Critical Precipitation Period for Dryland Corn Production

D.C. Nielsen, A.D. Halvorson, and M.F. Vigil

USDA-ARS, Central Great Plains Research Station, Akron, CO and Soil Plant Nutrient Research, Fort Collins, CO

ABSTRACT

Grain yields for dryland corn (*Zea mays* L.) production in the semi-arid Great Plains of the United States can be very unpredictable because of the erratic nature of growing season precipitation. Because input costs for corn production can be very high, farmers need to have a tool that will help them assess the risk associated with dryland corn production. The objectives of this work were to determine the critical period for precipitation during the corn growing season and to develop a relationship between critical period precipitation and corn yield to use as a tool to quantify expected yield variability associated with dryland corn production in this region. Corn yield data were collected at Akron, CO from two dryland cropping systems experiments (1984-2009) in which corn was grown in a wheat (*Triticum aestivum* L)-corn-fallow rotation. Yields were correlated with weekly precipitation amounts from planting to harvest in search of the period of time in which yield was most influenced by precipitation. Soil water contents at planting were measured either by gravimetric sampling or by neutron attenuation. Yields were found to be most closely correlated with precipitation occurring during the six-week period between 16 July and 26 August. The data separated into two linear relationships defined by whether the sum of available soil water at planting and May precipitation was less than or greater than 250 mm. These two linear relationships between precipitation during this critical period and yield were used with long-term precipitation records to determine the probability of obtaining a corn yield of at least 2500 kg ha^{-1} at three locations across the central Great Plains precipitation gradient. This analysis quantified the production risk associated with the highly variable corn yields that result from erratic summer precipitation in this region.

Introduction

- ➢Dryland corn comprises an important fraction of the dryland hectares farmed in the Great Plains (10-15% in Colorado).
- ➢Dryland corn yields are highly variable, greatly affected by water stress occurring during the reproductive stage.
- ➢A previous study indicated that the critical period for precipitation influences on dryland corn production in Colorado was 16 July to 26 August.

Objectives

- ➢Verify the critical period for precipitation during the corn growing season.
- ➢Develop a relationship between critical period precipitation and corn yield as a tool to quantify expected yield variability.
- ➢Determine the probability of achieving a dryland corn yield of 2500 kg/ha (break-even yield) at three locations.

Materials and Methods

- ➢Location: Akron, CO
- ➢Years: 1984-1992 Nitrogen Fertility experiment (NF)
  1993-2009 Alternative Crop Rotation experiment (ACR)
- ➢Plot size: 9.1 m by 30.5m in NT W-C-F plots (ACR) with three replications; 4.6 m by 12.2 m (NF) experiment with four replications
- ➢Seeding rate: 35,000 seeds/ha; row spacing: 76 cm; planting date early to mid-May
- ➢N fertilization rate averaged 72 kg N/ha (ACR); yield data averaged from the 56 and 84 kg N/ha treatments from NF.
- ➢Soil water was measured at planting by gravimetric sampling (NF) and with a neutron probe (ACR) in the 0-180 cm soil profile. Available water was calculated by subtracting off the lower limits for water extraction for corn grown on a Weld silt loam.
- ➢Precipitation was measured in the plot area (ACR) or at a weather station approximately 730 m from the plot area (NF)
- ➢Weekly precipitation amounts were computed from daily values.
- ➢Yields were averaged across replicate measurements and correlated with various combinations of weekly precipitation.

Water stress effects on corn vegetative and reproductive development – 4 Sept 2009

Available water at planting plus May precip = 300 mm
Critical period precip = 84 mm

Available water at planting plus May precip = 237 mm
Critical period precip = 65 mm

Available water at planting plus May precip = 178 mm
Critical period precip = 65 mm

Table 1. Linear regression [yield (kg/ha) = a + b × precipitation (mm)] statistics for several relationships between precipitation during various periods and dryland corn yield at Akron, CO (1984-2009).

Precipitation Period	Weeks	a	b	R^2	P
2 July – 8 July	1	2829	32.8	0.06	0.27
9 July – 15 July	1	3528	-26.3	0.05	0.32
16 July – 22 July	1	3119	5.6	0.00	0.78
23 July – 29 July	1	2517	45.3	0.18	0.04
30 July – 5 August	1	2550	38.2	0.26	0.01
6 August – 12 August	1	2680	24.7	0.13	0.09
13 August – 19 August	1	2634	47.0	0.28	<0.01
20 August – 26 August	1	3268	-4.10	0.00	0.82
27 August – 2 September	1	3492	-22.7	0.06	0.24
23 July – 5 August	2	1844	41.9	0.45	<0.01
23 July – 12 August	3	1462	32.2	0.52	<0.01
23 July – 19 August	4	1478	26.0	0.58	<0.01
16 July – 19 August	5	1275	23.2	0.53	<0.01
16 July – 26 August	6	1100	23.6	0.67	<0.01
16 July – 2 September	7	921	21.4	0.48	<0.01
9 July – 26 August	7	716	23.4	0.54	<0.01
9 July – 2 September	8	655	21.5	0.44	<0.01
2 July – 26 August	8	611	22.0	0.55	<0.01
2 July – 2 September	9	501	20.8	0.46	<0.01
25 June – 26 August	9	496	21.5	0.57	<0.01
25 June – 2 September	10	375	20.5	0.49	<0.01

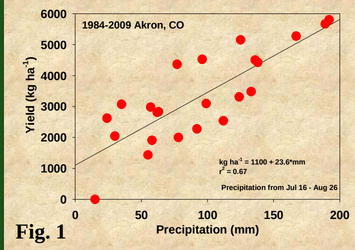

Fig. 1

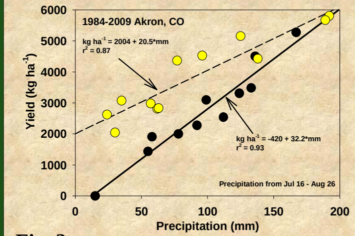

Fig. 2

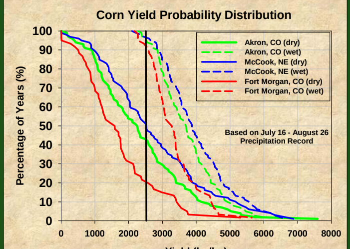

Fig. 3

Results and Discussion

Corn yields ranged from 0 to nearly 6000 kg/ha (Fig. 1) and were most highly correlated (R^2=0.67) with precipitation falling in the 6-week period from 16 July to 26 August (Table 1). Rain during this period increased grain yield at a rate of 23.6 kg/ha per mm of rain.

Closer inspection of the data revealed that the data points fell into two distinct groups (Fig. 2) defined by the sum of available soil water at planting (for corn in a WCF system) and May precipitation. When that sum was greater than 250 mm (yellow points) a greater yield was achieved with less precipitation during the 16 July to 26 August period. When the sum was less than 250 mm (black points) less yield was achieved for the same about of critical period precipitation.

When critical period precipitation is greater than about 150 mm, the effects of large amounts of stored soil water at planting or precipitation stored early in the season in May are minimized.

The years of record occur with approximately equal frequency for each of the two classes defined by the sum of available soil water at planting and May precipitation.

Annual precipitation in the west-central Great Plains (in the rain shadow of the Rocky Mountains) increases from west to east at a rate of about 63 mm every 100 km. Fort Morgan, CO, Akron, CO, and McCook, NE are separated by about 270 km along this west to east transect

Using the long-term precipitation record for these three locations with the relationships shown in Fig. 2 generates the probability distributions of yield shown in Fig. 3.

The probability of achieving at least 2500 kg/ha under wet conditions (when the sum of available water at planting and May precipitation is greater than 250 mm) is nearly the same for all three locations (93-97%). Under dry conditions the probability of having enough critical period precipitation to produce at least 2500 kg/ha is 21% at Fort Morgan, 43 % at Akron, and 52% at McCook.

Conclusions

Corn yields are highly correlated with precipitation falling between 16 July and 26 August.

Precipitation during this 6-week period is highly variable in the central Great Plains resulting in highly variable corn yields.

The slope of the linear response between critical period precipitation and corn yield depends on the sum of available water at planting and May precipitation.

Probability distributions of corn yield based on long-term precipitation records and the relationships defined in this study demonstrate that successful dryland corn production in the central Great Plains is highly risky, but the risk is significantly lower when available soil water at planting is near field capacity and /or May precipitation is much above average resulting in early season precipitation storage.

These results suggest that farmers could use measurements of available soil water at planting and long-term precipitation records to quantify the risk associated with dryland corn production and to make a decision about whether or not to plant corn.

Acknowledgement

We thank Tawney Bleak for her help with data analysis.