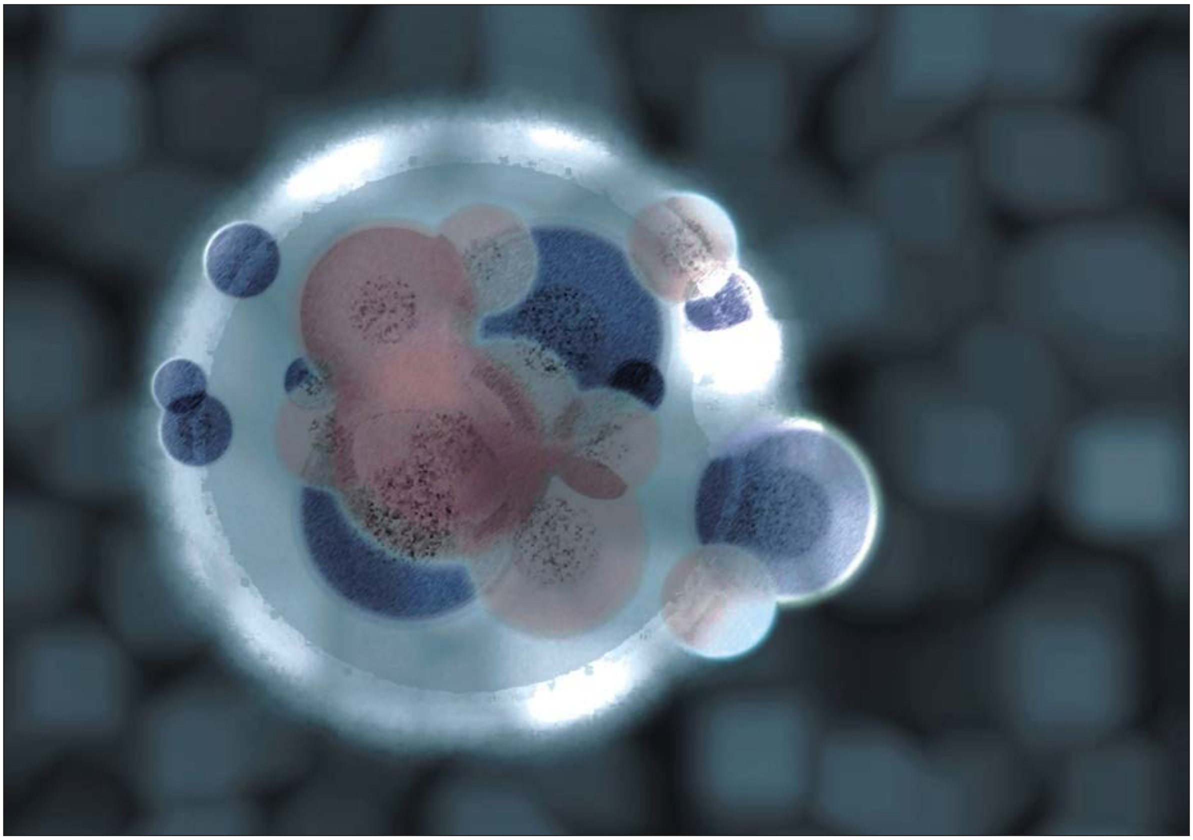

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Effects of Mulch and Irrigation Water Amounts on Lettuce's Yield, Evapotranspiration, Transpiration and Soil Evaporation in Isparta Location, Turkey

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Abstract: The effects of mulch and the several irrigation water amounts on soil evaporation and on lettuce's transpiration, evapotranspiration and yield were studied in a glasshouse pot experiment as Completely Randomised Experimental Design with three replications during 2001 (August 10 to October 2) at the Experimental Glasshouse in the Campus of the University of Süleyman Demirel, Turkey. Water losses by evaporation and/or transpiration were measured daily by weighing the pots. Irrigation water was applied twice a week. The water quantities were regulated by weight. Increasing the amount of irrigation water applied significantly increased crop evapotranspiration (mean 45%) in the Open Soil Surface (OSS) treatments and transpiration (mean 26%) in the Covered Soil Surface (CSS) treatments. In CSS treatments, evapotranspiration was significantly reduced, while transpiration was significantly increased compared with OSS treatments. Covering the soil surface reduced the amount of irrigation water required by the lettuce crop by about 60% for all irrigation treatments compared with the amount of irrigation water added in the OSS treatments, because wet soil surface evaporation was eliminated. The contribution of soil evaporation to total evapotranspiration and evaporation-transpiration ratio varied from a minimum of 40 and 66% at highest water level to maximum of 49 and 94% at lowest water level, respectively. Lettuce yield was significantly higher in CSS treatments than in OSS treatments. Especially at low water levels, lettuce yield was higher in CSS than in OSS treatment. Water use efficiency in CSS and OSS treatments was maximum for the highest water level and irrigation water use efficiency was maximum for the lower water level in CSS treatments and for the intermediate water level in OSS treatments.

Key words: Lettuce, mulch, evapotranspiration, soil evaporation, transpiration, evaporation-transpiration ratio

INTRODUCTION

Water availability is generally the most important natural factor limiting the widespread and development of agriculture in arid and semi-arid regions. A better understanding of the crop yield-water application interaction and the effects of irrigation level and mulch (covering the soil surface) on the relationship between transpiration, evaporation and evapotranspiration for various crops is needed to improve the management of irrigation and water resources. Despite current interest in crop evapotranspiration, few attempts have been made to investigate the evaporation-transpiration ratio and to separate evapotranspiration as transpiration and soil surface evaporation.

Evaporation involves in three events: transport of water to the evaporating surface, a phase change from liquid to vapour and transfer of water vapour from the soil surface to higher elevations within the atmosphere. When the plant is rooted in the soil, evaporation from the open soil surface is accompanied by transpiration from the plant, with water for transpiration being extracted from the soil by the root system. Detailed studies have been conducted on the partitioning of extracted water by the plant root system into water metabolised into the plant tissue and then transpired into the atmosphere[1,2,3], leading to the conclusion that >95% of water extracted from the soil is transpired and flows through the soil-plant-atmosphere system.

The transpiration coefficient or ratio was defined as the ratio of the mass of water extracted from the soil to dry organic matter of the plant[3]. Whisler *et al.*[4] suggested that separation between evaporation from the soil and transpiration through the soil-plant-atmosphere system is

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not a simple process. Hill *et al.*[5] showed that soil evaporation is a function of the basal crop coefficient, days since wetting, the time in days required for the soil surface to become dry, the average proportion of area wetted and reference crop evapotranspiration. Many researchers have reported a significant increase in vegetation and yield of different crops using mulch[6,7]. Mulching the soil surface reduces evaporation and increases the amount of water stored in the soil profile[8-10]. Abu-Awwad[11,12] showed that covering the soil surface reduced the amount of irrigation water required by the pepper and the onion crops by about 14 to 29 and 70%, respectively.

Turkey is located in semi-arid region and there are large areas which are not irrigated due to lack of irrigation water and also agriculture in greenhouse has increased in recent years. In the most of the greenhouses, the irrigation water need for agriculture is provided by the network of municipal drinking water lines, the fact that the use of expensive drinking water increases the cost of agricultural inputs. These have led to the necessity of optimising and managing the use of water for agricultural production.

Isparta is one of the most important agricultural areas in south part of Turkey. Crop production within the province includes cereals, sugarbeet, sunflower, vegetables and fruits like apples, grapes and melons. Total land area of the province is 893307 ha. Agricultural areas cover 27% of the total land area.

In this study, the effects of mulch and five levels of irrigation on soil evaporation and on lettuce's transpiration, evapotranspiration and yield were examined at Isparta location.

MATERIALS AND METHODS

A glasshouse pot experiment on lettuce was conducted during 2001 (August 10 to October 2) at the Experimental Glass House in the Campus of the University of Süleyman Demirel, Turkey. The experiment consisted of two main treatments, covered with clear polyethylene and open soil surface and five levels of irrigation. The experimental design was randomised plots with three replications. The experiment was started (on the transplanting date) with the soil water content of all pots at field capacity (measured by weight). The amount of water applied was 1,0 times the soil water depletion (the difference in mass between the soil at field capacity and the soil before irrigation) for W_1. The other four water levels were as follows: W_2= 0.75, W_3= 0.50, W_4= 0.25 and W_5= 0.0 times the soil water depletion in the W_1 open soil surface treatment for open surface treatments and times the soil water depletion in the W_1 covered soil surface treatment for covered surface treatments. Irrigation water was applied twice a week (on Tuesday and Friday).

Table 1: Some physical characteristics of pot's soils

Bulk density (g/cm^3)	Field capacity (%)	Wilting point (%)	Available water holding capacity (L/pot)
1.10	23.1	11.9	8.84

The water quantities were regulated by mass. Fertilizer and pest control chemicals were added as required. Each pot was 48.0 cm in diameter and 48.0 cm deep and contained similar growing media (soil, sand and manure in equal amounts). Some physical characteristics of soils as field capacity, wilting point, bulk density and available water holding capacity of the pot's soils are presented in Table 1.

Lettuce plants were transplanted on August 10, 2001, at the density of three plants per pot. Results of randomised design experiment were subjected to an analysis of variance and means were compared by Duncan's Multiple Range Test at the probability level of 1% ($p<0.01$).

In covered soil surface treatments, since wet soil surface evaporation was eliminated ($E_{(c)}$= 0.0) by covering the soil surface, evapotranspiration was equal to transpiration ($ET_{(c)}$= $T_{(c)}$). Daily transpiration in covered soil surface treatments was estimated as:

$$T_{(c)I} = (W_{i-1} - W_i) / (\rho_w A); I= 1, 2, 3, \quad (1)$$

Where, $T_{(c)I}$ is the transpiration (mm) in covered soil surface treatments at day I, W_{i-1} and W_i are masses (kg) of the pot at day I-1 and I, respectively, ρ_w is the unit mass of water (g/cm^3) and A is the surface area (m^2) of the pot.

In open soil surface treatments, daily evapotranspiration, evaporation, transpiration and evaporation-transpiration ratio were estimated as:

$$ET_{(o)I} = (W_{i-1} - W_i) / (\rho_w A); I= 1, 2, 3, \quad (2)$$

$$E_{(o)I} = ET_{(o)I} - T_{(c)I} \text{ ; for } ET_{(o)} > T_{(c)} \text{ and}$$
$$E_{(o)I} = 0.0; \text{ for } ET_{(o)} \le T_{(c)} \quad (3)$$

$$T_{(o)I} = ET_{(o)I} - E_{(o)I} \quad (4)$$

$$ETR_{(o)I} = ET_{(o)I} / T_{(o} \quad (5)$$

Where, $ET_{(o)I}$, $E_{(o)I}$, $T_{(o)I}$ and $ETR_{(o)I}$ are the evapotranspiration (mm), evaporation (mm), transpiration (mm) and evaporation-transpiration ratio, respectively, in open soil surface treatments at day I.

Water Use Efficiency (WUE) and Irrigation Water Use Efficiency (IWUE) were estimated as:

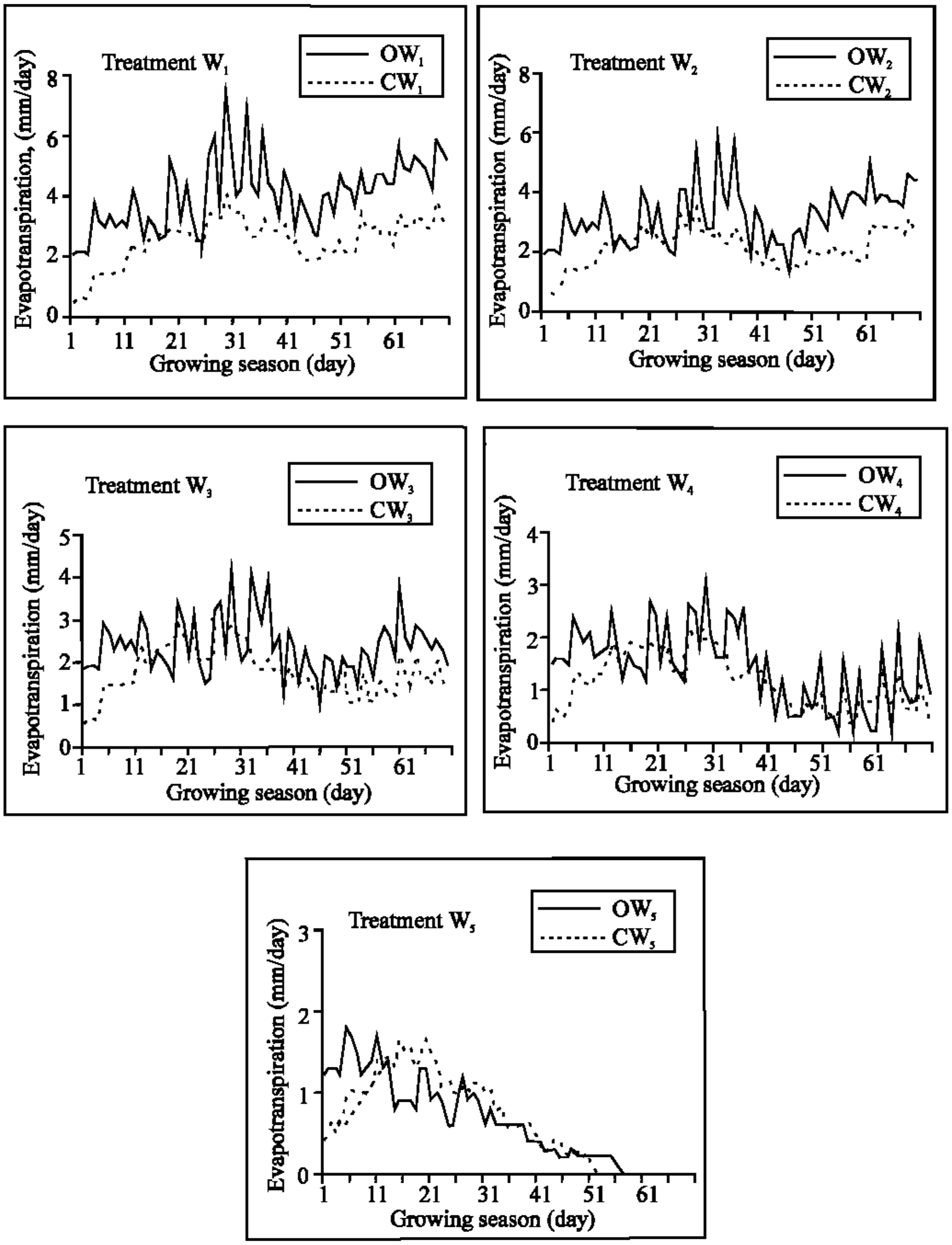

Fig.1: Daily evapotranspiration at covered (C) and open (O) soil surface

$$WUE = LY/ET \quad (6)$$

$$IWUE = (LY_I - LY_{NI})/I \quad (7)$$

Where, WUE is the water use efficiency (kg mm^{-1} ha^{-1}), LY is the lettuce yield (kg ha^{-1}), ET is the seasonal evapotranspiration (mm), IWUE is the irrigation water use efficiency (kg mm^{-1} ha^{-1}), LY_I is the yield of irrigated lettuce, LY_{NI} is the yield of non-irrigated lettuce and I is the irrigation depth (mm)[13].

The relationship between lettuce yield and evapotranspiration or transpiration (yield response factor) was determined according to Stewart model[14].

RESULTS AND DISCUSSION

The effects of covering the soil surface and irrigation treatments on soil surface evaporation, transpiration, evaporation-transpiration ratio, irrigation depth,

Table 2: Measured water balance components and the effect of mulch and the five irrigation levels on soil Evaporation (E), Transpiration (T) and Evaporation-Transpiration Ratio (ETR), Irrigation depth (I), Evapotranspiration (ET), Lettuce Yield (LY), Water Use Efficiency (WUE) and Irrigation Water Use Efficiency (IWUE)

Treatments	Open soil surface					Covered soil surface				
Water level	W_1	W_2	W_3	W_4	W_5	W_1	W_2	W_3	W_4	W_5
E (mm)	113	95	69	49	18					
T (mm)	172	131	96	52	25	180	151	122	82	44
ETR (%)	66	73	72	94	72					
I (mm)	267	201	134	67	0	165	124	83	41	0
ET (mm)	285	226	165	101	43	180	151	122	82	44
LY (t ha^{-1})	43.4^{ab**}	33.0^{b-d}	19.9^{e-g}	9.0^{h}	4.3^{h}	49.4^{a}	37.6^{bc}	27.0^{d-f}	20.9^{e-g}	7.3^{h}
WUE (kg mm^{-1} ha^{-1})	152^{b-d**}	146^{cd}	120^{cd}	89^{d}	99^{cd}	274^{a}	249^{a}	221^{ab}	254^{a}	166^{bc}
IWUE (kg mm^{-1} ha^{-1})	163^{d**}	164^{d}	148^{d}	134^{d}		299^{c}	303^{c}	325^{c}	509^{a}	

Significant at 0.01 level

evapotranspiration, water use efficiency, irrigation water use efficiency, lettuce yield and Duncan's groups by Duncan's Multiple Range Test at the probability level of 1% ($p<0.01$) are presented in Table 2 and daily evapotranspiration at covered and open soil surface treatments are presented in Fig. 1.

In general, increasing the amount of irrigation water applied significantly increased crop evapotranspiration (mean 45%) in open soil surface treatments and transpiration (mean 26%) in covered soil surface treatments. Thus, increasing the amount of irrigation water applied increased the water available for both evaporation and transpiration. Also, covering the soil surface significantly reduced evapotranspiration compared with open soil surface treatments. However, covering the soil surface increased transpiration compared with open soil surface treatments because of the elimination of wet soil evaporation, which increased water available for transpiration.

Covering the soil surface reduced the amount of irrigation water required by the lettuce crop by about 60% for all irrigation treatments as compared with the amount of irrigation water added in the open soil surface treatments. The total amount of irrigation water applied decreased from 267 mm in the W_1 open soil surface treatment to 165 mm in the W_1 covered soil surface treatment. With irrigation, increasing the amount of water applied increased the amount of soil evaporation, but not changed significantly the percentage of soil evaporation, evaporation-transpiration ratio and its contribution to total evapotranspiration. The contribution of soil evaporation to total evapotranspiration and Evaporation-transpiration Ratio (ETR) varied from a minimum of 40 and 66% at treatment W_1 to maximum of 49 and 94% at treatment W_4, respectively.

At the beginning and middle of the lettuce's growing season, with complete irrigation, evaporation in open soil surface treatments was maximum (potential) on the day of irrigation. However, the evaporation rate decreased with time, with actual evaporation being less than potential evaporation and the difference between actual and potential evaporation increased with time. Also, the soil water content continued to decrease with time and hence the rate of water movement to soil surface also decreased. Thus, soil evaporation is not only a function of the factors indicated by Hill *et al.*[5], but is also a function of the amount of water applied and canopy shading.

Results indicate that approximately half of the irrigation water was lost as soil evaporation in all of the treatments. Thus, using mulch or covering soil surface significantly reduced the amount of irrigation water required.

At low water levels, transpiration in covered soil surface treatments was significantly higher (mean 35%) than that in the open soil surface treatments. Thus, the available soil water in the covered soil surface treatments remains higher than that in open soil surface treatments, because of the high loss of water via evaporation in the first few days (potential evaporation) after irrigation in the open soil surface treatments. With the decrease in soil water, actual transpiration in open soil surface treatments decreased and, with further extraction of soil water, unsaturated hydraulic conductivity decreased causing a drastic reduction in transpiration.

Regression analysis of seasonal lettuce transpiration and evapotranspiration as influenced by total water applied resulted in the following relationships.

$$ET_{(o)} = 0.9071\ WA + 42.627\ ; \quad r^2 = 0.9997 \qquad (8)$$

$$T_{(o)} = 0.7968\ WA + 48.322\ ; \quad r^2 = 0.9874 \qquad (9)$$

Where, $ET_{(o)}$ (mm) and $T_{(c)}$ (mm) are seasonal evapotranspiration in the open soil surface treatment and in the covered soil surface treatment, respectively and WA (mm) is the total applied water.

In general, lettuce yield was significantly higher in the covered soil surface treatments than in the open soil surface treatments. Also, with deficit irrigation, increasing the amount of water applied significantly increased lettuce yield. At especially W_4 water levels, lettuce yield was higher in covered than in open soil surface treatment.

Water use efficiency (WUE) in the covered and open soil surface treatments was maximum (274 and 152 kg mm^{-1} ha^{-1}, respectively) in the W_1 treatment and irrigation water use efficiency (IWUE) in the covered soil surface treatments was maximum (509 kg mm^{-1} ha^{-1}) in the W_4 treatment, while in open soil surface treatments, IWUE was maximum (164 kg mm^{-1} ha^{-1}) in the W_2 treatment.

To allow comparison with production functions developed for other years or climate conditions[14], the lettuce yield factor for moisture stress was calculated as the ratio between relative yield (Y) decreased and relative evapotranspiration (ET) or transpiration (T) deficit.

$$[1-(Y_a/Y_m)] = 0.89[1-(ET_a/ET_m)]\ ;\ r^2 = 0.98$$
(For the open soil surface treatments) (10)

$$[1-(Y_a/Y_m)] = 0.92[1-(T_a/T_m)]\ ;\ r^2 = 0.98$$
(For the covered soil surface treatments) (11)

The subscripts a and m represent the actual and maximum values observed.

In the open soil surface treatment, lettuce's evapotranspiration and yield varied from a minimum of 43 mm and 4.3 ton ha^{-1} in the W_5 treatment to a maximum of 285 mm and 43.4 ton ha^{-1} in the W_1 treatment, respectively. In the covered soil surface treatment, lettuce's transpiration and yield varied from a minimum of 44 mm and 7.3 ton ha^{-1} in the W_5 treatment to a maximum of 180 mm and 49.4 ton ha^{-1} in the W_1 treatment, respectively.

REFERENCES

1. Slatyer, R.O., 1967. Plant-Water Relationship. Academic Press, London.
2. Slatyer, R.O., 1973. Plant Response to Climate Factors. UNESCO, Paris.
3. Penka, M., 1985. Transpiration and Consumption of Water by Plants. Academia, Prague.
4. Whisler, F.D., A. Klute and R.J. Millington, 1968. Analysis of steady state evapotranspiration from soil column. Soil Sci. Soc. Am. Proc., 32: 167-174.
5. Hill, R.W., E.L. John and K.D. Frevert, 1983. Comparison of Equations Used for Estimating Agricultural Crop Evapotranspiration with Field Research. Bureau of Reclamation, US Department Interior, Denver, CO, USA.
6. Clarkson, V.A. and W.A. Frazier, 1957. Effect of paper and polyethylene mulches plastic cap on cantaloupe yields and earliness. Proc. Amer. Soc. Hort. Sci., 69: 400-404.
7. Chen, Y. and J. Katan, 1980. Effect of solar heating of soils by transparent polyethylene mulching on their chemical properties. Soil Sci., 130: 271-277.
8. Gardner, W.R., 1959. Solution of the flow equation for the drying of soils and other porous media. Soil Sci. Soc. Am. Proc., 23: 183-187.
9. Bennett, L.L., D.A. Ashley and B.D. Doss, 1966. Cotton responses to black plastic mulch and irrigation. Agron. J., 58: 57-60.
10. Mahrer, Y., O. Naot, E. Rawtiz and J. Katan, 1984. Temperature and moisture regimes in soil mulched with transparent polyethylene. Soil Sci. Am. J., 48: 362-367.
11. Abu-Awwad, A.M., 1998. Effect of mulch and irrigation water amounts on soil evaporation and transpiration. J. Agron. Crop Sci., 181: 55-59.
12. Abu-Awwad, A.M., 1999. Irrigation water management for efficiency water use in mulched onion. J. Agron. Crop Sci., 183: 1-7.
13. Hillel, D. and Y. Guron, 1975. Relation between evapotranspiration rate and maize yield. Water Resources, 9: 743-748.
14. Doorenbos, J. and A.H. Kassam, 1979. Yield Response to Water. FAO Irrigation and Drainage Paper 33. FAO, Rome.