INFLUENCE OF SURFACE VS SUBSURFACE IRRIGATION ON CONSUMPTIVE USE OF MOUNTAIN MEADOW VEGETATION

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ABSTRACT

Measurements were taken in the Green River Basin of Wyoming to investigate the effects of surface versus subsurface irrigation on the consumptive use of mountain meadow vegetation. Water balance lysimeters were used to measure mountain meadow water use with surface irrigation during 1984 and 1985 and with both surface and subsurface irrigation during 1986.

Results indicate that for July through September, water use rates of mountain meadow vegetation for subsurface irrigation as compared to surface irrigation were 7%, 20%, and 33% lower for water table depths that were 0.0 inches, 19.5 inches, and 45.0 inches, respectively. These results were for mountain meadow vegetation during the first year of subsurface irrigation following a series of years during which surface irrigation had been practiced.

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Chapter 1

INTRODUCTION

Much work has been done to define the consumptive use of various crops. However, the basic question of the response of vegetation, growing in locations having high water tables, to variations in water table depths and soil moisture levels has not been addressed often. Many plants normally acquire a portion of their consumptive use from the water table.

In this study, the extent of water extraction from the water table was investigated for mountain meadow vegetation. In many instances, in order to analyze critical water supply problems, information is needed on whether water comes from the stream system (ie., the water table) or from precipitation or irrigation. Examples of this need are the estimation of natural water losses in streams and definition of the water use of subirrigated vegetation.

Practical and legal settings where consumptive water use considerations are important include water supply planning for urban, industrial, and agricultural development. Specific examples concerned with definition of the soil moisture and water table components of consumptive use include: (1) calculation of conveyence losses and potential resultant augmentation requirements, (2) determination of potential return flows through definition of the consumption use by plants and water returned to the stream, and (3) determination of the monetary value and assessment of the availability of dry-up credits associated with water right transfers.

Objectives

The overall objective of this study was to investigate the influence of irrigation method and depth of water table on consumptive use of mountain meadow vegetation. Specific objectives were:

1. To measure and analyze the difference in water use between subirrigated and surface irrigated mountain meadow vegetation.
2. To investigate the influence of varying water table depths on the consumptive use rates of grass type vegetation growing in the presence of a high water table.

The intent of the project was to use existing equipment and lysimeter installations. Fourteen water balance lysimeters had been operated in the Green River Basin of Wyoming during the summers of 1983 through 1985 as part of the study "Development of Evapotranspiration Crop Coefficients, Climatological Data, and Evapotranspiration Models for the Upper Green River". Following the summer of 1985, the lysimeters were no longer required for their initial purpose and, thus, were available for this study. Advantages in using the existing lysimeters were that no installation delay occurred or costs were required and that a documented history of water use and performance for each lysimeter existed.

Related Studies

Studies of the effects of the water table on crop water use have been conducted for some crops, especially alfalfa. However, many of the studies have considered the effects on yields rather than on water use. Tovey (1963) found that alfalfa yields varied with water table depth. He also investigated the influence of surface irrigation versus subsurface irrigation on alfalfa water use with surface irrigation leading to greatest water use. Benz and et al. (1981, 1982 and 1983) have recently conducted a series of studies concerning the effects of the water table on yields and water use of alfalfa and other crops. In studies with corn, sugarbeets, and alfalfa, they found that irrigation requirements and crop yields were both influenced by water table depths. They further found that the water table made a sizeable contribution to evapotranspiration and that this contribution increased as irrigation level decreased. On the other hand, Wilcox (1978) found only a small amount of annual water use from the water table for alfalfa with a water table depth of 5 ft or more and with irrigation.

Effects of water table depth and method of irrigation on water use of mountain meadows have been considered by Borrelli and et al. (1981) and Burman and Borrelli (1984). Results from lysimeter measurements show that water use varies from a relatively high rate in years when water supplies (thus, water tables) are high to a low rate in years when water supplies are low and water tables are deep. Their data indicate a decrease in water use rate as water table depths increase from 20 inches to 40 inches.

Many studies have been conducted to relate plant water use to soil water availability. Typical among these is the report by Abdul-Jabbar and et al. (1983) which measured the water use by alfalfa, maize, and barley as influenced by available soil water. Their results indicate that the relationship between the ratio of actual to maximum evapotranspiration and available soil water is different for the three crops.

Chapter 2

FIELD MEASUREMENTS

Measurements to define agricultural water consumption in the Green River Basin of Wyoming were taken for 3 consecutive growing seasons from 1983 through 1985 (Pochop and Burman, 1987). Fourteen water balance lysimeters measuring 5 ft deep and 3.3 ft on a side were installed in the Basin during the Fall of 1982 and Spring of 1983. Ten of the lysimeters were located along a 20 mile stretch of Horse Creek between the Bridger- Teton National Forest boundary and Daniel. These lysimeters consisted of eight with mountain meadow vegetation and one each of alfalfa and alta fescue. The remaining four lysimeters, which consisted of alfalfa and alta fescue, were located at Farson and Seedskadee. Weekly water use measurements were taken during the summers of 1983 through 1985. All lysimeter operations consisted of surface irrigation on a weekly schedule with maintainence of near constant water tables until harvest for all lysimeters. The measurements provide historical water use records for the lysimeters.

The lysimeters used in this study consisted of the ten lysimeters along Horse Creek. The alfalfa and alta fescue lysimeters located at Daniel and the evaporation pans at Merna and Daniel were used as references for water use rates. Two automated weather stations, one each at Merna and Daniel, were also operated.

Water Use Measurements

The locations and elevations of the lysimeters and weather stations used for this study are given in Table 1. The crop type and average water table depth during the study period are also given for each lysimeter. The lysimeter sites consisted of four pairs of mountain meadow lysimeters. The water table depths were selected so that each pair would have similar depths, which ranged from a surface water table for lysimeters 3C and 3D to a water table depth of slightly less than 4 ft for lysimeters 3E and 3F. Lysimeters 3A through 3F were subirrigated while lysimeters 4A through 4D were surface irrigated. Water use measurements were taken from late May through early October, but subirrigation of lysimeters 3A through 3F was limited to the period of July through the end of the season.

The operation of lysimeters 4A through 4D followed procedures that were developed and used during the previous 3 years. These procedures are explained in detail by Pochop and Burman (1987).

TABLE 1. LOCATIONS AND SITE DESCRIPTIONS

SITE	CROP	WATER TABLE DEPTH (IN)	LATITUDE (DEG MIN)	LONGITUDE (DEG MIN)	ELEVATION (FEET)
LYSIMETERS					
3A	MTN MDWS	21.5	42 57 N	110 22 W	7800
3B	MTN MDWS	17.5*	42 57 N	110 22 W	7800
3C	MTN MDWS	0.0	42 56 N	110 17 W	7500
3D	MTN MDWS	0.0	42 56 N	110 17 W	7500
3E	MTN MDWS	47.0	42 56 N	110 17 W	7500
3F	MTN MDWS	45.0	42 56 N	110 17 W	7500
4A	ALFALFA	**	42 52 N	110 04 W	7200
4B	ALTA FESCUE	**	42 52 N	110 04 W	7200
4C	MTN MDWS	**	42 52 N	110 04 W	7200
4D	MTN MDWS	**	42 52 N	110 04 W	7200
WEATHER STATIONS					
MERNA	-	-	42 57 N	110 22 W	7800
DANIEL	-	-	42 52 N	110 04 W	7200
EVAPORATION PANS					
MERNA	-	-	42 57 N	110 22 W	7800
DANIEL	-	-	42 52 N	110 04 W	7200

* The water table was near the surface toward the end of the season due to a malfunction of the float system (Table A4).

** These lysimeters were surface irrigated. Therefore, the water tables vary somewhat (Table A4).

Weekly irrigation of the surface irrigated lysimeters was performed to prevent the soil moisture depletion in the layer above the water table from becoming too great. Water tables in the surface irrigated lysimeters were maintained at reasonably constant levels. Maintenance of the water tables combined with surface irrigation was expected to result in near maximum possible water use rates.

The water table depths in the subsurface irrigated lysimeters were maintained at constant levels by use of a reservoir and float system. Each lysimeter had a 4 inch access tube. Small floats were placed in these access tubes and connected to a nearby reservoir to maintain near constant water table levels which were checked at two week intervals (Table A4). The float system in lysimeter 3B malfunctioned between the September 13 and 27 measurements, thus lysimeter 3B was flooded for the remainer of the season as shown by the data in Table A4. All other water table depths were maintained at the desired levels.

The reservoir and float systems were installed during the last week of June, so data comparing water use of surface versus subsurface irrigated lysimeters consists of the data from July through September, 1986. Comparison of the soil moisture depletion in the layer above the water table for the subsurface irrigated lysimeters (3A through 3F) and surface irrigated lysimeters (4A through 4B) during this period is shown in Table A5. As expected, the greater soil moisture depletions occurred for the subsurface irrigated lysimeters except for lysimeters 3C and 3D which had water table levels maintained at the surface and lysimeters 3A and 3B during September. The reasons for the relatively low soil moisture depletions in lysimeters 3A and 3B during September probably were due to the combined effects of somewhat high rainfall during late August and September and a slowing of the consumptive use rates in September as compared to July and August.

Water use measurements were taken throughout the summer approximately every two weeks (Table A1). Monthly water use rates for July through September are given in Table 2. Monthly rates were calculated by interpolating data from the measurements for the two-week periods. Some interpolation was required since actual measurements were taken on a two-week schedule and, thus, not on the first or last day of each month.

Evaporation Measurements

Class A evaporation pans with reservoirs were operated at Daniel and Merna with evaporation measurements taken on the same days that water use measurements were taken (Table A1). Monthly evaporation rates were calculated and are shown in Table 2 for July through September.

Climatic Measurements

Automated weather stations utilizing CR-21 microloggers by Campbell Scientific* of Logan, Utah were operated at Daniel and Merna. The stations recorded temperature, precipitation, wind, relative humidity, and solar radiation data. Weekly (Tables A2 and A3) and monthly (Table 3) averages or totals for each parameter were determined.

*The mention of brand names does not imply endorsement.

TABLE 2. MONTHLY MEASURED ET AND PAN EVAP FOR 1986*

LYSIMETER NUMBER	MONTH JUL	AUG	SEP	TOTALS FOR JUL-SEP
3A	3.83	4.34	2.35	10.52
3B	4.15	4.24	2.13	10.52
3C	3.43	4.39	2.01	9.83
3D	3.58	4.62	2.20	10.40
3E	3.61	1.59	1.57	6.77
3F	2.45	1.80	2.48	6.73
4A	5.15	4.83	2.80	12.78
4B	3.81	4.99	2.38	11.18
4C	5.56	4 77	2.34	12.67
4D	5.45	4.58	2.40	12.43
MERNA PAN	5.72	7.06	4.03	16.81
DANIEL PAN	5.17	7.15	4.18	16.50

* All values are in inches.

TABLE 3. SUMMARY OF MONTHLY CLIMATIC DATA

STATION	MON	MAX TEM (F)	MIN TEM (F)	MAX RH (%)	MIN RH (%)	DEW PT (%)	SOLAR RADIN (LY/DY)	TOTAL PRECIP (IN/MO)	WIND RUN (MI/DY)	D/N WIND RATIO
MERNA	JUL	70	36	89	27	37	572	2.01	105	1.67
	AUG	75	38	87	22	36	527	1.73	100	1.52
	SEP	56	27	91	36	29	361	2.17	95	1.75
DANIEL	JUL	73	38	98	30	42	605	1.85	38	1.01
	AUG	79	37	96	21	39	564	1.57	55	0.84
	SEP	59	25	96	34	29	420	1.69	74	1.10

Chapter 3

RESULTS AND DISCUSSION

The influence of method of irrigation and depth of water table on consumptive use of mountain meadow vegetation was analyzed through comparing 1986 water use rates of subsurface irrigated lysimeters with 1986 rates from surface irrigated lysimeters, with 1984 and 1985 rates from surface irrigation with the same lysimeters, and with estimated water use rates based on 1986 climatic data. Operation of the lysimeters during 1984 and 1985 provided a historical water use pattern for each lysimeter under conditions of surface irrigation. During 1986, two of the mountain meadow lysimeters (4C and 4D located at Daniel) were operated with surface irrigation as during the previous two years. The remaining six mountain meadow lysimeters were subirrigated during 1986 (Table 1). Water table depths during 1986 averaged 19.5 inches for lysimeters 3A and 3B, 46 inches for lysimeters 3E and 3F, and 0 inches for lysimeters 3C and 3D.

As indicated in Table 1, the mountain meadow lysimeters were located in pairs consisting of 3A and 3B, 3C and 3D, 3E and 3F, and 4C and 4D. During 1984 and 1985, although all lysimeters were surface irrigated, irrigation was discontinued following harvest in one lysimeter for each set of two. Harvest usually occurred during the middle to latter parts of July. Thus, the 1984 and 1985 August and September data from the lysimeters for which irrigation was discontinued cannot be used in the analysis of the effects of subirrigation and/or water table depths. These lysimeters consisted of 3B, 3C, 3E, and 4D (Table 4).

Surface Irrigated Water Use Rates

Measurements indicate that the July through September mountain meadow water use rates during 1986 for the surface irrigated lysimeters were somewhat lower than the average of the 1984 and 1985 rates (Table 5). The 1986 water use rates were 86% to 88% of the 1984-1985 rates, depending on which lysimeters are used for the comparison. If only lysimeter 4C is considered, then the water use rates were 12.8 inches in 1986 compared to 14.9 inches for the previous two years. If the data from both lysimeters 4C and 4D are considered for 1986, then the water use rates were 13.1 inches in 1986 compared to the 14.9 inches for the previous two years.

The lower 1986 water use rates are confirmed by considering July through September pan evaporation rates which in 1986 were about 90% (16.7 inches versus 18.6 inches) of the 1984-1985

Table 4. MEASURED ET AND PAN EVAPORATION FOR 84-86*

LYSIMETER NUMBER	YEAR	MONTH JUL	AUG	SEP
3A	1984	7.32	8.38	--
	1985	5.97	5.67	2.05
	1986	3.69	4.18	2.44
3B	1984	7.48	--	--
	1985	6.22	--	--
	1986	4.42	4.52	2.27
3C	1984	4.94	--	--
	1985	4.96	--	--
	1986	3.45	4.42	2.02
3D	1984	5.34	4.18	4.04
	1985	6.50	3.47	2.73
	1986	3.57	4.61	2.19
3E	1984	5.26	--	--
	1985	6.48	--	--
	1986	3.46	1.52	1.50
3F	1984	5.92	4.96	2.02
	1985	7.11	4.50	2.01
	1986	2.57	1.89	2.61
4B	1984	5.96	5.08	4.91
	1985	5.39	5.94	3.33
	1986	3.87	5.07	2.42
4C	1984	7.12	5.58	4.21
	1985	8.59	5.40	3.17
	1986	5.62	4.82	2.36
4D	1984	6.89	--	--
	1985	6.84	--	--
	1986	5.85	4.92	2.58
MERNA	1984	7.37	5.45	5.04
PAN	1985	7.17	6.79	4.17
EVAP.	1986	5.72	7.06	4.03
DANIEL	1984	7.86	6.84	4.72
PAN	1895	6.58	7.50	5.14
EVAP.	1986	5.17	7.15	4.18

* All ET and evaporation values are in inches.

evaporation rates when the pans at both Daniel and Merna are considered. If only the pan at Daniel (which is the location of the 4C and 4D lysimeters) is considered, then the 1986 pan evaporation was about 85% (16.5 inches versus 19.3 inches) of the 1984-1985 average pan evaporation. In addition, the July through September 1986 water use rate of alta fescue was about 75% (11.4 inches versus 15.3 inches) of the 1984-1985 alta fescue water use rate. Finally, the July through September 1986 estimated mountain meadow water use rate at Daniel was 13.8 inches when using the ASCE Penman equation with crop cofficients calibrated based on 1984-1985 data. This value was about 8% higher than the measured value of 12.8 inches for 1986 and about 9% lower than the 1984-1985 measured value of 14.9 inches for lysimeter 4C.

Measurements from 1984-1985 indicate that the lysimeters, when surface irrigated, did not have identical water use rates (Table 5). Reasons for differences in rates may include differences in the sites as well as differences in vegetation composition in the lysimeters. For example, elevations ranged from 7200 ft at Daniel to 7800 ft at Merna while vegetation composition has been documented by Pochop and Burman (1987). These differences in water use patterns between lysimeters need to be considered when analyzing the effect of subsurface irrigation and/or water table depth on water use rates.

Influence of Subsurface Irrigation

Measured 1986 mountain meadow water use rates for July through September indicate that the surface irrigated lysimeters 4C and 4D had greater water use rates than the subsurface irrigated lysimeters, including lysimeters 3C and 3D which had water tables maintained at the soil surface (Table 6). The data in Table 6 indicates little difference in results whether only the lysimeters which were irrigated throughout the entire growing season in previous years are considered or if both lysimeters of each pair for a given water table depth are considered. However, as pointed out in the previous section, the influence of subsurface irrigation cannot be determined by considering only the absolute values of the 1986 water use rates as shown in Table 6 since the previous water use patterns of the lysimeters were not identical. The changes from previous years' rates must be considered.

Comparison of 1986 water use rates with 1984-1985 water use rates for lysimeters 3A, 3D, 3F, and 4C show that the surface irrigated lysimeter 4C had a 14% lower (12.8 inches versus 14.9 inches) water use rate in 1986 (Tables 5 and 6). The subsurface irrigated lysimeters all had greater decreases in water use rates in 1986 as compared to 1984-1985 when each were surface irrigated. Lysimeter 3D which had the water table maintained at the surface

TABLE 5. ACCUMULATED WATER USE FOR PANS AND SFC IRRIG LYSIMETERS*

	LYSIMETERS 1984-85				LYSIMETERS 1986		PANS 1984-85		PANS 1986	
MON	3A	3D	3F	4C	4C	4C & 4D	DANIEL	MERNA	DANIEL	MERNA
JUL	6.6	5.9	6.5	7.1	5.6	5.7	7.2	7.3	5.2	5.7
AUG	13.7	9.7	11.3	12.2	10.4	10.6	14.4	13.4	12.3	12.8
SEP	15.7	13.1	13.3	14.9	12.8	13.1	19.3	18.0	16.5	16.8

* All values are in inches.

TABLE 6. ACCUMULATED 1986 WATER USE RATES*

	LYSIMETERS							
MONTH	3A	3D	3F	4C	3A & 3B	3C & 3D	3E & 3F	4C & 4D
JUL	3.7	3.6	2.6	5.6	4.1	3.5	3.0	5.7
AUG	7.9	8.2	4.5	10.4	8.4	8.0	4.8	10.6
SEP	10.3	10.4	7.1	12.8	10.7	10.1	6.8	13.1

* All values are in inches.

during 1986 had a 21% lower (10.4 inches versus 13.1 inches) water use rate in 1986 as compared to previous years when surface irrigated. Lysimeter 3A which was subsurface irrigated and had an average water table depth of 21.5 inches during 1986 had a 34% lower (10.3 inches versus 15.7 inches) water use rate in 1986 as compared to 1984-1985 when surface irrigated. Lysimeter 3F which was subsurface irrigated and had an average water table depth of 45.0 inches during 1986 had a 47% lower (7.1 inches versus 13.3 inches) water use rate in 1986 as compared to previous years when surface irrigated. Very similar results are observed when considering the data from the pairs of lysimeters as shown in Table 6.

The results presented in the previous paragraph indicate that subsurface irrigation as compared to surface irrigation gave water use rates that were 7%, 20%, and 33% lower for water table depths that were 0.0 inches, 19.5 inches, and 45.0 inches, respectively. These results are for mountain meadow vegetation during the first year of subsurface irrigation following a series of years during which surface irrigation was practiced. The results should not be taken as an indication of long-term water use differences that might occur due to dry-up of formerly irrigated mountain meadows. Long-term vegetative changes may occur that could greatly influence the water use rates of subsurface irrigated vegetation. The results are, however, important as an indication of the differences in water use rates that might be measured under various operational procedures for water balance lysimeters. In most instances, for mountain meadow vegetation maximum water use rates appear to be achieved with surface irrigation and an intermediate depth water table.

Chapter 4

SUMMARY

The primary purpose of this study was to investigate the influence of method of irrigation and depth of water table on consumptive use of mountain meadow vegetation. The study was conducted in the Upper Green River Basin of Wyoming using water balance lysimeters located along Horse Creek between Daniel and Merna. The study made use of existing lysimeters which had been operated during previous years and which provided a documented history of water use for each lysimeter under conditions of surface irrigation.

July through September measured water use rates of mountain meadow vegetation were from 7% to 33% lower for subsurface irrigated lysimeters as compared to surface irrigated lysimeters. The 33% value was for subsurface irrigation with a water table depth of 45.0 inches while the 7% value was obtained for a surface water table. The measured water use rate for subsurface irrigation with a 19.5 inch water table depth was 20% lower than water use rate under surface irrigation.

Since the current study was conducted only for a single growing season and with a limited number of lysimeters, inadequate replications were available to permit statistical analysis of the results. However, all results were consistent with respect to decreased water use rates with increasing water table depths and with increasing soil moisture depletion levels in the soil profile above the water tables.

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TABLE A1. MEASURED ET AND PAN EVAPORATION FOR 1986*

LYS OR PAN	6/19	7/03	7/17	7/31	8/14	8/28**	9/13	9/27**	10/8
3A	2.42	1.41	1.67	1.67	1.84	2.00	1.40	1.10	0.77
3B	3.76	2.57	1.99	1.90	1.93	2.28	1.34	1.37	--
3C	3.00	1.76	1.65	1.41	1.67	2.42	1.35	0.97	0.30
3D	2.18	1.62	1.54	1.67	1.78	2.42	1.64	0.95	0.58
3E	4.79	1.25	1.43	1.81	0.48	0.66	1.24	0.54	0.52
3F	3.82	0.63	1.07	1.36	0.82	0.53	1.81	1.40	--
4B	4.48	2.19	2.05	1.34	2.19	2.33	1.82	1.06	0.67
4C	7.08	2.07	3.25	1.92	2.05	2.19	1.86	0.98	0.35
4D	5.41	3.21	2.10	3.13	1.91	2.42	1.90	1.31	0.54
PANS									
MER	5.79	3.35	3.22	1.77	3.18	3.18	2.78	1.76	--
DAN	5.79	3.18	2.87	1.61	3.15	2.73	3.78	1.65	0.83

* Depths are in inches.
** For lysimeters 4A-4D the dates are 8/27 and 9/26.

TABLE A2. WEEKLY AVERAGES OF CLIMATIC DATA FOR DANIEL

MO	DY	YR	MAX TEMP (F)	MIN TEMP (F)	MAX RH (%)	MIN RH (%)	DEW PT (F)	SOLAR RADIN (LY/DY)	TOTAL PRECIP (IN/WK)	WIND RUN (MI/DY)	D/N WIND RATIO
6	07	86	70.7	42.9	88	24	40.6	624	0.04	111	0.9
6	14	86	69.4	38.7	96	30	40.3	673	0.51	108	1.0
6	21	86	74.4	38.1	98	21	38.5	747	0.00	71	1.1
6	28	86	80.5	39.3	96	18	39.8	712	0.00	44	0.8
7	05	86	74.8	37.8	97	23	38.1	706	0.12	36	0.9
7	12	86	69.3	37.1	98	35	40.8	619	0.43	34	1.1
7	19	86	74.8	38.9	98	31	43.5	606	0.63	33	1.2
7	26	86	72.5	40.6	97	36	44.6	496	0.63	34	0.9
8	02	86	77.2	34.2	98	20	38.9	685	0.04	58	0.8
8	09	86	78.8	35.5	97	18	38.9	587	0.16	59	0.7
8	16	86	79.9	33.4	97	14	34.6	634	0.00	55	0.8
8	23	86	78.2	40.6	94	25	40.8	493	0.83	55	1.0
8	30	86	76.5	39.0	96	30	44.9	457	0.59	44	0.9
9	6	86	70.0	30.0	97	25	35.6	559	0.00	63	0.8
9	13	86	64.2	28.4	96	33	33.2	449	0.87	77	1.2
9	20	86	61.2	27.2	96	25	28.6	435	0.00	68	1.0
9	27	86	50.7	20.9	96	41	23.5	302	0.55	87	1.4
10	04	86	44.1	20.3	97	54	25.5	312	0.79	92	1.5

TABLE A3. WEEKLY AVERAGES OF CLIMATIC DATA FOR MERNA

MO	DY	YR	MAX TEMP (F)	MIN TEMP (F)	MAX RH (%)	MIN RH (%)	DEW PT (F)	SOLAR RADIN (LY/DY)	TOTAL PRECIP (IN/WK)	WIND RUN (MI/DY)	D/N WIND RATIO
6	07	86	72.9	36.5	92	17	35.2	686	0.00	122	1.4
6	14	86	66.8	33.6	93	28	35.8	591	0.39	108	1.5
6	21	86	72.3	35.9	88	18	32.5	681	0.04	112	1.5
6	28	86	78.2	38.2	84	13	33.3	661	0.04	98	1.3
7	05	86	72.9	35.5	83	16	29.1	692	0.00	121	1.7
7	12	86	66.6	34.1	91	29	35.3	583	0.39	112	1.6
7	19	86	72.1	37.9	90	28	39.1	552	0.98	100	1.6
7	26	86	67.8	39.1	92	40	41.5	463	0.55	89	1.7
8	02	86	72.7	34.7	90	18	34.1	647	0.08	105	1.7
8	09	86	76.4	37.6	86	17	34.6	544	0.04	106	1.5
8	16	86	75.8	36.0	86	14	31.6	587	0.00	105	1.6
8	23	86	73.8	40.4	87	28	38.1	451	1.18	101	1.6
8	30	86	73.8	37.4	91	34	42.7	473	0.35	84	1.4
9	6	86	66.5	32.3	91	28	34.9	484	0.16	107	1.8
9	13	86	59.8	30.2	91	37	33.4	391	0.71	96	1.8
9	20	86	56.9	28.3	91	29	28.5	323	0.20	96	1.6
9	27	86	49.2	23.2	89	40	23.0	315	1.02	86	1.7

TABLE A4. WATER TABLE DEPTHS*

LYS.	7/03	7/17	7/31	8/14	8/28**	9/13	9/27**	10/8
	DATE							
3A	21.3	21.5	21.5	21.5	21.5	21.5	21.5	21.5
3B	17.5	17.5	17.5	17.5	17.5	15.5	1.5	1.3
3C	22.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3D	20.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2
3E	46.3	46.3	46.3	46.3	46.3	46.8	47.0	47.5
3F	43.8	43.8	43.8	43.8	43.8	46.3	46.3	46.1
4A	49.5	37.5	32.6	36.0	37.5	38.5	34.5	31.7
4B	38.5	33.5	37.4	39.5	42.5	42.0	36.6	35.6
4C	37.8	36.4	32.5	34.0	34.3	36.0	31.8	29.8
4D	43.0	32.5	36.5	35.0	36.0	38.5	33.6	30.9

* All depths are given in inches.
** For lysimeters 4A-4D dates are 8/27 and 9/26.

TABLE A5. AVERAGE MONTHLY SOIL MOISTURE DEPLETION*

LYSIMITER	MAY	JUNE	JULY	AUG	SEPT
3A	15	17	28	28	13
3B	11	25	41	37	12
3C	8	33	2	0	0
3D	9	2	0	0	0
3E	10	29	54	51	45
3F	8	28	48	48	48
4A	9	20	15	14	19
4B	8	17	16	17	16
4C	9	26	23	23	22
4D	11	20	17	20	18

* All readings are percent depletion of available water.