Managing Soil Fertility in Diverse Dryland Cropping Systems

D. G. Westfall[1], M. F. Vigil[2], and G. A. Peterson[1]

[1]*Department of Soil and Crop Sciences, Colorado State University, Fort Collins, CO.*
[2]*Soil Scientist and Research Leader, USDA-ARS, Central Great Plains Research Station, Akron, CO. Corresponding author, D. G. Westfall (970-491-6149, Dwayne.Westfall@colostate.edu)*

Abstract
Management of fertilizer in intensive no-till dryland cropping systems is important to their economic and environmental sustainability. In the past, much work has been done on the fertilizer requirements of traditional stubble-mulch tillage wheat-fallow (WF). However, with the increase in biomass production and change in nutrient cycling that occurs in intensive no-till cropping systems, we must take a second look at current fertilizer management strategies. The objective of this paper is to summarize the latest findings on this subject. It has been reported that fertilizer N rate is more critical than placement and/or source. The N requirement of intensive cropping systems is about 73% greater than WF. However, due to the increased N use efficiency and greater water use of these intensive systems, the probability of nitrate leaching is less. If intensive systems are fertilizer properly, wheat yields will equal those obtained in WF. Sunflower generally respond to up to 30 lb N/A, and rarely to 60 lb N/A. However, there is also a small decrease in oil content of sunflower with increased N rates. Phosphorus requirements of intensive systems are similar to stubble-mulch managed systems. If wheat is fertilized properly in a wheat-corn-fallow (WCF) system, there will be adequate P carryover to satisfy the corn crop's requirement. We have not observed significant corn grain yield responses to P in WCF systems. Soil testing coupled with previous experience are critical factors in development of economically and environmentally sound fertilizer management practices.

Introduction
With the implementation of no-till management practices and its increased ability to store rainfall, more crops can be produced over a given number of years than under traditional WF in the semi-arid western Great Plains Region. It has been shown that more intensive no-till dryland cropping systems are economical (Peterson, et al., 1993). Potential crops grown in these systems include winter wheat, corn, millet, sunflowers, sorghum, and forages. Converting from traditional stubble-mulch tillage WF to intensive no-till cropping systems raises several questions concerning fertilizer management. It has been reported that nutrient cycling change occurs when no-till practices are initated (Bauer and Black, 1981; Gilliam and Hoyt, 1987). Soil carbon (C) sequestration is increased as cropping intensity increases (Sherrod, et al., 2003). Continuous cropping with annual crops resulted in as much as a 35% increased soil C level after 12 years under no-till intensive cropping, compared to WF. This increase was correlated with annualized residue (stover and straw) production. Peterson et al. (2001) reported that a 75% increase in grain production occurs in a three-year cropping system (WCF) as compared to WF. Crop residue accumulation on the soil surface also influences many factors that impact fertilizer management (Doran, 1980). No-till changes the dynamics/distribution of residue accumulation in soils (Ortega, et al., 2002). They found that as much as 6,600 lbs/A of recognizable plant residue was present in the 0-4 inch soil depth. It is intuitive that if as much as 75% more grain is produced and nutrient cycling is changed, the plant nutrient requirements will increase, particularly nitrogen (N). At the same time, losses of fertilizer N to the environment, particularly by nitrate leaching, need to be minimized. Fertilizer management is a key component for efficient, economical, and environmentally safe intensive no-till dryland production system management.

The focus of this paper is to summarize fertilizer management strategies of intensive no-till dryland cropping systems in the semi-arid western Great Plains Region that will result in economically and environmentally sustainable systems.

Materials and Methods

The N fertilizer requirements of two cropping systems under no-till management were evaluated, WCF and WF. Nitrogen rates, sources and methods of placement were compared on a Weld loam soil near Sterling, CO. and on a Keith clay loam near Stratton, CO over a 5 yr period. The N placements and timings were: i) UAN pre-plant broadcast on the soil surface (UAN PPB); ii) UAN split placement (30% of N banded below the seed at planting plus 70% of N dribbled over the seed after row closure at planting) (UAN SP); iii) UAN split timing (30% of N banded below the seed at planting and 70% side-dressed below the soil surface at the following growth stages: corn, 12-18" high and wheat, in spring after breaking dormancy) (UAN ST); and iv) Granular urea broadcast pre-plant (UREA). The N rates were: Wheat, 0, 30, 60 and 90 lbs N/A; and Corn, 0, 35, 70 and 105 lbs N/A.

In another experiment (USDA-ARS Akron) the N response and N requirement of sunflower (over 7 yrs) and millet (over 4 yrs) was measured in a wheat-millet (corn)-sunflower-fallow rotation. The experiment was replicated four times, where each rep was mapped as different soils (Weld silt loam, Rago silt loam, Platner silt loam, or Platner silt laom grading into Norka –Colby complex). Nitrogen was top dressed as AN (34-0-0) prior to planting at N rates of 0 , 30, 60, or 90 lbs N/A. Grain yield, biomass N, and preplant inorganic soil N and post harvest inorganic N was measured in each N rate plot. In 1999 and 2000, a micronutrient cocktail containing 0.2 lbs Cu, 0.3 lbs Mn, 0.4 lbs Zn and 0.4 lbs of B/A was foliar applied to pre-bud and then again just at early flowering to sunflower to evaluate micro nutrient response of sunflower.

Results

<u>Nitrogen</u>

<u>Wheat Production</u>

Wheat grain yields responded significantly to N rate and N source/placement at both Sterling and Stratton. However, the response to N at Stratton (7 bu/A) was larger than at Sterling (5 bu/A) (Figure 1). The soil profile NO_3-N level at Sterling was 50 to 60 lb N/A more than at Stratton, thus the reason for the larger response to N fertilizer at Stratton.

The two N source/placement treatments that produced the highest grain yields were UAN SP and UREA. (Figure 2). The UAN PPB treatment generally performed better at Stratton than at Sterling. Performance of UAN ST generally was inconsistent and dependent on weather conditions following the side dress application. If dry weather occurred after application, the fertilizer is positionally unavailable in the dry soil, thus not available to the plant.

When one compares the effect of placement vs. N rate on grain yield, it is very evident that rate is more important than placement. Therefore, producers should focus their attention on applying the correct N rate, understanding that rate has much more effect on economic return than does placement. Soil testing is the key to determining the most economical and environmentally safe N rate to apply.

There was an interaction between rotation and N rate (Figure 1) at Stratton. Lower wheat yields were observed in the WCF as compared to the WF rotation at lower N rates. This was due to the greater depletion of residual soil NO_3-N in the more intense cropping system (Figure 3) when adequate N rates were not applied. This greater N depletion at inadequate N fertilizer rates is directly related to the larger quantity of grain that is produced in the WCF system as compared to

WF. Under adequate N fertility the WCF system produced about 75% more grain than WF, resulting in more demand on the N supplying capacity of the soil. Therefore, there is a need for larger N fertilizer applications in intensive cropping systems as compared to traditional WF. If adequate N rates are applied, wheat yields in the WCF will equal those in the WF (Figure 1). This is of prominent importance to the economics of these systems.

Corn Production

Corn grain yield increased substantially with N rate (Figure 4) ranging from 39 and 17 bu/A at Stratton and Sterling, respectively. At Sterling, when no N was applied the yield averaged about 14 bu/A more (55 Vs. 41 bu/A) than at Stratton. This relationship was observed with wheat yields and attributed to the higher residual soil NO_3-N levels present at Sterling (Figure 4).

Differences among N source/placement treatments were not consistent. Broadcast urea (UREA) appeared to be the highest yielding treatment but was not significantly better than the others. It is very evident that N placement is of less importance than N rate in dryland corn production. This is the same conclusion we came to with winter wheat.

Cropping system N use efficiency

Cropping system grain production per lb. of N uptake in WCF is greater than in WF. This increase in N use efficiency was probably due to the greater ability of corn to absorb N and produce grain biomass. The WCF system produced 1 bushel grain (wheat plus corn) with 1.1 lbs N uptake whereas it took 1.4 lbs N uptake to produce 1 bushel wheat in the WF system. The WCF system required about 73% more N fertilizer input (Westfall et al., 1996 and Kolberg, et al., 1996). This increased N application is not of environmental concern because the increased N demand of the WCF system, plus, probability of the soil profile in the intensive cropping system becoming saturated with water to a point where leaching could occur is small. The more intensive cropping system has a greater water demand as compared to WF, making the WCF system more environmentally safe from the NO_3 leaching standpoint.

Proso millet Production

The average yield response of proso millet to the first increment of N (30lbs N/A) was 18% (Table 1). In 1996 and 1997, the yield response was not significant. If the 4 yr average yields are normalized (100% being the maximum average yield), the maximum yield is obtained with 60 lbs of N /A. However, the average yield increase from the 30 lb N rate to the 60 lb N rate was only 6%, about 2 bu/A. At current N fertilizer costs, and average proso prices, the additional grain yield would not pay for the cost of the extra 30 lbs of N fertilizer. Averaged over years, there was a negative yield response to 90 lb N/A. Based upon these results and those of Rodriguez et al. (1989), we conclude that the optimal N rates for proso for our region are between 30 and 60 lbs of N/A in N deficient soils. Soil testing is the only way to determine the predicted N response. A buildup of inorganic N at the 60 and 90 lb N rates in the top 4 feet of the soil profile was observed in the range of 65 and 200 lbs N/A. This buildup indicates N rates in excess of 60 lb N/A will not be used by the crop, resulting in soil profile N accumulations.

Table 1. Proso millet grain yield response to fertilizer N at USDA-ARS, Akron, Colorado.

N rate	1995	1996	1997	1998	4 yr average	Normalized yield
lbs/acre	----------------------- bushels/acre				--------------------------	
0	15	40	20	44	30	76
30	23	45	18	62	37	94
60	24	52	30	51	39	100
90	25	42	19	53	35	89
P>F 0.05%	*	*	ns	*	*	

* Indicates ANOVA was statistically significant at an alpha level of 0.05%.

Sunflower Production

Nitrogen application increased sunflower yields only one year of 7 yrs (Table 2). However, a significant decrease in sunflower oil content occurred with N applications. An evaluation of total biomass N accumulated at early reproductive stage R1 indicates that sunflower requires about 6 to 7 lbs of N per 100 lbs of seed production. As with proso millet, a buildup of inorganic soil N accumulated in the top 4 feet of the soil profile with the 60 and 90 lbs N/A rates.

Table 2. Sunflower response to N rate and row spacing averaged over 7 yrs and to micronutrients in 1999.

N rate	Row spacing			7 year average
lbs/acre	30 inch rows	20 inch rows no micronutrients	20 inch rows with micronutrients (1999 only)	Grain yield 1995-2001
	Grain yields, lbs/acre			
0	1540 (39.2) χ	1780 (39.9)	1965 (41.6)	1109
30	2070 (38.0)	2420 (39.3)	2595 (40.4)	1142
60	2090 (37.4)	2680 (37.2)	2560 (38.8)	1155
90	2225 (36.9)	2505 (38.1)	2865 (38.6)	1208
P>F 0.05%	*	*	*	ns

χ Values in parenthesis are the seed oil contents (%). * Indicates ANOVA was statistically significant at 5%

A significant increase in sunflower oil content (2%) from a foliar micronutrient application containing Cu, Zn, Mn and B was observed in 1999. However, the increase in oil content was not great enough to pay for the cost of the fertilizer application. Grain yield also tended to increase with micronutrient application, but the increase was not significant. In 2000, neither oil or grain yield responded to micronutrient application. The yield and micronutrient response of sunflower measured in 1999 was probably the result of 6.5 inches of rainfall that came in August. Most years we can expect only about 2 inches of rain in August. In general, water is more limiting for sunflower production in our region than is either N or other nutrients.

PHOSPHORUS

Yield responses to P fertilization is usually smaller than those observed with N. Over a 7-year study, we have found wheat yield responses in the range of 1-5 bu/A with the application of 20 lb P_2O_5 banded below the seed on soils testing medium in available sodium bicarbonate extractable-

P. On the same soils the long-term corn yield response to P has not occurred. However, an early-season growth response is consistently observed, but it does not translate into a grain yield response at harvest. Usually, economic yield increases to P fertilizer on corn grown in a WCF will not occur if adequate P is applied to the wheat, the most P sensitive crop in the rotation, because there will be enough fertilizer P carryover to meet the P needs of the corn crop.

Phosphorus fertilizer placement is very important. Several researchers have investigated this under various tillage systems in the region. On low or medium soil test P level soils, broadcast applications of P fertilizer are not as effective as band applications. The advantage of band versus broadcast is dependent upon the soil test level (Peterson, et al., 1981). On low to medium soil testing soils, the advantage of band application may be as large as 3:1, while on soils testing in the high range, there may be no difference between methods of application. Our recommendation is to apply 50% of the broadcast rate if you are going to band apply the P fertilizer (Motrvedt, et al., 1994).

MICRONUTRIENTS

Western Great Plains soils can be deficient in iron (Fe) and zinc (Zn), but other micronutrient problems have not been documented. However, Fe and Zn deficiency are very crop specific. Wheat is relative insensitive to micronutrient levels while corn and sorghum are very sensitive. Unfortunately, there is no effective Fe fertilizer that is economical and effective for correction of Fe deficiencies on our alkaline soils. The Fe sources are rapidly tied up with soil bases and become ineffective shortly after application. Consequently, the only economical alternative for management of Fe deficient soils is to grow a less Fe sensitive crop.

There are many Zn sources available in the market, but not all are effective. The agronomic effectiveness of granular Zn fertilizers is directly related to their water solubility (Amrani, et al,. 1999). A granular Zn fertilizer should have a water-soluble Zn levels of at least 50% to be effective in supplying adequate Zn levels to the crop.

SOIL TESTING/FERTILIZER RECOMMENDATIONS

One of the first steps in fertilizer management is to assess the inherent and acquired soil fertility status of a soil. This is accomplished through soil testing. However, the reliability and accuracy of a soil test is highly dependent on soil sampling and the use of locally tested correlation data. Improper soil sampling can lead to large errors in fertilizer recommendations; sampling is the most important step of the soil testing procedure. Surface soil samples (0-6 in. depth) should be collected from similar soils in a field for pH, soil organic matter, NO_3-N, P, K, and micronutrient analyses. A minimum of 15- 20 individual soil cores should be collected and composited for analyses. Subsoil samples (6-24 or 48 in. depths) also should be collected to determine the residual NO_3 levels resulting from previous cropping and fertilizer history. The environmental consequences of N fertilizer recommendations are also of primary importance in to days' production systems.

Many of the soils in the Great Plains are deficient in available P. Soil testing procedures are available for development of P fertilizer recommendations. The most frequently deficient micronutrients are Fe and Zn. These deficiencies normally occur on high pH soils that contain free lime and on eroded areas where calcareous subsoils are exposed. However, the DTPA soil test accurately identifies deficient soils and sound fertilizer recommendations can be made for Zn.

Soil testing is the first step in efficient, environmentally safe fertilizer management. By following these recommendations growers will decrease the adverse environmental risk and increase the probability of economic return to their fertilizer dollar.

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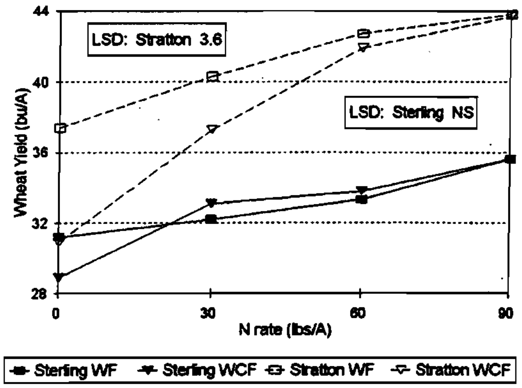

Figure 1. Dryland winter wheat yields at two locations as affected by cropping system and N rate. (Westfall, et al., 1996)

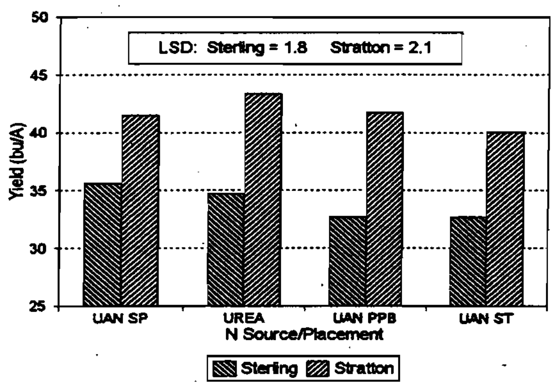

Figure 2. Dryland winter wheat yields as affected by N fertilizer placement/source. (Westfall et al., 1996)

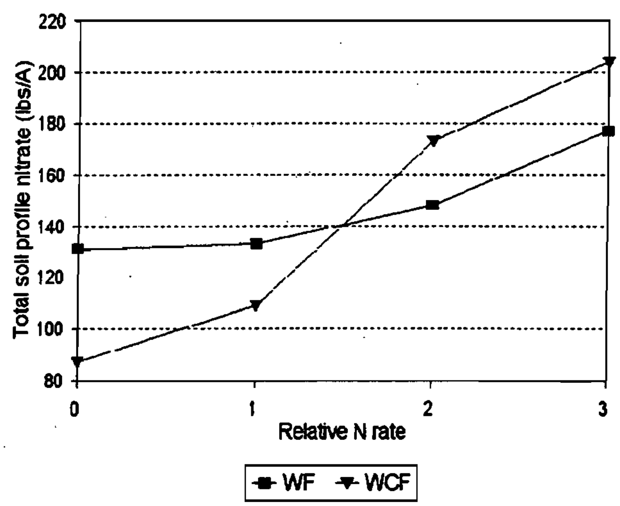

Figure 3. The residual soil profile NO_3-N levels as affected by N rate and cropping system. (Rate 1=0, 2=30/35, 2=60/70, 3=90/105 lb N/A, wheat/corn, respectively)

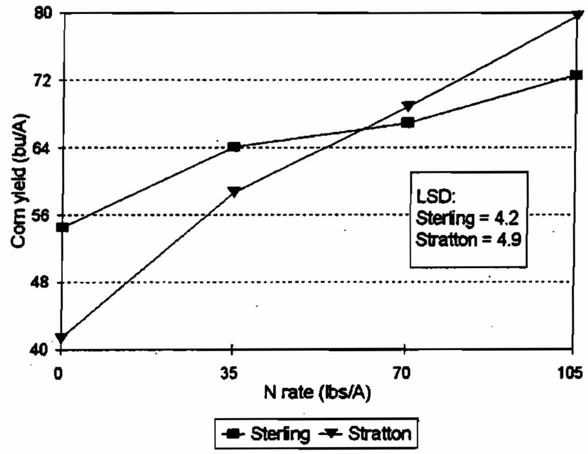

Figure 4. Dryland corn yields as affected by N rate (Westfall et al., 1996)