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LEPA AND TRICKLE IRRIGATION OF COTTON IN THE SOUTHEAST ANATOLIA PROJECT (GAP) AREA IN TURKEY

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Introduction

Integrated environment and natural resources management is becoming a priority for the 21st century. Increasing demand for water has created a whole new set of issues and problems for irrigated agriculture. For many years, the emphasis of sustainable irrigated agriculture has been on improving the effectiveness of water management, water conservation, and salinity. As we move into the 21st century, emphasis is on alternative water allocations and their impacts on the environment and national economy, the utilization of water resources to meet agricultural and environmental needs, and the management of water resources to ensure the integrity, productivity, diversity, and vitality of aquatic ecosystems and their watersheds (Bucks, 1995).

Micro-irrigation is one of the technologies which offers unique agronomic, water conservation, and economic advantages needed to address the challenges for irrigated agriculture in the future. The use of micro-irrigation systems continues to increase in the world. According to a survey carried out by ICID in 1991, micro-irrigation systems are used on 1.8 million ha of land in the world (Bucks, 1993). This constitutes only 1% of total irrigated land in the world.

Low Energy Precision Application (LEPA) is a self-moving circular or linear irrigation system that

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applies water at or near the soil surface. The primary purpose of LEPA is to efficiently apply irrigation water for the production of crops and forage in an energy efficient manner (Lyle and Bordovsky, 1981).

Low energy precision application (LEPA) irrigation concept was developed by Lyle and Bordovsky (1981) to maximize the use of seasonal rainfall, and increase irrigation efficiencies by reducing sprinkler irrigation losses associated with droplet evaporation and drift in high winds, which commonly occur in Texas. Lyle and Bordovsky (1983) tested the LEPA concept and compared with sprinkler and furrow methods. The LEPA system was found to be superior to sprinkler and furrow methods in terms of application efficiency, water use efficiency, and energy savings potential. They also reported advantages for alternate furrow LEPA compared to every-row LEPA, besides the obvious reduction in hardware costs. Irrigation runoff prevention from the furrows, as well as rainfall retention, is achieved with furrow diking which enhances surface water storage. Currently, LEPA devices are commercially available to operate in bubble, chemigation (inverted spray) modes as well as in double ended socks mode (Howell et al., 1991).

The Southeastern Anatolia Project (GAP) is the most comprehensive project ever implemented in Turkey. This project covers, in addition to irrigation and hydropower schemes, all the related social and economic sectors including industry, transportation, mining, telecommunications, health, education, tourism, and infrastructure for the region. With the implementation of Southeast Anatolia Project (GAP), 1.65 million hectares of land will be irrigated within a time span of 30 years. Within this developmental framework, application of advanced irrigation and agricultural technologies has gained notable importance. Unless new irrigation and agricultural technologies are introduced, soil degradation and salinity build up in the soil profile will be inevitable due to high clay content and flat slopes. Water shortage will arise if traditional methods of irrigation are to be practiced (Yazar et al., 1999).

Cotton is the most important crop in the Southeastern Anatolia Region (GAP) in Turkey. Common irrigation methods for cotton production in this region are furrow and basin. The farmers use generally over irrigation water, which results in high losses and low irrigation efficiencies, thus in turn causes drainage and salinity problems.

Cotton yield is dependent upon the production and the retention of bolls, and both can be decreased by water stress (Guinn and Mauney, 1984). Development of economically viable microirrigation systems could improve the precision of water placement and reduce energy requirements. Two major disadvantages of microirrigation are high initial system cost, and annual replacement of many system components (Camp et al., 1995).

Cotton yields for two lateral placements (1m and 2m) and three nitrogen sidedress methods were compared near Florence, South Caroline. Microirrigation laterals were installed 0.30 m below the soil surface, either directly under each row or under the midpoint of alternate furrows. The wider lateral spacing and lower N rate could significantly reduce the cost of cotton production with microirrigation, and make this technology more attractive to cotton growers (Camp et al., 1995).

Drip-irrigated cotton was first used commercially in Texas in 1984. The economic benefit derived from drip-cotton come from labor savings, reduced cultivations, increased yield on the drip-irrigated plots and a corresponding increase in yields on the conventionally irrigated fields (Henggeler, 1995).

LEPA irrigation of corn and sorghum was evaluated on Pullman clay loam soil at Bushland, TX by Howell et al., (1991 and 1995) Yazar et al., (1999) and they concluded that both crops responded similarly to LEPA as to more traditional methods such as graded furrow and sprinkler; however, LEPA permitted greater partitioning of the applied water into crop water use. Bordovsky et al., (1992) reported that deficit, high frequency irrigation with LEPA methods enhanced cotton lint yields and provided efficient use of limited water on the Southern High Plains region of Texas. Segarra et al., (1999) compared the levels of expected net revenues to management and risk above variable and fixed costs of twelve irrigation system-irrigation application strategies. Overall, it was found that even when irrigation under subsurface drip irrigation was found to result in higher cotton yields, the economics of its adoption would not be necessarily as profitable as adopting LEPA irrigation in Texas High Plains. Spurgeon and Makens (1992) also evaluated LEPA system at the Southwest Kansas Research-Extension Center at Garden City, Kansas on corn and soybean. They recommended furrow diking for all LEPA systems.

It has been shown that water losses from center pivot systems operated in windy environments can reach almost one half of the water applied, and over the growing season almost 30%.of it. Low Energy Precision Application (LEPA) and Low Elevation Spray Application (LESA) have been investigated as a technology to conserve water and reduce energy costs. These approaches use drop tubes to discharge irrigation water at low pressure near the soil surface, and have been applied to row crops (in the case of LEPA) and to free standing crops (in the case of LESA) in the United States where application efficiencies typically exceed 95% (Fipps and New, 1990; Lyle and Bordovsky, 1983; Schneider and Howell, 1993).

A research was carried out to determine the effects of LEPA, drip, sprinkler, mobile drip, and furrow irrigation methods on the yield and water use efficiency of cotton in the Harran Plain of the Southeast Anatolia Project (GAP) area in Turkey during the years 1991-1992. The results revealed that LEPA and mobile drip did not show any significant water savings as compared to furrow method of irrigation. Highest row cotton yield was obtained from the drip irrigated plots with 4650 kg per hectare followed by sprinkler with 3710 kg/ha and LEPA with 3210 kg/ha, and furrow method resulted in a yield level of 3120 kg/ha. The amount of irrigation water applied varied from 726 mm for sprinkler, 1059 mm for mobile drip, 1076 mm for LEPA, 1003 mm for furrow and to 987 mm for drip method (CETIN et al., 1994).

A similar research was carried out to determine the effects of different irrigation methods namely LEPA, drip, sprinkler, mobile drip, and furrow irrigation methods on the yield, fiber quality and water use efficiency of cotton in the Menemen Plain in the Aegean Region of Turkey. In the experiment, various pan coefficients varying from 0.25 to 1.5 increasing at 0.25 increments were used. According to research results, the amount of pan coefficient of 0.75 resulted in the highest yield. Higher water use efficiency and fiber strength values were observed from trickle irrigated plots (SENER, 1995).

SENER (1994) provided the cost estimates for the different irrigation methods used for irrigating cotton in Harran and Menemen Plains in Turkey. The results showed that drip irrigation was the most expensive method, followed by mobile drip and LEPA. Sprinkler and furrow methods are still the most economical systems in both regions according to the experimental results.

SHANMUGHAM et al. (1977) compared furrow and trickle irrigation methods for cotton crop in India and found out that the two methods resulted in similar yields. However, the amount of irrigation water applied with trickle method was almost 50% less than the furrow method.

The objective of this article is to report the results of a research on the adaptation of LEPA and trickle irrigation methods for irrigating cotton crop in the Southeast Anatolia Project (GAP) area in Turkey. In addition, to report water use efficiency results , to evaluate the yield response of cotton to LEPA and trickle systems on a slowly permeable soil in the region.

Materials and Methods

This study was conducted at the Koruklu Research Station of the Scientific and Technical Research Council of Turkey (TUBITAK) in the Sanlıurfa Province in Southeast Anatolia Project (GAP) area during 1999. The station has a latitude of 36°41' N and, a longitude of 38°58' E and is at 375 m above mean sea level. The soil of this site is classified as Harran soil series (*Vertic Calciorthid aridisol*) and clay textured. Total available water within the top 120 cm of soil depth is 241 mm. Mean bulk density varies from 1.31 to 1.45 g/cm^3.

A hose-reel boom sprinkler system (48 m long) was modified into LEPA system by installing LEPA heads on the drop tubes at alternate rows. LEPA drag-socks mode was utilized in this study. The LEPA system consists of a hose-reel system and LEPA heads on the drop tubes, which are spaced at 140 cm apart. PE pipe section (1 m long, 1/2″ diameter), was used as drop tubes, on which pressure regulators (100 kPa, 3/4″), nozzles (4 different sizes were used on the system), LEPA adapters and double-ended Fangmeier LEPA drag socks were connected. Water to the system was pumped from a deep well at the research station. The design nozzle sizes were determined from:

$$q_i = CA$$

Where q_i is flow rate in L/s for the LEPA applicator; C irrigation capacity L/s/m^2; and A is the service area in m^2 by a LEPA applicator. The nozzle diameter was selected from Nelson catalogue for 100 kPa pressure rating. The design value of C was selected to represent 15 mm/day irrigation capacity at a travel speed of 20 m/h. Irrigation application amounts were determined by the application rates and system travel speed controlled at the hose-reel system. The trickle system consisted of control unit and distribution lines. The control unit of the system contained a venturi injector (1″), a fertilizer tank (75 L), a disk filter, control valves and a water flow meter. Distribution lines consisted of PE pipe manifolds (supply and discharge) for each plot. Irrigation laterals of 16 mm in diameter and 30 m long had inline emitters spaced 0.7 m apart, each delivering 4 L/h at 100 kPa pressure. Each discharge manifold had removable end caps for flushing. Trickle irrigation lines were 1.40 m apart, equally spaced between two cotton rows. Water was supplied from hydrant and filtered through disk filter.

Commercial farm equipment was used for agronomic practices. An experimental plot was planted with a 4-row planting machine at 70 cm row spacing, at 5 and 7.5 cm depth. Plants were thinned to an approximate spacing of 15 cm apart when the plants were about 15 cm in height. Stonville-453 cotton variety was planted on May 18, 1999.

Fertilizer applications were based on soil analysis recommendations. A compound fertilizer of (20-20-0) was applied (80 kg N and 80 kg P_2O_5 as pure matter Per ha) at a rate of 400 kg per ha at planting. At first irrigation, 45 kg of ammonium nitrate per hectare were applied to all the treatment plots. The rest of the N was applied to the experimental area of LEPA plots in the form of Urea ($CO(NH_2)_2$) incorporated to soil by a lister. In trickle plots, remaining nutrient requirements (UAN 32-0-0) were applied by chemical injection using a venturi injector (Netafim) with irrigation water.

The experimental design was a complete randomized block design with three replication for LEPA system and split-plot design with three replications for trickle irrigation system. Irrigation water was applied based on cumulative Class-A Pan evaporation within the irrigation intervals. In the study, two irrigation intervals of 3-days and 6-days for trickle, and only 6-days in LEPA were studied. A control treatment designated to receive 100% of cumulative Class-A pan evaporation on a six-days basis was used to guide irrigation applications for LEPA and 3-and 6-days for trickle method. Deficit irrigation treatments of I_{75}, I_{50} and I_{25} received 75%, 50%, 25% of full irrigation treatment (I_{100}) for LEPA and two deficit irrigation treatments received 67%, 33% of the control treatment of I_{100} for trickle irrigation system. The soil water content measurements were made at 12-days intervals until harvest in the three replications for all treatments by gravimetric sampling and neutron methods. Each plot was designed 120 m long, 2.80 m wide, equally spaced 4 rows for LEPA method and 30 m long, 5.6 m wide for trickle method.

Plant and soil water measurements and observations were started 21 days after planting, and were terminated 121 to 145 days after planting depending on the harvest date. In order to determine the leaf area index and the total dry matter above the ground level, 3 plants from a distance of 0.5 m in the second row of each plot were cut from the above of the ground level. The cotton leaves were separated from the stem and the leaf area of plants was measured by using an optical leaf area meter. Plant samples were dried at 65°C until constant weight was achieved in oven.

Yield was determined by hand harvesting, the two adjacent center rows in each plot 121, 133, 145 days after planting, respectively. The harvest area was 16.8 m^2 (two rows, each 12 m long).

Water use (ET) was estimated by water balance methods using soil water measured by the neutron method assuming no runoff (likely due to furrow dikes) and no deep percolation (less likely to be valid). Even though runoff and percolation could not be directly accounted, it is unlikely they were significant.

Irrigation water use efficiency and total water use efficiency were determined by the equations given by Howell et al., (1994).

Results and Discussion

The 1999 cotton growing season climatic conditions were typical of the conditions that prevail in the GAP area. Table 1 summarizes the monthly climate data compared with the long-term mean climatic data for the Harran Plain, where the experiments were carried out. No rainfall was received during the growing season.

Table 1. Historical monthly and growing season climatic data of the experimental area

Years	Climatic Parameters	Apr	May	Jun	Jul	Aug	Sept
Long-Term Means 1929-1999	Min. Air Temperature (°C)	-3.4	1.0	9.4	11.0	9.2	3.4
	Max. Air Temperature (°C)	34.8	43.0	45.4	46.8	46.6	44.0
	Average Temperature (°C)	15.2	21.4	28.0	31.4	30.4	25.6
	Rainfall (mm)	25.4	25.6	4.8	0.1	-	0.1
	Relative Humidity (%)	54	42	35	33	36	34
	Wind Speed (m/s)	1.6	1.9	2.5	2.6	2.1	1.5
	Evaporation, CAP (mm)	118.6	195.6	320.5	403.9	376.5	280.4
Growing Season 1999	Min. Air Temperature (°C)	5.8	13.7	18.3	21.5	19.2	14.4
	Max. Air Temperature (°C)	24.0	32.0	35.8	39.2	38.4	33.8
	Average Temperature (°C)	16.0	23.9	28.0	30.9	28.9	24.1
	Rainfall (mm)	17.8	1.0	1.5	-	-	-
	Relative Humidity (%)	61.1	37.4	37.1	42.4	50.8	49.1
	Wind Speed (m/s)	1.2	1.5	1.5	1.4	1.0	0.9
	Evaporation, CAP (mm)	137.6	279.5	334.6	370.8	304.4	193.3
	Solar Radiation (cal/cm^2)	519.1	635.1	659.2	671.4	592.8	514.6

Five uniform rate applications varying from 20 mm to 80 mm were made during the plant establishment period. The first and second applications were made on June 6 and June 26 in the spray mode with LEPA system. The third and fourth applications were made on July 2 and July 6 with a sprinkler system. The final uniform application was made on July 8 with drip and LEPA in spray mode on their respective plots. Treatment irrigations were started on July 15. The total amount of water applied to LEPA and trickle irrigation plots is given in Table 2. As shown in this table the amount of irrigation water applied varied from 332.8 mm in LEPA-25 plots to 814.3 mm in LEPA-100 the full irrigation treatment plots. LEPA-75 and LEPA-50 treatments received 653.8 and 493.3 mm, respectively. Trickle irrigated plots received irrigation water varying from a low of 384.2 mm in heavy stress plots (IF3 and IF6-33%) to a high of

814.3 mm in none-stress plots (IF3 and IF6-100%). IF3 and IF6-67% treatment plots received a total of 604.4 mm.

Cotton harvest data, irrigation amounts, water use and water use efficiency data are summarized in Table 2. The irrigation levels both in LEPA significantly increased seed cotton yield and trickle irrigated plots. Highest yield, averaging 5870 kg/ha, was measured in trickle irrigated plots with 6 days intervals in IF6-100% treatment. Followed by IF3-100% trickle plots with 5040 kg/ha. There was no significant difference in yield between the 100% and 67% trickle plots. The highest yield in LEPA plots was obtained in 100% plots with an average value of 4750 kg/ha. As the amount of irrigation water decreased, seed cotton yields also decreased. Dry matter yields were also significantly different among the treatments. Highest dry matter yield, averaging 1.509 kg/m^2, was measured in IF6-100 treatment plot followed by IF3-100 treatment with 1.215 kg/m^2. LEPA irrigated plots resulted slightly lower dry matter yields than the corresponding trickle irrigation plots. In addition, both dry matter and leaf area index (LAI) remained consistently greater in 100% treatments both in LEPA and trickle irrigated plots. Cotton yields in LEPA irrigated plots in this study were comparable with the cotton yields from previous experiments in the Harran Plain, however, the yields from trickle irrigated plots were significantly higher than those from the previous experiments utilizing surface and sprinkler irrigation methods (Cetin et al., 1994; Kanber et al., 1996).

Table 2. Water use and water use efficiency data for LEPA and trickle irrigated cotton

Treatment	Seed Cotton Yield (kg/ha)	Seasonal Irrigation (mm)	Water Use (mm)	Water use Efficiency (kg/ha-mm)	Irrigation Water use efficiency (kg/ha-mm)
LEPA-100	4750 a	814.3	854.0	5.562	5.833
LEPA-75	4020 ab	653.8	694.5	5.788	6.149
LEPA-50	3270 ab	493.3	541.8	6.035	6.629
LEPA-25	2590 b	332.8	383.4	6.755	7.782

$LSD_{0.01}$	*2017*				
TRICKLE					
IF3-100	5040 a	814.3	868.4	5.804	6.189
IF3-67	4520 a	604.4	650.4	6.950	7.478
IF3-33	2660 b	384.2	456.4	5.828	6.923
IF6-100	5870 a	814.3	853.9	6.874	7.209
IF6-67	4900 a	602.4	661.1	7.412	8.134
IF6-33	2310 b	384.2	462.3	4.997	6.012
$LSD_{0.05}$=	*1627*				

Seasonal water used by cotton varied from 383.4 mm in LEPA-25 to 854.0 mm in LEPA-100 treatment plots. In trickle irrigated plots, water use changed from 456.4 mm in IF3-33 to 868.4 mm in IF3-100 treatments. Water use in IF6 treatments was almost the same as those in IF3 treatments. Thus, two different irrigation intervals in trickle plots resulted in similar water use.

Highest water use efficiency (WUE), averaging 7.412 kg/ha-mm, was obtained in trickle irrigated treatment of IF6-67. In general, WUE values decreased with increasing water use. However, the WUE values in the different treatments were higher as compared to WUE values of cotton irrigated by furrow or sprinkler system in the same experimental station (Kanber et all. 1996). Irrigation water use efficiencies (IWUE) were slightly higher than the WUE values. Since no rainfall received during the growing season, the slight differences between the two values can be attributed to water used from soil storage.

All treatment plots received the same amount of total fertilizer. At planting, 80 kg N and 80 kg P_2O_5 Per hectare (20-20-0 combined fertilizer) were applied on May 18. After thinning the plants to an approximately 15 cm in row spacing, all plots received 45 kg N per ha (26% Ammonium Nitrate) on July 1. The rest of N in trickle irrigation treatments was applied as liquid nitrogen through trickle irrigation system (fertigation) in three different times during the growing season. LEPA plots received the same total amount of N in granular form. The amount of fertilizers applied to different treatments and application dates are shown in Table 3.

Table.3 Amounts of fertilizers applied in different irrigation treatment plots

Irrigation system	Date	Trickle			LEPA			
Irrigation Level		I 100	I 67	I 33	I 100	I 75	I 50	I 25
Applied Fertilizer at planting NPK (20-20-0), kg/ha	29.04	400	400	400	400	400	400	400
Ammonium Nitrate (26 % N) kg/ha	01.07	45	45	45	45	45	45	45
UAN (32-0-0) Liquid fertilizer kg/ha	15, 21, 27.07	45	45	45				
Urea (CO(NH2)2) kg/ha	15.07				45	45	45	45

Significant linear and curvilinear relationships between the cotton yield and evapotranspiration in LEPA and trickle irrigation treatments, respectively, are shown in Figure 1 and Figure 2.

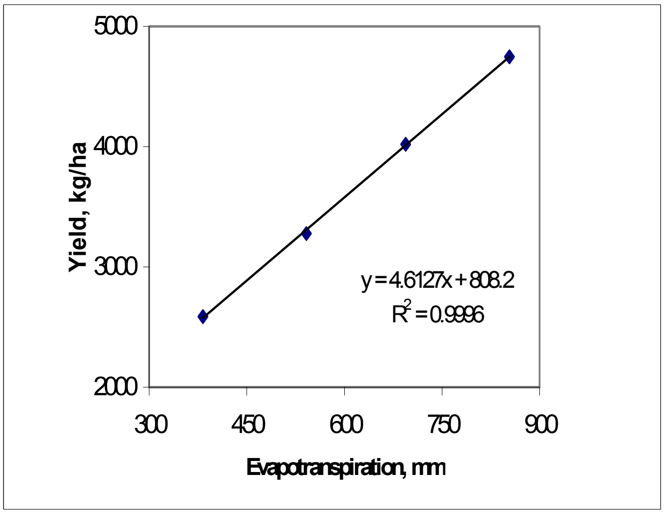

Figure 1. The relationship between cotton yield and evapotranspiration for LEPA treatments.

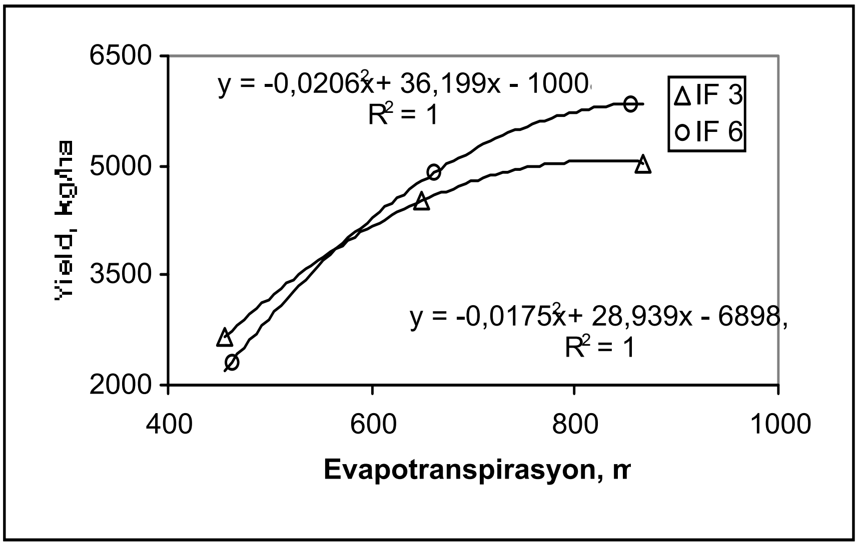

Figure 2. The relationship between cotton yield and ET for trickle irrigated treatments.

Seed cotton yield increased with increasing ET in the LEPA irrigated treatments. In trickle irrigated plots, irrigation intervals resulted in similar curvilinear relationships between yield and ET values. However, in order to develop the relationship between relative yield decrease versus relative ET deficit for trickle treatments, a linear yield-ET function was utilized due to the linear nature of this relationship.(Fig. 3). The slopes of these relationships are called as yield response factor by Doorenbos and Kassam (1979) and determined as 0.84 and 1.20 for the trickle and LEPA irrigated treatments, respectively. Yield response factor for sprinkler irrigated cotton was found to vary between 0.8 and 1.1 in previous studies carried out in the same location by Kanber et all. (1996). Doorenbos and Kassam (1979) give yield response factor for cotton as 0.84.

Water deficits from onset of flowering to peak flowering may cause a more negative effect on yield as compared to when occurring after peak flowering. With severe deficits during late flowering and early boll formation, boll shedding can be excessive. Moderate water deficits occurring during flowering but high enough to restrict vegetative growth, will lead to good boo-set and higher yields, despite a reduction in number of flowers (Doorenbos and Kassam, 1979).

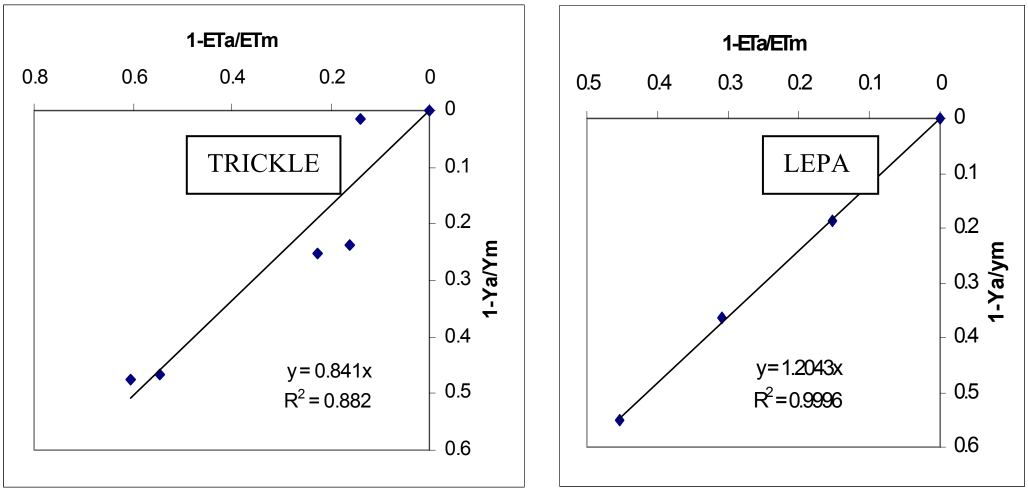

Figure 3. Relative yield reduction vs. relative ET deficit relationships for LEPA and trickle irrigated treatments

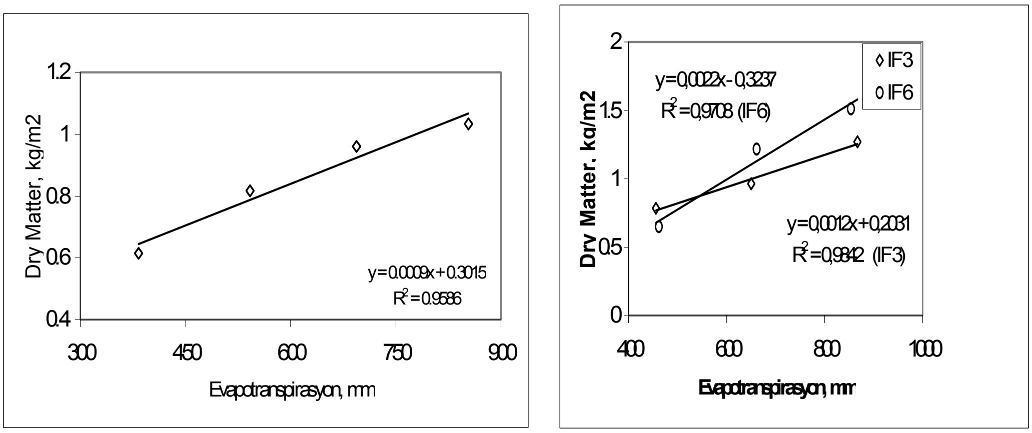

Figure 4. Relationship between dry matter yield and evapotranspiration

Significant linear relationships between dry matter yield and evapotranspir ation were found both for LEPA and trickle irrigated cotton (Fig.4). Dry matter yields increased with increasing evapotranspiration as with seed cotton yield. Trickle irrigation system resulted in higher dry matter yield as compared with LEPA irrigated cotton.

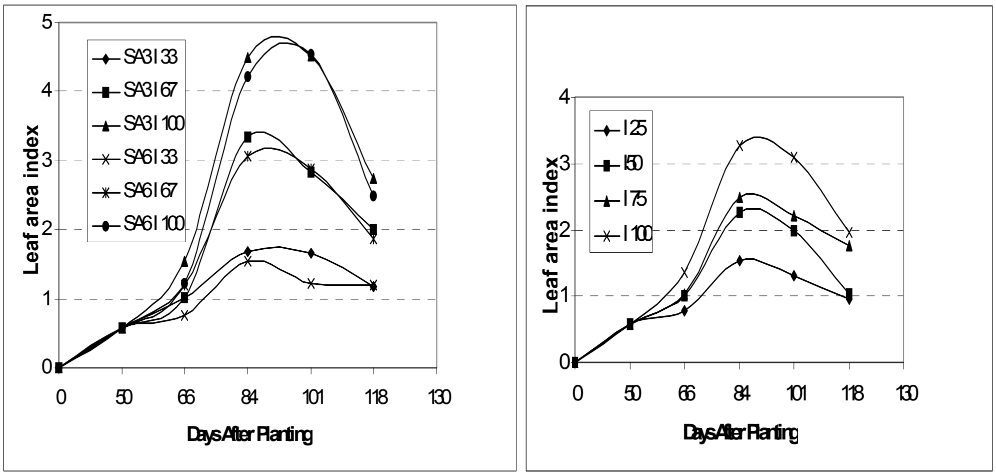

Figure 5. Leaf Area Index development in trickle and LEPA irrigated treatments.

Biomass samples were taken throughout the growing season at three weeks intervals from the irrigation treatments. The relationship between dry matter yield and evapotranspiration for LEPA and trickle irrigated treatments are shown in Figure 4. As with the seed cotton yield, dry matter yields decreased with decreasing evapotranspiration. In addition to dry matter data, leaf area index (LAI) values were determined for trickle and LEPA irrigated cotton and development of LAI with time as shown in Figure 5.

Highest LAI value, averaging 4.7, was measured in trickle irrigated treatment of IF3 and IF6-100. LAI values increased with increasing water use in both irrigation methods. The highest LAI value in LEPA treatments was measured in LEPA-100 plots as 3.4, followed by other irrigation levels.

Conclusions

Trickle and LEPA irrigation of cotton in GAP region of Turkey were found to be comparable to other irrigation methods such as sprinkler and furrow. Deficit LEPA and trickle irrigation of cotton generally reduced seed cotton yield. Both trickle and LEPA systems permitted precise control of the irrigation applications and provided uniform irrigations.

Applications with the double-ended Fangmeir LEPA socks performed superior to spray mode used. Water distribution uniformity along the direction of travel of the linear move hose reel machine was observed to be very high compared to sprinkler and conventional furrow irrigation methods used in the region. LEPA should be managed to apply as much water as can be efficiently stored in the furrow-dike basins, and then irrigation frequency is simply determined by the gross irrigation capacity of the system (Howell et all. 1995).

With proper management, LEPA and trickle irrigation can avoid some application losses, which are inevitable with sprinkler and surface methods.

Although the seed cotton yields from the LEPA-100 and trickle IF3-100 and IF6-100 were not statistically significant, trickle irrigation with 6-days intervals resulted in the highest yield among the treatments studied. However, the duration of water application in IF6-100 treatment is considerably high as compared to IF3-100 or LEPA-100 treatments. Lateral spacing of 1.4 m is found to be sufficient for trickle irrigation of cotton.

In order to reduce evaporation losses in surface trickle irrigated plots, subsurface drip irrigation (SDI) might be recommended for this region. Considering the agronomic practices, SDI may result in less water use for the same yield.

References

Bordovsky, J.P. and W.M. Lyle, R.J. Lascano and D.R. Upchurch. 1992. Cotton irrigation management with LEPA systems. Transactions of the ASAE 35(3):879-884.

Bucks, D.A. 1993. Micro irrigation worldwide usage report. pp 11-30. In Proc. of Workshop on Micro Irrigation Worlwide, The Hague, The Netherlands, 2 Sept. ICID, New Delhi, India.

Bucks, D.A. 1995. Historical developments in microirrigation. 1995. In Microirrigation for A Changing World. Proc. of Fifth Inter. Microirrigation Congress. Ed F.R. Lamm. April 2-6, Orlando, Florida. ASAE Publication. pp 1-6.

Camp, C. R., P :G. hunt, and P. J. Bauer. 1995. Subsurface microirrigation management and lateral spacing for cotton in the Southeastern USA. In Microirrigation for A Changing World. Proc. of Fifth Inter. Microirrigation Congress. Ed F.R. Lamm. April 2-6, Orlando, Florida. ASAE Publication. pp 368-375.

Cetin, O., E. Ozyurt, and S. Sener, 1994. The effects of different irrigation methods on the yield and water use efficiency of cotton in Harran Plain. ICID 17th European Regional Conference on Efficient and Ecologically Sound Use of Irrigation Water with Special Reference to European Countries. 16-22 May, Varna, Bulgaria,.

Doorenbos J. and A.H. Kassam. 1977. Yield response to water. FAO Irrigation and Drainage Paper No:33, Rome, Italy. FAO, UN.

Fipps, G. and L.L. New. 1990. Six years of LEPA in Texas-Less water, high yields. In Vision of the Future., Proc. Of the Third National Irrig. Symp., 115-120., St. Joseph, MI., ASAE.

Guinn, G. and J.R. Mauney. 1984. Fruiting of cotton. I. Effects of moisture status on flowering. Agronomy Journal. 76:90-94.

Henggeler, J.C. 1995. A history of drip irrigated cotton in Texas. In Microirrigation for A Changing World. Proc. of Fifth Inter. Microirrigation Congress. Ed F.R. Lamm. April 2-6, Orlando, Florida. ASAE Publication. pp 669-675.

Howell, T. A., A.D. Schhneider, D.A.Dusek. 1991. Corn and sorghum response to LEPA irrigation. 1991. ASAE Paper No:91-2520, St. Joseph, MI,. ASAE.

Howell, T. A., A.Yazar, A.D. Schhneider, D.A.Dusek and K.S. Copeland. 1995. Yield and water use efficiency of corn in response to LEPA irrigation. Transactions of the ASAE 38:1737-1747.

Kanber, R., S. Onder, M. Unlu, H. Koksal, B. Ozekici, S. M. Sezen, A. Yazar, K. Koc. 1996. Optimization of surface irrigation methods for cotton and comparison with sprinkler irrigation. Research Report No:18, GAP Research Projects. Cukurova Univ. Faculty of Agriculture Publication No:155. July, 1995, Adana,Turkey.

Lyle, W. M. and J. P. Bordovsky. 1981. Low energy precision application (LEPA) irrigation system. Trans. ASAE 24: 1241 - 1245.

Lyle, W. M. and J. P. Bordovsky. 1983. LEPA irrigation system evaluation. Trans. ASAE 26: 776 - 781.

Schhneider A.D., and T. A Howell. 1993. Sprinkler application methods and sprinkler system capacity. ASAE Paper No:93-2053, St. Joseph, MI,. ASAE

Segarra, E., L. Almas, and J. Bordovsky. 1999. Adoption of advanced irrigation technology: LEPA vs. Drip in the Texas High Plains. Texas Tech University, Dept. of Agric. Economics Research Publication No: CER-99-41.

Sener, S., 1994. The effects of water and energy saving irrigation methods on the yield and water use efficiency of cotton in Aegean Region and GAP Area. International Workshop on New Agricultural Technologies: Low Input Sustainable Agriculture Methods. 14-15 July, 1994 TUBITAK-Marmara Research Center, Gebze, Istanbul.

Shanmughan, K., D.C. Meenakshisundaram, And V. Seshadri, 1977. Drip Irrigation on the Efficient Technique. Soils and Fertilizers, June 1977 (40). No:6.

Spurgeon, W. and T. Makens. 1992. LEPA irrigation report. Southwest Kansas Research-Extension Center Report Progress 657. Agric. Exp. Stat. 1992 Field Day Report.

Yazar, A., Howell, T. A., D.A. Dusek and K.S. Copeland. 1999. Evaluation of crop water stress index for LEPA irrigated corn. Irrigation Science 18:171-180

Yazar, A., R. Kanber, S. M. Sezen, B. Ozekici. 1999. Adoption of LEPA and trickle irrigation systems for cotton and corn irrigation in the GAP region. TUBITAK-TARP No:1856. Annual Research Report 1 and 2. Cukurova Univ. Faculty of Agriculture, Dept. of Irrigation. Adana-Turkey.