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# Evaluating Crops for a Flexible Summer Fallow Cropping System

Douglas G. Felter,* Drew J. Lyon, and David C. Nielsen

## ABSTRACT

**Substituting a short-season, spring-planted crop for summer fallow when soil water is sufficient at planting might reduce soil degradation without significantly increasing the risk of crop failure. The objectives of this study were to determine the relationship of crop grain or forage yield to plant available soil water at planting. The study was conducted on silt loam soils in 2004 and 2005 at Sidney, NE, and Akron, CO. A range of soil water levels was established with supplemental irrigation before planting. Four crops [spring triticale (*X Triticosecale* rimpaui Wittm.) for forage, dry pea (*Pisum sativum* L.) for grain, proso millet (*Panicum miliaceum* L.) for grain, and foxtail millet (*Setaria italica* L. Beauv.) for forage] were no-till seeded into corn (*Zea mays* L.) residue in a split-plot design with four replications per location. Triticale forage yield increased by 229 kg ha$^{-1}$ for each centimeter of soil water available at planting in 2004. Foxtail millet forage yield and grain yield of proso millet increased by 399 kg ha$^{-1}$ cm$^{-1}$ and 148 kg ha$^{-1}$ cm$^{-1}$, respectively, at Akron in 2004. Spring triticale, foxtail millet, and proso millet did not respond to soil water at planting in 2005, when precipitation was above the long-term average. Dry pea did not demonstrate a consistent positive response to soil water availability at planting. Soil water at planting may be a useful indicator of potential yield for selected short-season spring-planted summer crops, particularly when crop production is limited by growing season precipitation.**

WINTER WHEAT–FALLOW has been the dominant cropping system in the Central Great Plains for many years. Variable precipitation, temperature fluctuations, hail, and other unpredictable conditions make dryland farming in the region inherently risky (Dhuyvetter et al., 1996). Though average precipitation is low, less than 500 mm annually, the amount can often be half or double the historic annual amount (Cannell and Dregne, 1983). Summer fallow was adopted as a means to store soil water, increasing the chances for successful establishment and development of winter wheat and stabilizing winter wheat yields (Lyon et al., 1995; Dhuyvetter et al., 1996; Peterson et al., 1996; Farahani et al., 1998).

When summer fallow began, fallow management consisted of intensive tillage operations. Only 19% of precipitation received during summer fallow was stored in the soil for the following winter wheat crop (Greb, 1979). Chemical fallow and no-till management have had positive effects on precipitation storage, but the efficiency of fallow has been stagnant at about 40% since the 1970s (Greb, 1983; Unger, 1984; Tanaka and Aase, 1987; Dao, 1993; Peterson et al., 1996).

McGee et al. (1997) suggested that greater water storage efficiency could be achieved by terminating fallow in the spring and planting a summer crop. The principle behind cropping intensification is replacement of soil evaporation with crop transpiration (Farahani et al., 1998). Intensified systems in the region generally produce two crops in 3 yr or three crops in 4 yr through the addition of summer crops such as corn, sunflower (*Helianthus annuus* L.), sorghum [*Sorghum bicolor* (L.) Moench], or proso millet.

Dryland cropping systems intensification has exhibited pronounced increases in biomass and grain production on an annual basis (Peterson et al., 1993, 1996; Norwood, 1994; Jones and Popham, 1997). Peterson and Westfall (2004) found intensification of cropping systems increased net return to producers by 25 to 45% compared with wheat-fallow.

The amount of soil water at planting has been used as an indicator of potential yield in some flexible systems. Bauer (1972) selected crops based on the amount of soil water at planting and determined that the production factor most related to crop growth and grain yield was the quantity of stored soil water. Nielsen et al. (2002) reported a strong positive linear relationship between winter wheat grain yield and available soil water at planting. However, Campbell et al. (1988) found growing season precipitation explained 5.4 and 1.5 times as much yield variability in spring wheat as available spring soil moisture in fallow-seeded and stubble-seeded wheat, respectively. Burt and Allison (1963) used a dynamic programming approach based on soil water levels at planting time to decide whether to plant wheat or fallow. Long-term expected returns per year using the dynamic approach were approximately \$7.40 ha$^{-1}$ more than continuous winter wheat and approximately \$14.80 ha$^{-1}$ greater than a static system of alternate winter wheat and fallow.

Lyon et al. (1995) studied the response of five spring-planted crops [corn, sorghum, pinto bean (*Phaseolus vulgaris* L.), proso millet, and sunflower] to varying initial soil water levels in the year following winter wheat harvest. Dry matter accumulation 12 wk after planting demonstrated a strong positive response to increasing soil water in all crops. However, as the number of days from planting to harvest increased, the response of grain yield to soil water at planting decreased.

Lyon et al. (2004) studied the economics of replacing summer fallow with spring-planted crops. They found proso millet for grain and a forage mixture of oat (*Avena sativa* L.) + pea were economically competitive with systems involving summer fallow. These crops also add diversity to rotations and increase marketing opportunities.

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D.G. Felter and D.J. Lyon, Dep. of Agronomy and Horticulture, Univ. of Nebraska, Panhandle Research & Extension Center, 4502 Ave. I, Scottsbluff, NE 69361; and D.C. Nielsen, USDA-ARS Central Great Plains Research Station, 40335 County Road GG, Akron, CO 80720. Journal Series no. 15084 of the Univ. of Nebraska Agric. Res. Div. Received 16 Dec. 2005. *Corresponding author (FelterDouglasG@JohnDeere.com).

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677 S. Segoe Rd., Madison, WI 53711 USA

water use explained 67% of the variability in dry matter. Water use had no significant relationship with dry matter yield at Sidney (Fig. 3b). Water use and yield values were similar for all treatments in 2005.

Plant available water at planting explained 69% of water use variability at Akron in 2004 (Table 7). Plant available water explained approximately 45% of the variability in water use at Sidney in 2005, but the response was different from that at Akron in 2004.

Forage quality of foxtail millet was impacted by water treatments at Akron (data not shown). Crude protein decreased from 190 to 161 g kg$^{-1}$ and acid detergent fiber increased from 298 to 331 g kg$^{-1}$ as soil water at planting increased. Neutral detergent fiber (mean = 536 g kg$^{-1}$) and relative feed value (mean = 111.4) showed no significant differences across water treatments in 2004. No significant differences existed at Sidney in 2005. Maturity of foxtail millet ranged from less than 25% spike emergence for low-water treatments to 75% emergence in high-water treatments at Akron. Visual signs of water stress, and delayed maturity, were evident in the low and medium treatments. Differences in foxtail millet forage quality in 2004 are attributed to maturity differences (Twidwell et al., 1987; Ben-Ghedalia et al., 1995; Khorasani et al., 1997) resulting from differential water stress between water treatments.

The results for foxtail millet forage yield response under water-limited conditions in 2004 indicate that soil water at planting may be an important variable for use in a flexible summer fallow decision support tool for the Central Great Plains. As with triticale, foxtail millet biomass accumulation at Akron in 2004 was strongly related to seasonal water use under water-limited conditions. Plant available water at planting explained 69% of water use differences at Akron. Additional research will be necessary to further understand the relationship of foxtail millet forage yield and soil water at planting. Preliminary data from this study indicate that it may be possible to determine the lowest soil water level that will provide a reasonable yield in water-limited conditions. Again, nonwater-limited conditions may result in underestimation of yield, but profitable yield levels will still be achieved.

## Proso Millet

Proso millet, like foxtail millet, was also impacted by hail and emergence problems, resulting in only two site-years of data. The response varied greatly, so site-years were considered independently.

Grain yield of proso millet increased with plant available water at planting at Akron in 2004 (Fig. 4a). Linear regression analysis revealed that 58% of the variability in grain yield was explained by the quantity of plant available water at planting (Fig. 4a). For Sidney, the response of grain yield to soil water at planting was not significant. Little difference existed in water availability between treatments in 2005 (Table 1).

Proso millet grain yield increased as seasonal water use increased at Akron (Fig. 4b). The linear function of water use explained 73% of grain yield variability. This response was not seen for proso millet at Sidney in 2005. The magnitude of yield increase at Akron was approximately 148 kg ha$^{-1}$ for each additional centimeter of water use. Shanahan et al. (1988) reported a similar increase of 123 kg ha$^{-1}$ for each centimeter of water use, and the linear function of water use explained approximately 85% of the variability in proso millet grain yield. Plant available water at planting explained 78% of water use variability at Akron in 2004, but only 42% for Sidney 2005 (Table 7).

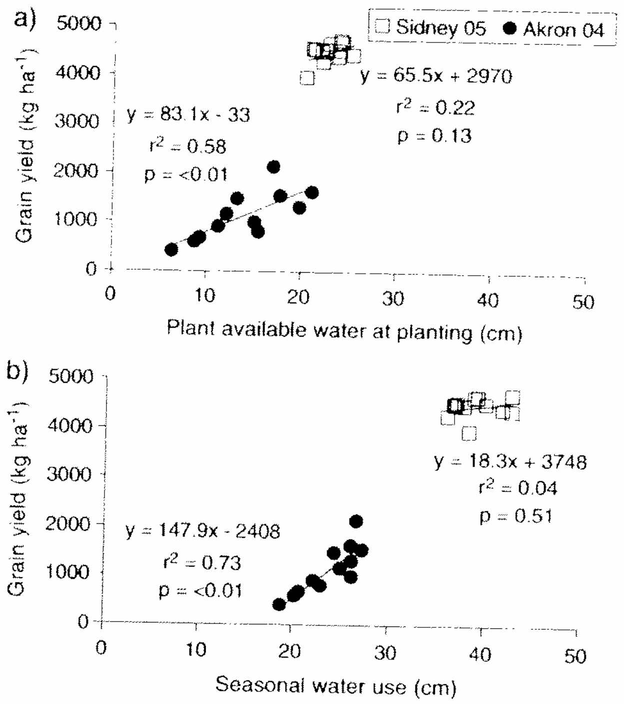

**Fig. 4. (a) Plant available water at planting, and (b) seasonal water use–yield relationships for proso millet.**

Grain yield of crops is sensitive to timing of water supply. For proso millet, Shanahan et al. (1988) found a linear relationship of grain yield to water use. Proso millet has a low water requirement, possibly the lowest of any cereal (Theisen et al., 1978; Hulse et al., 1980). This is likely attributed, in part, to the $C_4$ photosynthetic mechanism (Martin et al., 1976) and low straw/grain ratio (Greb, 1979).

The efficient water use patterns of proso millet and linear relationship of grain yield to water use indicate that it may be successfully used in a cropping system based on soil water at planting. Additional research will be necessary to further quantify the relationship of proso millet grain yield to plant available water at planting under water-limited conditions. Use of this relationship will help minimize the occurrence of unacceptable proso millet yields for producers.

## SUMMARY

Results of this study indicate the amount of plant available soil water at planting may be a suitable indicator of yield potential for selected short-season, spring-planted crops. The forage crops in the study, spring

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**Table 2. Planting and harvest dates for spring-planted crops.**

| Location | Year | Spring triticale | Dry pea | Foxtail millet | Proso millet |
|---|---|---|---|---|---|
| Sidney | 2004 | 6 Apr./23 June | 6 Apr./15 July | – | – |
| | 2005 | 7 Apr./24 June | 7 Apr./20 July | 8 June/16 Aug. | 8 June/30 Aug. |
| Akron | 2004 | 7 Apr./23 June | 7 Apr./13 July | 2 June/26, 30 Aug.† | 2 June/30 Aug. |
| | 2005 | 4 Apr./24 June | 4 Apr./14 July | – | – |

† At Akron in 2004, foxtail millet plots receiving the high level of supplemental water were harvested on 26 August as a result of more rapid crop development. The remaining foxtail millet plots were harvested on 30 August.

proso millet plots. At Sidney in 2005, forage crops were harvested with a forage harvester. Harvest areas were 8.1 m$^2$ and 9.3 m$^2$, respectively, for spring triticale and foxtail millet. An area of 18.1 m$^2$ was harvested from the center of dry pea and proso millet plots using a small plot combine. Spring triticale was hand-harvested from 1.2 m$^2$ at Akron in 2005. Dry pea was harvested with a small plot combine from variable plot areas ranging from 18.1 to 19.5 m$^2$.

The targeted harvest date for forage crops was when approximately 50% of the plants had spikes fully emerged from the stem, however, spring triticale harvest was delayed until about 75% of the plants had spikes emerged at Akron in 2005. Rain delayed foxtail millet harvest until 95% of plants had spikes emerged at Sidney in 2005. At Sidney in 2004, spike emergence for triticale was about 20, 50, and 90% for the low-, medium-, and high-water treatments, respectively. Foxtail millet at Akron had about 20, 50, and 75% spike emergence for the low, medium and high treatments, respectively. Harvest samples were weighed in the field at harvest moisture, a subsample was taken and oven-dried at 50°C until weight remained constant. Dry weights were taken and moisture content determined. Forage quality (dry matter, crude protein, neutral detergent fiber, acid detergent fiber, and relative feed value) was determined by the University of Nebraska Soil and Plant Analytical Laboratory using near infrared analysis (NIRS-5000, Foss North America, Eden Prairie, MN). Moisture and test weight of grain crops were determined using a Dickey-John Grain Analyzer (GAC-2000, Dickey-John, Auburn, IL). Grain yield was adjusted to 150 g kg$^{-1}$ moisture for dry pea and 120 g kg$^{-1}$ for proso millet. Data were analyzed using the GLM and REG procedures in SAS (SAS Institute, 1985). Quadratic responses of yield to planting water content and seasonal water use were tested but not significant for any crop, so analysis is limited to linear models.

## RESULTS AND DISCUSSION

Growing season precipitation and 30-yr normals are shown in Table 3. Precipitation amounts during the April to August period were 89 and 133% of normal at Sidney in 2004 and 2005, respectively. At Akron, precipitation was 77 and 98% of normal for the April to August period in 2004 and 2005, respectively. Despite some month-to-month variation, average daily temperatures for the April to August growing season were near normal at both locations in 2004 and 2005 (Table 4).

**Table 3. Monthly and growing season precipitation for Sidney and Akron.**

| Location | Year | Apr. | May | June | July | Aug. | Apr.–Aug. |
|---|---|---|---|---|---|---|---|
| | | | | | cm | | |
| Sidney | 2004 | 5.5 | 2.6 | 6.6 | 6.7 | 4.1 | 25.5 |
| | 2005 | 5.4 | 5.0 | 15.4 | 6.0 | 6.3 | 38.1 |
| | 30-yr normal | 3.8 | 7.3 | 7.0 | 5.7 | 4.8 | 28.6 |
| Akron | 2004 | 4.4 | 4.4 | 6.6 | 4.3 | 3.6 | 23.3 |
| | 2005 | 4.6 | 5.1 | 7.6 | 4.3 | 8.0 | 29.6 |
| | 30-yr normal | 3.6 | 7.6 | 5.8 | 7.5 | 5.7 | 30.2 |

The low-water treatment represents the amount of water stored in the soil since the previous corn crop. The medium and high treatments received supplemental irrigations to establish a range of preplanting water levels. Water levels were monitored in the upper 120 cm of the soil profile (Table 1). In general, little difference in plant available water content existed between water treatments in the upper 60 cm of the profile (data not shown). Plant available water was present in the 60- to 90-cm layer in medium-water treatments, and throughout the 120-cm profile in high treatments. In 2005 at Sidney, however, little difference in profile water content existed at foxtail and proso millet planting due to above normal spring rainfall.

## Spring Triticale

Forage yield of spring triticale increased with increased plant available water at planting in 2004 (Table 5). In 2005, the yield response was not significant at either location. This was presumably due to above average rainfall amounts in 2005. Precipitation in June was 222 and 132% of normal for Sidney and Akron, respectively. This ample amount of precipitation during the crop's peak water requirement period reduced the dependence on soil water reserves for plant function. When all spring triticale data were pooled together, the linear function of plant available water at planting explained more than 55% of the variability in dry matter yield (Fig. 1a). In 2004, under water-limited conditions, plant available water at planting explained 76% of dry matter yield variability (Table 5).

Water use explained approximately 65% of the variability in spring triticale dry matter yield when all data were considered (Fig. 1b). For 2004, water use explained 66% of dry matter yield differences (Table 6). Previous research has shown seasonal water use and biomass yield are linearly related for a number of crops under water-limited conditions (Hanks et al., 1969; Stewart et al., 1977; Hanks, 1983; Nielsen, 2004). Water use was similar across water treatments in 2005, and the response was not significant. Water use increased as soil water at planting increased, except at Sidney in 2005 (Table 7). When combined across locations and years, plant avail-

**Table 4. Average daily temperature for Sidney and Akron.**

| Location | Year | Apr. | May | June | July | Aug. | Apr.–Aug. |
|---|---|---|---|---|---|---|---|
| | | | | | °C | | |
| Sidney | 2004 | 8.0 | 13.7 | 16.9 | 21.2 | 19.2 | 15.8 |
| | 2005 | 6.7 | 11.9 | 18.4 | 23.3 | 20.4 | 16.1 |
| | 30-yr normal | 6.7 | 12.2 | 18.1 | 21.7 | 20.7 | 15.9 |
| Akron | 2004 | 9.3 | 15.3 | 18.2 | 21.9 | 20.1 | 17.0 |
| | 2005 | 8.0 | 13.8 | 19.9 | 24.9 | 21.6 | 17.6 |
| | 30-yr normal | 7.8 | 13.3 | 19.1 | 22.6 | 21.6 | 16.9 |