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Replacing fallow with forage triticale in a dryland wheat-corn-fallow rotation may increase profitability

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ABSTRACT

A common dryland rotational cropping system in the semi-arid central Great Plains of the USA is wheat (*Triticum aestivum* L.)-corn (*Zea mays* L.)-fallow (WCF). However, the 12-month fallow period following corn production has been shown to be relatively inefficient in storing precipitation during the summer months and in some years could leave the soil vulnerable to wind erosion. The objective of this experiment was to determine the effect on system productivity when the fallow period in a WCF rotation was replaced with spring-planted forage triticale (*X Triticosecale* rimpaui Wittm.). The 3-yr study was conducted at Akron, CO and Sidney, NE under both dryland and very limited irrigation conditions (to approximate average precipitation during the growing season). Growing season precipitation during the course of the study was above-average in five of the six site-years. Over a wide range of wheat water use (361–591 mm) wheat yields ranged from 1696 kg ha^{-1} to 5527 kg ha^{-1}. Wheat yields averaged 17% lower when triticale (T) replaced fallow, primarily because of reductions in water content at wheat planting. Corn yields were unaffected by triticale replacing fallow and ranged from 3159 kg ha^{-1} to 8085 kg ha^{-1}. Triticale yields ranged from 2967 kg ha^{-1} to 6724 kg ha^{-1}. System productivity as quantified by system net returns was greater for WCT than for WCF when growing season precipitation was above-average resulting in triticale production over 6000 kg ha^{-1}, but even in drier years net income was not reduced when the fallow phase was replaced with triticale production. A WCT rotation can be recommended over WCF provided that growing season precipitation is not far below average and there is an available market for the triticale forage produced.

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1. Introduction

Summer fallow, leaving fields unplanted during the growing season, has been a common practice in rainfed agriculture in semi-arid regions such as the Great Plains. Nielsen and Calderón (2011) provided a succinct definition and review of fallow as a farming practice in semi-arid regions of the world. They stated that the pri-

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mary reason for summer fallow is to stabilize crop production by forfeiting production in one season in anticipation that there will be at least partial compensation by increased crop production the next season. Greb (1979) observed that summer fallow was almost universally adopted as a crop production practice in the semiarid U.S. Great Plains in response to the 1930s Dust Bowl and higher wartime prices. Additionally he stated that improvements in tractor power systems and implements needed to control weeds during fallow facilitated the adoption of fallow as a farming practice. Additional precipitation is stored in the soil during the fallow period because of improved water intake, snow trapping, and decreased evaporation. In addition to storing precipitation and making more soil water available for crop production after fallow, other objectives of fallowing are to maximize plant nutrient availability; minimize soil erosion hazards (when increased crop residues can be maintained on the soil surface); and minimize energy and economic inputs (Greb, 1979). Summer fallowing can reduce weed pressure in the subsequent crop and provide an opportunity to diversify weed control strategies. However, when weed control during the fallow period is achieved by the use of tillage, crop residues are reduced (Unger et al., 1997), organic matter contents in the surface soil layer decline (Peterson et al., 1998; Mikha et al., 2006), and soil water is lost through stimulated evaporation as dry soil at the surface is replaced with wetter soil from below (Nielsen and Vigil, 2010).

With the advent of herbicidal weed control during the fallow period and implementation of no-till production systems in the past three decades, greater amounts of previous crop residues and less soil disturbance have led to greater precipitation storage efficiency (Farahani et al., 1998; Nielsen and Vigil, 2010; Unger et al., 2010). This greater availability of stored soil water allowed for intensification of the traditional wheat-fallow (WF) cropping system (one crop in two years) to two crops in three years (e.g., WCF, W-sorghum (*Sorghum bicolor* Moench L.)-F, W-millet (*Panicum miliaceum* L.)-F), three crops in four years, or continuous cropping (Peterson and Westfall, 2004; Nielsen et al., 2010). Hansen et al. (2012) documented the increase in no-till adoption in the northern and central Great Plains, with less than 3% of acres managed under no-till in 1989 rising to nearly 25% in 2004. They also reported estimates of 60% adoption of no-till in the northern Great Plains in 2011. Additionally, they noted the increased use of more intensive cropping systems (reduced fallow frequency) that has occurred over the same time period in conjunction with more stored soil water due to use of no-till. These systems have incorporated the production of pulses, oilseeds, millet, corn, sorghum, and forages.

The significant questions facing central Great Plains wheat farmers when making a decision to replace a fallow period with crop production are: (1) What crop should be grown? (2) What impact will growing that crop have on subsequent crop yields in the system? (3) How will net income of the cropping system change as a result of eliminating fallow? Nielsen et al. (2011) proposed a method of crop selection based on available soil water content at planting and expected growing season precipitation using published water use/yield production functions. Use of no-till management improves precipitation infiltration and water storage in the soil, but crop production remains water-limited in semi-arid dryland production systems, and replacing fallow with crops reduces available soil water content at planting and subsequent crop yield (Nielsen et al., 2002; Lyon et al., 2007; Saseendran et al., 2010; Nielsen and Vigil, 2014). Early planted, short season summer fallow replacement crops have been shown to have less impact on available soil water content at planting of the following wheat crop and wheat yield than later planted, long season fallow replacement crops (Lyon et al., 2007). The success of alternative rotations with reduced fallow frequency depends on whether the benefits of replacing fallow with crop production offset effects on water availability and yield in subsequent crops.

The past few years have seen an increased promotion of the use of cover crops in farming systems to improve soil quality/soil health (USDA-NRCS, 2015; SARE, 2015). The use of cover crops in the water-short environment of the semi-arid Great Plains (200–500 mm annual precipitation) is an intentional intensification of the cropping system by eliminating a portion of the fallow period. While there have been some reports of successful use of short-season legumes as cover crops/green manure in the northern Great Plains (Pikul et al., 1997; Miller et al., 2006; Biederbeck and Bouman, 1994; Burgess et al., 2014), both past and current research has questioned the viability of growing cover crops in the central and southern Great Plains because of the detrimental effects of cover crop water use on the subsequent wheat yield in these higher evapotranspirational demand regions (Unger and Vigil, 1998; Nielsen et al., 2016a). While it is possible that over time there may be some positive effects regarding soil quality/soil health with the use of cover crops in semi-arid systems (e.g., increased soil carbon stocks, improved microbial properties, recycling nutrients; Blanco-Canqui et al., 2015), the costs associated with incorporating cover crops into a cropping system (seed, planting, fertilizer, termination of cover crop by herbicide applications or mechanical operations, reduction in subsequent wheat yield due to cover crop water use) will likely make the system unprofitable unless some income is derived from the use of the cover crop forage produced. This use of cover crops for animal feed seems to be allowed under some current definitions of cover cropping (Franzlubbers and Stuedemann, 2008).

Lyon et al. (2004) showed that replacing fallow with an oat (*Avena sativa* L.)-pea (*Pisum sativum* L.) forage mixture reduced subsequent wheat yield by 22% compared with wheat after fallow in western Nebraska, but provided a greater economic return compared with WF. Lyon et al. (2007) found that wheat following forage triticale at two Central Great Plains locations over two years yielded 1464 kg ha^{-1}, however they did not report yields for wheat after fallow.

Felter et al. (2006) proposed the use of spring triticale for forage as a fallow replacement crop in flexible fallow systems for the Central Great Plains and reported a water use-yield production function of kg ha^{-1} = 38.51 × (mm of water use − 68.5). This relationship estimates a triticale dry matter yield of 6445 kg ha^{-1} for a water use of 250 mm (from within season precipitation and stored soil water use). Saseendran et al. (2013) modeled spring triticale forage production at two Central Great Plains locations over a 61-year period and found average spring triticale biomass ranging from 5060 to 7570 kg ha^{-1}, varying with available soil water at planting. They reported estimated average net returns of $200 to $500 ha^{-1} for triticale forage production.

Other studies quantifying the impact of forage triticale production on subsequent wheat yields and overall system productivity for the Central Great Plains have not been reported. Therefore, the objectives of this study were to (1) quantify available soil water content at crop planting, crop water use, and crop yield for all crops grown in both WCF and WCT rotational systems; (2) determine the effect that growing spring triticale for forage in place of fallow following corn in a wheat-corn-fallow rotation had on system productivity (net income).

2. Materials and methods

Field studies were conducted in 2009, 2010, and 2011 at the USDA-ARS Central Great Plains Research Station (40°09′ N, 103°09′ W, 1383 m elevation above sea level) located near Akron, CO and at the High Plains Agricultural Laboratory of the University of Nebraska (41°12′ N, 103°0′ W, 1315 m elevation above sea level) located near Sidney, NE. The soil texture at both locations was