EFFECTS OF DECREASED WATERING ON CROP YIELDS

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ABSTRACT

Water resource planners use water-production functions, which are the relationships between yield and evapotranspiration, to determine the economic impact of various water allocation decisions. They also need to know the transferability of the functions within and among states.

Cotton (Gossypium hirsutum L.) and alfalfa (Medicago sativa L.) were irrigated for three years at Las Cruces, New Mexico, with a range of water levels using a sprinkler-line source to determine yield and evapotranspiration under deficit irrigation. Alfalfa was grown at five locations and cotton was grown at two locations in New Mexico using flood irrigated nonweighing lysimeters to measure the yield and evapotranspiration under nonlimiting soil-moisture conditions.

A linear water-production function was observed for alfalfa. This function appeared to be transferable to any location in New Mexico, based on the data from five locations within the state. The New Mexico relationship was statistically the same as alfalfa water-production functions for Nebraska and North Dakota. The New Mexico alfalfa water-production function had the same slope as the water-production function for Nevada ($P \leq 0.05$) but had a different intercept.

A linear water-production function was also observed for cotton, but was applicable only for the two areas in southern New Mexico where the study was conducted. The water-production function for the third year of the study was different from that obtained from the first two years of the sprinkler-line source study and the lysimeter study. The cotton water-production function for New Mexico was statistically different from that reported in a similar study conducted in California. The cotton water-production function had a lower coefficient of determination than that of the alfalfa water-production function since cotton was harvested for lint and seed rather than biomass. This study indicated that biomass production may require the same amount of evapotranspiration regardless of site and management differences, as in the case of alfalfa, but that lint or seed production per unit of water will vary from place to place, and from year to year.

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INTRODUCTION

Most western states have initiated a policy of determining the most beneficial utilization and allocation of their scarce water resources. In years of less-than-normal water supplies, knowledge about the effect of water shortages on yield and the most beneficial ways of allocating water becomes important to the economic well-being of an area.

By using water-production functions, defined as the relationship between evapotranspiration and crop yield, planners can determine the economic impact of various alternate water allocation decisions. In addition, water-production functions give guidelines for the capacity of irrigation systems, procedures for scheduling irrigations, and a means of comparing relative water-use efficiencies.

In the past, research has been conducted on the irrigation requirements of alfalfa and cotton and the corresponding yield (5, 6, 7, 11, 12, 13, 14, 15, 17, 18, 19, 20, 22, 23). These are not the same as water-production functions, since irrigation requirements depend upon the evapotranspiration, efficiency of the irrigation system, and management practices.

In many studies, yield did not proportionally increase with applied water because all of the water was not beneficially used by the crop. The studies resulted in a curvilinear functional relationship between applied water and yield. Past studies have concentrated more on the upper and near-optimal irrigation levels and yields, and have not measured the response of alfalfa and cotton to severe moisture stress.

The objective of the research reported here was to develop water-production functions for alfalfa and cotton and to determine if the relationship between yield and evapotranspiration could be described by a linear function. Research was conducted making water the only limiting variable in controlling growth. High yields and evapotranspiration rates, due to intensive management practices, were accomplished with small lysimeter plots. A sprinkler-line source was used to define the water-production function in the range of limited water.

Research conducted in the past has also been oriented toward determining water use for a crop in specific areas. The transferability of this knowledge is usually limited by lack of validation in other locations. The study reported here was conducted in different areas of New Mexico to determine the transferability about the state of the measured water-production function for alfalfa and cotton.

MATERIALS AND METHODS

Lysimeter studies with alfalfa and cotton were conducted at five branch stations of the Agricultural Experiment Station throughout the state. Sprinkler-line source studies with alfalfa and cotton were conducted only at the station near Las Cruces.

Nonweighing lysimeters were 1.8 x 1.8 meters and 1.21 meters deep and lined with 1.9 cm thick (3/4 inch) plywood and five layers of 4-mil black plastic. Suction candles and drainage pipe, 1.27 cm in diameter (1/2 inch), were installed at the bottom of each hole. The bottom of the lysimeter was then covered with 15 cm of sand and the remainder was backfilled with the original soil material according to the order that it was removed. The soil type at each location is presented in Table 1.

Neutron probe access tubes were installed and soil moisture was measured weekly at 15 cm depth increments. Rainfall was measured at nearby weather stations. Measured quantities of irrigation water were applied from 189-liter (50 gallon) barrels. Excess irrigation water was applied weekly by surface flooding to insure that the soil profile in the lysimeter would be wet to field capacity. Drainage water was removed using a vacuum pump.

'Mesilla' alfalfa was planted in 1976 in single lysimeters at San Juan Branch Station in Farmington, Middle Rio Grande Station in Los Lunas, Southeastern Branch Station in Artesia, Plains Branch Station in Clovis; and in three lysimeters at the Plant Science Research Center in Las Cruces. The surrounding fields at each location were also planted in alfalfa.

Irrigation water quality is given in Table 1. Fertilizer was applied at a rate of 120 kg/ha of phosphorus to the alfalfa. Evapotranspiration was calculated for each crop by a water-balance method:

$$ET = I + R - D \pm \Delta SM \qquad (1)$$

Table 1. The soil type and irrigation water quality at the study sites.

Location	Soil Type	Water Quality EC x 10^{-3} (mmhos/cm)
Las Cruces	Sandy Loam	1.23
Artesia	Karro Loam	1.61
Los Lunas	Clay Loam	1.45
Clovis	Pullman Silty Clay Loam	.43
Farmington	Fine Sandy Loam	.46

where

ET = evapotranspiration, cm

I = irrigation, cm

R = rainfall, cm

D = drainage, cm

ΔSM = change in soil moisture, cm

Oven-dried yields from the lysimeters, containing negligible moisture, were measured after each cutting.

With the sprinkler-line source method, alfalfa varieties (mixed 'Moapa' and 'Hairy Peruvian') were grown in plots approximately 30 by 50 meters at a site near Las Cruces, New Mexico, and irrigated with a sprinkler-line source. Plants near the sprinkler line received sufficient water to prevent stress. Decreasing amounts of water were received by plants located away from the line. Various levels of water stress were generated in this way. The sprinkler-line source design is described by Hanks (9).

The alfalfa field was planted in October 1977 and fertilized with 40 kg/ha of nitrogen and 103 kg/ha of phosphorus. The field was then fertilized in March 1979 and 1980 with 103 kg/ha of phosphorus. The field was flood irrigated at planting and again in March 1978 which gave a good stand. The alfalfa crop was harvested five times in 1978, 1979, and 1980. The first cutting in 1978 was made before evapotranspiration measurements were started on May 1, 1978. This cutting consisted of mustard plants (Desurainia sophia) that had overgrown the emerging alfalfa plants, and was not included in the analysis. After the first cutting, the field was irrigated with the sprinkler-line source. At each subsequent harvest, alfalfa was harvested from three plots. Nine cuttings in strips one meter wide and 10 meters long were taken in each plot to measure yield at varying distances from the sprinkler-line to the outer edge of the sprinkler area. Evapotranspiration was also calculated for each yield plot throughout the growing season using the water- balance method described by Equation 1. Applied water was measured with catchment cans and soil moisture with a neutron probe. The irrigation system was operated, based on lysimeter data from previous years, so that crop evapotranspiration was satisfied and deep drainage was minimal at the sprinkler-line. Runoff was negligible because the water-application rate did not exceed the infiltration rate. The groundwater table was six meters at the site so that upward flow was negligible during the growing season. The alfalfa plot was irrigated weekly throughout the growing season and salinity of the applied water varied from 3.75 mmhos/cm in 1978 to 2.18 mmhos/cm in 1979 and .7 mmhos/cm in 1980. Rainfall was 18 cm during the growing season in 1978, 30 cm in the 1979 growing season, and 22.5 cm in 1980.

Acala cotton 1517-V was planted in lysimeters located in cotton fields adjacent to the alfalfa fields at the Las Cruces and Artesia Experiment Stations. The construction and operation of the lysimeters were the same as described for the alfalfa lysimeters, except that 120 kg/ha of nitrogen and 120 kg/ha of phosphorus was applied during the growing season.

Cotton, irrigated with the sprinkler-line source method, was planted May 5, 1978, April 19, 1979, and May 5, 1980 with 101 cm row spacing. During the growing season, 120 kg/ha of nitrogen and 120 kg/ha of phosphorus were applied to the field in 1978 and 1979. In 1980, 98 kg/ha of nitrogen and 48 kg/ha of phosphorus were applied to the field. The cotton plot was preirrigated for germination and subsequently irrigated weekly. Catchment cans were installed with a 101 cm spacing in a line at a right angle to the sprinkler line, one can per row. Yield and evapotranspiration data were taken only on the west side of the sprinkler-line source in 1978, due to poor-stand establishment on the other side. The cotton plot was subdivided into three subplots, each being 10 meters long parallel to the line. Rows from these subplots were harvested separately by hand at the end of the growing season, October 18, 1978, November 28, 1979, and November 20, 1980.

Data for the evapotranspiration calculations (Equation 1) were obtained in the manner described for alfalfa. Total precipitation was 17 cm in 1978, 12 cm in 1979, and 14.5 cm in 1980 during the cotton growing season.

RESULTS AND DISCUSSION

Alfalfa

Alfalfa yield and evapotranspiration (ET) data obtained with sprinkler-line source irrigation method are presented in Table 2.

Yield is a linear function of evapotranspiration (Table 3, Equation 1, 2, and 3) with a coefficient of determination of 0.97 for 1978, 0.57 for 1979, and 0.87 in 1980.

The lysimeter data for alfalfa from all sites and years are

Table 2. Yield and evapotranspiration (ET) of alfalfa grown with the sprinkler-line source data.

Year - 1978		Year - 1979		Year - 1980	
ET	Yield	ET	Yield	ET	Yield
(cm)	(ton/ha)	(cm)	(ton/ha)	(cm)	(ton/ha)
54.66 1/	4.27	70.79 1/	7.56	36.63	0.36 1/
60.96	5.45	79.83	12.41	40.63	1.20
63.85	6.40	83.34	14.84	45.03	1.52
81.20	7.75	85.67	15.55	50.44	2.20
79.67	9.03	95.33	16.07	55.68	5.04
89.99	10.19	108.64	17.28	65.58	6.64
92.61	11.40	115.24	18.74	76.50	8.81
104.67	11.78	130.38	19.65	89.08	10.79
115.01 2/	14.49	129.92	19.95	116.33	11.66
		136.91	18.87	111.20	13.35
		145.74 2/	22.10	120.98	14.13
		133.53	20.35	131.22	15.02
		137.87	19.16	147.14	14.93
		130.43	16.85	156.67	14.88
		137.11	15.61	149.00	15.09 2/
		126.60	14.74	162.81	13.93
		115.27	15.09	152.25	13.87
		115.34	14.95	149.12	12.54
		103.12	12.31	141.02	12.26
		108.48	10.01	123.98	12.71
		86.87 1/	7.83	116.03	12.54
				105.03	11.61
				98.12	10.10
				89.59	9.31
				79.37	8.61
				69.19	7.50
				58.32	6.05
				48.13	5.65 1/

1/ Row or area farthest away from sprinkler line.

2/ Row or area nearest sprinkler line.

Table 3. Linear water production of alfalfa for studies in New Mexico, Nevada, North Dakota, and Nebraska.

Equation Number	Water-Production Functions	Coefficient of Determination	Location and Year
	(ton/ha)[1/] ET(cm)[2/]		
1	yield = -4.3 + 0.16 ET	0.97 [4/]	Las Cruces-1978 Sprinkler-line source
2	yield = 0.43 + 0.14 ET	0.57	Las Cruces-1979 Sprinkler-line source
3	yield = -0.86 + 0.11 ET	0.87	Las Cruces-1980 Sprinkler-line source
4	yield = -1.24 + 0.13 ET	0.79[a]	Las Cruces-1978-1979-1980 Sprinkler-line plus Lysimeter-1975-1976
5	yield = 0.53 + 0.14 ET	0.98 [b]	Nevada-Tovey (21) Average of 1960-1961 data forced through origin
6	yield[3/] = -0.83 + 0.16 ET	0.97[ab]	North Dakota-1978 Bauder et al. (1)
7	yield = 1.84 + 0.13 ET	1.00[ab]	Nebraska-1970 Daigger et al. (6)
8	yield = 0.77 + 0.12 ET	0.80	Composite of Las Cruces, Nebraska, North Dakota, Nevada-1960-1961 data

1/ All yield is a near zero percent moisture except Tovey (21) who did not report a moisture content.

2/ ET = evapotranspiration.

3/ Includes 1973, 1974, and 1976 data.

4/ Equations followed by different letter are significantly different at the five percent level. The slope of all the equations are statistically the same. Any differences are due to different intercepts.

presented in Table 4. The slopes of the regression equations for the sprinkler-line source and lysimeter data are statistically similar ($P \leq 0.05$) and, therefore, can be combined. However, the intercept of the 1979 sprinkler-line source data is statistically different ($P \leq 0.05$) from the intercept of the 1980 linear regression. From year to year there can be a variation in the intercept due to different evaporation amounts that occur; but the slope for all the different years is statistically the same, and the best represented water production function consequently would be represented by the combination of all of the data sets for all years.

The function is described in Table 3, Equation 4, and shown in Figure 1. The coefficient of determination was 0.79. The relationship between yield and evapotranspiration in New Mexico shows that 7.7 cm of water are required to produce 1 ton/ha of alfalfa, at near zero percent moisture content.

The lysimeter data represent different climatic conditions, growing season lengths around the state, and new as well as established crops. All the data fall generally on the same production-function line with the variation being as high from year-to-year as from location-to-location. The data also include three data points from a lysimeter study conducted by Curry (2, 3, and 4) in Las Cruces where the alfalfa was irrigated by maintaining a water table 91 cms deep in lysimeters. These data are close to the function as shown in Figure 1.

Equation 4, in Table 3, represents an average water-production function for alfalfa throughout the State of New Mexico.

Table 4. Yield and evapotranspiration of alfalfa grown in lysimeters.

Crop and Location	Year	Planting Date	Lysimeter	Evapotrans-piration Measured	Time Duration
			Yield* T/ha	cm	
ARTESIA					
Alfalfa (New)	1976	8/29/75	22.46	189.7	1/21-12/31
Alfalfa (Mature)	1977	12/03/76	23.38	184.6	1/01-12/19
CLOVIS					
Alfalfa (New)	1976	3/24/76	10.35	125.6	4/26-12/31
Alfalfa (Mature)	1977	3/24/76	15.87	169.7	1/01-12/08
FARMINGTON					
Alfalfa (new) North Site	1976	4/13/76	9.80	107.5	4/26-11/12
Alfalfa (Mature) South Site	1976	Spring 75	19.23	166.1	4/26-11/12
Alfalfa (Mature) South Site	1977	Spring 75	14.73	157.7	3/24-11/21
Alfalfa (Mature) North Site	1977	4/13/76	16.83	124.2	3/24-11/21
LAS CRUCES					
Alfalfa (Mature) Site B	1976	11/05/75	21.90	171.6	1/01-10/29
Alfalfa (New) Site A	1976	2/04/76	13.27	156.5	2/09-12/06
Alfalfa (New) Site C	1976	2/09/76	21.46	165.4	2/09-12/06
Alfalfa (Mature) Site B	1977	11/05/75	22.55	157.5	1/05-12/13
Alfalfa (Mature) Site A	1977	2/04/76	25.60	174.9	1/05-12/13
Alfalfa (Mature) Site C	1977	2/09/76	22.04	173.9	1/05-12/13
Los Lunas					
Alfalfa (New)	1976	6/29/76	5.16	41.7	7/28-11/16
Alfalfa (Mature)	1977	11/16/76	18.16	151.8	1/18-12/21

* Dry weight near zero percent moisture content.

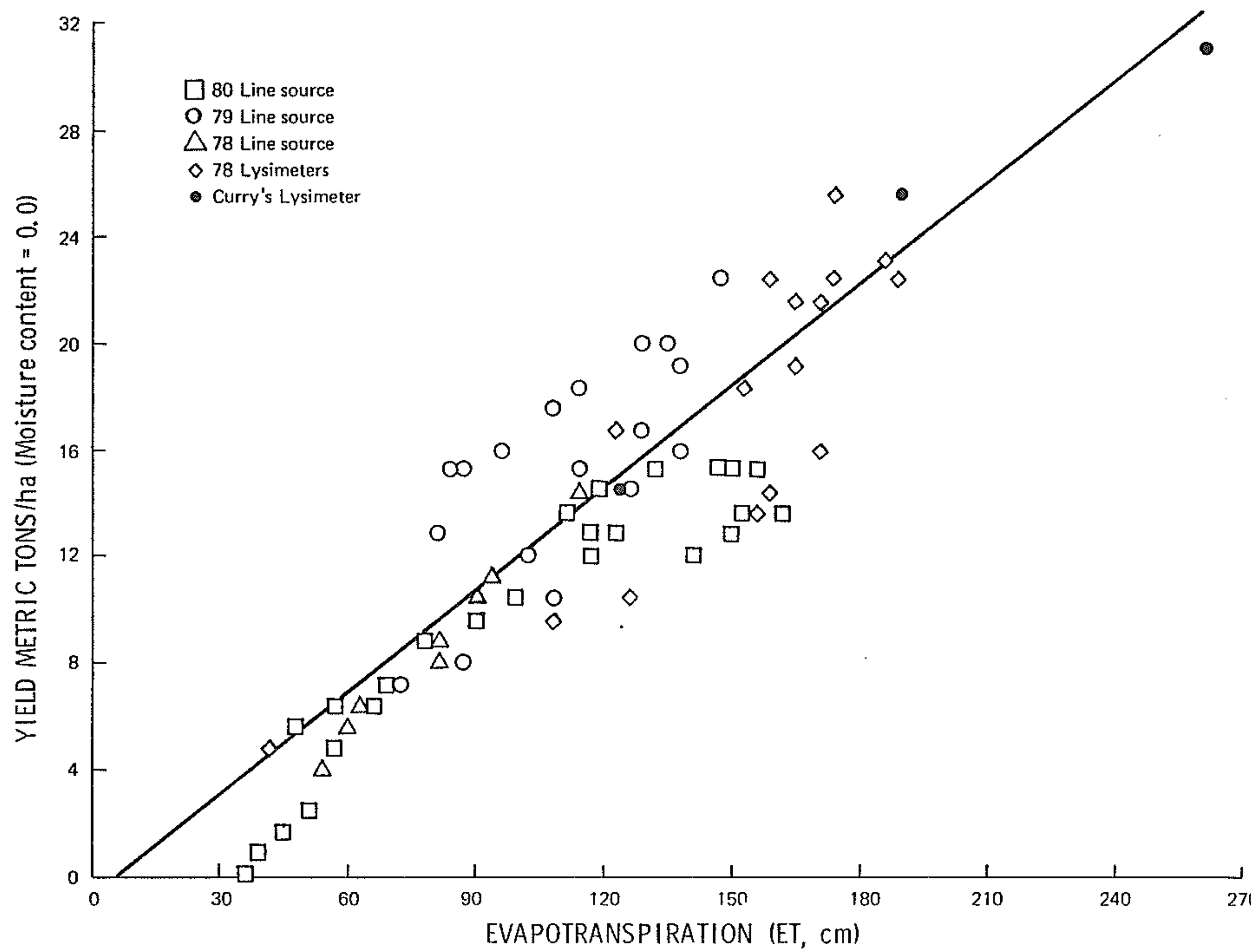

Figure 1. Water-production function for alfalfa, New Mexico.

Conjecture arises that the same function might be transferred to other states.

Lysimeter studies were conducted by Tovey (21) in Nevada, using varying height water tables, both irrigated and non-irrigated, and different soil textures as treatments. The 1959 data were statistically different, at the .05 percent level of confidence, than the 1960 and 1961 data. The water-production functions derived from this data are described by the regression equations listed in Table 5. The data do not include values at the low end of the water-production function and only in 1961 is the variation explained satisfactorily by a linear function. If evaporation losses are assumed negligible then the data should pass through the origin.

When the water-production function is forced through the origin by adding 4 zero data points to the data base, the coefficient of determination increases and the slope of the average of the 1960-1961 water-production function statistically ($P \leq 0.05$) is the same as the composit Las Cruces' water-production function. However, the equations are statistically different due to the intercepts.

Bauder et al. (1) conducted a study on alfalfa water use and production in southeastern North Dakota. Each year had four levels of evapotranspiration and yield. The water-production function (Table 3, Equation 6) has a linear coefficient of determination of 0.97 and is statistically the same as the Las Cruces data.

Daigger et al. (6) collected three years of data on alfalfa yield and evapotranspiration, one data point each year. The linear function of that data (Table 3, Equation 7) has a coefficient of

Table 5. Water-production functions for alfalfa based upon data from Tovey (22) collected in Nevada.

Year	Cutting	Water-Production Functions	Coefficient of Determination
		(ton/ha) ET(cm)	
1959	1	yield = 3.00 + 0.12 ET	0.54
	2	yield = 4.73 + 0.05 ET	0.04
	3	yield = 3.80 + 0.06 ET	0.26
	Yearly total	yield = 9.70 + 0.10 ET	0.51
1960	1	yield = 2.80 + 0.06 ET	0.49
	2	yield = 1.81 + 0.10 ET	0.68
	3	yield = 1.41 + 0.08 ET	0.83
	Yearly total	yield = 5.60 + 0.08 ET	0.51
1961	1	yield = 3.26 + 0.06 ET	0.50
	2	yield = 1.03 + 0.15 ET	0.76
	3	yield = 1.43 + 0.07 ET	0.80
	Yearly total	yield = 5.10 + 0.09 ET	0.87

determination of 1.00 and is statistically the same as the Las Cruces water-production function.

Statistical analysis shows that a common production function of alfalfa for four states can be represented by Equation 8 which has a coefficient of determination of 0.80.

The combined water-production function shows that 8.3 cm of water are required to produce one ton/ha of alfalfa, which is slightly larger than the amount of water required to produce one ton/ha, based only on New Mexico data.

The production function is different for different cuttings. Table 6 shows the alfalfa water-production function for the second, third, fourth, and fifth cuttings measured at Las Cruces with the sprinkler-line source data in 1978, and for all five cuttings in 1979 and 1980. The slopes (water-use efficiency) in 1978 vary from 0.12 ton/ha/cm to 0.16 ton/ha/cm. When water-production functions in 1978 for the different cuttings are compared, only the second and third cuttings are statistically the same, with the fifth cutting having the highest water-use efficiency. In 1979, the coefficients of determination for the water-production function of the individual cuttings have a greater variation than in 1978 with the slopes varying from 0.09 ton/ha/cm to 0.18 ton/ha/cm. Again, based on the statistical analyses, the last two cuttings had the highest water-use efficiency. In 1980, the coefficient of determination for the water production function of the individual cuttings is higher than in 1978 and 1979, with the slopes varying from 0.06 to 0.15 ton/ha/cm. Statistically ($P \leq 0.05$) the last two cuttings do not have a higher water-use efficiency than the first three cuttings,

Table 6. Water-production functions for alfalfa measured at Las Cruces, New Mexico.

Year	Cutting	Equation: yield (ton/ha) = ... ET (cm)	Coefficient of Determination
1978	2	yield = -1.22 + 0.13 (ET) a[1/]	0.70
	3	yield = -0.69 + 0.12 (ET) a	0.83
	4	yield = 0.20 + 0.12 (ET) b	0.80
	5	yield = 0.08 + 0.16 (ET) c	0.29
1979	1	yield = -1.00 + 0.09 (ET) d	0.38
	2	yield = 1.46 + 0.11 (ET) ab	0.40
	3	yield = 2.25 + 0.10 (ET) a	0.48
	4	yield = -0.77 + 0.18 (ET) c	0.65
	5	yield = 0.09 + 0.16 (ET) bc	0.50
1980	1	yield = 0.72 + 0.06 (ET) a	0.68
	2	yield = 0.42 + 0.12 (ET) b	0.65
	3	yield = 0.68 + 0.08 (ET) c	0.82
	4	yield = 0.08 + 0.15 (ET) bc	0.65
	5	yield = 0.71 + 0.14 (ET) a	0.51

1/ Equations followed by different letters are significantly different at the 5 percent level.

even though the water-use efficiencies are large for those last two cuttings. The water-production functions for the individual cuttings have lower than desired coefficients of determination and additional information is needed before a recommendation can be made concerning when to apply a limited water supply to maximize yearly production of alfalfa. However, the data supports the idea that photosynthetic efficiency may be higher for the last cuttings in Las Cruces due to lower air temperatures that are closer to the optimal level for photosynthesis. Table 5 shows water-production functions for each cutting in the Nevada study, not forced through the origin. These vary from year to year with no consistent trend as to which cutting had the highest production per unit of water.

Cotton

Cotton yield and evapotranspiration (Table 7) obtained from the sprinkler-line source irrigation, is shown in Table 8 and Figure 2 as a linear function with a coefficient of determination of 0.98 in 1978, 0.51 in 1979, and 0.48 in 1980.

The regression equations for the sprinkler-line source studies in 1978 and 1979 and the lysimeter study (Table 9) are statistically the same ($P \leq 0.05$); therefore, they can be combined. The coefficient of determination of this function is only 0.66 due to the large amount of variation in the lysimeter data and 1979 sprinkler data. Some rows from the sprinkler-line source study in 1979 were not included in the analysis due to flooding. Data from light irrigation treatments previously reported by Hanson (10) are

Table 7. Yield and evapotranspiration (ET) of cotton grown with sprinkler-line source irrigation.

Year - 1978		Year - 1979		Year - 1980	
ET	Lint Yield	ET	Lint Yield	ET	Lint Yield
(cm)	(kg/ha)	(cm)	(kg/ha)	(cm)	(kg/ha)
16.87 1/	376.60	32.18	760.73	38.40	506.29 1/
20.19	380.87	34.21	749.97	34.47	397.21
24.52	418.72	48.39	813.46	40.34	470.88
32.55	540.80	47.68	776.33	44.27	567.34
27.27	582.91	55.91	821.53	38.25	444.67
33.59	658.60	58.14	880.71	45.67	446.83
34.18	617.70	63.27	870.48	51.33	527.24
42.14	747.71	55.83	872.99	48.59	521.53
44.36	780.06	50.19	753.56	53.44	646.88
46.68 2/	824.62	52.32	787.27	52.88	469.63
		48.84	842.51	58.62	586.33 2/
		45.03	804.85	46.15	595.22
		43.79	779.02	44.42	468.26
		42.62	687.56	48.89	330.77
		45.47	725.58	36.63	473.19
				43.51	429.06
				41.68	380.77
				44.68	402.55
				39.67	304.88
				37.16	292.78
				31.65	297.57
				26.01	239.92 1/

1/ Row or area farthest away from sprinkler line.

2/ Row or area near sprinkler line.

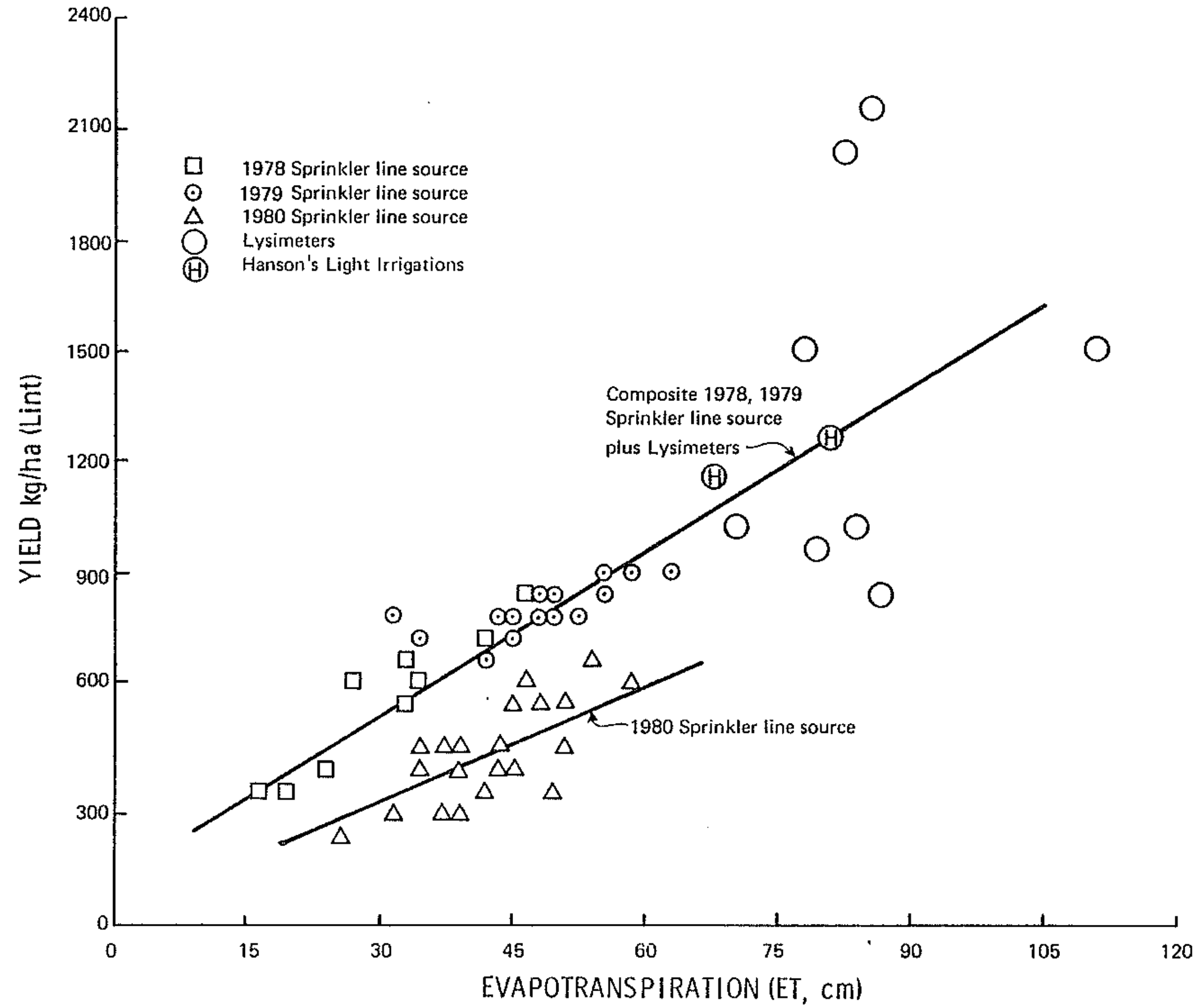

Figure 2. Water-production function for cotton, New Mexico.

Table 8. Linear water production of cotton in New Mexico and California.

Equation Number	Water-Production Functions	Coefficient of Determination	Location and Year
	(kg/ha) ET(cm)		
1	yield = 86.02 + 15.72 ET	0.98 a[1/]	Las Cruces - 1978 Sprinkler Line
2	yield = 563.69 + 4.80 ET	0.51 a	Las Cruces - 1979 Sprinkler Line
3	yield = 134.87 + 14.25 ET	0.66 a	Las Cruces - 1978, 1979 - Sprinkler Line Sources and Lysimeter
4	yield = -498 + 31.40 ET	0.96 b	California West Side Field Station
5	yield = 26.24 + 9.74 ET	0.48 c	Las Cruces - 1980 Sprinkler Line

1/ Equation followed by different letters are significantly different at the 5 percent level.

Table 9. Yield and evapotranspiration of cotton grown in lysimeters.

Crop and Location	Year	Planting Date	Lysimeter Yield	Evapotranspiration Measured	Time Duration
				(cm)	
ARTESIA					
Cotton	1976	4/13/76	1006 kg/ha	70.2	4/12-10/25
Cotton	1977	4/20/77	1491 kg/ha	111.2	4/25-10/17
LAS CRUCES					
Cotton Site A	1976	5/06/76	861 kg/ha	87.0	5/04-10/30
Cotton Site B	1976	5/06/76	1044 kg/ha	84.1	5/04-10/30
Cotton Site C	1976	5/06/76	960 kg/ha	80.2	5/04-10/30
Cotton Site A	1977	4/22/77	2063 kg/ha	83.0	4/23-10/25
Cotton Site B	1977	4/22/77	2134 kg/ha	85.8	4/23-10/25
Cotton Site C	1977	4/22/77	1522 kg/ha	78.7	4/23-10/25

also included with the lysimeter data. The water-production function for the 1980 sprinkler line source is statistically different from the 1978 and 1979 plus lysimeter data. This supports the observation by Retta and Hanks (16) based on their corn study, that there can be large differences in year by year water-production functions.

The Artesia lysimeter data are closer to the water-production function than the 1977 lysimeter data at Las Cruces. Part of the scatter is due to the small sample size from a lysimeter and to the variability among lysimeters as a result of management practices. When lysimeters are used to measure evapotranspiration-yield relationships for a seed crop, small sample size and variability from plot to plot become critical factors in the reliability of the data. The sprinkler-line data represent an increase in sample size and consistent management practices.

Figure 3 presents the water-production function data for cotton measured in 1976 at the University of California, West Side Field Station (5). The data were obtained from a sprinkler-line source experiment similar to the experiment reported here. These data fit the relationship described in Table 8, Equation 4.

The slope of the water-production function for the California cotton is greater than that for functions described by data taken in New Mexico. It requires 0.03 cm of water to make 1 kg/ha of cotton in California and 0.07 cm to 0.10 cm in Las Cruces, indicating that a water-production function for cotton is not transferable.

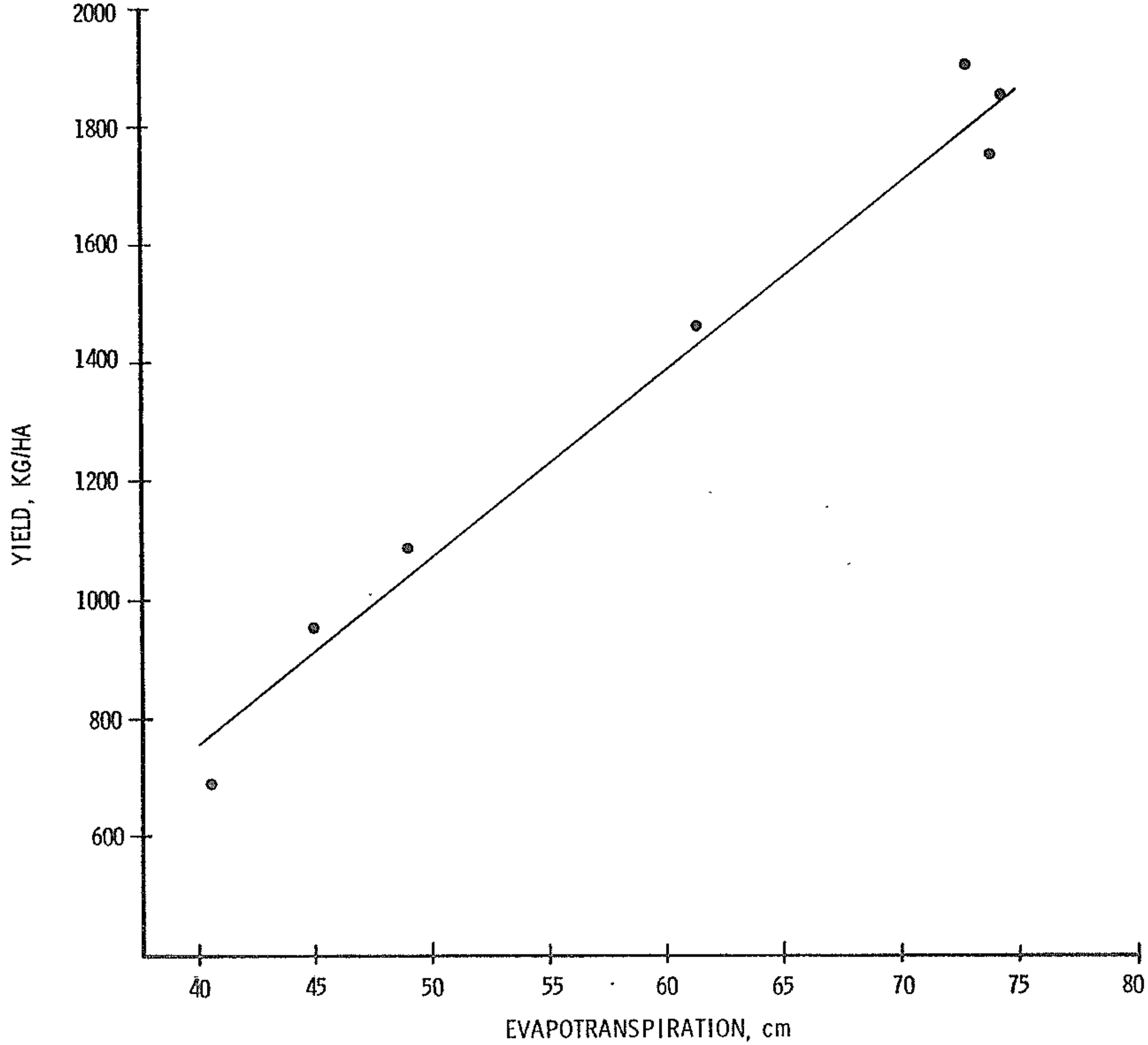

Figure 3. Water-production function for SJ2 cotton, University of California West Side Field Station, 1976.

CONCLUSION

A linear water-production function for alfalfa was derived for New Mexico which appears to be transferable to any location in the state. A common water-production function was derived which is statistically the same as the individual derived water-production functions for New Mexico, Nebraska, and North Dakota. The Nevada water-production function was the same as the Nebraska and North Dakota water-production function, and statistically ($P \leq 0.05$) had the same slope but different intercepts as the New Mexico water-production function. This shows that the relationship between alfalfa growth and transpiration is independent of where the alfalfa is grown.

Water-production functions are different for each cutting with the water-use efficiency being higher for the last two cuttings. This indicates that water-use efficiency of alfalfa grown in Las Cruces is higher toward the end of the season than during the hot summer months. The water-production functions of the individual cuttings from the Nevada data show no consistent trend.

The linear water-production function for cotton is applicable for two areas in southern New Mexico where the crop is grown. It has more variability than the alfalfa water-production function because it is harvested only for cotton instead of total biomass.

The third year of cotton data from the sprinkler-line source study resulted in a different water-production function than that derived from the first two years of data from the sprinkler-line source study plus the lysimeter study, indicating that for a seed crop the water-production function may vary from year to year.

Results of this study indicate that total biomass production may require the same amount of evapotranspiration regardless of site and management differences as is the case in harvesting alfalfa, but that lint or seed production per unit of water will vary from place to place and year to year. This is supported by corn studies in Colorado, Utah, Arizona, and California by Hanks et al. (8). These studies show that corn dry-matter production per unit of evapotranspiration was more consistent than grain yield per unit of evapotranspiration which varied from location to location and year to year.

The data on alfalfa and cotton support the use of lysimeters to define the upper portion of the water-production function and the use of the sprinkler-line source to define the lower end of the function. The data from the lysimeters, compared with data from the sprinkler-line source, also emphasize the need for large samples when lysimeters are used.

The alfalfa water-production function can be used by the resource planners with a high degree of confidence. The cotton water-production function needs additional research to define the year to year variability.

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