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Assessment of Economical Threshold for Different Crop Yields at Different Soil Salt Concentrations in Harran Plain

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Abstract

This study was conducted to determine the effects of increased soil salinity on six different crops' yield grown in Harran plain, and evaluate the possible farming strategies to increase the agricultural production profitability under certain salinity levels. Salinity levels used ranged from 0.0 to 30.0 dS m^{-1}, which were present at lower laying part of the Harran plain. Farming inputs included field preparation and sowing, maintenance, harvest and transportation, and other costs. On the other hand, value of revenue included the revenue plus additional revenues.

Economical analyses of the data revealed that under the 10.0 dS m^{-1} salinity, vegetables were more profitable, especially eggplant (13.0 dS m^{-1}) followed by tomato (10.0 dS m^{-1}) and pepper (6.0 dS m^{-1}). As far as agronomic crops concerned, their salt tolerance was high with profitable farming up to 14 dS m^{-1}. Among those agronomic crops, wheat was the most profitable crop as compared to cotton and the second crop corn. However, since the governmental subsidizes were high for cotton, cotton cultivation was more profitable. Therefore the farmers in the lower-laying part of the Harran plain prefer to grow cotton.

Key words: Soil salinity, crop yield, economic threshold, vegetables, field crops.

INTRODUCTION

Soil salinity is one of the major problems inhibiting plant growth and resulting yield, especially in arid and semiarid regions such as Harran plain. The irrigation started in Harran plain in 1995, and since then low laying part of the plain that covers about 27 000 ha of agricultural land, is at high salinity risk. Soluble salts are leached and moved to lower part of the soil profile and with the high evapotrasporation, water is moved back to the soil surface leaving the salt behind (Ergene, 1982; Kara, 2002). Some part of the plain is already experiencing salinity problems with salt concentrations ranging from 1 to 30 dS m^{-1}. Farms located at the south side of the Harran plain are being threatened by salinization and water logging due to the use of drainage water in irrigation and saline shallow water table.

Salt affected lands are generally less productive. Subsurface drainage systems could successfully lower water table, facilitate salts leaching, and make farmlands more productive. However, there has not been enough subsurface drainage systems set up in the problematic agricultural areas of the Harran plain. Soil salinity affects crop growth, yield, and yield components through its impact on soil and plant such by (i) reducing leaf expansion and stomata closure and (ii) increasing osmotic pressure (Kanber et al., 1992; Güngör and Erözel, 1994). Sometimes, there could be enough water in the soil for plants; however, crops can not use it due to high osmotic pressure.

Previous studies conducted with different agronomic and horticultural crops such as corn, cowpea, wheat and vegetables (Lunin et al., 1963; Francois et al., 1988; Maas and Poss, 1989) have revealed that crop sensitivity to soil salinity vary depending on crop growth stage. Sönmez and Yurtseven (1995) conducted a study to determine the effect of salinity on tomato seed germination and growth. They reported that at 10 dS m^{-1} concentration, seeds did not germinate, and at 4 dS m^{-1} concentration, plant growth was reduced. Yurtseven et al. (1996) reported that pepper plant seeds were also substantially affected by soil salinity of 3 dS m^{-1}. Maas and Hoffman (1977) claimed that vegetables were more resistive to soil salinity than other agricultural crops. A study conducted by Sooneveld and Voogt (1990) reported that tomato plant growth was not altered by salinity up to 10 dS m^{-1}. On the other hand, Miyamoto et al. (1985) claimed that tomato seed germination was substantially reduced by soil salinity at 12 dS m^{-1}, while growth at 4 dS m^{-1} was limited. Limited germination of seeds and growth of tomato usually resulted with lowered yield (Caro et al., 1991). However, Mizrahi et al. (1988) indicated that salinity improved tomato quality in terms of taste and color.

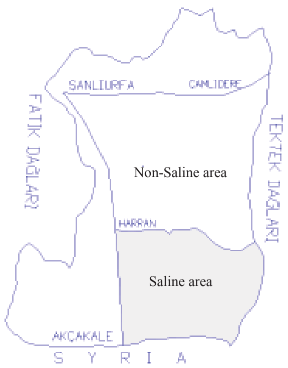
In general, agronomic crops are considered less resistive to soil salinity then horticultural crops. Grain sorghum growth is more resistive to salinity than germination and maturation (Ulery and Ernst, 1997). Salinity tolerance thresholds of different agricultural crops were summarized at USDA (1993).

Since farm lands located lower side (south side) of the Harran plain were at high risk of salinity problem, there was a need for recommendations regarding the effect of salinity at different concentrations to crop yield and also to the total income of the farms. Therefore, the goal of this study was to determine crop yield and economical threshold of six different irrigated crops (wheat, cotton, corn, pepper, tomato, and eggplant) under various soil salinity levels, found at Harran plain.

MATERIAL AND METHODS

Farming costs used in this study were obtained from Şanlıurfa Rural Services Annual Report (2006) prepared for the year of 2005. Crops used were cotton, wheat, second crop corn, eggplant, tomato and pepper. The plants chosen were widely cultivated under irrigated conditions of the Harran plain. The Harran plain, covering 151 000 hectare of agricultural land, of which currently 130 000 ha is irrigated. The plain was opened to irrigation in 1995 as a part of Southeastern Anatolian Project (GAP). GAP was planed to irrigate about 1.7 million ha of agricultural land when project is completed. Salt affected areas were reported as 20 000 ha (Çullu et al., 1999) in the Harran plain and it was expected to increase (Figure 1).

Figure 1. Salt affected areas of Harran plain. Source: "GIS Monitoring of the Salinity Problem Areas in the Harran Plain", International Conference on Sustainable Land Use and Management, page, 326-331. June, Çanakkale, Turkey. (2002).



Since irrigation water pricing is based on field size and crop type, not the amount of irrigation water, farmers tend to use more water with surface irrigation methods with low irrigation efficiencies, resulting in high water losses, sediment transportation, increased water table, and salinity problem especially at lower side of the plain, which is about 25-30% of the Harran plain.

Farming costs considered in this study included soil cultivation and planting costs, maintenance costs, harvest and transportation costs, and other not fixed costs. Details of expenditures used for all crops were presented in Table 1.

Relative crop yield was calculated with the following equation outlined in USDA chapter 2 of the National Engineering Handbook (USDA, 1993). The decrease in crop yield per unit increase in salinity and threshold salinity levels of yield for the crops used were also obtained from USDA (1993) (Table 2).

$$Y_r = 100 - Y_d * (EC_e - EC_t)$$

Where;

Y_r = Relative crop yield (%)

Y_d = Yield decrease per unit increase in salinity (dS m^{-1})

EC_e = Average root zone salinity (dS m^{-1})

EC_t = Threshold salinity level (dS m^{-1})

Table 2. Some of the threshold values used to calculate relative yield of crops studied.

Crop type	Yd (dS m-1)	ECt (dS m-1)	ECe (dS m-1)	Salinity concentration of 0,0% Yield
Cotton	5.2	7.7	1-30	26.9
Wheat	5.9	3.8	1-30	20.8
Eggplant	6.9	1.1	1-30	15.6
Tomato	9.9	2.5	1-30	12.6
2nd crop corn	12	1.7	1-30	10.0
Pepper	14	1.5	1-30	8.7

Salt concentration of the plain experiencing salinity problem is ranging from 0.0 to 30.0 dS m^{-1}, thus salt concentration used to calculate relative yields also ranged from 0.0 to 30.0 dS m^{-1}. To calculate economical crop yield threshold, which was

Table 1. Different farming costs of the crops studied with some economical analysis results.

Expenditures (YTL da-1)		Cop type					
		Cotton	Wheat	Eggplant	Tomato	2nd C.	Corn Pepper
Field Preparation and Sowing (YTL da-1)		26.82	12.73	26.34	13.8	13.38	35.44
Maintenance (YTL da-1)		28.23	13.68	115.6	148.75	23.86	167.57
Harvest and Transportation (YTL da-1)		54.4	15.19	205.97	85.21	18.68	220.69
Other Costs (YTL da-1)		45.55	33.88	57.65	80.4	68.5	51.81
Fixed Cost (Total cost) (YTL da-1)		155	75.48	405.56	328.16	124.42	475.5
yield (kg da-1)		400	600	5000	5000	800	3000
Price (YTL da-1)		0.55	0.35	0.26	0.22	0.16	0.3
Additional Products Revenue (APR) (YTL da-1)		11.6	25.5	NO APR	NO APR	NO APR	NO APR
Value for Revenue (YTL da-1)		231.6	235.5	1300	1100	128	900
Profit (YTL da-1)		76.6	160	894.4	771.8	3.6	424.5
Economical Threshold	Yield (kg da-1)	281.8	215.7	1559.8	1491.6	777.6	1585
	Salinity dS m-1	14.6	13.4	11	9.6	2	4.9

Source: T.C. Ministry of Agriculture Research Institute, Şanlıurfa soil and water sources research institute. 1 USD = 1.395 YTL.

assumed to be the yield amount that produce equal amount of capital to total expenditures, equation 1 was utilized. In addition, those economical crop yield threshold values were compared with the relative yield calculation results for different salt concentrations. Then the crop yield at a certain salinity level equal to economical threshold yield amount was set to be salinity threshold. That certain salinity concentration level was assumed to be the highest salt concentration at which one of the studied crops could economically produce yield. Any higher salinity concentration would reduce yield further and makes that specific crop uneconomical. Hence, another crop with higher salt tolerant was considered for farming (Table 3 and in Figures 2 and 3).

Table 3. Relative yield results of crops studied at soil salinity levels evaluated.

		Cop type Relative yield (%)					
		Cotton	Wheat	Eggplant	Tomato	2nd c	Corn Pepper
EC (dS m-1)	1.0	100	100	100	100	100	100
	2.0	100	100	93.8	100	96.4	93
	3.0	100	100	86.9	95.05	84.4	79
	4.0	100	98.82	80	85.15	72.4	65
	5.0	100	92.92	73.1	75.25	60.4	51
	10.0	88	63.4	38.6	25.8	0.4	0
	15.0	62	33.9	4.1	0	0	0
	20.0	36	4.42	0	0	0	0
	25.0	10	0	0	0	0	0
	30.0	0	0	0	0	0	0

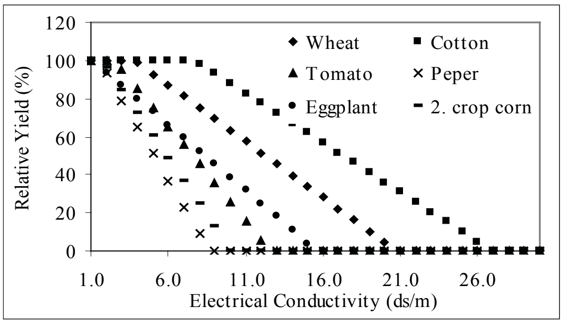
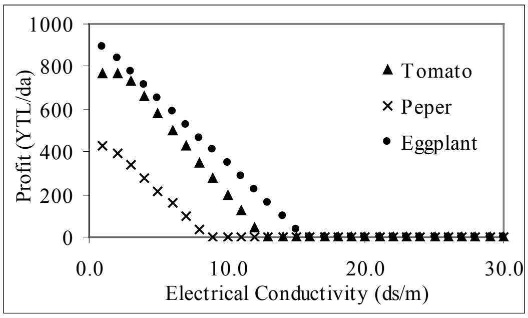


Figure 2. Soil salinity effect on crops yields as relative yield.

RESULTS AND DISCUSSION

Salinity sensitivity of the crops used starting from the most to the least resistive one were cotton (7.7), wheat (3.8), eggplant (1.1), tomato (2.5), 2nd crop corn (1.7) and pepper (1.5). Therefore, yield decrease was started at those threshold levels. Yields of the crops reached to 0.0 kg/ha at 20.8, 26.9, 12.6, 10.0, 8.7 and 15.6 dS m^{-1}, respectively (Figure 2).

Average annual wheat, cotton, 2nd crop corn, tomato, pepper and eggplant yields were 6000, 4000, 8000, 50000, 30000 and 50000 kg/ha, respectively, with 0.35, 0.55, 0.16, 0.22, 0.30 and 0.26 YTL kg^{-1} prices for the respective crops. Total expenditures (fixed costs) to obtain agricultural production of wheat, cotton[1], 2nd crop corn, tomato, pepper, and eggplant were



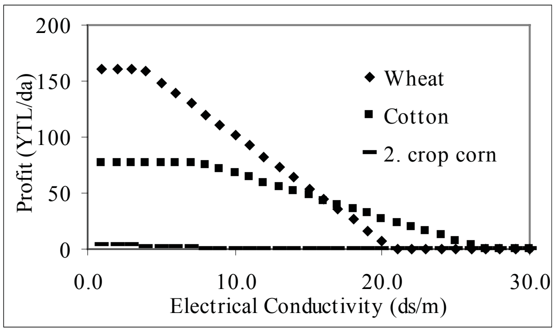


Figure 3. Relationship between soil salinity and economical profit of vegetables (a) and field crops (b). 1 USD = 1.395 YTL.

754.80, 1550.00, 1244.20, 3281.60, 4755.00 and 4055.60 YTL ha^{-1}, respectively. While, total economical income for the same crops at current status of the Harran plain (assumed to be less then salinity sensitivity level of the studied crops) were 2355, 2316, 1280, 11000, 9000, and 13000 YTL ha^{-1} with resulting profits of 1600, 766, 36, 7718, 4245, and 8944 YTL ha^{-1} for wheat, cotton, 2nd crop corn, tomato, pepper, and eggplant crops, respectively (Table 1). The reason for the vegetables expenditures were higher than agronomic crops was high labor and maintenance requirements needed for farming practices such as chemigation and fertilization, and hand harvesting. For the farmers to continue cultivating one of the studied crops yields were calculated as 2818, 2157, 7776, 14916, 15850, and 15598 kg ha^{-1} for wheat, cotton, 2nd crop corn, tomato, pepper, and eggplant, respectively (Table 1). Therefore, those yield threshold values had to be reached to economically continue farming of those crops regardless of soil salinity concentration.

Since crop growth and development are affected by soil salinity and crop yield depending on marketing value of product becomes the economical threshold at certain concentration. Those economical salinity threshold values of crops studied were calculated as 14.6, 13.4, 11.0, 9.6, 2.0, and 4.9 dS m^{-1} and resulting yields were 2818, 2157, 15598, 14916, 7776, and 15850 kg ha^{-1} for cotton, wheat, eggplant, tomato, 2nd crop corn, and pepper crops, respectively (Table 1 and Figure 1). Economical analysis of the data indicated that horticultural crops were more profitable as compared to agronomic crops at relatively lower salinity levels up to 4.9, 9.6, and 11.0 dS m^{-1} for pepper, tomato, and eggplant, respectively. While, economical threshold soil salinity for 2nd crop corn, wheat and cotton crops were 2.0, 13.4, and 14.6, respectively. At economical soil salinity threshold values, the crop yield from eggplant followed by pepper, tomato, 2nd crop corn, wheat and cotton were 15600, 15850, 14920, 7780, 2160, and 2820 kg ha^{-1}, respectively. For

1 1 USD = 1.395 YTL

the respective crops, soil salinity concentrations up to 11.0 dS m^{-1}, eggplant was the favorable with the highest income followed by tomato, pepper, wheat, cotton and 2nd crop corn. Since horticultural crops require extensive labor, planting those crops in large areas would be limited. In the Harran plain, cultivation of horticultural crops is carried out with family labor; therefore those vegetables probably will not be planted in large areas. In a larger scale, saline affected fields up to 13.4 dS m^{-1} salinity should be utilized for wheat cultivation. With higher salinities, cotton would be a better choice. Since government subsidizing is higher for cotton, farmers are better of with cotton then any other agronomic crops.

Economical analyses of the data also indicated that for one unit increase in soil salinity above economical threshold level, profit was reduced at the rate of 9.44, 3.98, 76.41, 59.43, 61.71, and 0.43 YTL (dS $m^{-1})^{-1}$ for wheat, cotton, tomato, pepper, eggplant, and 2nd crop corn, respectively. The results revealed that the most resistive crop to soil salinity was economically tomato followed by other horticultural crops and agronomic crops as expected.

CONCLUSION

Overall, results of this study indicated that tomato, pepper and eggplant were more susceptible to soil salinity compared to wheat, cotton and 2nd crop corn as expected. However, due to higher marketing value, horticultural crops produced higher capital than agronomic crops at even higher yield losses. Therefore, horticultural crops could still be economically produced in saline soils However, since horticultural crops studied require high labor; planting larger areas with horticultural crops would not be possible. The agronomic crops in general are more tolerant to salinity along with high governmental subsidize, hence, with farmers having larger fields could prefer to plant agronomic crops such as cotton and wheat.

On the whole, eggplant (13.0 dS m^{-1}) was the most economical crop followed by tomato (10.0 dS m^{-1}) and pepper (6.0 dS m^{-1}) about 10.0 dS m^{-1} salinity. Wheat, cotton and 2nd crop corn were the most economical crops at higher salinity levels about 14.0 dS m^{-1}, respectively. The results clearly indicated that horticultural crops should be encouraged by governmental policies to reach a sustainable agriculture in the plain.

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