TECHNOLOGY IMPACT ON EVAPOTRANSPIRATION — YIELD RELATIONSHIPS FOR SPRING WHEAT IN NORTH DAKOTA

L. J. Brun, E. J. Deibert, E. W. French and B. K. Hoag

The impact of technology on grain yield can be shown by plotting yield versus time as illustrated by Hueg (1977). Regression models can be used to obtain equations that show how much yield has changed with time (Thompson, 1964). Thompson points out the equations obtained in this manner may not properly account for variations in climate. For example, if poor weather conditions existed at the beginning of the period and good weather existed at the end of the period, the resulting equation could be biased and overemphasize technologic factors. We will attempt to avoid this problem in our analysis by evaluating spring wheat yield in terms of available water or evapotranspiration using historic and current information.

HISTORICAL

Numerous scientists have tried to quantify the relationship of water to grain yield, especially its availability and distribution over the growing season. An early study conducted by Cole (1938) compared precipitation and spring wheat yield over the period 1906 to 1935 when soil moisture and evapotranspiration data were not generally available. Annual precipitation was correlated with spring wheat yield at 14 Northern Plains experiment stations, including five from North Dakota.

The equation developed for spring wheat under continuous cropping conditions was

$$Y = 2.11\ (AP - 9.64)$$

where Y is the yield in bushels per acre and AP is the August 1 through July 31 precipitation in inches. The correlation coefficient (r) was 0.76 which is quite high for this relatively simple comparison. The equation indicates that 9.64 inches of precipitation were needed to reach the initial yield point or the point at which some grain yield is expected. Each additional inch of precipitation beyond the initial yield point resulted in 2.11 bushels per acre. We should keep in mind that soil water storage from non-growing season precipitation received from August 1 until planting is 30 to 50 percent efficient. Thus, only 3 to 4 inches of the 9.64 inches of precipitation are stored in the soil for plant use.

Brun and Deibert are associate professors, Department of Soil Science; French is superintendent, Williston Experiment Station; Hoag is superintendent, North Central Experiment Station, Minot.

Cole found spring wheat grown on fallow produced the equation

$$Y = 2.05\ (AP - 5.87)$$

with an $r = 0.67$. The yield response per inch of water or slope is similar (2.05 vs. 2.11) for both equations. However, the initial yield point is much less for fallow with the difference of 3.77 inches (9.64 – 5.87) reflecting soil water stored in previous fallow period. Thus, the initial yield point is reached with less precipitation required.

Bauer (1972) conducted a detailed analysis of growing season water supply and spring wheat yield relationships from existing data for North Dakota, South Dakota, Montana, and Saskatchewan.The equation obtained for this area was

$$Y = -8.92 + 2.39\ SW + 2.44\ P$$

where SW is soil water in inches and P is the actual growing season precipitation in inches. Soil water was expressed in several ways including available soil water at seeding, soil water at seeding minus soil water at harvest and total soil water at seeding.

The equation Bauer obtained for North Daktoa data was

$$Y = -4.15 + 2.33\ SW + 2.33\ P$$

which indicates each inch of soil water or precipitation resulted in 2.33 bushels per acre. Unfortunately, no correlation coefficients were given to indicate the reliability of these equations.

Bauer (1972) pointed out that the distribution of precipitation during the growing season and the time at which water stress might occur affect yields differentially. For example, moisture stress at the heading-flowering period had the greatest impact on yield. Various models have been proposed (Rasmussen and

Hanks, 1978) to account for stress at various growth stages. However, it has been difficult to obtain the proper factors to weigh the stress periods.

CURRENT

In a given year, climatic factors will affect the plant and grain yield similarly. If all other growth factors are non-limiting, high correlations of evapotranspiration to grain yield can be obtained. We will now examine recent evapotranspiration-spring wheat yield data obtained at-Fargo, Williston, and Minot. The high r values for the Fargo and Williston data indicate the climatic factors affected yield similary over the period of the study and the evapotranspiration measurements were very accurate.

Fargo data were obtained from spring wheat planted after soybean in 1981 and sunflower in 1982. The equation

$$Y = 4.96\ (ET - 4.93)$$

with $r = 0.98$ was obtained where ET is the growing season evapotranspiration in inches. After the initial yield point of 4.93 inches, each inch of water used in evapotranspiration produced 4.96 bushels of wheat.

Data collected and analyzed for tillage-management experiments under continuous spring wheat culture at Williston from 1977 through 1982 resulted in the following equations:

Tillage Management System	Equation	r
No Till	Y = 4.36 (ET – 6.37)	0.98
Pony Press	Y = 5.13 (ET – 6.96)	0.96
Spring Sweep	Y = 4.66 (ET – 7.13)	0.99
Crop Fallow	Y = 3.77 (ET – 5.52)	0.97

The lower slopes on the no-till and sweep systems are partially associated with increased foliar disease and weed competition found in these systems. The pony press system has historically performed well at Williston which is reflected in the highest slope (5.13) of the four equations. This system gave more bushels per acre per inch of evapotranspiration after the initial yield point than the other systems.

The same tillage-management experiment was conducted at Minot. Large variations among years and systems that may be associated with runoff or runon of surface water or possible subsurface water movement affected the ET evaluation at this location. Thus, the calculations were not reliable enough for comparing individual mangement systems. However, the data from the four systems were combined into one equation for a general evaluation. The equations for minot, Williston and Fargo are illustrated graphically in Figure 1. The combined systems equation for Williston is $Y = 4.99\ (ET - 6.60)$ with $r = 0.96$ and for Minot it is $Y = 5.23\ (ET - 6.82)$ with $r = 0.59$.

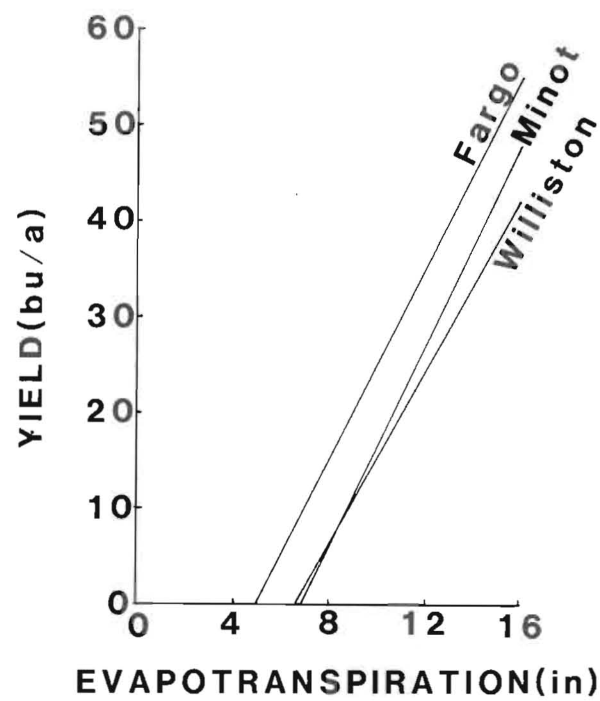

Figure 1. The relationship between yield of spring wheat and growing season evapotranspiration at Fargo, Minot and Williston.

CONCLUSIONS AND INTERPRETATION

A point of speculation is worthwhile in comparing the Williston and Fargo curves since these are the most reliable predictors. Fargo is in a more humid environment than Williston. This means there is a lower vapor pressure gradient between soil and/or plant and the atmosphere which should cause less evapotranspiration. The higher initial yield point calculated for Williston indicates more evaporation from soil, and the lower slope of the curve (4.49 vs. 4.96) compared to Fargo means more transpiration per unit of grain production. This is expected in theory and seems to be supported by these data.

These data show the slope of the yield-evapotranspiration curve has approximately doubled in the last 40 years. This means a given amount of evapotranspiration results in twice as much spring wheat now compared to 40 years ago. This is readily verified in statistics gathered by the North Dakota Crop and Livestock Reporting Service. This yield doubling reflects a wise investment in agricultural technology.

Hueg (1977) lists the following factors as responsible for Minnesota wheat yield increase from 1940 to 1975:

1. Yield increase from breeding for yield was 26 to 29 percent;
2. Increase from breeding for disease resistance was 25 to 29 percent;

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Table 5. Average quality data for Agassiz and three other winter wheat varieties grown in North Dakota.

Variety	Baking data Absorption	Loaf volume	Symmetry[1]	Grain & texture[1]	Crumb color[1]	Farinogram data Peak time	Tolerance	MTI	Classification[2]
	%	cc				min.	min.		
Agassiz	61.5	820	8.2	7.5	7.1	6.6	7.2	31	4.7
Roughrider	61.7	875	9.7	8.2	7.7	9.0	13.2	16	6.5
Norstar	59.6	883	10.0	7.9	8.5	11.4	12.4	25	6.7
Winoka	61.8	870	10.0	7.9	8.5	15.8	16.4	15	7.3

[1]Highest score 10.0.
[2]Highest score 8.0.

High flour extraction is a very important and desirable quality trait. The flour yields of Agassiz and Winoka are similar but less than those of Roughrider and Norstar. However, the flour ash value of Agassiz is less than that of Roughrider.

The baking test provides the cereal chemist with another set of criteria upon which to judge the quality of a wheat. The baking absorption of a flour refers to its ability to take up water and produce a dough with the correct consistency for baking. A flour with a high absorption is desirable from an economical standpoint. The baking absorption of Agassiz as shown in Table 5 is similar to that of Roughrider and Winoka and superior to that of Norstar.

The average loaf volume of Agassiz is less than that of the other three wheats in this comparison, reflecting a difference in protein quality. Agassiz also is less desirable for loaf symmetry and the internal characteristics, grain and texture, and crumb color, but these are not considered major faults.

The mixing properties of a dough are measured by an instrument called a Farinogrpah. The data recorded in Table 5 include peak time, which is the time required for a flour-water dough to reach a specified consistency; tolerance, which is the length of time a dough can be mixed before the gluten properties begin to deteriorate; MTI, an index of mixing tolerance; and an overall classification. Most desirable are a relatively short peak time with good tolerance and a large classification number. Agassiz exhibits considerably weaker mixing properties than the other three varieties being compared and would be considered somewhat undesirable from this aspect.

Summary

Agassiz is a new hard red winter wheat variety released by North Dakota Agricultural Experiment Station. Agassiz is higher yielding than Roughrider and has outyielded Norstar in the central and eastern portions of North Dakota. Its winterhardiness is superior to that of Winoka although slightly less than that of Roughrider. Agassiz displays field resistance to stem rust but is susceptible to leaf rust.

The overall milling and baking quality of Agassiz has been satisfactory. It was faulted for lower loaf volume than Roughrider and inferior crumb color and grain and texture. Agassiz has a similar protein percentage to Roughrider and Winoka but shows weaker mixing properties when compared to the other three varieties in this test.

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3. Improved cultural practices (feriltizer, pesticides) were 19 to 26 percent; and

4. Mechanization was 26 to 32 percent.

These factors can easily vary with the situation. For example, doubling of yield is not unusual in fertilizing nitrogen-depleted soils.

The equations quantify the value of water. Each inch of water after the initial yield point produces about 5 bushels of spring wheat per acre. If the stored soil water is increased 1 inch by weed control or other water conservation practices, the value to the grower is $17.50 per acre with wheat selling for $3.50 per bushel.

These curves or equations can be used in estimating spring wheat production. Seasonal evapotranspiration is predicted from estimates of soil water and probabilities of precipitation for the growing season. For example, if there are 5 inches of stored soil water at Fargo at planting time and precipitation probability tables indicate a 72 percent chance of receiving at least 6 inches of growing season precipitation, there would be 11 inches of water available for evapotranspiration. The equation could then be used to estimate yield at this probability level. The maximum growing season ET for spring wheat in North Dakota is about 16 inches, which gives an upper limit to yield. Precipitation probability data for North Daktoa can be found in "Soil Water Guidelines and Precipitation Probabilities" available from the Departmentof Soil Science.

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