FLEXIBLE SUMMER FALLOW IN THE CENTRAL GREAT PLAINS

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ABSTRACT

Summer fallow has played a significant role in dryland cropping systems in the Central Great Plains for many years. Although it helps to stabilize crop yields, frequent use of summer fallow jeopardizes the long-term sustainability of dryland systems by degrading the soil resource and reducing profitability. We argue that a dynamic system involving flexible summer fallow, whereby a grower's decision to transition from a summer crop to winter wheat with a short-duration spring crop or summer fallow is based on several dynamic factors including soil water and economics, would be preferable to a static system incapable of responding to the highly variable climatic and economic scenarios indicative of the region.

INTRODUCTION

Water is the most limiting resource for dryland crop growth in the semiarid areas of the U.S. Great Plains (Smika, 1970). Summer fallow, the practice of controlling all plant growth during the non-crop season, is commonly used to stabilize winter wheat production in this region of high environmental variability. Wheat-fallow is the predominate cropping system in the Great Plains, but water storage efficiency during fallow is frequently less than 25% with conventional tillage (McGee et al., 1997). The advent of reduced- and no-till systems have generally enhanced the ability to capture and retain precipitation in the soil during non-crop periods of the cropping cycle, making it more feasible to reduce the frequency of fallow and intensify cropping systems relative to wheat-fallow (Peterson et al., 1996).

In the Great Plains, annual precipitation is concentrated during the warm season from April to September. Hence, inclusion of a summer crop, e.g., corn or grain sorghum, in a 3-yr system of wheat-summer crop-fallow increased the efficient use of precipitation by reducing the frequency of summer fallow and using more water for crop transpiration (Farahani et al., 1998). In addition to increased precipitation use efficiency and grain yield, more intensified dryland cropping systems increase potentially active surface soil organic C and N (Peterson et al., 1998), effectively control winter annual grass weeds in winter wheat (Daugovish et al., 1999), and increase net return and reduce financial risk (Dhuyvetter et al., 1996).

In the 1970s, Montana and North Dakota initiated "Flexible Cropping" to use precipitation more effectively to increase spring small grain yields and help prevent and control saline seeps (Brown et al., 1981). A dynamic programming approach determined that using soil water at wheat planting time would give an expected return per year of about \$7.50 ha^{-1} more than continuous wheat and about \$15.00 ha^{-1} more than winter wheat-fallow (Burt and Allison, 1963).

INVESTIGATING THE ELIMINATION OF SUMMER FALLOW

A study was initiated in the spring of 1999 to investigate the impact of eliminating summer fallow as the means to transition from a summer crop to winter wheat. Spring-planted crops (oat/pea for forage, spring canola, proso millet, dry bean, and corn) were no-till seeded into sunflower residue at the High Plains Agricultural Laboratory located near Sidney, NE in 1999, 2000, and 2001. A chemical summer fallow treatment was included for comparison purposes. The spring-planted crops served as whole plot treatments (15.2 x 15.2 m plots) in a randomized complete block design and five fall-applied nitrogen fertilizer rates (0, 22, 45, 67, and 90 kg N ha^{-1}) in winter wheat served as the split-plot treatments (2.4 x 15.2 m plots). Treatment combinations were replicated five times in each of three seasons beginning with the 1999-2000 season. Gravimetric soil water contents were collected to a depth of 1.2 m, in 0.3 m increments, immediately prior to seeding winter wheat (Table 1). Gross returns were calculated based on five-year average prices for the region, excluding any government payments. Cost of production budgets were developed for each spring-planted crop using common production practices and the University of Nebraska budget generator. These values were used to determine the return to land and management for each observation with an annualized return developed for the two-year spring-planted crop–winter wheat system. In early spring each year, plant samples were collected from 0.5 m of the center row in plots treated with 0 and 45 kg N ha^{-1}, washed clean of adhering soil, and given a disease severity rating of 0 to 4, with 4 being most severe.

Table 1. Gravimetric soil water content in the surface 1.2 m at winter wheat seeding following six spring crop treatments at Sidney, NE.

Preceding spring crop	1999-2000	2000-2001	2001-2002	3-yr mean
	---------- g kg^{-1} ----------			
Summer fallow	141	149	160	150
Oat/pea forage	102	102	124	110
Spring canola	91	92	121	102
Proso millet	91	85	122	99
Dry bean	94	104	115	104
Corn	72	94	102	89
LSD (0.05)	15	10	12	11

Precipitation during the wheat growing season was less than the 30-yr mean in two of the three years of the study. During the grain filling period (June), precipitation was considerably less than normal in all three years of the study. Averaged across all three years, oat/pea for forage and proso millet provided greater financial returns than summer fallow. Winter wheat grain yields and returns, averaged across all three years, were greatest after summer fallow, with wheat after oat and pea for forage providing the next greatest yields and returns. Annualized returns to land and management suggests that systems involving oat/pea for forage and proso millet are economically competitive with systems using summer fallow. The system involving dry bean had the largest range in returns and was slightly less competitive than the previous systems over the three years of study. Corn and canola are not economically viable as transition crops in these systems, although regionally adapted canola germplasm could change this.

Wheat yield following proso millet responded positively to the first increment of applied N in 2000 and 2001, but no other yield responses to N were observed. Grain protein was not affected by N application (data not shown). In all three years, the most severe root disease was observed on plants in plots previously cropped with proso millet, dry bean, and summer fallow, while the oat/pea for forage, spring canola, and corn treatments resulted in significantly lower disease severity ratings (data not shown).

The cost of summer fallow was \$91.90 ha^{-1}. A combination of returns to the transition crop (fallow replacement crop) + relative wheat returns indicates that systems without summer fallow are feasible (Table 2). System improvement may come from improving transition crop yields or decreasing the negative effects of the transition crop on wheat yields.

Table 2. Annualized net return for the spring crop and subsequent winter wheat crop at Sidney, NE.

Preceding spring crop	1999-2000	2000-2001	2001-2002	3-yr mean
	----------------------------------	\$ ha^{-1}	----------------------------------	
Summer fallow	-6.33	41.56	-57.88	-7.55
Oat/pea forage	91.05	-22.43	-56.03	4.20
Spring canola	-50.29	-106.49	-127.85	-94.88
Proso millet	6.21	-25.45	-1.50	-6.91
Dry bean	101.63	-127.60	-63.01	-29.66
Corn	-34.15	-115.56	-93.78	-81.17
LSD (0.05)	17.42	13.65	14.09	19.38

This suggests that it may be feasible to eliminate summer fallow in the Central Great Plains. However, the risk of persistent drought is great in this region. A partially fixed, partially flexible cropping system might be of value to balance the benefits of more intense cropping systems with the environmental uncertainties of dryland agriculture in semiarid western Nebraska. A winter wheat-summer crop-flexible fallow system, whereby the decision to replace summer fallow with a spring-planted crop is partially based on soil water in the spring and the price relationships of potential crops, might allow growers to continuously crop during periods of above normal precipitation, but fall back to a more conservative rotation during times of below normal precipitation.

DISCERNING WHEN TO USE SUMMER FALLOW

In a previously conducted study (Lyon et al., 1995), the grain yields of two short duration crops (pinto bean and proso millet) consistently responded positively to increasing soil water at planting (Table 3). The long-duration crops (corn, grain sorghum, and sunflower) did not consistently respond to increasing soil water at planting with increased grain yield, although there was a significant positive correlation between soil water at planting and dry weight of the crop at 12 wk after planting. The correlation of grain yield to soil water at planting appeared to decrease as the days from planting to harvest increased. There might still be a substantial amount of initial soil water available at flowering for short-duration crops, but not for long-duration crops, which may use this initial water for stover production, leaving little available for grain development.

Table 3. Correlation coefficients (r) showing the relationship between soil water at planting and dry weight accumulation 12 wk after planting, grain yield, and water use.

Crop	Dry weight	Grain yield	Water use
	--	r	--
Proso millet	0.87***	0.89**	0.55*
Pinto bean (1992)	0.72*	0.81*	0.77**
Pinto bean (1993)	0.93***	0.87**	0.89**
Sunflower	----	0.65**	0.85**
Corn	0.93***	-0.64**	0.85**
Grain sorghum	0.8***	-0.51*	0.81**

*, **, *** Indicates significance at 0.05, 0.01, and 0.001 levels, respectively.

EVALUATING CROPS FOR USE IN A FLEXIBLE SUMMER FALLOW SYSTEM

Taken together, these previous studies suggested that short duration crops, particularly short duration crops that are harvested by mid-summer (such as oat/pea for forage), are critical for the success of the winter wheat-summer crop-flexible fallow system. In 2004, a study was initiated 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 prior to planting. Four crops (spring triticale for forage, dry pea for grain, proso millet for grain, and foxtail millet for forage) were no-till seeded into corn residue in a split-plot design with four replications per location.

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.

Triticale forage yield increased by 229 kg ha^{-1} for each cm of soil water available at planting in 2004 (Table 4). 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.

Table 4. Regression equations for plant available soil water at planting (cm)–yield (kg ha^{-1}) functions for four short-duration crops.

Crop	Location	Year	Equation	r^2
Spring triticale	Akron & Sidney	2004	y = 568 + 229x	0.76
		2005	y = 56 400 + 36x	0.03
		04 & 05	y = 855 + 293x	0.56
Dry pea	Akron & Sidney	2004	y = 936 + 79x	0.49
		2005	y = 1270 + 7.6x	0.01
		04 & 05	y = 1310 + 17.8x	0.04
Foxtail millet	Akron	2004	y = 1480 + 398x	0.62
	Sidney	2005	y = 10 200 -118x	0.08
Proso millet	Akron	2004	y = 33 + 83x	0.58
	Sidney	2005	y = 2970 + 65.5x	0.22

Results of this study indicate that 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 triticale and foxtail millet, demonstrated a linear relationship of dry matter accumulation to soil water availability at planting. Proso millet also showed potential as a grain crop for use in a flexible summer fallow cropping system based on soil water at planting. Dry pea did not appear to be suited for such a system. Dry pea yields are unstable and sensitive to temperature and water stress near flowering.

The relationship of soil water at planting to yield is strongest during water-limited years such as 2004. A decision system based on plant available water at planting may underestimate yield when above normal growing season precipitation is received, but the risk of unacceptable yields will be decreased. Additional research will be necessary to further quantify the relationship of plant available water at planting to yield for the crops demonstrating potential for use in a flexible summer fallow system. It may then be possible to develop a decision support tool to determine when to use a short-season spring-planted crop and when to fallow.

Studies are currently underway to determine the impact of these crops and water treatments on yield of the subsequent winter wheat crop.

Growers should begin to view summer fallow as a necessary evil that should play a smaller role in their cropping systems. Summer fallow needs to change from a strategic practice to a tactical practice that is only used during drier phases of the climate cycle. A possible use of summer fallow would be to use it in a winter wheat-summer crop-flexible fallow system, where a short duration, spring-seeded crop, for example dry pea or spring triticale for forage, is used to transition from the summer crop to winter wheat when soil water at planting time is sufficient, but where summer fallow is used when soil water levels are low.

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