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SPRAY LOSSES AND PARTITIONING OF WATER UNDER A CENTER PIVOT SPRINKLER SYSTEM

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SUMMARY:
Spray losses and partitioning of water in a corn (*Zea mays* L.) canopy were analyzed under a center pivot sprinkler system. Spray losses (averaging 12% in 1980 and 16% in 1981) were correlated with vapor pressure deficit, a vapor pressure deficit-windspeed term, and temperature. We found 2.7 mm of canopy storage in full canopy corn.

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1.0 INTRODUCTION

Center pivot sprinklers are an important irrigation system in the Great Plains region of the United States. Several thousand systems have been installed since the early 1950's because irrigators feel they offered improved efficiencies over existing surface irrigation methods, lower labor requirements, and greater management flexibility. The development of center pivot systems opened up new areas to irrigation, allowing development in regions which have soil types and topographies unsuitable for surface irrigation methods. However, sprinkler irrigation systems are more capital and energy intensive than surface systems; the rapid increase in energy costs and interest rates are causing irrigators and researchers to examine the efficiencies of center pivot systems closely.

A project was initiated to examine the efficiency of a center pivot system operating under conditions of high wind, temperature, and vapor pressure deficit which are common in the southern Great Plains. Data which we present include spray losses and partitioning of water within the canopy of a corn (*Zea mays* L.) crop.

2.0 MATERIALS AND METHODS

Data were collected at the Garden City Experiment Station in southwestern Kansas in 1980 and 1981. The fields were located on a Ulysses fine sandy loam soil (a fine-silty, mixed, mesic, Aridic Haplustoll). Our measurements were made under a center pivot sprinkler system (Zimmatic* electric drive) which is about 400 m long and irrigates about 55 hectares of land. The system is nozzled with Senniger* low angle nozzles which spray at a pressure of 379 kPa (55 psi) at the pivot. The field was planted with Pioneer* 3183 corn on 22 May 1980 and with Pioneer 3194 corn on 23 May 1981. Plant populations were 53,000 and 44,000 plants per hectare in 1980 and 1981, respectively.

Water reaching the top of the canopy was caught in plastic rain gauges with 37 cm^2 openings, which were graduated to about 0.25 mm (.01 in.). Water falling through to the soil surface was caught in plastic rain gauges with 20 cm^2 openings, which were graduated to the nearest 1.27 mm (0.05 in.). A light mechanical oil was used for evaporation suppression. Stable repeated readings from the rain gauges over a period of a few days indicated that the oil prevented evaporation from the rain gauges. The rain gauges were deep enough to eliminate splash errors.

The field plot arrangements for 1980 and 1981 are shown in Figures 1 to 3. In 1980, we located 20 rain gauges along an arc in the southeast quadrant of the field, at 170 m radius from the pivot point, to determine the amount of water reaching the top of the canopy. In 1981, we used 12 rain gauges at each of three sites to determine the amount of water reaching the top of the

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*Inclusion of trade name is for information purposes only and does not constitute an endorsement by Kansas State University or USDA-ARS.

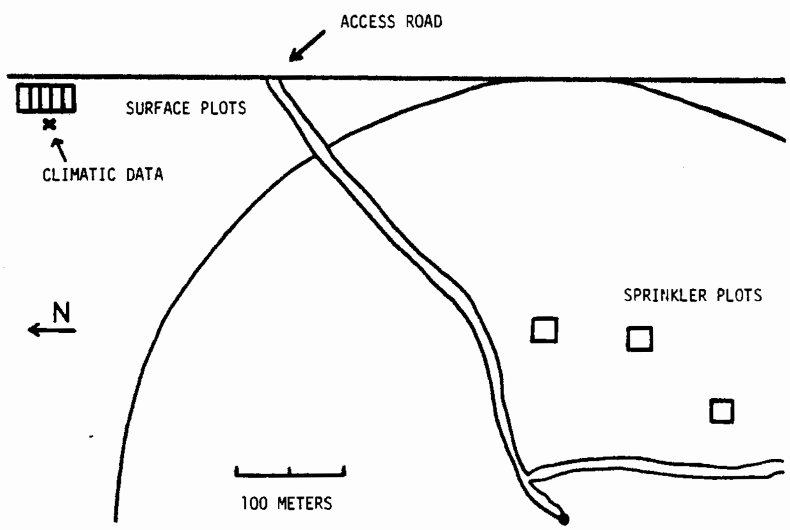

Figure 1. Surface and sprinkler irrigated plots. Garden City, Kansas. 1980 and 1981.

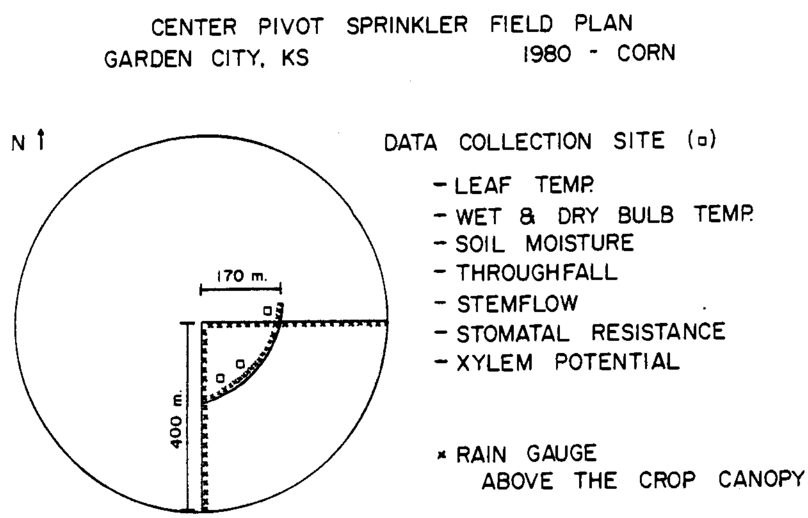

Figure 2. Orientation of the data collection sites on the sprinkler irrigated field. Garden City, Kansas. 1980.

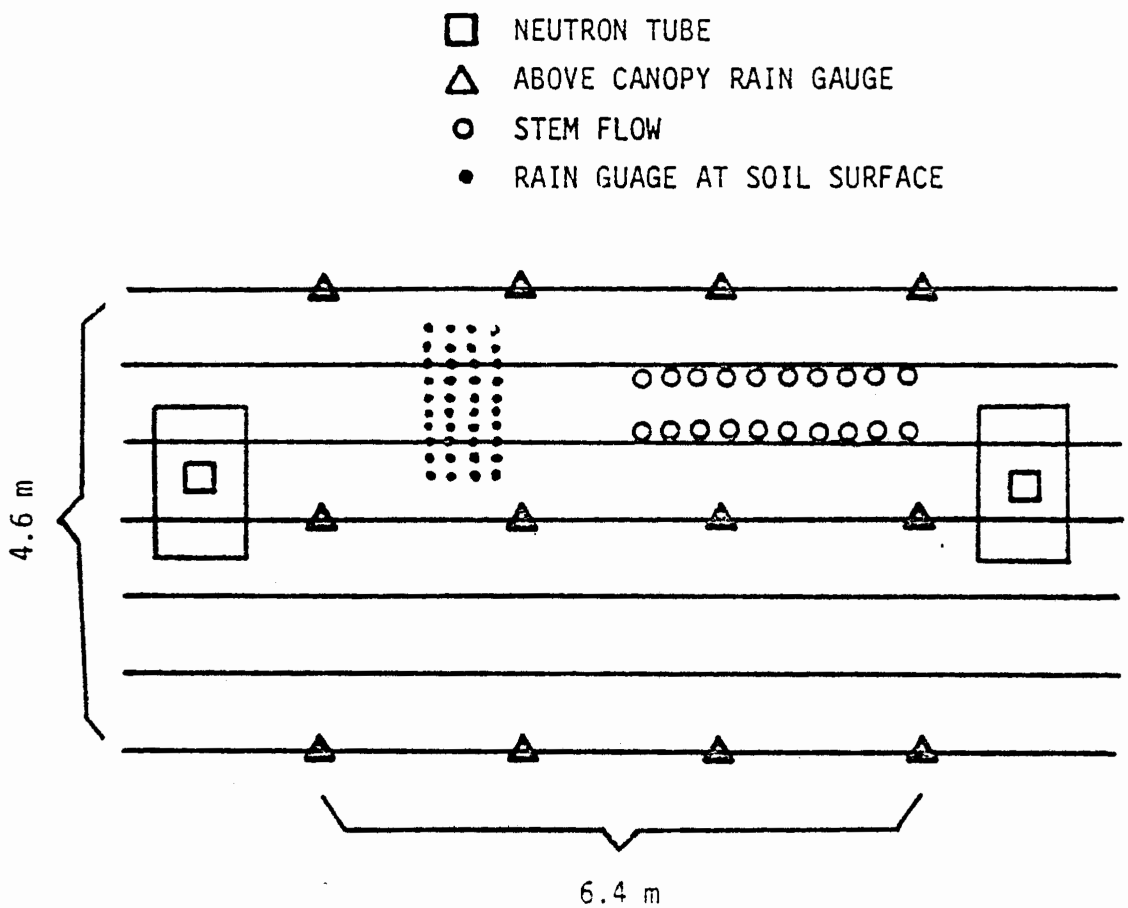

Figure 3. Rain gauge network on the sprinkler plots. Garden City, Kansas. 1981.

canopy. The rain gauges were mounted on iron rods that were raised as the corn grew, to keep the rain gauges near the top of the canopy. In 1980 and 1981, throughfall was measured at three sites in the field in 1.1 m^2 networks of 40 rain gauges arranged at the soil surface, spanning two rows of crop from mid-row to mid-row. All measurements of the partitioning of sprinkled water were made midway between two towers of the center pivot system.

Stemflow was measured using acetate catchment funnels which were sealed around the cornstalk with silicon and wire. The captured water ran through tubing to 3.8 L holding bottles for later measurement (Figure 4). The catchment devices extended only a few cm beyond the diameter of the cornstalk to minimize the capture of water falling through the corn canopy. One or two leaves were removed from the lower part of the plant to expose a smooth stalk surface before sealing the funnels to the stalks. We measured stemflow at three locations in the field on 20 plants--10 adjacent plants in two adjacent rows. Conversion of captured water volume to depth of catch was based on the soil area occupied by the 20 plants at the given location of measurement.

The application rate was determined by measuring the flow rate of water at the center of the pivot and the rate of travel of the irrigation system at a known radius. The depth of water applied, D, is calculated as:

$$D = QR^{-1}A^{-1} = \frac{\text{volume } H_2O}{\text{time}} \times \frac{\text{time}}{\text{distance}} \times \frac{\text{distance}}{\text{area}} = \frac{\text{volume } H_2O}{\text{area}} \qquad [1]$$

where Q is flow rate (m^3 h^{-1}), R is the rate of movement of the pivot (m h^{-1}) and A is the area of the field watered per unit distance travelled (m^2 m^{-1}). The water meter used to measure flow rate was calibrated at the Conservation and Production Research Laboratory at Bushland, Texas.

The percent spray loss, L, was calculated as the difference between the depth of water applied, D, and the depth of water caught in the rain gauges at the top of the canopy, D_n, divided by the depth of water applied.

$$L = \frac{D - D_n}{D} \times 100 \qquad [2]$$

Plant interception of water, I_p, is calculated as the net depth of water applied minus throughfall (T), and stemflow (S), and evaporation within the canopy during sprinking (E_c).

$$I_p = D_n - T - S - E_c \qquad [3]$$

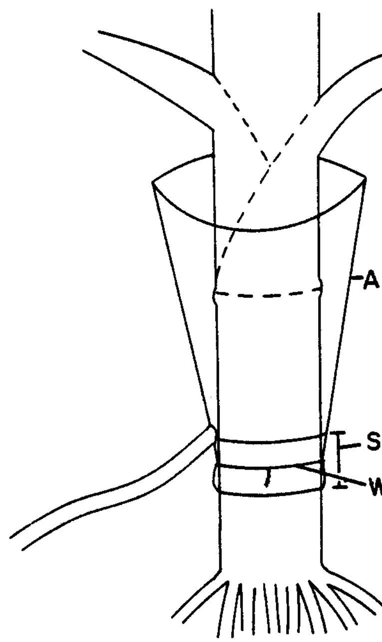

Figure 4. Stemflow catchment funnel attached to a corn stalk. Garden City, Kansas. 1980 and 1981.

E_c was assumed to be negligible. Norman and Campbell (1982) suggests that evaporation from plant surfaces during sprinkling might constitute a large portion of the total plant interception losses, under high evaporative conditions. Separation of I_p and E_c is not possible with our data.

Windspeed and wind direction at a 2 m height, ambient wet and dry bulb temperature at 1.5 m, and solar radiation were measured near the research plot over an uncropped surface as shown in Figure 2, at 30-min intervals. Windspeed, wind direction, and solar radiation measurements were integrated over the scanning period. Similar data, collected about 2 km from our plots at the Garden City Experiment Station at 60-min intervals, were used, as necessary, to replace missing values in our 1981 climatic data set.

3.0 RESULTS AND DISCUSSION

3.1 Spray Losses

Table 1 and 2 summarize the water balance under a center pivot sprinkler system for 1980 and 1981. An average of about 85% of pumped water was intercepted at the top of the canopy, but the amount at different times of pumping varies considerably. Small differences in the 1980 and 1981 results may be attributed to different arrangements of rain gauges in the two years. In our experiment, no separation of droplet evaporation and wind drift is possible. A spray loss of 15% is consistent with values which Clark and Finley (1975) measured in fixed nozzle measurements.

Evaporation of spray droplets will depend upon climatic conditions at the time of pumping. Clark and Finley (1975) found that evaporation losses are related most strongly to windspeed when windspeeds exceeded 4.5 m s^{-1} and to vapor pressure deficit and windspeed at lower windspeeds. In Arizona, Frost and Schwalen (1955) found that spray losses are related primarily to vapor pressure deficit in measurements made at relatively low windspeeds.

There are very few data reporting spray loss amounts from center pivot systems, particularly relating spray losses to climatic conditions at the time of pumping. Our data provides illustration of some of the difficulties involved in attempting such a determination. Table 3 lists spray losses in 1981 and climatic conditions at the time of pumping. The correlation of spray loss to the various climatic variables is given in Table 4. Our data show correlation between spray loss and vapor pressure deficit, temperature, and a term combining vapor pressure deficit with windspeed, at the 1, 2, and 3% level of significance. However, we can explain only one-fourth of the variability in our data with correlation to a climatic factor. Since all of our significant correlations involve related climatic variables, a multiple variable model does not improve our ability to predict spray loss.

A great deal of the variability in our data can be explained by the difficulty of precisely determining the application rate at a specific area of the field. We measured the flow rate into the entire center pivot system, rather than to a particular nozzle or set of nozzles, and thus have an average application rate for the field. No center pivot system applies water

Table 1. Pumped water (D), net irrigation (D_n), and partitioning of water within the corn canopy under center pivot irrigation. Garden City, Kansas. 1980.

Date	Water Pumped	Top of Canopy		Throughfall		Stem Flow		Plant Interception
	— mm —	mm	%†	mm	%‡	mm	%‡	---- mm ----
7/2/80	--	21.3	--	19.3	90			
7/7	--	26.4	--	16.3	62			
7/14	34.4	27.4	79.7	12.2	44			
7/22	35.1	27.9	79.5	--	--			
7/27	32.6	32.2	98.8	12.3	38			
7/30	32.8	28.7	87.5	13.2	46			
8/1	32.4	26.7	82.4	11.7	44			
8/6	31.5	26.5	84.1	10.7	40			
8/11	31.1	27.2	87.5	14.7	52	11.7	43	1.3
8/20	31.0	32.0	103.2	13.5	42	12.2	38	6.3
9/5	--	28.9	--	16.5	58	11.7	41	0.5
Mean	32.6		87.8		52		41	2.7

†% of pumped water.
‡% of water reaching the top of the canopy.

Table 2. Pumped water (D), net irrigation (D_n), and partitioning of water within the corn canopy under center pivot irrigation. Garden City, Kansas. 1981.

Date	Plot	Time	Pumped	Top of Canopy		Spray Loss		Throughfall		Stem Flow		Plant Interception
			— mm —	mm	%†	mm	%†	mm	%‡	mm	%‡	---- mm ----
6/26/81	A	18:30	23.6	14.5	61.3	9.1	38.7	11.9	82.3			
	B	10:00	23.6	18.3	77.5	5.3	22.5	18.0	98.5			
	C	3:00	21.9	20.5	93.6	1.4	6.4	22.6	103.2			
7/1	A	20:30	34.7	29.5	84.9	5.2	15.1	30.4	103.3			
	B	6:30	34.7	29.7	85.6	5.0	14.4	20.8	70.1			
	C	16:30	35.9	32.8	91.3	3.1	8.7	21.6	65.8			
7/3	A		rain	23.1				19.6	84.7			
	B			23.6				19.1	80.7			
	C			23.6				21.6	91.5			
7/8	A		rain	2.0				1.0				
	B			2.0				0.8				
	C			2.3				1.3				
7/9	A	17:00	35.8	27.9	78.0	7.9	22.0	17.3	48.2			
	B	2:30	35.8	31.2	87.3	4.6	12.7	12.4	34.8			
	C	13:00	35.8	34.8	97.2	1.0	2.8	16.0	46.0			
7/17	A	4:00	34.8	28.7	82.5	6.1	17.5	16.8	58.4			
	B	13:00	34.8	27.2	78.1	7.6	21.9	--				
	C	23:00	34.8	26.2	75.2	8.6	24.8	--				
7/22§	A	22:45	34.8	26.2	75.2	8.6	24.8	14.5	55.3	--		--
	B	8:45	34.8	36.1	103.6	-1.3	-3.6	20.1	55.6	12.7	35.2	3.3
	C	18:45	34.8	24.6	70.8	10.2	29.2	11.4	46.5	11.4	46.5	1.7

Table 2. Continued.

Date	Plot	Time	Pumped	Top of Canopy		Spray Loss		Throughfall		Stem Flow		Plant Interception
			— mm —	mm	%†	mm	%†	mm	%‡	mm	%‡	---- mm ----
7/27	A		rain	42.7				18.3	42.8	--		
	B			42.9				19.6	45.7	--		
	C			43.2				17.8	41.2	20.8	48.2	4.6
8/1	A		rain	19.1				7.4	38.6	10.7	55.9	1.0
	B			19.6				6.1	31.1	8.4	42.8	5.1
	C			19.3				7.6	39.5	10.9	56.6	0.8
8/4	A	14:45	35.0	29.0	82.7	6.0	17.3	15.0	51.7	15.5	53.4	-1.5
	B	4:45	35.2	32.3	91.6	2.9	8.4	9.7		10.9		--
8/3	C	18:45	35.2	28.5	80.8	6.8	19.2	12.1	42.8	12.4	43.5	4.0
8/7	A	14:45	31.5+††	31.5	83.8	5.1	16.2	16.8	53.2	12.4	39.5	2.3#
8/6	B	22:45	31.5	31.2	99.2	0.3	0.8	11.8	35.8	--		--
8/9	B		rain	5.1		--		1.3		--		
8/6	C	13:45	31.5+	25.6	65.3	10.9	34.7	10.2	40.0	16.5	64.0	
8/13	A	22:45	33.8	29.7	87.9	4.1	12.1	13.2	44.5	14.7	49.6	1.8
	B	12:45	34.3	30.2	88.0	4.1	12.0	9.7	32.0	13.5	44.6	7.0
	C	3:15	33.2+	35.6	94.3	1.9	5.7	14.0	39.2	15.0	42.1	6.6#
	A		rain	4.3				1.8	41.3	1.8	41.3	
	B			4.3				0.8		1.5		
Mean			33.0		84.0		16.0		43.2¶		46.8	2.7

†% of pumped water.
‡% of water reaching the top of the canopy.
§LAI = 3.0 on July 19.
¶Mean of data after full cover (LAI $\geq$ 3) was reached.
#Interception from two wetting events.
††'+' indicates that irrigation and rainfall readings are not separated in the rest of the table.

Table 3. Spray losses, windspeed (u), vapor pressure deficit (vpd), solar radiation (R_s), temperature (Temp.), and wind angle at the time of pumping. Garden City, Kansas. 1981.

Spray Loss	u	vpd	R_s	Temp.	Wind Angle
%	m s^{-1}	kPa	W m^{-2}	C	° from lateral
-3.6	2.25	0.40	426	21.5	31
0.8	0.51	0.24	0	19.4	66
2.8	7.78	2.02	705	31.8	65
5.7	4.34	0.08	0	19.4	10
6.1	3.98	0.46	0	21.7	32
8.4	2.12	0.33	0	21.4	51
8.7	5.29	1.11	35	29.1	61
12.0	5.52	1.08	768	27.4	84
12.1	3.16	0.33	0	22.1	27
12.7	3.45	0.63	0	21.7	51
14.4	3.60	0.14	0	20.9	1
15.1	3.41	1.23	0	25.2	30
16.2	2.86	1.84	544	27.9	2
17.5	1.77	0.31	0	20.2	3
19.2	1.58	0.96	14	27.5	32
19.2	5.16	1.97	740	33.1	19
21.9	2.58	2.64	859	32.2	81
22.0	4.19	2.14	551	31.1	41
22.5	6.19	2.47	77	31.9	90
24.8	4.89	0.33	0	20.3	85
24.8	2.76	0.48	0	23.6	70
29.2	2.04	0.85	14	25.2	28
34.7	3.47	1.20	803	28.1	9
38.7	7.73	3.49	35	35.5	76

Table 4. Correlation coefficients of spray losses and climatic conditions. (n=24). Garden City, Kansas. 1981.

		Spray Loss	u	e^u	$\sqrt{u}$	vpd$\sqrt{u}$	vpd	Temp.	R_s	Angle
Spray Loss	$r_{x,y}$:	1.00	0.19	0.14	0.21	0.45	0.49	0.47	0.08	-0.02
	p:	0.00	0.37	0.52	0.30	0.03	0.01	0.02	0.73	0.94
u			1.00	0.75	0.98	0.73	0.57	0.60	0.24	0.32
			0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.13
e^u				1.00	0.66	0.74	0.59	0.54	0.15	0.27
				0.00	0.00	0.00	0.00	0.01	0.47	0.19
$\sqrt{u}$					1.00	0.68	0.54	0.57	0.25	0.25
					0.00	0.00	0.01	0.00	0.23	0.24
vpd$\sqrt{u}$						1.00	0.96	0.91	0.38	0.34
						0.00	0.00	0.00	0.06	0.11
vpd							1.00	0.94	0.49	0.28
							0.00	0.00	0.02	0.19
Temp.								1.00	0.57	0.24
								0.00	0.00	0.26
R_s									1.00	0.07
									0.00	0.75
Angle										1.00
										0.00

uniformly across the entire field. As one moves from the center of the system outward, each nozzle (spaced evenly along the lateral) irrigates an increasing acreage and the nozzle output increases correspondingly. Depending upon the orientation of the wind direction to the pivot, a given parcel of land can receive water from either higher or lower output nozzles than normally would spray that area.

In addition, if the wind is blowing parallel to the lateral, the effects of ambient climatic conditions on spray losses will be minimized since the air mass moving over our measurement site will have been cooled and humidified while moving over the sprinkler system (Figure 5). We hypothesize four situations which could occur during the measurement periods, as shown in Table 5. With a parallel wind, conditions at the collection site are similar (low vapor pressure deficit, cool temperatures) regardless of the ambient evaporative conditions. The only time that maximal spray losses would be observed is during a cross wind and high evaporative conditions.

Some data points which help to illustrate this interaction are shown in Table 5b. Three measurements taken with winds parallel to the lateral indicate very similar spray losses, even though climatic conditions at the time of pumping were quite different. Measurements taken with the wind blowing across the lateral show a response to ambient conditions, with high losses measured under high evaporative conditions and low losses measured under low evaporative conditions.

Tables 6 and 7 show the correlation of spray loss to climatic variables when the data set is divided into periods with parallel and cross winds. With a parallel wind (angle $\leq 20^{o}$), we found no significant correlation of windspeed, vapor pressure deficit or temperature to spray losses. A correlation of 0.73 between spray loss and solar radiation, significant at the 10% level, might be due to the correlation between solar radiation and vapor pressure deficit and temperature or it might be coincidental. With wind blowing across the system (angle $\geq 45^{o}$), the correlation of spray loss with vapor pressure deficit and with the wind-vapor pressure deficit term was slightly higher than the correlation found in the complete data set, though the significance levels dropped with the smaller data set.

Given the influence of wind angle on the measured spray loss and of wind angle and windspeed on wind drift of droplets, it will be difficult to make measurements to determine accurately the spray losses at any given time for the whole field. Perhaps a better way to determine patterns of spray loss for the entire system will be to model the complex interactions of climatic conditions, nozzle output, wind direction, and other factors using solid set spray evaporation measurements and detailed information about the design of a specific center pivot system.

3.2 Partitioning of Water within the Canopy

Throughfall of water to the soil surface was measured throughout the irrigation season. The proportion of water reaching the canopy which falls through to the surface is very high early in the season and declines as the plant canopy develops.

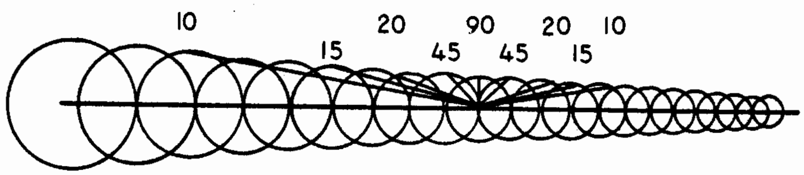

Figure 5. Relative distance that an air mass travels over a center pivot spray pattern at various angles between the wind and lateral directions.

Table 5a. Interaction of wind orientation and evaporative conditions, relative to spray loss measurement.

Wind Orientation	Evaporative Conditions	Effect of Climatic Conditions on Spray Loss
Cross	high	maximal losses
	low	minimal losses
Parallel	high	minimal losses
	low	minimal losses

Table 5b. Illustration of the interaction of wind orientation and evaporative conditions, relative to spray loss measurement.

Wind Orientation	Evaporative Conditions			Spray Loss
	u	vpd	T	
° from lateral	m s^{-1}	kPa	C	%
90 (cross)	6.19	2.47	31.9	22.5
84	5.52	1.08	27.4	12.0
66	0.51	0.24	19.4	0.8
1 (parallel)	3.60	0.14	20.9	14.4
2	2.86	1.84	27.9	16.2
3	1.77	0.31	20.2	17.5

Table 6. Correlation coefficients of spray loss and climatic conditions with the wind blowing parallel to the lateral (angle $\leq 20^{o}$, n=6). Garden City, Kansas. 1981

		Spray Loss	u	e^u	$\sqrt{u}$	vpd$\sqrt{u}$	vpd	Temp.	R_s	Angle
Spray Loss	$r_{x,y}$:	1.00	-0.13	-0.11	-0.11	0.41	0.43	0.54	0.73	0.13
	p:	0.00	0.81	0.82	0.82	0.42	0.38	0.27	0.10	0.80
u			1.00	0.89	0.99	0.43	0.28	0.45	0.34	0.80
			0.00	0.02	0.00	0.39	0.59	0.37	0.50	0.05
e^u				1.00	0.84	0.58	0.41	0.56	0.37	0.91
				0.00	0.03	0.23	0.41	0.24	0.47	0.01
$\sqrt{u}$					1.00	0.43	0.27	0.44	0.35	0.75
					0.00	0.39	0.60	0.38	0.50	0.08
vpd$\sqrt{u}$						1.00	0.97	0.98	0.88	0.59
						0.00	0.00	0.00	0.02	0.21
vpd							1.00	0.95	0.89	0.44
							0.00	0.00	0.02	0.38
Temp.								1.00	0.94	0.61
								0.00	0.01	0.20
R_s									1.00	0.52
									0.00	0.28
Angle										1.00
										0.00

Table 7. Correlation coefficients of spray loss and climatic conditions with the wind blowing across the lateral (angle $\geq 45^o$, n=11). Garden City, Kansas. 1981.

		Spray Loss	u	e^u	$\sqrt{u}$	vpd$\sqrt{u}$	vpd	Temp.	R_s	Angle
Spray Loss	$r_{x,y}$:	1.00	0.33	0.20	0.39	0.52	0.53	0.41	-0.17	0.52
	p:	0.00	0.31	0.55	0.24	0.10	0.09	0.22	0.62	0.09
u			1.00	0.79	0.98	0.76	0.63	0.72	0.22	0.35
			0.00	0.00	0.00	0.00	0.04	0.01	0.51	0.29
e^u				1.00	0.69	0.80	0.66	0.66	0.22	0.07
				0.00	0.02	0.00	0.02	0.03	0.51	0.83
$\sqrt{u}$					1.00	0.71	0.60	0.69	0.23	0.34
					0.00	0.01	0.05	0.02	0.50	0.29
vpd$\sqrt{u}$						1.00	0.96	0.66	0.22	0.07
						0.00	0.00	0.03	0.52	0.82
vpd							1.00	0.95	0.38	0.44
							0.00	0.00	0.25	0.17
Temp.								1.00	0.47	0.40
								0.00	0.15	0.22
R_s									1.00	0.33
									0.00	0.32
Angle										1.00
										0.00

Measurement of stemflow and estimation of plant interception was made only under full canopy conditions, when LAI exceeded 3.0. Almost half of the water which reached the top of the canopy reached the surface by stemflow (Tables 1 and 2). The proportions of stemflow and throughfall were similar whether the water was applied as irrigation or as rainfall. The seasonal estimate of plant interception of water was 2.7 mm per wetting event in 1981. This is consistent with an average of 2.7 mm of plant intercepted water estimated from three irrigations in 1980. Plant intercepted water was determined by subtraction. Errors in measurement of water at the top of the canopy, throughfall or stemflow can introduce large errors in the estimate of plant interception. There are very few measurements of plant intercepted water for a corn crop reported in the literature. Our value is higher than values reported by Stoltenberg and Wilson (1950), which average 0.64 mm, but the authors used a weighing technique to determine plant interception which involved moving the plants. Additional water may be held on undisturbed plants. In addition, the authors were working with a smaller plant population than in our experiment. Rijtema (1965) reported a canopy storage of 1.8 mm in grass. Clark (1940) reported canopy storage capacities of 2.3, 1.8, 1.6, and 0.8 mm for big bluestem grass, clover, buffalo grass, and sudan grass, respectively. Seginor (1967) cited work which indicates interception of 2-4 mm for many crop canopies.

The canopy storage capacity of a corn crop depends on leaf area index; spacing of plants; and varietal characteristics, such as erectness and hairiness of leaves. The storage capacity of a canopy will be relatively constant under full canopy conditons, but the percentage of pumped water which is stored in the canopy depends on the amount of water which is applied with each irrigation.

3.3 Evaporation of Plant Intercepted Water

Many researchers have pointed out that evaporation of water from wetted leaves will suppress transpiration which would be occurring if the leaves had not been wetted. Monteith (1981) and Rutter (1975) describe a form of the Penman equation which expresses the rate of evaporation from wet foliage, E_{wet}, as a multiple of the evapotranspiration rate from dry foliage, E_{dry}, as follows

$$E_{wet} = \frac{s + \gamma (1 + r_c/r_a)}{s + \gamma} E_{dry} = 1 + (\frac{\gamma r_c/r_a}{s + \gamma}) E_{dry} \qquad [4]$$

where s is the slope of the saturation vapor pressure curve and γ is the psychrometric constant, and r_c and r_a are canopy and aerodynamic resistances, respectively. Since both s and γ are functions of temperature, the evaporation of plant intercepted water relative to evaporation from an unwetted canopy will be a function of temperature and of the ratio of canopy and aerodynamic resistances.

If the evaporation rate from an unwetted canopy is defined as being 100% efficient, then evaporation from a wetted canopy at a higher rate can be defined as inefficient. Any water which evaporates from a sprinkled canopy at a rate greater than that which would occur in an unwetted canopy can be defined as a net plant interception loss. Figure 6 shows the relative ET rates and seasonal losses for wet canopies under different temperature and resistance conditions. Sprinkling a well-watered, healthy, transpiring corn crop will have a minimal effect on ET rates, because r_c/r_a will be low (probably < 1.0), and little additional water will be lost compared to an unsprinkled crop. The warmer the temperature, the less the difference in ET from wetted and dry canopies. Sprinkling at night, when r_c is high and temperatures are low, results in evaporation rates which are much higher than from unwetted crops. While the rate of evaporation will be lower than daytime ET, the efficiency of the nighttime evaporation of intercepted water, where the dry canopy evaporation rate is defined as 100% efficient, will be quite low. Figure 6c shows the seasonal net interception losses which could result if all irrigation was applied under similar climatic conditions. Nighttime irrigation has often been recommended because it reduces spray losses, but adopting this practice could result in net plant interception losses as high as 5 to 6% of the pumped water. Only 1 or 2% of pumped water might be a net interception loss under daytime conditions.

Under a center pivot sprinkler system which is operating under a wide range of conditions, evaporation from wetted canopies might be very efficient during the day and inefficient at night. The seasonal plant interception losses will depend on the number of irrigations, the canopy cover at the time of irrigation, and the amount of water applied. The net seasonal losses of plant intercepted water in a corn crop would probably be about 2 to 4% of pumped water under conditions in our experiment, with pumping occurring day and night.

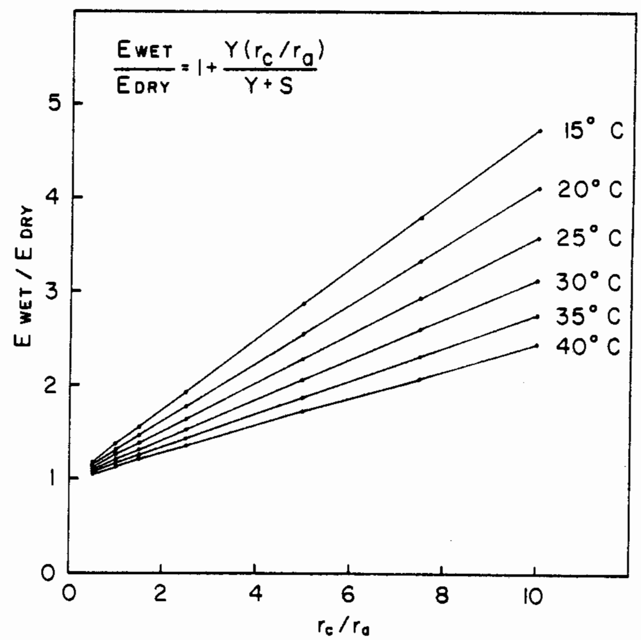

Figure 6a. Relative evaporation rates and seasonal losses of wetted and unwetted areas of a crop canopy. a) Evaporation from a wetted canopy as a multiple of the evaporation from a dry canopy. (after Rutter, 1975 and Monteith, 1981)

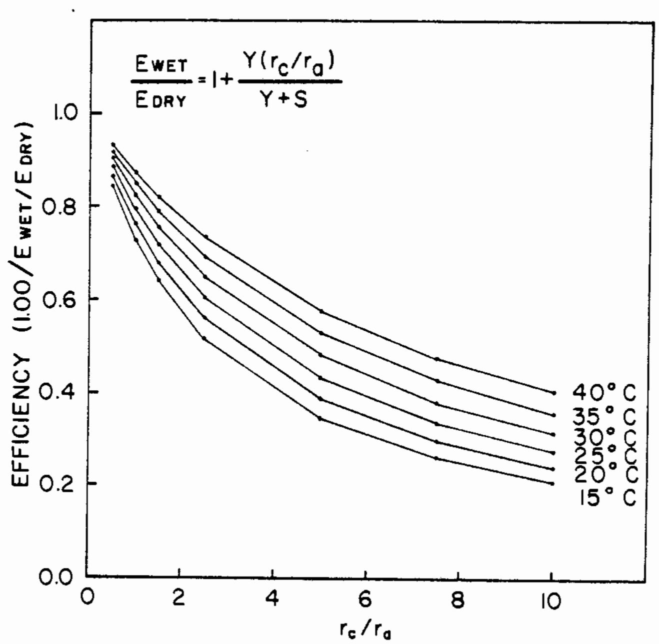

Figure 6b. Relative evaporation rates and seasonal losses of wetted and unwetted areas of a crop canopy. b) Efficiency of evaporation from a wetted portion of the canopy, assuming that evaporation from an unwetted portion of the canopy has an efficiency of 1.0.

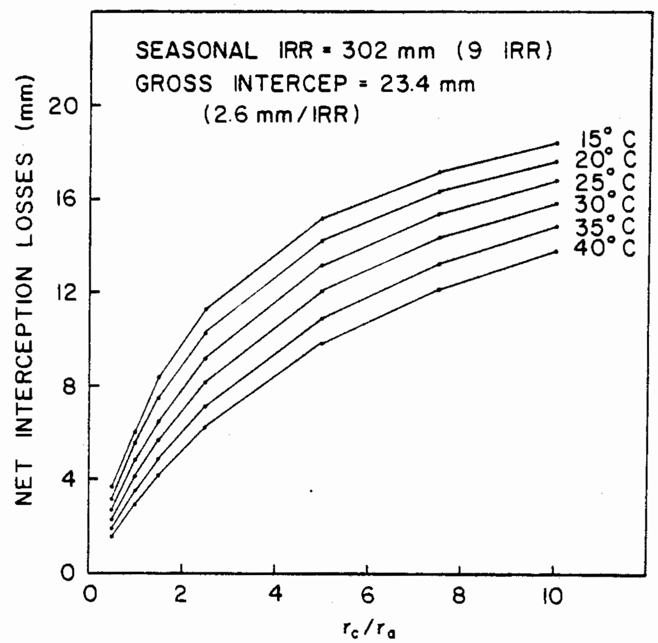

Figure 6c. Relative evaporation rates and seasonal losses of wetted and unwetted areas of a crop canopy. c) Seasonal interception losses from nine irrigations under constant temperature and resistance conditions. (after Rutter, 1975 and Monteith, 1981).

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