, the built-up of salts along the soil profile explored by roots. Some methods were proposed to determine the amount of water to be supplied, in addition to the crop water requirements, for removing, from the root zone, the salts brought in by irrigation. But, these methods, supposing a permanent irrigation regime and neglecting the leaching effect of rainfall, are more suitable for desert regions than for semi-arid, sub-humid and humid regions where the rainfall, occuring after the irrigation season, can remove a relatively high portion of the salts brought by the irrigation water.

In this paper, potential usage of unconventional water resources in Turkey is discussed according to water and soil resources. In the first section, information about climate, soil and water resources of Turkey are presented briefly and then the sufficiency of water resources is compared with total irrigable lands in the case the latter is opened to irrigation in the future. In addition, unconventional water potential including brackish, drainage and shallow ground water in Turkey is presented. In the third section, some scientific results related with the use of unconventional water are discussed for arraying attention to future problems which are to be rose when poor quality water is used for irrigation.

CLIMATE, SOIL AND WATER RESOURCES OF TURKEY

Climate

Turkey forms an elongated rectangle roughly 1,700 kilometers in an east-west direction and 1,000 kilometers north to south. Anatolia, except for its eastern parts, is surrounded by seas and has a total coastline of over 10,000 km, including Thrace and islands. Turkey is a bridge between Europe and Asia, with about 3 percent of its land in Europe and the rest in Asia.

Turkey is under the effect of both maritime and continental weather patterns, which cause extreme geo-climatic diversity when combined with a highly varied topography. The Mediterranean type of climate with hot, dry summers and mild winters prevails in the Southern coastal and the Aegean regions (Western Anatolia). The Black Sea region receives rain throughout the year and lives both mild summers and winters. Central Anatolia is a vast high plateau with an average altitude of 1,000 meters above sea level and a semi-arid continental climate, i.e. hot and dry summers. Southeastern Anatolia region has arid climate which is characterized by hot and dry summers and mild winters.

The average annual temperature are 18-20 ^oC on the south coast, 14-15^oC for the west coast, and finally in the interior regions, depending on the location of the place from the mean sea level, it fluctuates between 4 and 19 ^0C. The annual average precipitation is 643 mm, but it varies from 250 mm in the central part to 3000 mm in the Eastern Black Sea region. Seventy-five percent of annual rainfall is received in the winter season. Except for the coastal areas, Thrace and Eastern Anatolia, annual rainfall is less than 500 mm; therefore irrigation is of paramount importance.

Generally, agricultural production is adversely affected by the shortage and inconsistency of the rainfall during the growing season. Solar energy makes it possible to grow arid and semi-arid crops like bananas and citrus. Moreover, it is possible to have 2-3 crops from irrigated areas by allowing 270-day crop growing seasons. However, some crops may be harvested before maturation, particularly in Eastern Anatolia with its 60-90 growing days. The southeast region records very low humidity levels. The coastal regions have quite high levels being in line with precipitation rates. Inevitably, the topographical features are main factors shaping the distribution. The highest average speed of wind is measured in the Çanakkale province, located on the northwest Aegean coast. Moreover, a speed of about 136 km per hour is detected in the provinces of Ankara, Kırsehir and Iskenderun. The long-term annual evaporation rates indicate a high rate particularly in the southeast region, which receives almost no rainfall during the summer and reaches more than 2000 mm per year in Southeastern region.

Soil and Water Resources

Soil Potential

Turkey occupies a total area of about 78 million ha, of which about 1.1 million is inland lakes. The total arable lands are almost 28 million ha, and almost 26 million ha of arable lands is irrigable and 2 million ha is non-irrigable land. The irrigated area is 4.3 million ha. The area which would be economically feasible to irrigation by surface methods is estimated to be totally 8.5 million ha by DSI (State Hydraulics Works) (Table 1). Irrigated lands developed by DSI in the different region in Turkey are given in Table 2. Tables 1 and 2 show that Turkey can not use soil resources effectively due to personnel, coordination and political and economical reasons.

Table 1. The distribution of irrigable land in Turkey

Land	Area, Million ha	%
Irrigable land	26.00	
Economically irrigable land	8.50	33
With surface water resources	7.90	93
With ground water resources	0.60	07
Equipped with irrigation	4.30	51
Surface water	3.80	90
Ground water	0.40	10
To be irrigated in the next future	4.20	49
Surface water	4.00	96
Ground water	0.15	04

Source: DSI, 2001

Today, 17 % of the total irrigable lands are developed for irrigation by different agencies including DSI being the first, KHGM (General Directorate of Village Affair), and Private Publics Organizations. Before two years ago, for the Irrigation Master Plan of Turkey, 227 projects, covering a gross irrigable area of 2.94 million ha, have been analyzed. 139 of these projects, covering a gross irrigable area of 2.07 million ha, or 70 % of the total area reviewed, have an IRR of 8% or more. If that same percentage is applied to the area still to be developed, a potential additional irrigable area of 3.2 million ha will be added.

Irrigated lands in the regions vary from a maximum value of 21.2 % for irrigated lands in Central Anatolia to a minimum of 9.2 % in Black Sea region. Mediterranean region follows Central Anatolia with 19.1 % of the irrigated lands.

Table 2. Irrigated lands in the different region in Turkey

Regions	Irrigable Lands 1000 ha	Irrigated Lands[1] ha	Ratio	
			Irrigated Lands %	Irrigable Lands in the Regions, %
Marmara	4,615	418,902	9.8	9.1
Aegean	1,797	656,390	15.4	36.5
Mediterranean	3,633	813,048	19.1	22.4
Southeastern	4,895	476,239	11.2	9.7
East Anatolia	1,073	600,404	14.1	56.0
Black Sea	1,236	390,599	9.2	31.6
Central Anatolia	8,386	905,603	21.2	10.8
Total	25,635	4,261,185		

Source: DİE, 1995

[1] Total irrigated areas developed by DSI, KHGM, and PO. The values of 1995 year are updated for 2004.

The maximum irrigable lands of 8.386 million ha are placed in the Central Anatolia region, a minimum of 1.073 million ha is in East Anatolia due to their topographic properties. The ratios of irrigated lands to total irrigable areas for every regions vary between a maximum of 56% in the East Anatolia and a minimum of 9.1% in the Marmara region. Central Anatolia region, which has maximum irrigable area is, however, a region which has small ratio. The irrigated areas in Southeastern Anatolia region has rapidly expanded during the last decade since some irrigation structures of Southeastern Anatolia Project have started to operate.

Water Potential

The average annual precipitation of the country is 642.6 mm, which corresponds to a water potential of 501 km^3 per year. Runoff amounts to 238 mm, corresponding to an average rate of 37 %, and the remaining 63% is lost by evapotranspiration. A certain amount of the runoff is allocated to meet the water rights and requirements of the neighboring countries. The amount of surface water, which is utilized for consumptive purposes, is within the range of 95 km^3 per year. According to the studies based on groundwater resources, the total safe yield of groundwater resources is estimated to be 11.6 km^3. Thus, total potential available water resources from surface flow and groundwater would amount to 106.6 km^3 per year (Table 3).

Table 3. Water potential

Average Annual Precipitation: 643 mm Water Potential from Precipitation: 501.0 km^3			
Surface Water Potential, km^3		Groundwater Reserves, km^3	
Annual flow	186.05	Surfaced annual reserve of groundwater	12.3
Runoff coefficient	0.37	Annual water reserved by the SHW	9.0
Utilizable potential	95.00	Actual annual potential	6.0
Actual annual potential	31.49		

Source: DSI, 2001

In order to regulate the whole surface waters in the country, the construction of 662 dams is required. Today, total dams and HEPP under operation are 504 which are suite to the rules of International Commission of Large Dams, ICOLD. Almost 100 dams and HEPP are under construction. Thus, it is obvious that the possibilities mentioned above require great amounts of investments and a long period of construction. The water supplies from these dams would be regulated to achieve the following objectives: irrigation of 6,609,382 ha; drainage of 135,801 ha, flood control of 636,794 ha; conveyance of 7,726 km^3 of water to urban areas and generation of 121,484 MKwh of electric power by the hydroelectric power plants with a total electricity capacity of 34,484 MW.

Water Resources Utilization

Water consumption increased slightly during the last decade depending on the development of soil and water resources, expanding of urban population and development of industrial sector. Total water consumption rose to 42.0 km^3 by the end of 2000 as a result of numerous projects developed by various agencies, including the DSI who is in charge of developing water resources. Breakdown of the total figure is as follows: Irrigation (31.5 km^3, 75%); drinking water (6.4 km^3, 15%); and for industrial purposes; 4.1 km^3, 10% (Table 4). Sectarian breakdown of utilized surface water resources is as follows: Irrigation (82 %), drinking-use (10 %) and industrial purposes (8 %). Corresponding percentages for the utilization of groundwater are 39, 37 and 24, respectively.

Table 4. Actual water consumption in the last decade of 1990-2000

Year	Total water consumption km^3	Potential use (%)	Water Consumption by Sectors, km^3					
			Irrigation		Drinking-Use		Industrial	
			Volume	%	Volume	%	Volume	%
1990	30.6	28	22,016	72	5,141	17	3,443	11
1992	31.6	29	22,939	73	5,195	16	3,466	11
1998	38.9	35	29,200	75	5,700	15	4,000	10
2000	42.0	38	31,500	75	6,400	15	4,100	10

Source: SPO, 2001

Water Potential Sufficiency

Water amount utilized for irrigation is calculated and given in Table 5; industrial and urban consumptions were not considered in the calculations. Average steady flow for whole Turkey is estimated as 1.1 $l\ s^{-1}\ ha^{-1}$ using steady flow values from irrigation systems placed at the different regions. All plants grown in the different regions are assumed to be irrigated 120 days per year.

Table 5. Net water requirements of the average crops pattern grown on the irrigated and to be irrigated areas

Lands, ha	Average Steady Flow $l\ s^{-1}\ ha^{-1}$	Average Irrigation Season, day	Net Water Requirement, $km^3\ year^{-1}$
4,261,185 (being irrigated)	1.1	120	49.0
8,500,000 (to be irrigated)	1.1	120	96.0
25,635,000 (to be irrigated in future)	1.1	120	296.5

It is clear that water resources in Turkey are considerably limited: when all irrigable lands are opened to irrigation, roughly 200 km^3 water deficits can be expected and interbasin water transfer should not be considered as a sufficient and suitable solution. Water is a constraint to agricultural productivity in comparison with the extent of existing irrigable land resources, especially for Mediterranean, Central and Southeast Anatolia regions, which are arid and semi-arid regions. Turkey has approximately 26 Mha irrigable lands in spite of the water resources to be allocated for irrigation are not seem to be enough to irrigation of all the lands. It is estimated, as mentioned in Table 5, that only 8.5 Mha areas can be irrigated with present water resources.

Applying deficit irrigation programmes and managing the irrigation systems according to deficit irrigation approach can be considered a good solution. However, this solution is very expensive and requires new approaches. 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. To use unconventional water such as brackish water (treated waste water, drainage water), shallow ground water and saline water supplied from different resources is considered to be one of the best solutions. Table 7 shows the wastewater amount in Turkey from urban and industrial consumption in 2001. However, the figures given in the Table 7 show that they can only complete part of the deficiency of water resources.

Table 7. Waste water amount from urban and industrial consumption in 2001

Resources	Amount, km^3
Urban wastewater	3.700
Industrial wastewater	3.000

Source: DIE, 1995*

*The values of 1995 year are updated for 2004.

The use of drainage and saline water for irrigation seems to be an attractive alternative for solving water scarcity problems. 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 sustainable management strategies for their utilization are evolved. Such waters occur 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. Some times saline water is blended with fresh water and used to irrigate the salt sensitive crops. There are enough evidences taken from several studies carried out either in Turkey or in other countries to show the potentiality of using water with a salinity up to 6 dS/m for major cereal crops (Hamdy, 2002). Unconventional water use for irrigation gradually increased in a lot of countries where irrigation is evident but water resources are scarce.

THE POTENTIAL OF USING UNCONVENTIONAL WATER IN IRRIGATION

In Turkey, several studies were conducted for obtaining some applicable parameters regarding the use of unconventional water including wastewater and saline water in agriculture during more than 20 years. Studies were carried out to obtain the threshold values, which crop yield is affected by salinity, and the effects of saline water on some plant characteristics.

Use of wastewater, which has convenient properties for irrigation, is suggested where there is water scarcity (Çakmak and Kendirli, 2001). However, wastewater has various inorganic matters and pathogens which have negative impacts on the crop production, the environment as well as users and consumers health; for these reasons, precautions must be taken (Aşık *et al*., 1997). The mentioned precautions or criterions for the use of wastewater in irrigation are controlled with "instructions for water pollutions" (Anonymous, 1991). The instructions used in Turkey are given in Tables 8 and 9 as examples.

Table 8. The foundations and technical limitations related with usage of wastewater in the agriculture

Agriculture Type	Technical Limitations
Fruit Growing and Viniculture	• It is forbidden to irrigate using sprinkler irrigation • The fruit which fell out ground mustn't be eaten • The numbers of fecal coliform 1000/l00 ml
The production of seed and plant with fibers	• Surface or sprinkler irrigations methods can be used • Biological refined and chlorinated waste waters can be used • The numbers of fecal coliform 1000/l00 ml
Fodder plants, Oil plants, not eaten raw plant and floriculture	• Surface irrigation, mechanic refined waste water

Table 9. Appropriates of industrial wastewater that can be used as irrigation water

I	II	III
It can be used as irrigation water in case of appropriate land conditions	It is suitable to use as irrigation water in a certain conditions	It is not suitable to use as irrigation water
Beer, malt, wine, potatoes, vegetable, canned food, marmalade, fruit canned food, milk, potatoes starch factories	Ferment, sugar, rice and wheat starch, leather glue, bone glue factory, slaughterhouse, meet combine foundations, tannery, margarine factory, paper factory, cardboard factory, textile industry, wool washing, fish flour, fish canned, mining	Polish and and paint factories, soap factory, inorganic heavy chemical matter industry, medicine factories, metal factory, sulfite cellulose factory, viscose artificial silk factory, air gas foundation, metallic oil industry, coal washing, dynamite industry, wood industry

Wastewater Use

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

Bilgin *et al*. (1997) have carried out studies to determine the effects of Ankara stream-water, which is polluted by wastes from urban and industrial sources, on soil, plants (lettuce and broccoli) and environment. Experiment was conducted in the open areas and greenhouse conditions. According to results, heavy metal concentrations of Ankara stream were found to be at a level not hazardous to plants and soils. However, microbiological pollution of the water was found to be too high. Irrigations caused yield decrease due to detergent content of the stream flow.

Drainage Water Use

Yarpuzlu (1999) has studied the response of cotton and wheat grown on 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) as well as salinity build-up in the soil profile was evaluated during each growing season in Tarsus plain. The results of the studies showed that the effect of irrigation with different leaching fractions statistically were not important on the yield of wheat crop, and it was determined that the effect of different leaching fractions on cotton yield was statistically significant at the 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. In addition, after long years of winter rainfalls, these precipitations were effective for leaching the salt accumulations in the soil.

Bahçeci (1991) has determined, using groundwater 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 the boron amount in the soil has increased and the increasing amount of exchangeable sodium statistically was significant. The exchangeable sodium accumulation was taken into consideration as a trend function and YB= 0.193+0.309X relationships 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) study focused on the quality and the suitability of 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 serious environmental problems.

Saline Water Use

There are various studies regarding the use of saline water for irrigation purposes. In these studies, surface and pressurized irrigation methods are used with saline water which is diluted at different levels.. In surface irrigation methods, different amounts of irrigation water with different salinity 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).

Kanber and Bahçeci (1995) have used line source sprinkler irrigation approach to obtain the relationship between yield and water salinity levels for field bean in Konya province. In this experiment, 3 lateral lines in which one is placed in the middle of the system and conveys saline water, and the outer ones carry fresh water (Fig. 1). During experiment, the same amount of water with different salinity levels could be applied using this system.

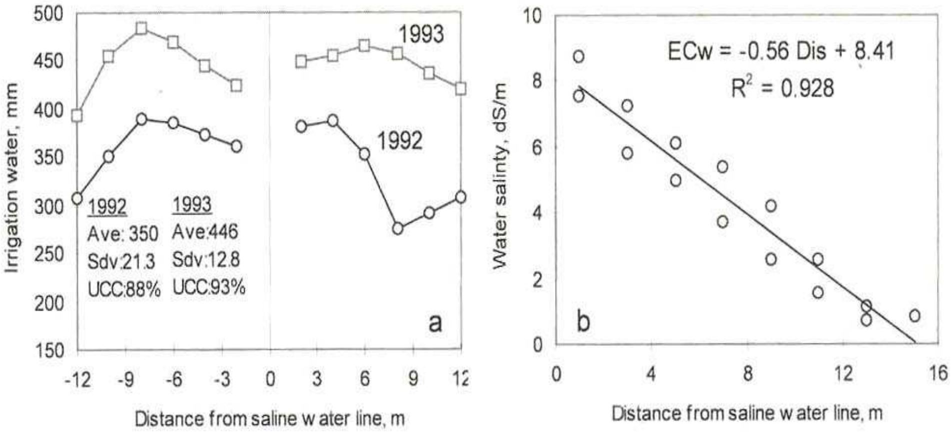

Figure 1. Irrigation water amount applied with three lines. The figure (a) represents centre line that gives saline water and two outside lines conveys fresh water; and figure (b) shows the salt content of water which is received at the area between centre and one of the outside line

The areas placed between middle and outsides lines have received different saline levels which varied from a maximum one next to centre line to a minimum value near to the outside line.

From the results, it was concluded that bean yield decreases according to the distance from centre sprinkler line (Fig. 2). The responses of the yield to water quantity and salinity levels are similar in both years.

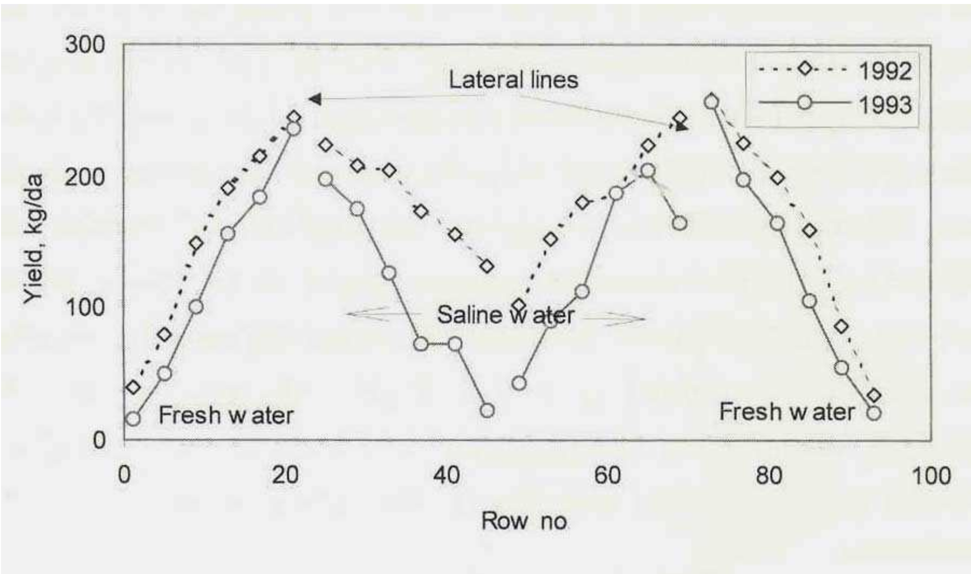

Figure 2. Grain yield of bean at the distance from the sprinkler lines. Yield decreases near the central line and reaches to maximum values around of outside lines which give fresh water

The yield increases as the fresh water applications increase. The maximum yield was obtained in the plots close to the outside lines with an average of 2400 kg per hectare. Average minimum yield under salt stress conditions was 760 kg per hectare which shows a yield reduction of 63 percent.

There was statistically significant relation between soil salinity and grain yield shown as: *Y=-66.95 ECe +265.4* for two growing seasons (Fig. 3). The relationship between the relative grain yield and soil salinity was evaluated and the salinity threshold value (Ct) and slope (s) for bean were estimated as 0.81 dS/m and 67.84, respectively. According to these results, the grain yield begins to decrease approximately linearly when salinity increased; and no yield was produced at ECe=4.0 dS/m (Fig. 3).

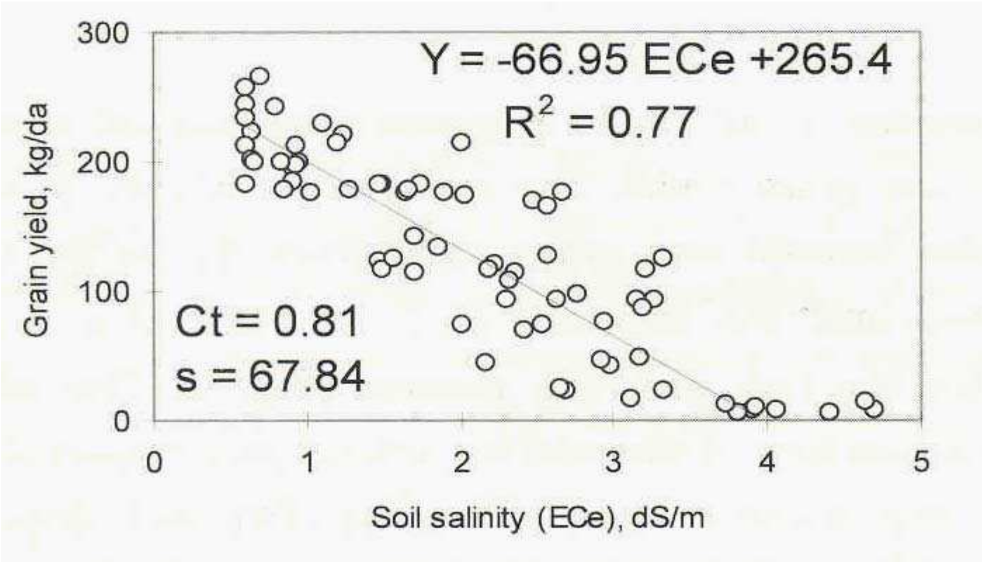

Figure 3. Grain yield and soil salinity relationship; and threshold and slope for field bean

Ödemiş (2001) has investigated the effects of irrigation water, which have different EC, on the salt resistance of cotton, with different levels of leaching fractions using the line source sprinkler irrigation technique in the Çukurova region. In this study, three growth stages namely vegetative, flowering and ball formation, and ball opening, were taken into consideration and different leaching and different amounts of water were applied at each growth stage. According to the results, irrigation water with different EC affected the yield and biomass of cotton, especially, the growth stages were affected by different water and salt levels. Evapotranspiration and yield of cotton decreased when the salt content of irrigation water increased. The salt content in irrigation water caused salt accumulation in the soil however both winter rainfall and leaching fractions decreased salt accumulation in the soil. It was found that the salts removed from the soil were lower in the treatments in which high leaching fractions were used.

Various experiments on the irrigation of vegetables are carried out under Ankara conditions to determine the principles regarding to use of saline water. Sönmez and Yurtseven (1995) examined the effects of water salinity and alkalinity on germination, seedling development and the final yield of tomato plant under field and greenhouse conditions. Irrigations were applied at the different growing stages. Results showed that no germination was observed at 10 dS/m of salinity. EC and SAR affected adversely the seedling length and dry matter; increasing EC increases dry matter, while increasing SAR decreases seedling length. Similar experiment was conducted by (Yurtseven *et al.*, 1999a) using plastic pots in the open area.

The effects of saline irrigation at the different growing stages on the same yield criterions of pepper were examined in greenhouse conditions with pots (Yurtseven *et al.*, 1996). They stated that, there was no significant effect of saline water with 3.0 dS/m on the germination and biomass values of pepper; however, plant length decreases by 13% at this EC level.

Another study was carried out with lettuce (Yurtseven and Bozkurt, 1997). In this study, the effects of irrigation water with different EC and SAR values on yield and quality of lettuce were investigated. The experiment was conducted with plastic pots in greenhouse using different soil water contents. The pots were weighed periodically and saline water was prepared with $NaHCO_3$, $MgSO_4$ and $CaCl_2$. Results showed that increasing EC and SAR decreases yield and dry matter, conversely, total ash increased. High soil water content increases the yield and compensates the effects of salinity and alkalinity.

Çizikçi (1998) has tested the effects of 5 different EC and 3 SAR level and 3 different Ca/Mg ratios of irrigation water on the yield and germination of spinach under laboratory and greenhouse conditions. According to the results under laboratory conditions, increasing water EC decreases germination percentage. The analysis of the plant grown in the greenhouse showed that all the values are under the toxic levels. The threshold value of spinach was determined as 3.5 ds/m, and yield lost per unit increased salinity was 6.6%.

Yurtseven and Öztürk (2001), has examined the effects of irrigation water with different salinity levels and different Ca/Mg ratios on yield of egg plant and salt accumulation in loamy soil under open field conditions. High salinity levels caused severe salt accumulation in the 90 cm soil profile depth and decreased egg plant yield.

Yurtseven *et al*. (2002) have studied the use of saline irrigation on bean for determining the yield and some yield parameters. In this experiment, different water salinity levels and different nitrogen amounts were tested. Bean yield is affected by salinity levels and nitrogen amount. Biomass and total ash values are affected by nitrogen amounts which are changed by salinity and fertilizers levels.

Şener (1993) studied cotton in a lysimeter system for testing the effects of saline irrigation water on yield and salt budget in an alluvial soil. In this study, saline water with 600, 1000, 2000, 4000, 8000, 12000 and 16000 dS/cm were used as experimental treatments. According to the results, it was obtained that cotton threshold value was 5.7 dS/m which is determined in soil saturation extract. Unit yield lost was 5% per unit EC increase. High salinity levels increase salt accumulation in 90 cm soil depth.

CONCLUSIONS

Turkey has approximately 26 Mha irrigable lands. The water resources of the country allocated for irrigation do not seem to be enough to irrigate all the arable lands. It is estimated that, only 8.5 Mha areas can be irrigated with the present water resources. When all irrigable lands are opened for irrigation, roughly 200 km^3 more water is required.

Water is a constraint to agricultural productivity in comparison with the extent of existing irrigable land resources, especially for Mediterranean, Central and Southeast Anatolia regions, which are arid and semi-arid regions.

Deficit irrigation programmes and managing irrigation systems according to deficit irrigation approach and finding new water resources for different purposes should be considered among the best alternative to overcome the actual water shortage. Unconventional water such as brackish water (treated wastewater, drainage water), shallow ground water and saline water supplied from different resources must be used in the next future.

The wastewater amounts in Turkey from urban and industrial use seem to complete only little part of the deficiency of water resources. To use diluted sea water seems to be only way in the future.

The results given in this paper showed that saline water decreases the yield and quality of all the plants considered in the experiments. On the other hand, it is verified again that the salt resistance of the plants were not similar and vegetables are more sensitive than others. However, the criterions regarding the use of unconventional water in irrigation of many crops grown in the different region of Turkey are being obtained and the studies should continue.

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.

Anonymous, 1991. Su Kalitesinin Kontrolünde Teknik Yöntemler. T. C. Resmi Gazete, 7.1.1991 Tarihli, No.20748, Ankara.

Aşık, Ş., Avcı, M. and Balcı, A. 1997. Atık Suların Sulamada Kullanım Stratejileri. 6. Ulusal Kültürteknik Kongresi Bildirileri, Kirazlıyayla-Bursa,. p.564-567

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

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,

Çakmak, B., Kendirli, B. 2001. Tarımda Atık Su Kullanımı. Ziraat Mühendisliği Dergisi, Zir. Yük. Müh. Birliği Yayını No.332, Ankara, p.31-37

Caliandro, A., Cucci, G., De Caro, A., and Cordella, S., 1991. Irrigation with brakish water: Influence of the irrigation regime on salt built-up in the soil and leaching effect and rainfall. In European Mediterranean Conference on The Use of Saline Water in Irrigation. 25-26 July, 1991. Bari-Italy, p. 273-286

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.

DSI., 2001. Evaluation Report on Irrigation Schemes Operated or Transferred By DSI (2001), *General Directorate of DSI,* Ankara.

Hamdy, A., 1991. Water, soil and crop management relating to the use of saline water. In European Mediterranean Conference On The Use of Saline Water in Irrigation. 25-26 July, 1991. Bari-Italy, p. 239-272

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

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

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.

Ragap, R., 2002. Climate change and water resources management in the Southern Mediterranean and Middle East Countries. Int. Com. on Irr. And Drain. ICID.paper, 29 pp.

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.

Şener, S., 1993. Ege Bölgesinde Lizimetre Koşullarında Değişik Kalitedeki Sulama Sularının Pamuk Verimine ve Toprak Tuz Dengesine Etkileri. K.H. Menemen Araştırma Enstitüsü Genel Yayın No.192, İzmir, Türkiye.

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, (2001), Report by the Special Commission on Water Basins and Management, *SPO*, Ankara.

Westcot, D. W., 1985. Reuse and disposal of higher salinity subsurface drainage water- A review. Agric. Water Manag., 14:483-511

World Band., 1993. A strategy for managing water in Middle East and North Africa. World Bank pub.

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.

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., Kütük, C., Ünlükara, A., Kezmez, G.D., 2002. The effect od-f 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.

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