Spring Wheat and Water Use Relationships At Fargo, North Dakota - Six Year Summary

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Spring wheat was grown on precision weighing lysimeters at the Microclimate Research Station (MRS) of the North Dakota State University Agricultural Experiment Station at Fargo in 1981, 1982, 1985, 1986, 1987, and 1988. The use of these lysimeters along with hand harvesting provides an accurate measurement of evaportranspiration (ET) and grain yield. This research facility is described in more detail in Brun, Enz, and Larsen (1983).

The management systems used are described in Table 1. In addition each lysimeter was tilled (hand spading) in the fall and in the spring (hand spading and raking) at planting. Wheat was planted on the lysimeters by hand in 6-inch rows with one kernel every 0.75 inches which is equivalent to 1,393,920 kernels per acre. Phosphorus fertilizer was periodically broadcast in the spring to maintain soil test values at the high to very high level. Total weed control was accomplished by hand weeding and/or recommended chemical application.

Water related variables and yield data are listed in Table 2. Soil water content was measured by neutron attenuation with a volumetric water content of 20 percent used as the permanent wilting percentage (Brun et al, 1985). Table values indicate the available water in the 3 inch to 51 inch layer. Precipitation (P), irrigation (I), and ET were determined by weight changes on each lysimeter (recorded hourly). It is not unusual to observe precipitation differences of 10 percent between lysimeters spaced 50 feet apart in summer precipitation events.

Linear regression was used to examine various relationships among water variables and yield. These analyses, using all data points, are found in the following text. The same analyses deleting two data points (1987 NE, 1988 SE) are found in APPENDIX Table 1. These two points differ somewhat in response from the others when observed graphically and the results are presented for the interest of the reader.

The relationship between yield (Y) and growing season (GS) ET is illustrated in Figure 1 and described by the equation

$$Y = 5.77\,(GSET) - 34.5 \tag{1}$$

with a coefficient to determination (R^2) equal to 0.91. Figure 2 shows the relationship between Y and GSP plus I plus available soil water at planting (AWP) which is described by

$$Y = 3.86\,(GSP + I + AWP) - 12.8 \tag{2}$$

with R^2 equal to 0.85. While there is a strong relationship between Y and the dependent variables the slopes of the equations are different. A comparison of GSET and GSP plus I plus AWP resulted in the equation

$$GSET = 0.67\,(GSP + I + AWP) + 3.81 \tag{3}$$

with R^2 = 0.93. This relationship and regression line are shown in Figure 3.

Table 1. Management systems for wheat grown on lysimeters.

Year	Lysimeter	Variety	Management systems*
1981	NW	Ellar	a
	NE	Ellar	a
1982	SE	Ellar	a
	SW	Ellar	a
1985	NW	Marshall	a,d
	NE	Marshall	a,d
	SE	Marshall	a
	SW	Marshall	a
1986	NW	Marshall	a
	NE	Marshall	a
	SE	Marshall	a
	SW	Marshall	a
1987	NW	Marshall	b,c
	NE	Marshall	b,c,d
	SE	Marshall	a,d
	SW	Marshall	a
1988	NW	Marshall	a
	NE	Marshall	a
	SE	Marshall	b,c,d
	SW	Marshall	b,c,d

*a - 80 to 100 pounds/acre N broadcast shortly after planting.
b - 150 pounds/acre N broadcast in 2 applications.
c - 1 or 2 fungicide (Diathane M-45) applications at 2 pounds/acre.
d - 1 or 2 supplemental irrigations.

Brun is professor and chairman, Enz is associate professor, and Larsen is research specialist, Department of Soil Science.

Table 2. Growing season water and yield variables at the Microclimate Research Station.

Year	Lysimeter	Available Soil Water (inches) Planting	Available Soil Water (inches) Harvest	Growing Season Precipitation (Irrigation) (inches)	Precipitation + Irrigation + Available Soil Water at Planting (inches)	Growing Season Evapotranspiration (inches)	Yield (bu/a)
1981	NW	4.82	2.46	9.15	13.97	13.18	39.02
	NE	8.02	3.24	8.92	16.94	13.55	44.66
1982	SE	2.70	0.17	7.12	9.82	11.09	30.37
	SW	2.29	0.46	7.39	9.68	10.61	28.57
1985	NW	9.15	4.13	13.05 (3.43)	25.63	19.57	74.84
	NE	8.16	4.40	12.20 (3.31)	23.67	18.38	67.65
	SE	9.28	2.56	13.70	22.98	20.34	72.44
	SW	9.89	2.50	12.78	22.67	19.16	70.39
1986	NW	8.08	4.55	10.99	19.07	16.81	60.19
	NE	8.49	5.44	10.76	19.25	17.28	68.15
	SE	8.54	5.79	11.74	20.28	15.62	61.93
	SW	7.71	4.85	10.98	18.69	16.98	61.46
1987	NW	7.40	1.72	9.15	16.55	14.91	63.17
	NE	6.96	2.33	8.44 (2.00)	17.80	17.25	79.01
	SE	7.23	1.30	9.03 (2.00)	18.26	17.35	68.21
	SW	6.28	1.61	8.78	15.06	13.71	56.95
1988	NW	3.05	0.61	4.21	7.26	7.50	10.19
	NE	4.07	0.87	3.99	8.06	8.36	11.69
	SE	3.11	-0.17	4.12 (2.00)	9.23	11.45	16.02
	SW	3.08	1.25	3.97 (2.00)	9.05	8.53	9.08

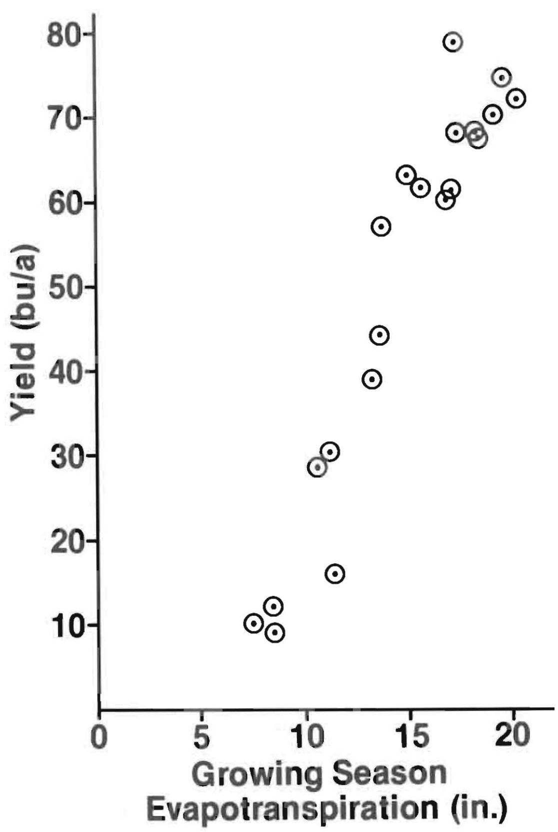

Figure 1. Relationship between spring wheat yield and growing season evapotranspiration.

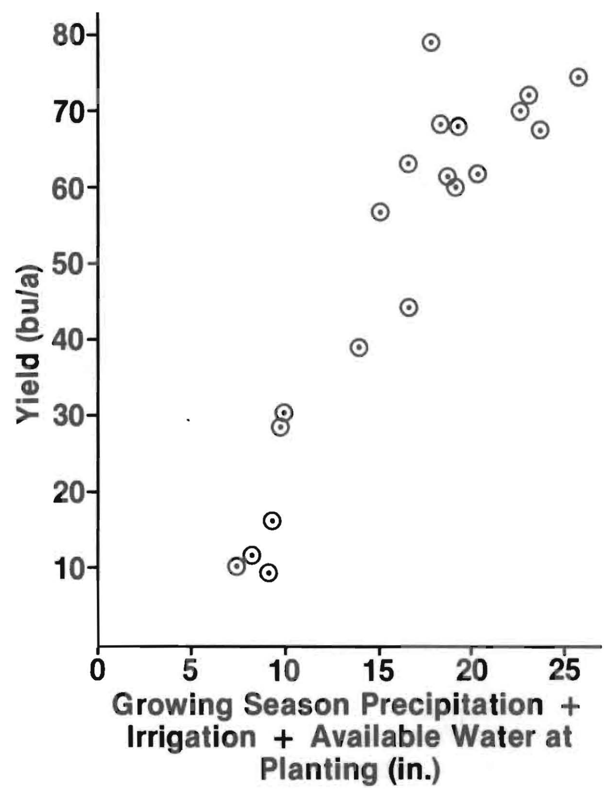

Figure 2. Relationship between spring wheat yield and growing season precipitation plus irrigation plus available soil water at planting.

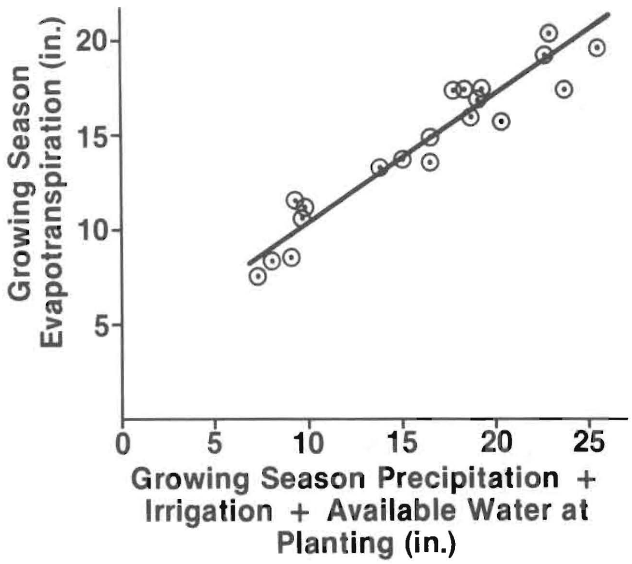

Figure 3. Relationship between growing season evapotranspiration and growing season precipitation plus irrigation plus available soil water at planting.

This analysis indicates that GSET should not be equated to GSP plus I plus AWP and that all available soil water is not consumed with the higher soil water levels. This is illustrated by Table 3. When 10 inches of water are available over the growing season the expected GSET is about 10 inches. However, with 20 to 25 inches of available water we expect 3 or more inches of this to remain in the soil at harvest time.

Figure 4 illustrates equations 1 and 2 and shows that GSET should not be equated to GSP plus I plus AWP. The values are similar at low levels of available water (water stress conditions) but diverge markedly at high levels of available water.

We can observe a number of effects (or non-effects) due to treatment differences. In 1985 irrigation of 3.43 inches on the NW lysimeter and 3.31 inches on the NE lysimeter had no impact on GSET or Y (Table 2). The greatest amounts of AWP and GSP throughout the experiment and the highest GSET, ranging from 18.38 inches to 20.34 inches, occurred in 1985.

Table 3. Relationship of growing season evapotranspiration to growing season precipitation plus irrigation plus available soil water at planting from Equation 3.

Growing Season Evapotranspiration (inches)	Growing Season Precipitation + Irrigation + Available Soil Water at Planting (inches)
10.5	10
13.8	15
17.2	20
20.6	25

In 1987, there was a Y response to more intensive management (b,c,d) with irrigation but not to intensive management (b,c) without irrigation (Table 2). The 1988 growing season was characterized by severe heat and water stress. There was no advantage to intensive management (b,c,d) with irrigation compared to conventional management (a).

The water and Y variables were further examined to see if there were apparent relationships among AWP, GSP + I and Y. The relationship between Y and AWP is shown in Figure 5 and described by the equation

$$Y = 8.40\,(AWP) - 4.17 \qquad (4)$$

with $R^2 = 0.79$. The relationship between Y and GSP + I is described by

$$Y = 6.18\,(GSP + I) - 10.7 \qquad (5)$$

with $R^2 = 0.78$.

However, equations 4 and 5 must be used with caution. This is because of the relationship observed in Figure 6. The AWP was not followed by a random behavior in GSP. Low AWP was followed by low GSP. High AWP was followed by high GSP. The relationship is

$$GSP = 1.10\,(AWP) + 1.99 \qquad (6)$$

with $R^2 = 0.79$.

This is likely just a quirk of the data set or perhaps it says something about the non-random nature of our climate!

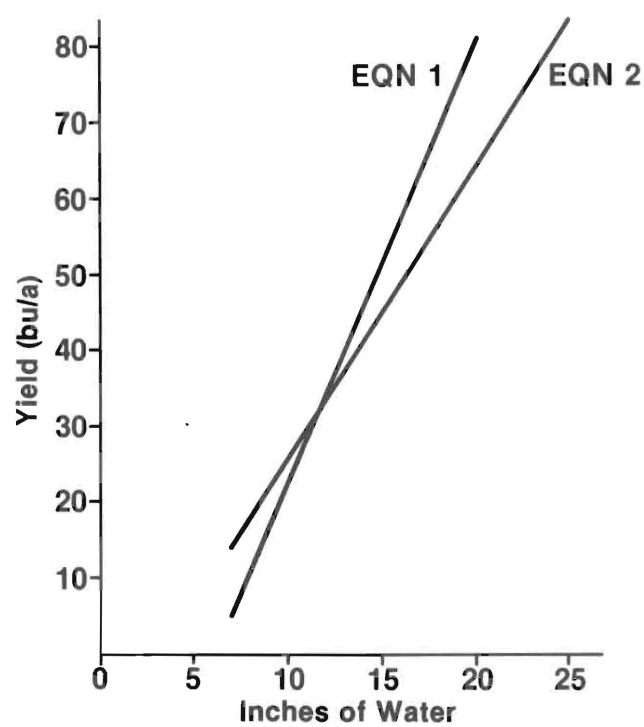

Figure 4. Comparison of equation 1 showing yield as a function of growing season evapotranspiration and equation 2 showing yield as a function of growing season precipitation plus irrigation plus available soil water at planting.

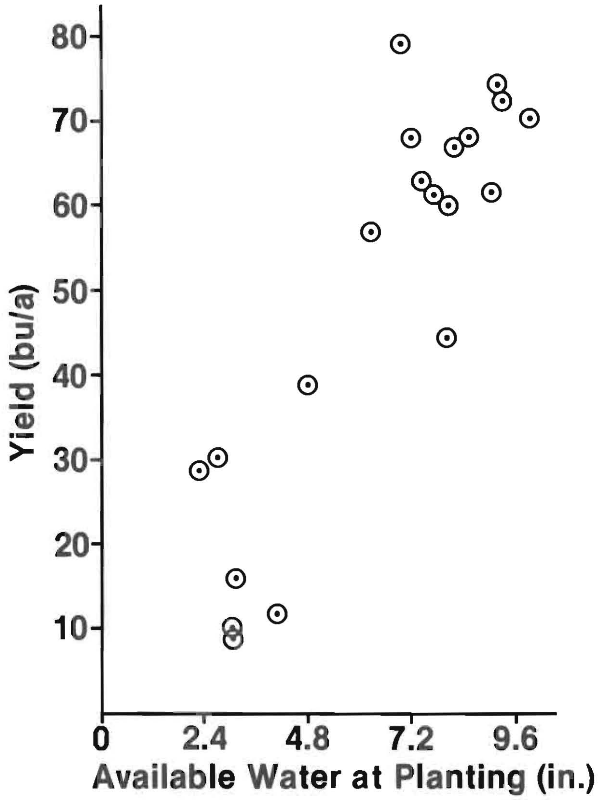

Figure 5. Relationship between spring wheat yield and available soil water at planting.

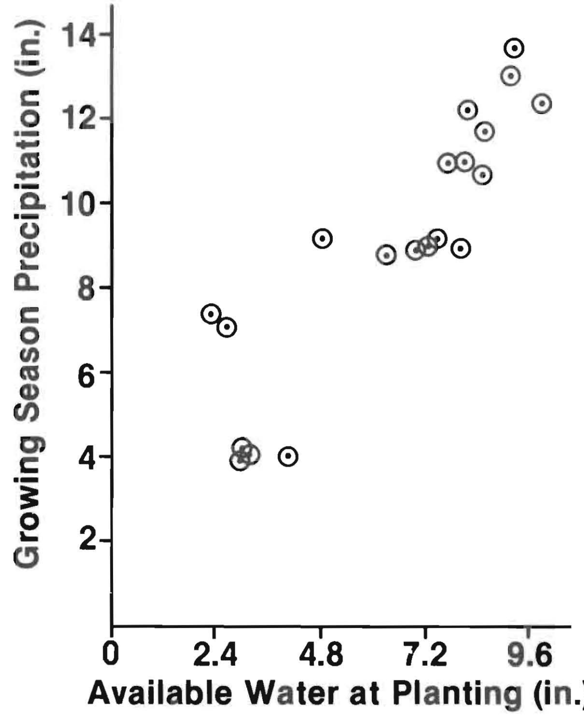

Figure 6. Relationship between growing season precipitation and available soil water at planting.

SUMMARY

The yield of spring wheat at Fargo was closely related to GSET and GSP plus I plus AWP. However, the responses are quite different because all GSP plus I plus AWP is not consumed as ET in years with high levels of available water. The results indicate that GSET equals GSP + AWP is not a valid assumption for dryland agriculture in North Dakota in wetter years.

Yield was also related to AWP and GSP plus I. However, the results would seem to be biased by an apparent non-random behavior of GSP.

LITERATURE CITED

Brun, Lynn J., John W. Enz, and Jay K. Larsen. 1983. Climatic research in the Department of Soil Science. ND Farm Research. 41(1) 9-11 and 23.

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APPENDIX

Table 1. Regression analysis deleting data points 1987 NE and 1988 SE.

Equation Number	Equation	R^2
1	Y = 5.46 (GSET) - 29.9	0.94
2	Y = 3.72 (GSP + I + AWP) - 11.3	0.88
3	GSET = 0.68 (GSP + I + AWP) + 3.38	0.94
4	Y = 8.11 (AWP) - 3.39	0.81
5	Y = 5.87 (GSP + I) - 8.34	0.80
6	GSP = 1.06 (AWP) + 2.36	0.77