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COMPUTERIZED FERTILIZER APPLICATION BY SOIL TYPE

M.A. SCHMITT, W.G. WALKER, D. FAIRCHILD

As a farmers looks out over a field during the growing season, he usually wants to see a very homogeneous appearance of crop growth. However, he often observes a very heterogeneous appearance of soils and crop yields associated with these soils in this same field while preparing the seed bed and harvesting the crop. Visual observations show that high spots in the field are lighter in color and often yield less than low spots in the field, which are often darker and higher yielding.

Several factors are important in soil formation: these include soil age, parent material, vegetation, time, and relief or slope of the soil. In most crop producers' fields, these factors are constant except for soil slope, with a slope of as little as 0.5 percent actually causing visual differences. In addition, fields are usually not organized by soil type, but rather, are laid out on the basis of either convenience to the producer or a predesigned grid arrangement.

The result of having several soil types within one field is that, unless farmers manage the soils individually in a field, resources and yields will not be optimized. Several soil properties vary within a field that could influence a producer's management scheme. Obviously, a soil's fertility status can vary with it's location within a field. Table 1 shows soil properties, including nutrient content, for three areas within three different fields.

Herbicide rates and effectiveness can also vary as the soils change both chemically and physically. Factors such as organic matter content, soil pH, and soil texture influence a majority of the herbicides that are used today (Table 2). If a producer uses an average field organic matter content for a herbicide recommendation, the rate could be too low on the darker, lowland soils and too high for the lighter, eroded soils.

The selection of yield goals is another management practice that can be affected by differing soil properties within a field because uniform yields are not achieved across a field. Table 3 shows yield variations within some fields due to differing soil type. If yields vary, then practices such as fertilizer rate, planting populations and possibly, varieties should be changed accordingly.

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The need and awareness for technology to handle different soils within a field has been growing steadily in recent years. While some researchers have predicted this technology will not be implemented for 5 - 15 years, several fertilizer applicators are currently being used which utilize modern technology to treat soils individually within a field. Soil Teq Incorporated, the company developing this technology under the trade name of "Soilection System", is a joint venture of three Minnesota-based companies. Soil scientists from CENEX and the University of Minnesota have provided the technical expertise to make this project agronomically sound.

The fertilizer applicator, the first application of the Soilection System, has the capability to change fertilizer blends and the rate of material application as soil types change in a field. By using a computer, the system incorporates both soil information from a memory board and electronic sensors to regulate flow of fertilizer material from bins on the unit to individual soil bodies in the field.

The first step in the operation of the fertilizer unit is making a digitized map of each field. During the early spring of the year, before the vegetation is present, infrared photographs are taken of the fields. These photographs depict varying shades, primarily due to soil color. Color is influenced by soil organic matter and soil moisture, which can reflect soil texture.

The infrared photographs are then enhanced using a computer to produce a digitized soil map. The enhancement delineates the shades of color into any number of divisions. Currently, the computer program delineates three soils, with a capacity for eight soils. In the enhancement process, the concurrent use of a recent soil survey for the area has been beneficial. Even if an aerial photograph is not available, a digitized map can be made solely from a soil survey. Once this digitized map has been produced, it can potentially be used for many years since soil properties do not change very readily.

The digitized maps are being stored on a programmable read-only memory (PROM), which is inserted in a microprocessor in the cab of the vehicle. The digitized map is displayed on a computer monitor that also is mounted in the cab. As the vehicle moves across the field, a cursor blinks to designate its location. This is accomplished with a radio signal navigation system that interacts with the microprocessor. By using PROMs and the navigation system in a soil sampling vehicle, samples can be taken and tested from each of the different soil types and recommendations can be made for each soil.

When one is ready to spread fertilizer, the operator must enter the recommendation rates for each soil type into the microprocessor, along with some other, general application information. The application rig has six bins for carrying dry fertilizer and four compartments for herbicides that can be impregnated on the fertilizer. As the applicator passes over different soils, the microprocessor sends signals to the different fertilizer bins on the back of the rig. This signal regulates the dispensing rate of the bin by hydraulically controlling the rotation rate of the starwheel at the bottom of the bins, thus dispensing the correct amount of each product to produce the required blend. As the soils change according to the PROM, the fertilizer blend changes.

The economics of this system are somewhat difficult to assess. Naturally, more money is invested in this unit, and almost inevitably, the per-acre application charge will increase. Another cost to be dealt with is soil sampling and testing fees. If a crop producer currently takes only one sample per entire field, the sampling and testing fees will increase. However, if an intensive soil sampling system or multiple samples are being taken presently from a field, costs should not change. In addition, there is an added initial cost to have the PROMS made. However, this is a one-time charge, and some local dealers are buying and keeping the PROMs as a customer service for crop producers.

While the economic liability of this system may be easy to determine, the system also promises monetary returns, although they are difficult to measure. When a crop producer treats a field as an entity, whether 20 or 200 acres, an average is used that will undoubtedly apply too many inputs in some areas and too little in others. But, looking at this from the positive side, the phenomenon also would enable producers to set different yield goals for different areas of a field, based upon soil type. Then, the producer can apply ample fertilizer in good soil areas of the fields, while applying less fertilizer on the poorer areas where lower yields are common.

Additionally, this system can correct micronutrient deficiencies that generally occur in the small portions of a field. A producer would probably not treat an entire field because of prohibitive costs and, thereby, would suffer some yield decreases on those deficient soils. Economic gains should also be seen with precision application of herbicides. Depending on the acreages of the different soil types within a field, a large savings can be realized by treating the soils separately.

This technology is currently being used only with soil sampling trucks and with dry fertilizer spreaders. However, the principles of digitized soil maps and the related technology have other applications as well. Work is presently being done to apply this technology to liquid spreaders, both for fertilizer and pesticides. This concept could also be used on anhydrous ammonia applicators to control the flow rates on various soil types and to apply nitrogen stabilizers on appropriate soils. This technology could also be included on irrigation systems to control water flow and fertilizer and chemical slows based on soil types and their respective water holding capacities.

The technology that reconizes and treats fields as a composite of soils has arrived. To an agronomist, soils scientist, or crop producer, this provides a sound application of the principles of efficient input of resources. The goals of the developers should reflect the goals of the crop producer: to enhance profitability through the efficient use of resources.

Table 1. Soil Property Variations in Three Minnesota Fields as Affected by Soils Within Each Field

Field	Soil	Texture	pH	O.M. (%)	P (lb/A)	K (lb/A)	S (ppm)	Zn (ppm)
1	A	CL	8.0	6.1	29	357	50	1.4
	B	CL	6.8	3.4	46	462	5	1.3
	C	CL	7.8	1.8	34	260	12	0.7
2	A		7.3	10.7	57	280	42	2.8
	B		7.6	3.9	90	432	50	2.2
	C		6.9	1.7	34	294	6	0.6
3	A	SiCL	7.4	4.2	29	243	...	0.8
	B	SL	7.3	3.3	20	170	...	0.4
	C	SL	7.9	1.5	11	164	...	0.3

Table 2. Some Selected Herbicides that are Affected by Soil Physical and Chemical Properties

Soil pH	Organic Matter	Soil Texture
Sencor	Lasso	Treflan
Lexone	Dual	Aatrex
Aatrex	Princep	Bladex
Bladex	Lorox	Lasso
Glean	Bladex	Dual
	Banvel	Sonolan
	Prowl	Prowl
	Sencor	
	Lexone	
	Aatrex	

Table 3. Grain Yield Variations in Four Field as Affected by Soil Types within Each Field, Montana State University

Field	Soil	Yield (bu/A)
1	A (Telstad)	33.7
	B (Joplis)	32.6
	C (Hilton)	29.6
2	A (Bearpaw)	58.7
	B (Vida)	58.1
	C (Fahill)	33.4
3	A (Scobey)	33.2
	B (Kevin)	28.2
	C (Hilton)	23.9
4	A (Kobar)	39.5
	B (Marvan)	11.9

The Role of Ammonium Nutrition in Higher Yields[1]

S. R. Olsen[2]

ABSTRACT

A real need exists to increase N fertilizer use efficiency by crops and to determine what soil and plant factors related to available N may limit crop productivity in given environments. Two forms of available N, NH_4^+ and NO_3^-, may be supplied to a crop by choosing fertilizer N forms and nitrification inhibitors. The potential to supply a crop with two N forms, NH_4^+ and NO_3^- and to increase crop yields and the efficiency of N use by the crop was studied in field experiments with corn. Yield increases from 807 to 2421 kg/ha (12 to 36 bushels/acre) were obtained from treatments that increased the amount of available N in NH_4^+ form. Nitrogen use efficiency by the crop was increased 18% by these treatments which can be utilized in farm practices.

INTERPRETIVE SUMMARY

The potential to supply a crop with both N forms, NH_4^+ and NO_3^-, and increase crop yields and the efficiency of N use by the crop, compared with the same amount of available N in either form alone, has been studied only in a few field experiments. The conditions where these phenomena are most likely to occur are those crop and soil environments that produce high yields and photosynthate supply and reduced N levels in leaves become limiting for grain yields.

The fertility treatments and crop yields with different varieties will provide information on how to improve production practices and crop quality, and the data will lead to knowledge about soil nutrient supply interactions with crop varieties. This research has the potential to increase the efficiency of N fertilizer use by crops and reduce the impact of escalating costs of agricultural chemicals on farm income. This research has the potential to explore and identify the factors which currently limit crop productivity in soils in a given environment.

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Net income per acre increases when farmers can apply management practices that improve soil productivity and increase corn yields per acre to maximum economic levels. For example, if a farmer produces 140 bu/ac (average yield for U.S. is 110 bu/ac), his net income will be approximately $80 per acre. If a farmer can produce 300 bu/ac, his net income will be about $520 per acre.

The potential to supply a crop with both N forms, NH_4^+ and NO_3^-, and increase crop yields and the efficiency of N use by the crop, compared with the same amount of available N in either form alone, has been studied only in a few field experiments. The conditions where these phenomena are most likely to occur are those crop and soil environments that produce high yields and photosynthate supply and reduced N levels in leaves become limiting for grain yields. In this paper we summarize evidence from the literature to suggest that about equal amounts of these two N forms will increase yields and N use efficiency by crops.

A real need exists to increase N fertilizer use efficiency by crops and to explore what soil and plant factors related to available N limit crop productivity in given environments. In a normal sequence of events, fertilizer N is applied to soil and NH_4-N forms are rapidly nitrified to NO_3-N, which is then the form of N mainly used by plants. This NO_3 form also leaches readily and it may be displaced from the root zone. Studies with nitrification inhibitors have been mainly designed to keep more fertilizer N in the slowly leachable NH_4^+ form, and thus conserve N for the crop. Crop residues and farmyard manure, as N sources for crops, also conserve N to some degree by holding N in non-leachable forms.

The relative effectiveness for corn growth of NH_4^+ and NO_3^- sources of N has been studied mainly in solution cultures and short-term greenhouse trials. Cox and Reisenauer (1973) found that wheat yield was increased 50% by adding NH_4^+ to cultures supplying the maximum utilizable concentration of NO_3^-. They suggested this yield increase may be related to more efficient utilization of the plant's limited energy supply. Schrader et al. (1972) observed that growth of corn was most rapid when both N forms were supplied. More N was absorbed and assimilated when both N forms were provided and uptake rates were similar. When both forms of N were absorbed, NH_4^+ was used preferentially for synthesis of amino acids and proteins. Tomato yields were highest in nutrient culture when the N supply was an equal mixture of NH_4^+ and NO_3^- forms.

The relative physiological capability for NH_4^+ and NO_3^- uptake may change between vegetative and ear development growth in corn. The extent of this alteration may be influenced by source-sink relationships during ear growth, i.e., the grain is a sink for reduced N and zein plus glutelin are the main storage proteins in the endosperm. In solution-grown sweet corn, NO_3^- uptake was slightly greater than NH_4^+ uptake, from equal concentrations of each form, prior to silking, but NO_3^- uptake decreased about three times compared to NH_4^+ uptake during ear development. The major transport form of N to the developing endosperm is glutamine, which is also the major product formed in roots absorbing NH_4^+. In other experiments with corn where NO_3^- was the main source of N, the progressive loss of reduced N from the stover showed that the rate of supply of newly reduced N from NO_3^- was insufficient to compensate for or to delay the remobilization of vegetative N during ear growth. Under these conditions stalk NO_3^- remained nearly the same. Below et al. (1981) assumed that NO_3^- has to be transported to the leaves to be reduced. Their data show that stalk NO_3^- acts as a storage reserve; however, utilization of this reserve is slow. Thus, the physiological response of corn to the two N forms in soil under conditions of equal availability, and subsequent effects on grain yield are not well characterized.

The effectiveness with which N is used by corn (Zea mays L.) is important because of increasing costs of manufacture and distribution of N fertilizer. In the past 30 years the increase in corn yields has not been proportional to increased N use (Messmer et al., 1984). The isolation of genotypes that are better able to utilize N fertilizer to produce higher grain yields per unit area would improve this relationship. Differences in N utilization among corn genotypes have been shown, not only in differential responses to N fertilizer, but also in differences in absorption and in utilization of absorbed N (Schrader et al., 1972; Beauchamp et al., 1976; Chevalier and Schrader, 1977; Moll and Kamprath, 1977; Tsai et al., 1978; Pollmer et al., 1979; Reed et al., 1980; Below et al., 1981; Moll et al., 1982; Swank et al., 1982; Messmer et al., 1984; Pan et al., 1984; Tsai et al., 1984). The potential for developing and finding superior, N-efficient hybrids appears to exist.

The metabolism of carbon and nitrogen are closely linked and with the increased use of fertilizer N being closely associated with higher corn yields, it is logical that both C and N metabolism should be considered in attempts to identify factors that limit productivity. Shading, plant density, and canopy studies indicate effects on photosynthesis as well as on nitrate reduction and assimilation. For rice, high yields are possible only under high levels of N supply and plant characteristics that confer high yielding abilities are often associated with responsiveness to N. Nitrogen has two major roles, 1) the establishment of the yield capacity and 2) the establishment and maintenance of photosynthetic capacity (Yoshida, 1972). Other work showed 90% of the N lost from the leaves during normal senescence was from the chloroplasts (Morita, 1980). Wittenbach et al. (1980) showed the loss of N from leaves of field-grown soybeans was concurrent with changes in chloroplast structure and loss of photosynthetic activity during the grain-filling period. In cereals, Mengel and Kirkby (1982) note that an adequate N supply during early growth stages was important in determining the number of ears per unit area. Tollenaar (1977) has suggested that sink sizes may frequently limit crop yields.

For corn, little information is available on the physiological processes that determine ear and kernel initiation. Krantz and Chandler (1954) showed that increasing soil N level from deficient to sufficient increased grain weight 3 or 4 times more than stover weight. A decrease in leaf N of corn during the grain-filling period was concurrent with the loss of chlorophyll (Christensen et al., 1981). A third role for N as a factor limiting corn yields is indicated by work showing that protein accumulation in the kernel, especially zein, could be a factor in regulating kernel development (Tsai et al., 1978, 1984).

Efficiency in uptake and utilization of N in the production of grain requires that those processes associated with absorption, translocation, assimilation, and redistribution of N operate effectively. The relative contribution of these processes to genotypic differences in N use efficiency is unknown and may vary among genetic populations and in different environments, including N supply and the form of N, whether NH_4^+ or NO_3^-. The physiological response of corn to the two N forms in soil under conditions of equal availability, and subsequent effects on grain yield are not well characterized. Vegetative growth of solution-grown corn was increased by the simultaneous presence of both N forms in the root environment compared with either form alone (Schrader et al., 1972). Solution-grown sweet corn exhibited a greater affinity for NH_4^+ over NO_3^- during ear development (Mills and McElhannon, 1982). Nitrogen uptake during ear development contributes significantly to the N translocated to the grain (Friedrich and Schrader, 1979; Moll et al., 1982). Swank et al. (1982) suggest it is the continued input of N into the plant that is responsible for the maintenance of leaf duration and continued photosynthetic activity. The availability of current photosynthate and reduced N ensures the longer duration of grain fill. The end result was a higher yield per plant.

The supply of reduced N to the ear during reproductive growth is important in the establishment and maintenance of a viable sink (Tsai et al., 1978, 1980, 1984). However, a balance between N in the vegetative plant parts and the N supply to the developing sink (kernels) must be achieved to allow maximum productivity. Extensive accumulation of reduced N in plant tissues could indicate a potential for maximum photosynthate production and sink development. Sinclair and de Wit (1976) concluded that the improvement of photosynthetic capabilities during seed development in soybeans without an increase in N assimilation at some point in the life cycle would be useless because maintenance of higher photosynthetic rates would be at the expense of seed development. In simulation model studies they found an enhanced rate of N assimilation greatly increased grain yield. Christensen et al (1981) concluded that the loss of N from corn leaves to the stalk and ear is a major cause of senescence. A long period of grain-fill could be facilitated by a large N supply in leaves at the start of rapid grain filling. A large N supply in leaves should allow a more appropriate redistribution of N to support ear development and leave more N in the leaves to maintain the photosynthetic apparatus (Messmer et al., 1984).

Pan et al. (1984) found that with NO_3^- as the N source for corn, grain yields for the five genotypes differing in prolificacy (capacity to produce more than one ear) indicate that the reproductive sink capacity of the prolific genotypes was under utilized and resulted in smaller yields than the nonprolific genotypes. The inability to absorb NO_3^- during ear development appeared to be a critical factor in limiting yields in the prolific genotypes. Grain yields were increased when these prolific genotypes were grown with the high supply of urea-supplied N rather than

NO_3^-. Thus, NH_4^+ was a more utilizable source of N in prolific plants during grain fill.

The relative physiological capability for NO_3^- and NH_4^+ uptake may change between vegetative and reproductive growth in corn, and the extent of this alteration may be influenced by source-sink relationships during reproductive growth. With solution-grown sweet corn, NO_3^- uptake was slightly greater than NH_4^+ uptake (50-50 ratio of NO_3^- and NH_4^+) prior to silking, but dramatically declined during ear development. In contrast, they observed that NH_4^+ uptake rates increased during ear development and were nearly three times greater than NO_3^- uptake rates 3 weeks after silking (Mills and McElhannon, 1982).

The differential response to N source may be energy related. With rice, uptake of NO_3^- decreased considerably more than NH_4^+ uptake as the energy status of the plants was changed from high to low (Mengel and Viro, 1978). No evidence is available concerning the relative responses to energy status during reproductive growth nor to the possible effects of plant density on these processes. Very few, if any, critical studies have been made of the relative effectiveness of NH_4^+ and NO_3^- for plant growth through the grain filling period or to maturity, with soil as the growth medium. Whereas, plant utilization of NO_3^- has been investigated extensively, the conditions associated with beneficial assimilation of NH_4^+ and of the mixed forms are largely unknown and call for further investigation in both laboratory and field.

Results with a number of plant species subjected to NH_4^+ and NO_3^- nutrition have shown that each ion produces a different physiological response within the plant (Cox and Reisenauer, 1973; Richter et al., 1975; Haynes and Goh, 1978). Weight gains by adding NH_4^+ to an all NO_3^- system have been observed in 14 crop species (Haynes and Goh, 1978; Tsai et al., 1978; Ganmore-Neumann and Kafkafi, 1980; Mengel and Kirkby, 1982; Mills and McElhannon, 1982; Pan et al., 1984). Why NH_4-N has this growth promoting effect is not known. However, the reduction of NO_3^- to NH_3 requires energy and it may be reasoned that by supplying NH_4^+, energy is conserved and diverted to other metabolic processes including ion uptake and growth (Viets and Hageman, 1971; Cox and Reisenauer, 1973; Tsai et al., 1978; Pan et al., 1984). Three reports show that NH_4^+ stimulates the activity of ribulosediphosphate carboxylase compared with NO_3^- in a marine alga (Paasche, 1971), in chloroplasts (De Benedetti et al., 1976), and in corn (Tsai et al., 1978).

Uribe and Lüttge (1984) discussed how the plant cell derives and uses energy, and how this use of energy is related to the movement of solutes across cell membranes. A pair of cell membranes, the plasmalemma and tonoplast, are the sites of solute transport systems driven by adenosine triphosphate (ATP). These membranes also serve as barriers to the diffusional movement of solutes out of the cell. The cell contains enzyme systems that conserve energy released in glycolysis and respiration, or energy captured in photosynthesis, in the form of ATP. Adenosine triphosphate is a major source of metabolic energy. Large amounts of energy are released from ATP in hydrolysis (by ATPase), when the molecule loses one atom each of hydrogen and inorganic phosphate to become adenosine diphosphate (ADP). A question central to solute transport is the means by which the free energy derived from the hydrolysis of ATP is used to drive this process.

The free energy obtained from hydrolysis of ATP by membrane-localized enzymes may thus be used to establish a proton gradient. Proton-translocating ATPases of this type are now known to have a widespread distribution in nature, which suggests a central role for the electrochemical proton gradient in processes of energy conversion. Thus, the use of the free energy of ATP hydrolysis in generating a transmembrane electrochemical proton gradient provides a general mechanism for energy-driven solute movement across plant cell membranes (Uribe and Lüttge, 1984).

The existence of ATPase localized in the plasma membrane has been shown for corn leaf mesophyll cells (Perlin and Spanswick 1981) and the roots of barley (Nagahashi et al. 1978) and corn (Dupont et al. 1981). The tonoplast exhibits ATPase activity in a variety of higher plant tissues, including corn roots (Dupont et al. 1982), red beet roots (Walker and Leigh, 1981, and Kalanchoe (Aoki and Nishida, 1984).

The function of the proton pumping ATPase provides the link from the utilization of the chemical bond energy conserved in photosynthesis and respiration to the establishment of a high-energy state common to the entire membrane. The ability to utilize metabolically generated energy in achieving the transport of solutes across semipermeable membranes is a prime requisite for the survival of a plant. The capacity to control the process is crucial so that cellular solute composition and concentration is maintained at levels that are optimal for the function of enzyme systems. These requirements of solute transport, as related to metabolic activity must be met while cell water potentials are also regulated, to provide the cell with an adequate supply of water (Uribe and Lüttge, 1984).

The properties of ATPase activity of the tonoplast of red beet cells shows an interesting possible connection with the metabolism and utilization of N forms by corn or other crops. The ATPase had a specific requirement for Mg^{2+} and in the presence of Mg^{2+} it was stimulated by salts of monovalent cations (Walker and Leigh, 1981). The degree of stimulation was influenced mainly by the anion and the order of effectiveness of the anions tested was $Cl^- > HCO_3^- > Br^- >$ malate > acetate $> SO_4^{2-}$. For any given series of anions the magnitude of the stimulation (at 50 mM) was influenced by the accompanying cation ($NH_4^+ > Na^+ > K^+$). In eight experiments with chloride salts the stimulation produced by NH_4Cl was always greater than NaCl or KCl.

This ATPase was inhibited by KNO_3 and by N, N'-dicyclohexylcarbodiimide, diethylstilbestrol, and mersalyl, an -SH group poison (Walker and Leigh, 1981). For example, the relative ATPase activity (with $MgSO_4$) was 1.00, 1.89 with KCl, 2.18 with NH_4Cl, 1.45 with KNO_2, and 0.28 with KNO_3. The cause of inhibition with KNO_3 is not known. However, stimulation of ATPases by specific ions is often taken as evidence that the ATPase is directly involved in the membrane transport of those ions. Butz and Jackson (1977) proposed that a transmembrane nitrate reductase (NR) tetramer functions as a carrier for NO_3^- transport across root cells. An ATPase is visualized to be closely associated with the NR tetramer and this ATPase is inhibited by ADP. The connection between these cellular reactions and the utilization of NH_4^+ and NO_3^- forms of N by crops in grain production is not known at present, but the evidence suggests a relationship that needs to be investigated.

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WATER CONSERVATION TECHNOLOGY FOR THE SOUTHERN GREAT PLAINS

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ABSTRACT

Irrigation rapidly expanded in the southern Great Plains in the 1940's and 1950's, with most of the water for irrigation being pumped from the Ogallala Aquifer. The aquifer, however, is limited and has little recharge; therefore, the water level has declined rapidly in much of the region and some of the once-irrigated land has reverted to dryland farming. Many practices have been developed to use the remaining irrigation water more efficiently and to conserve and use more of the water received from precipitation for crop production. Practices for irrigated, limited irrigated and combination irrigated-dryland, and dryland crop production systems are discussed. By adopting the practices that are based on extensive research, the remaining water can be used more efficiently and the rate of reversion to dryland can be reduced. Use of available practices also can result in favorable crop yields on present dryland areas and on those returning to dryland farming.

INTRODUCTION

The need to conserve water for improved crop production in arid and semiarid regions has long been recognized. Consequently, extensive research regarding water conservation has been conducted in the southern Great Plains since the early 1900's. Most of the early research pertained to tillage methods, row spacings, fallowing, crop rotations, etc., and crop responses to these practices (Smika and Unger, 1986). In the 1940's, work began on the stubble mulch system, which proved effective for controlling erosion and conserving water (Johnson and Davis, 1972; Johnson et al., 1974). These studies involved dryland crops. After World War II, irrigation greatly increased in the southern Great Plains. This resulted in a major shift in research to irrigated crops with a concomitant decrease in research for dryland crops. Renewed interest in research for dryland crops or crops with limited irrigation has developed in recent years because of the declining supply of water and the sharply rising cost of energy for pumping water for irrigation. In this report, we discuss water conservation practices for irrigated, limited irrigation and irrigated-dryland, and dryland crop production systems.

IRRIGATED LAND

Most irrigated land in the southern Great Plains is in the High Plains portion of that region. The water is pumped from the Ogallala Aquifer that underlies most of the region. Because recharge to the aquifer is slight (< 1/2 inch/year, Jones et al., 1985), the water level declined rapidly in much of the region after irrigation began in the 1940's and 1950's. Where the saturated thickness was thin, the aquifer was soon depleted and the land reverted to dryland farming by the 1960's. Reversion to dryland continues, especially south of the Canadian River. In contrast, some new irrigation development still occurs, especially north of the Canadian River where irrigation development began later and where the saturated thickness was greater, but deeper below the surface.

The furrow method of irrigation is most common in the High Plains portion of the southern Great Plains. In that portion, slowly permeable soils and land slopes usually < 1% permit relatively long irrigation runs and sets without major land leveling or percolation losses of water. Common practices, however, often result in about 20% tailwater runoff, which is allowed so that the lower end of the field is adequately wetted. To minimize loss of tailwater, many operators capture and recycle it through the irrigation system. Other operators allow less tailwater runoff, but often at the expense of reduced crop yields on the lower ends of fields.

Water conservation under irrigated conditions also has been achieved by using improved application methods, water conveyance methods, and irrigation timing methods, and by improved management of entire irrigation systems. Improved application methods include (1) sprinkler systems that apply water at rates compatible with infiltration rates and in response to plant needs; (2) the low-energy precision applicator (LEPA) method, which uses very low pressure and drop tubes and achieves about 98% application efficiency when used in conjunction with furrow diking (Lyle and Bordovsky, 1980); (3) the surge irrigation system for which water is applied intermittently to alternate blocks of furrows, and which results in more uniform distribution of water throughout the length of the field and reduces excessive water percolation on more permeable soils; and (4) drip irrigation, which permits applying water in response to plant needs without significant losses to evaporation and/or deep percolation. Drip irrigation in the southern Great Plains is limited to high-value crops, such as grapes and pecans, and is used only on a few hundred acres (J.T. Musick, Bushland, Texas, personal communication).

Most irrigation water 25 to 30 years ago was conveyed from pumps to fields by open ditches. Now, most water is conveyed by underground concrete or plastic pipelines, which has greatly decreased water losses due to seepage and use by non-crop plants. Losses are further reduced when aluminum or plastic pipes convey water from undergound pipelines to invididual furrows in the field.

In addition to using improved conveyance and application methods, many irrigators apply water in response to plant needs and at critical growth stages. This results in obtaining greatest crop responses to applied water, reduces water losses due to deep percolation, and reduces nutrient losses due to leaching. When to irrigate and how much water to apply is based on an understanding of a crop's need and response. This understanding may result from practical experiences, use of computer services to predict evapotranspiration and plant responses, or by determining soil water depletion with tensiometers, electrical resistance blocks, neutron attenuation, or gravimetric sampling. By use of the above technologies, along with testing irrigation systems and repairing or replacing inefficient systems, many irrigators now efficiently manage the water that remains available for irrigated crop production.

LIMITED IRRIGATION AND IRRIGATED-DRYLAND SYSTEMS

Full irrigation normally results in the highest crop yields. Where full irrigation is practiced, water from precipitation often is largely ignored. This water, however, can play a major role in crop production where limited irrigation and irrigated-dryland cropping systems are used.

Limited irrigation

Limited irrigation involves either reducing the amount of water applied to a crop or reducing the portion of land area for a crop that is irrigated. One technique that requires less than full irrigation, but still results in favorable yields, is that of applying water at critical growth stages. Although yields are lower than with full irrigation, favorable yields are still obtained. Irrigating at critical stages has been shown to be satisfactory for grain sorghum [*Sorghum bicolor* (L.) Moench] by Musick and Dusek, 1971; for wheat (*Triticum aestivum* L.) by Musick et al., 1984; and for sunflower (*Helianthus annuus* L.) by Unger (1982, 1983). Limiting irrigations is not practical for corn (*Zea mays* L.) in the southern Great Plains (Musick and Dusek, 1980).

dryland crops resulted in a slight (2.3%) increase in total water use, but also an 8.5% increase in water use efficiency.

Average gains in soil water during fallow after irrigated wheat averaged 1.5, 2.1, 2.4, and 2.8 inches with disk-, sweep-, limited-, and no-tillage treatments, respectively, in the wheat-sunflower rotation study by Unger (1981). Seed yields of the dryland sunflower planted after fallow averaged 1,120, 1,100, 1,100, and 1,230 pounds/A, respectively, but the differences were not significant at the 5% level. The wheat-sunflower rotation, however, permitted wheat to be planted soon after sunflower harvest and without a fallow period that is normally used when wheat follows grain sorghum in rotation.

DRYLAND SYSTEMS

Land leveling

Land leveling is the most effective means of conserving water and preventing soil erosion by water; however, it may be expensive, particularly if slopes are steep (> 3%) or benches are wide. With laser-controlled equipment, leveling costs are declining and precision is increasing. Land leveling has no direct effect on erosion by wind. Such erosion is most effectively controlled by a cover of surface residues.

Practical, narrow bench terrace systems (minibenches) can be constructed for $50 to $100/A on gently sloping land (0 to 2% slope). Grain sorghum yield increases of 300 to 600 pounds/A/year are required to pay for installing and maintaining minibench terrace systems. At Bushland, Texas, average grain sorghum yields on land with minibench terraces are 1040 pounds/A higher than yields with graded furrows. With minibench terraces only one or two equipment widths wide, shallow soil cuts reduce soil fertility problems usually associated with land leveling, and much less soil is moved (Jones, 1981).

Conservation bench terrace systems have also proven effective for conserving soil and water on slowly permeable soils (Jones, 1975). With conservation bench terraces, the lower one-third of the terrace interval is leveled to capture runoff from the cropped watershed. At Bushland, Texas, the leveled bench of the conservation bench terrace system receives an average of 4.2 inches more water annually than adjacent sloping land. This conserved runoff provides enough additional water to allow annual cropping of sorghum, wheat, sunflower, and alfalfa (*Medicago sativa* L.) (for seed production) on the level bench.

Furrow diking

Furrow diking was developed in the Great Plains in the 1930's. The practice generally was abandoned by 1950, however, because of problems with the slow operating speed of diking equipment, poor weed control, difficulty with seedbed preparation and subsequent tillage, and increased erosion when dams washed out. Engineers at Bushland and Lubbock, Texas, revived the practice in 1975 by designing improved equipment, using herbicides to control weeds, and applying the practice to summer-grown crops that could benefit more than wheat by preventing runoff during the spring and summer when the potential for runoff is highest (Clark and Jones, 1981). Furrow diking (basin tillage) is a proven soil and water conservation practice that farmers have adopted rapidly for both dryland and irrigated crop production in the Southern High Plains and Red Rolling Plains. An estimated 2 million acres were diked in 1984.

No- and minimum tillage

Dryland farmers are adopting conservation tillage systems, including no-till, in which herbicides replace all or some tillage operations. Increasing fuel and equipment costs often make applying herbicides more economical than performing tillage

The amount of irrigation water required for a crop can be reduced also by eliminating the pre-plant irrigation, which often is the most inefficient irrigation. By eliminating this irrigation, a portion of the soil water reservoir may be left available for storage of more water from precipitation. Also, the loss of water by evaporation is decreased during the period when the potential for evaporation is relatively high because of the bare soil surface.

Further techniques for limiting irrigation are those of not irrigating all furrows or of only irrigating a part of the land area. In the first case, water is applied to alternate furrows. The non-irrigated furrows may be diked or remain undiked. If diked, 50% of the water that would be lost as storm runoff is retained on the area, thus increasing the effectiveness of precipitation for crop production. Where irrigation water is extremely limited, skip-row cropping with two rows planted and one or two rows unplanted may be used. The furrow between planted rows is irrigated and the remainder of the furrows are diked to capture water from precipitation. Skip-row planting and irrigation is used extensively for cotton (Gossypium hirsutum L.) in the southern Great Plains (Jones et al., 1985). Musick and Dusek (1982) used a two-in, one-out cropping pattern for corn and grain sorghum with irrigation of the furrow between the planted rows. Water infiltration during one irrigation was reduced 46% as compared to that for every-furrow irrigation. Skip-row systems reduced yields on a total area basis, but increased yields and water use efficiencies on a planted-area basis.

Limited irrigation-dryland

Stewart et al. (1983) developed a limited irrigation-dryland (LID) system that efficiently uses water from precipitation and irrigation for grain sorghum production on furrow-irrigated, slowly permeable soils. With LID, the upper one-half of a field is managed as fully irrigated, the next one-fourth as a tailwater runoff section to capture runoff from the irrigated section, and the lower one-fourth as a dryland section with furrow dikes to capture runoff from rainfall and, in some cases, from irrigation on the upslope irrigated sections. Seeding and fertilizer application rates are varied according to expected yields on the different sections of the field. Alternate furrows are irrigated; the remaining furrows are diked to capture water from precipitation. The objective is to minimize or prevent runoff from the field. In tests at Bushland, runoff was slight with the LID system as compared with a conventional furrow irrigation treatment. The LID system resulted in an average of 350 pounds of grain/A-inch of applied water compared to 215 pounds of grain/A-inch with the conventional treatment.

In contrast to the above system where a part of the same crop was irrigated and the other not irrigated in a given year, the irrigated-dryland system can be used also to irrigate alternate crops on a given area with the following crop being non-irrigated (dryland). Such systems have been evaluated by Unger (1984) and Unger and Wiese (1979) for winter wheat and grain sorghum in rotation, by Unger (1977) for continuous wheat, and by Unger (1981) for winter wheat and sunflower in rotation. For the wheat-sorghum rotation, wheat was irrigated and yielded an average of about 7,000 pounds residue/A. In the study by Unger and Wiese (1979), 15, 23, and 35% of the fallow period precipitation was stored as soil water with disk-, sweep-, and no-tillage treatments, respectively. The non-irrigated sorghum planted after fallow yielded an average of 1,720, 2,230, and 2,800 pounds grain/A with the respective treatments. Precipitation storage during fallow averaged 29% for moldboard, 34% for disk, 27% for rotary, 36% for sweep, and 45% for no-tillage in the study by Unger (1984). The respective grain yields were 2,280, 2,110, 1,950, 2,470, and 2,980 pounds/A for the non-irrigated sorghum planted after fallow.

When irrigated and dryland winter wheat were alternated on the same area, grain yields averaged 10% greater than where irrigated and dryland crops were grown continuously on the separate areas (Unger, 1977). Alternating the irrigated and

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Addendum

Fertility research by USDA personnel in the southern Great Plains:

1. Evaluation of nitrate-nitrogen levels under no-tillage and sweep tillage conditions in a wheat-sorghum-fallow sequence and in a no-tillage continuous wheat system on dryland. H.V. Eck, Bushland, TX.
2. Effect of applied nitrogen and phosphorous fertilizer on dryland wheat in the tillage systems mentioned above. H.V. Eck, Bushland, TX.
3. Determination of the rates of phosphorous fertilizer needed to obtain optimum yields of irrigated crops. H.V. Eck, Bushland, TX.
4. Interactive effects of nitrogen and soil water on growth, development, and yield of winter wheat at several Great Plains locations. J.L. Hatfield, Lubbock, TX.
5. Effect of long-term cultivation on soil productivity. Fertility treatments are applied to soils (Amarillo series) that have been out of cultivation for 35 years and others in cultivation continuously for 50 years. T.M. Zobeck, Big Spring, TX.

(Wiese and Unger, 1983). While research has shown little difference in soil water accumulation or yield between stubble mulch tillage and no-till on dryland (Wiese et al., 1980; Wiese et al., 1967), the additional crop residues retained on the soil surface with no-tillage provide increased protection against wind erosion.

With no-till, applying atrazine[1/] to wheat stubble immediately after wheat harvest to control weeds through the 11-month fallow and into the sorghum growing season is particularly successful in a wheat-sorghum-fallow sequence. This eliminates three to five subtillage operations and possibly one or two cultivations. Problems with grassy weeds during fallow may require an application of glyphosate or subtillage with sweeps.

Glean (chlorsulfuron) was labeled for use on wheat in 1982. In research trials, Glean has controlled weeds and volunteer sorghum during fallow after sorghum, and during the wheat growing season. The economics of Glean in the wheat-fallow-sorghum-fallow sequence are not as favorable as for the triazine herbicides.

Recent advances in application systems for Roundup (glyphosate) and paraquat make these contact herbicides economically attractive for controlling weeds and volunteer crops on dryland. By applying ultra-low volumes of carrier (3 gallons of water/A) with controlled droplet applicators or less than 7 gallons of water/A with fantips, rates of Roundup or paraquat as low as 0.25 pounds/A have effectively controlled weeds (Green et al., 1982). This is only 50% of the level recommended by the label for use with conventional sprayers.

Crop sequence and fallow

Long fallow (non-cropped) periods result in inefficient use of precipitation under the high evaporative demand conditions prevalent in the southern Great Plains. Thus, most cultivated areas are cropped annually to wheat, cotton, or sorghum rather than in an alternate crop-fallow system which produces one crop in 2 years. Well adapted sequences with shorter 11-month fallow periods are wheat-sorghum-fallow or, farther south where cotton is grown, a wheat-cotton-fallow sequence. These systems produce two crops in 3 years.

A wheat-sorghum-fallow sequence, with the option of following wheat with wheat or sorghum with sorghum if soil water conditions are favorable at planting time (> 5 inches of plant available water in the root zone) is probably the best sequence for maximum water conservation and use for crop production for the southern Great Plains.

SUMMARY AND CONCLUSIONS

Extensive water conservation research has been conducted in the southern Great Plains, which has led to the development of improved practices for irrigated and dryland crop production. By adopting the improved practices, more of the water resources can be used for crop production. For irrigated crops, greater conservation and use of precipitation along with the remaining supply of water in the aquifer can result in favorable crop yields and/or decrease the rate of reversion of the irrigated land to dryland. Use of improved conservation practices on dryland can result in favorable and more reliable yields of crops grown on those areas.

[1/] This paper reports the results of research only. Mention of a pesticide does not constitute a recommendation for use by the U.S. Department of Agriculture nor does it imply registration under FIFRA as amended.

SOIL FERTILITY RESEARCH - TEXAS HIGH PLAINS

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ABSTRACT

Multirate nitrogen and phosphorus field studies were conducted for several years with irrigated wheat, grain sorghum and corn on the major soil types of the Texas High Plains for the purpose of developing soil test correlations for nitrogen and phosphorus. Soil samples were taken prior to fertilizer application in increments of 0-6, 6-12, 12-24, and 24-36 inches. These samples were analyzed for nitrate-N and soil test phosphorus. Regression analyses and analysis of variance were used to test various mathematical models relating grain yields to soil test measurements and fertilizer rates.

Second order polynomial equations of the form $\hat{y} = C + aN_f + bN_r + cN_f^2 + dN_r^2 + eN_fN_r$ were found to be useful in relating grain yield ($\hat{y}$) to applied fertilizer (N_f) and residual soil nitrate-N (N_r) measured to some sampling depth. It was necessary to use N_f and N_r as separate independent variables because the marginal rate of substitution of N_r for N_f was variable and thus N_r and N_f were not additive in their effects on yield.

The Cate-Nelson ANOVM (Analysis of Variance Method) for partitioning soils for expected crop response to applied P fertilizer was found to be superior to four other models tested when a standard extraction procedure was used. However, when phosphorus dissolution rates constants (k_A) were determined using the two constant rate equation, a semilog relationship was found between crop response (Δy) to applied P and the dissolution rate constant.

OBJECTIVES

Use of fertilizers in a crop production system is an economic investment and should be done with the expectation of a reasonable return for that investment. Insufficient fertilizer applications are costly in lost yields and over application results in unwarrented production costs. One of the keys to efficient use of fertilizers is to apply the amount necessary to obtain the desired crop production levels. In order to apply correct amounts of fertilizers, it is necessary to know the expected crop response to applied fertilizers in relationship to the nutrient supplying power of the soil. On the Texas High Plains it is necessary to apply nitrogen fertilizer to most irrigated crops and frequently it is necessary to also apply phosphorus fertilizer in order to achieve the yield potential.

The objectives of the research reported here were to 1) develop laboratory tests suitable for assessing the nutrient supplying power of Texas High Plains soils and 2) develop quantitative relationships between expected crop response, soil test values, and rates of applied fertilizer.

MATERIALS AND METHODS

Multirate nitrogen and phosphorus fertilizer irrigated field trials were conducted at various locations on the Texas High Plains from 1966 to 1983. The trials were conducted on the major soil types and included grain sorghum, corn and wheat.

Table 1. Regression equations for six location years of data with coefficients of determination (R^2) and standard errors of estimate (SE) for grain sorghum and corn yields ($\hat{y}$) in lbs/A as influenced by residual nitrate-N (N_r) measured to several depths and fertilizer N (N_f) in lbs/A. Models used were: $\hat{y} = C + aN_f + bN_f^2$, $\hat{y} = C + aN + bN^2$ where $N = N_f + N_r$, $\hat{y} = C + aN_f + bN_f^2 + cN_r + dN_r^2 + eN_fN_r$.

Soil Sample depth, in.	Equation Number	Regression Equation	R^2	SE
		Sorghum		
	1	$\hat{y} = 4745 + 39.34N_f - 0.116N_f^2$	0.592	1074
0-6	2	$\hat{y} = 3697 + 53.77N - 0.167N^2$	0.708	908
0-12	3	$\hat{y} = 3022 + 58.73N - 0.172N^2$	0.762	820
0-24	4	$\hat{y} = 2170 + 59.00N - 0.147N^2$	0.821	712
0-36	5	$\hat{y} = 1802 + 53.59N - 0.114N^2$	0.824	705
0-6	6	$\hat{y} = 2382 + 54.74N_f - 0.098N_f^2 + 164.71N_r - 0.818N_r^2 - 1.097N_aN_r$	0.808	793
0-12	7	$\hat{y} = 2093 + 56.45N_f - 0.103N_f^2 + 110.86N_r - 0.433N_r^2 - 0.671N_aN_r$	0.814	780
0-24	8	$\hat{y} = 3036 + 56.60N_f - 0.099N_f^2 + 13.70N_r + 0.328N_r^2 - 0.384N_aN_r$	0.803	745
0-36	9	$\hat{y} = 2042 + 55.74N_f - 0.117N_f^2 + 45.25N_r - 0.089N_r^2 - 0.225N_aN_r$	0.836	733
		Corn		
	1	$\hat{y} = 91.6 + 0.98N_f - 0.003N_f^2$	0.609	27.6
0-6	2	$\hat{y} = 39.7 + 1.44N - 0.004N^2$	0.877	15.5
0-12	3	$\hat{y} = 20.5 + 1.39N - 0.003N^2$	0.933	11.4
0-24	4	$\hat{y} = -6.9 + 1.35N - 0.002N^2$	0.933	11.4
0-36	5	$\hat{y} = -31.3 + 1.31N - 0.002N^2$	0.902	13.8
0-6	6	$\hat{y} = 51.6 + 1.45N_f - 0.002N_f^2 + 0.04N_r + 0.023N_r^2 - 0.014N_aN_r$	0.964	9.0
0-12	7	$\hat{y} = 47.2 + 1.41N_f - 0.002N_f^2 + 0.28N_r + 0.006N_r^2 - 0.008N_aN_r$	0.959	9.0
0-24	8	$\hat{y} = 47.4 + 1.47N_f - 0.002N_f^2 + 0.06N_r + 0.003N_r^2 - 0.005N_aN_r$	0.967	8.7
0-36	9	$\hat{y} = 49.3 + 1.55N_f - 0.002N_f^2 - 0.06N_r + 0.002N_r^2 - 0.004N_aN_r$	0.971	8.0

Table 2. Regression equations four location years data with coefficients of determination (R^2) for wheat grain yield ($\hat{y}$) in bu/A as influenced by residual nitrate-nitrogen (Nr) measured to several depths, and applied N (N_f) in lbs/A. Models used were: $\hat{y} = C + aN_f + bN_f^2$, $\hat{y} = C + aN + bN^2$ where $N = N_f + Nr$ and $\hat{y} = C + aN_f + bN_f^2 + cNr + dNr^2 + e\,N_fNr$.

Soil Sample depth, in.	Equation Number	Regression Equation	R^2
	1	$\hat{y} = 50.6 + 0.0246N_f - 0.0008N_f^2$	0.258
0-6	2	$\hat{y} = 40.2 + 0.369N - 0.0011N^2$	0.275
0-12	3	$\hat{y} = 28.5 + 0.490N - 0.0014N^2$	0.384
0-24	4	$\hat{y} = 11.6 + 0.558N - 0.0013N^2$	0.346
0-36	5	$\hat{y} = -1.2 + 0.580N - 0.0011N^2$	0.409
0-6	6	$\hat{y} = 6.5 + 0.440N_f + 2.611Nr - 0.0005N_f^2 - 0.0340Nr^2 - 0.0072N_fNr$	0.763
0-12	7	$\hat{y} = 17.2 + 0.447N_f + 1.023Nr - 0.0006N_f^2 - 0.0065Nr^2 - 0.0038N_fNr$	0.828
0-24	8	$\hat{y} = 42.5 + 0.528N_f + 0.129Nr - 0.0005N_f^2 - 0.0004Nr^2 - 0.003N_fNr$	0.841
0-36	9	$\hat{y} = 26.8 + 0.510N_f + 0.313Nr - 0.0005N_f^2 - 0.0009Nr^2 - 0.0022N_fNr$	0.839

Table 3. Amount of fertilizer nitrogen required to produce a given yield of sorghum grain at various levels of residual soil nitrate-N as determined by Equation 6, Table 1.

Yield lbs/A	Residual Nitrate-N (0-6") lbs/A						
	5	10	15	20	25	30	35
	----------	----------	----------	lbs/A	----------	----------	----------
4000	17	1					
5000	40	25	9				
6000	66	53	39	21			
7000	96	87	75	62	44	21	
7500	113	107	99	90	76	56	26
8000	133	131	131	138			

Table 4. Cate-Nelson ANOV partitioning method for P extracted with 0.025M EDTA in 1.4M acetate buffer using Δy_{max} for 22 location years of grain sorghum data.

Test No.	Δy_{max} lbs/A	P ppm	Range in class SS for three classes
4	2357	3.1	
1	2492	3.6	4,232,731 - 15,629,762
2	3131	3.8	7,977,890 - 15,096,846
3	2973	4.0	11,324,274 - 18,550,886
8	566	6.2	8,170,845 - 16,027,863
6	1029	6.4	6,820,667 - 15,300,682
11	3110	6.7	10,870,092 - 16,213,951
10	1952	6.8	12,204,454 - 16,265,256
5	1600	7.0	12,718,683 - 15,945,949
7	1670	7.1	13,662,682 - 15,774,137
12	1020	8.1	12,862,855 - 14,208,250
13	1954	8.5	15,173,485 - 15,390,972
9	198	10.0	12,244,621 - 12,811,867
15	1080	13.9	12,241,842 - 12,485,231
17	6	14.0	9,351,937 - 9,914,721
19	557	14.0	8,235,863 - 8,401,541
14	1037	15.0	8,720,395 - 8,790,787
18	66	15.1	6,577,023 - 6,648,370
16	-263	16.6	3,831,185
21	160	20.4	
20	298	24.9	
23	531	26.7	
22	311	43.5	

Nitrogen rates ranged from 0 to 240 lbs N/A, generally applied in 40 lb./A increments. Phosphorus rates ranged from 0 to 40 lbs. P/A generally applied in 20 lb./A increments. Soil samples were taken prior to fertilizer application in 0-6, 6-12, 12-24, and 24-36 inches. Nitrates were extracted using a 0.05 M sodium sulfate solution and determined on a Technicon AutoAnalyzer. Phosphorus was extracted using 0.025 M EDTA in 1.4 M ammonium acetate and determined on a Technicon AutoAnalyzer (Onken et al., 1980). Phosphorus dissolution rate constants were obtained by determining phosphorus in an EDTA extract at time intervals ranging from 1.0 minute to 24 hours (Onken and Matheson, 1982). Various mathematical models were utilized in analyzing the data including second order polynomials, power functions, logarithmic functions, Mitscherlich curves, and the Cate-Nelson ANOVM (Cate and Nelson, 1971) and the two constant rate equation.

RESULTS AND DISCUSSION

Several models were fitted to the response data for grain sorghum, corn and wheat in an effort to describe the relationship between grain yield and applied fertilizer N and residual soil nitrate-N, Tables 1 and 2. The poorest relationship was obtained when residual nitrate-N was excluded and only applied fertilizer N was considered (Eq. 1 in Tables 1 and 2, R^2 values of 0.592, 0.609 and 0.258 for sorghum, corn, and wheat respectively). The relationships were greatly improved when residual nitrate-N was included (Eqs. 2, 3, 4, and 5 in Tables 1 and 2) as measured by R^2 and standard error of the estimate (SE). For these equations, applied fertilizer N and residual nitrate-N were summed to produce a single independent variable. A further improvement in the relationship occurred when applied fertilizer N and residual nitrate-N were treated as separate independent variables and the equations developed by multiple linear regression (Eqs. 6, 7, 8, and 9 in Tables 1 and 2); the most pronounced being with wheat, Table 2. In general, inclusion of residual nitrate-N measured to depths greater than 6 inches had only small effects on R^2 and SE values, which indicates that soil samples taken to 6 inches would most often be sufficient to assess the N supplying power of the soil.

Inability to predict substantially beyond experimental data limits is one of the problems associated with the use of empirical equations. This problem is shown in Table 3. Equation 6 from Table 1 was used to calculate the N fertilizer requirement for several sorghum grain yields at seven levels of residual soil nitrate-N. For the studies used in developing this equation, yields ranged from 1,500 to 9,000 lbs/A and residual nitrate-N levels from 5 to 35 lbs/A in the top six inches. It can be noted in Table 3 that the equation began predicting spurious results at a yield level of 8,000 lbs/A and residual nitrate-N levels above 10 lbs/A. It predicted the same fertilizer requirement at 15 lbs of residual nitrate-N/A and a greater fertilizer requirement at 20 lbs of residual nitrate-N/A than at 10 lbs of residual nitrate-N/A. Therefore, empirical equations need to be used with some caution and should be developed over the widest possible range of experimental conditions.

In addition to providing information relative to N fertilizer requirements, these equations can also provide other useful information as illustrated in Figure 1. The relationship between fertilizer use efficiency (FUE) and grain yield, applied fertilizer N(N_f) and residual soil nitrate-N (N_r) measured to 6 inches is shown in Figure 1. Fertilizer use efficiency was calculated as follows:

$$FUE = (\text{yield a } N_f - \text{check yield})/N_f$$

As would be expected, due to the quadratic nature of the response equation, FUE decreased with increasing rates of fertilizer N and yield levels. The figure also shows that, pound for pound, residual soil nitrate in the six inch sampling increment had a greater depressing effect on FUE than applied fertilizer N. Thus, these types of response equations might also yield useful management information.

For developing P soil test correlations we have investigated two procedures. The Cate-Nelson Analysis of Variance Method for partitioning sample analyses was found to be useful in routine soil testing. It was found to yield higher R^2 values than the Mitscherlich, logarithmic or quadratic equations. Data from 22 location years are shown partitioned into three classes in Table 4. This partitioning was based upon actual yield changes (Δy max) due to the application of P fertilizer. The R^2 for this three class partitioning was 0.742.

Our second approach for relating extractable soil P to crop response involved dissolution kinetics. The solubility of soil P compounds and the reaction rates and products of applied P compounds are important to crop production. Thus, the dissolution of soil P compounds related to plant response would be useful in the study of P reactions in soil. Due to the many and varied P compounds in soils, the identification of each, determination of its dissolution in the presence of other soil components and its contribution to plant nutrition becomes a difficult task. However, if a combined P dissolution rate constant in a given solution could be related to plant response to applied P it could provide a measure of P reaction rates in soil and predict subsequent effects on plant growth. For this purpose we selected six soils on which grain sorghum response to applied P varied widely and extracted them with an EDTA solution. Dissolution rate constants were calculated using eight kinetic models. One that was found to be particularly useful was the two constant rate equation; $\ln C_A = \ln k_A + b\ln t$. We found that the P dissolution rate constants (k_A) were closely related to grain sorghum response to applied P, Figure 2. The availability of this measureable parameter to relate dissolution of soil P to crop response is seen as being very useful in agronomic research. Techniques may be developed for determination of reaction rates of fertilizer P, prediction of P availability over time, and evaluation of the effects of such factors on temperature, moisture, P sources, and organic and inorganic components of P reactions in soils.

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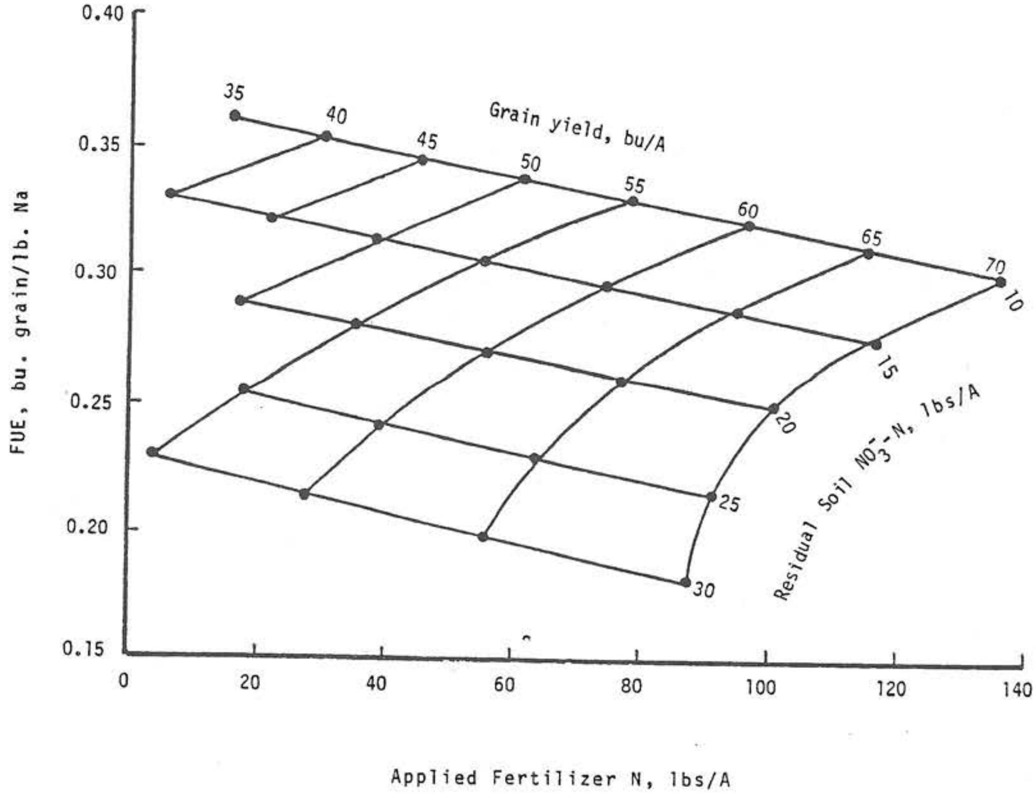

Figure 1. Relationship between fertilizer use efficiency and applied fertilizer nitrogen at several wheat grain yields and residual soil nitrate levels measured to 6.0 inches.

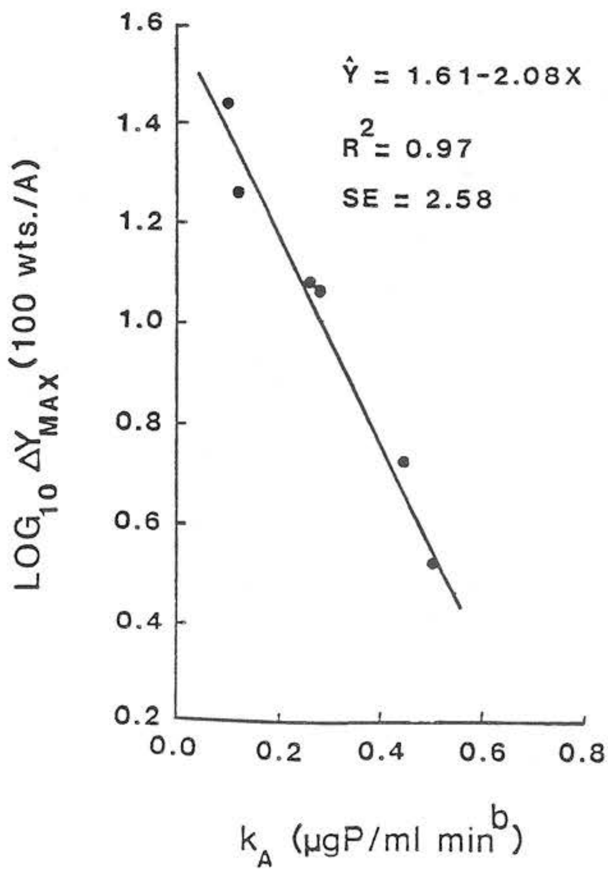

Figure 2. Relationship between grain sorghum yield response to applied P, Δy_{max}, and the rate constant, k_A, for the two-constant rate equation.

AMMONIUM THIOSULFATE AS A NITRIFICATION AND UREASE INHIBITOR - PRESENT STATUS

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ABSTRACT

Since most of the author's work on ammonium thiosulfate (ATS) as a nitrification or urease inhibitor has already been published, only an Abstract and Bibliography are presented here. Major findings are: 1) Thiosulfate ($S_2O_3^{=}$) has significantly inhibited nitrification in laboratory incubations. 2) This effect has been difficult to reproduce in the field, due to the fact that thiosulfate is too easily leached below the ammonium retention zone. 3) Thiosulfate has significantly inhibited soil urease activity in laboratory incubations. 4) Modest additions (1-5% v/v) of ATS to urea-ammonium nitrate (UAN) have significantly reduced ammonia volatilization in both lab and field tests. However, ammonia loss directly from ATS can occur if the inclusion of ATS is too high, as many ATS products are alkaline. 5) Common ammonium polyphosphate (APP, 10-34-0) can also reduce the ammonia volatilization potential of UAN, presumably because of a pH buffering effect. Addition of APP to UAN-ATS mixtures seems to prevent the ammonia loss from ATS observed at higher levels of ATS addition. 6) The beneficial effects of ATS and APP on ammonia loss are strengthened by dribbling rather than spraying the fertilizer on the soil surface. 7) Ammonia losses from UAN have consistently been the least when both ATS and APP were present. 8) Trial rates of 2% (v/v) ATS and 10-20% (v/v) APP in the fertilizer mixture are suggested for trial, until further research indicates otherwise. 9) These concepts may prove to reduce ammonia losses from surface applied UAN with very little extra expense and research in this area is urged. 10) In any case, adding ATS or APP will never replace incorporation as the most sure way of reducing ammonia loss. However, ATS-APP-UAN mixtures may prove to reduce ammonia losses in cropping systems where immediate incorporation is not feasible.

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Fertilizer Application with No-till Small Grain Seeding Equipment

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Abstract

Several innovative fertilizer application equipment designs have been developed by short line equipment manufacturers for no-till grain drills. The units allow anhydrous application at seeding time offering a new management alternative with potential for reduced production costs. Precise seed-fertilizer placement achieved with these units plus design simplicity make them attractive for adoption in both row crop and small grain seedings in other production areas.

Equipment Objectives

No-till seeding equipment has progressed through a series of design changes in efforts to seed and fertilize as a single pass operation. Need for a single pass operation lies in the inconvenience or incompatibility of other fertilization techniques.

Criteria strived for as design changes have progressed are as follows:

a) Minimal residue disturbance - Fringe area winter wheat production in the northern plains require upright residues to trap and hold a protective snow blanket for both over winter survival and added stored moisture.

b) Minimal seedbed disturbance - Conditions for rapid germination are difficult to establish and maintain in no-till seedbeds. Ideally, fertilizer equipment should assist preparation rather than disturb no-till seedbeds.

c) Maximize trash flow through seeding equipment - Trash plugging in heavy residues is intolerable in any no-till seeding unit design. Fertilizer equipment should compliment features designed to streamline trash flow through equipment.

d) Ammonia application at seeding - Production economics dictate using least cost plant food sources. Anhydrous ammonia applied prior to seeding dries the seedbed unevenly and reduces standing residues essential with winter wheat seedings.

e) Precise seed - fertilizer placement - Germination damage and agronomic needs for maximizing small grain seedling nutrient uptake have intensified efforts for better seed - fertilizer placement equipment. High nitrogen application rates dictate seed-fertilizer separation.

Fertilizer Placement Designs and Evaluation

It is important to recognize tillage management programs are equipment oriented and switch to a new production technique normally involves equipment purchases. Further, adoption of new technology, developed through public fund research, often lags until suitable equipment is available for its implimentation.

In recent years ideas for new field equipment design throughout the Great Plains have come from innovative growers and shortline equipment manufacturers. Little equipment design has been done by public funded institutions and major equipment manufacturers. As a result, most designs are for specific needs and have limited soil condition or geographic area application. This has been true for no-till grain drill designs and their fertilizer application equipment. However, local popularity has lead to market expansion and equipment modification to meet a broader spectrum of soil and seeding conditions.

Disk openers

The Yielder[1], deep bander design (Figure 1) introduced the first no-till grain drill suitable for anhydrous ammonia application. The deep bander is a conventional yielder seeding unit equipped with a Cold Flo[2] kit to chill ammonia maintaining it as a liquid until released at the bottom of the disk opener slit. The unit also accommodates simultaneous application of dry granular products.

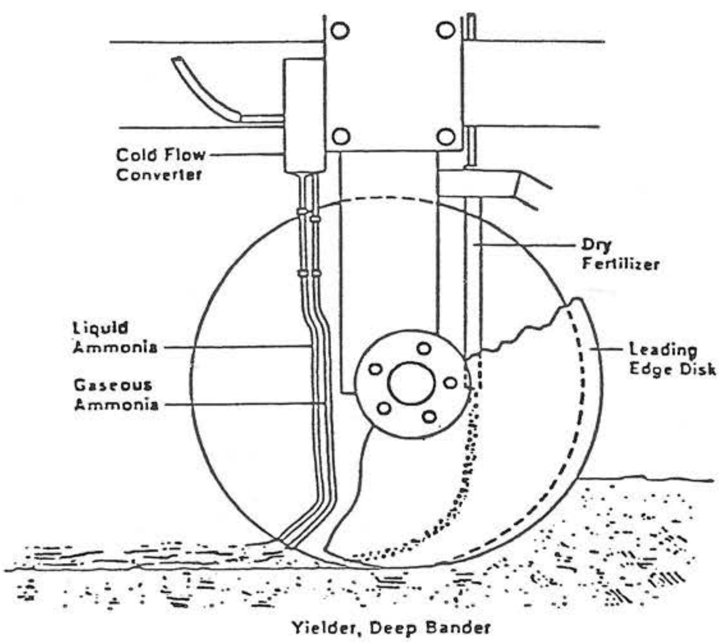

Fig. 1.

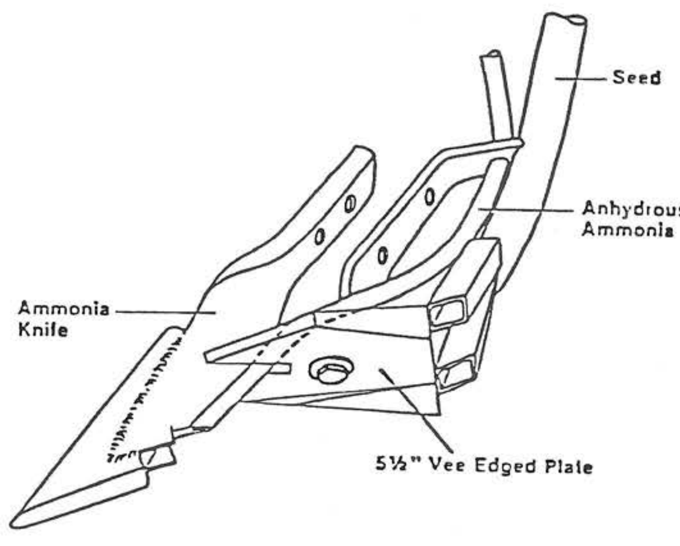

Fig. 2.

1/ Trade names are used solely to provide specific information. Mention of a trade name does not constitute a guarantee or endorsement by North Dakota State University or the U.S. Department of Agriculture.

2/ Ibid.

The deep bander unit is mounted ahead of two seeding units on the same bar. Current drill design mounts bars on 20" centers. Thus fertilizers are applied in rows on 20" centers. Seed-fertilizer spacings are ridgedly controlled by front to rear seeding units mounted on the same bar. Settings on each unit adjust relative operating depths. A hydraulic system controls running depths.

The deep bander followed by two seeding units has given rise to the paired row seeding concept, a system of fertilizer application between two narrow spaced rows with a wide space to the next paired row. Width of paired row and inter row spacings can vary within limits available for 20" fertilizer application centers.

The wide inter row space provides better trash flow in heavy residues. Also, seeding units moved close to the deep band trench have the advantage of operating in soil partially disturbed by the fertilizer application unit.

Shank openers

Haybuster, Inc.[3/], Jamestown, North Dakota, introduced the concept of anhydrous ammonia and seed application on the same shank. The original hoe drill design applied ammonia directly below the seed using a horizontal plate to crush the ammonia trench side walls and firm the soil over the trench for a seed bed. A modification of this design concept by Ace Services[4/], Colby, Kansas forms two small vee shaped seedbeds in disturbed soil on either side of the ammonia trench (Figure 2). This design duplicates the paired row configuration with narrow seed rows on either side of the fertilizer application trench. Phosphorus can be applied either in the trench or down the drop tube with seed in the seed rows. With a twisted shank, the unit mounts readily on chisel plows or field cultivators using air delivery seeding systems.

Seed-fertilizer placement spacing is fixed with the equipment design but is maintained precisely since both seed and fertilizer are applied on the same shank. In current designs, ammonia is applied 5 1/2 inches deep between 5 1/2 inch row spacings.

Seed and fertilizer on the same shank eliminates extra fertilizer shanks on the drill both reducing cost and improving trash flow through the unit. Seedbed moisture retention is excellent through use of a packer wheel and the fact soil disturbance which promotes drying is minimized.

Air seeders

The Vern knife[5/] manufactured in Champion, Alberta, is an adaptation prompted by need for equipment to apply anhydrous ammonia at seeding with air seeders using cultivator sweeps as a seeding shoe (Figure 3). The air seeder uses a chisel plow or field cultivator as its basic seeding unit

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3/, 4/, 5/ Ibid.

and high volume low pressure air for seed delivery. Improved seed covering depth is obtained when seed is delivered beneath the wings of cultivator sweeps.

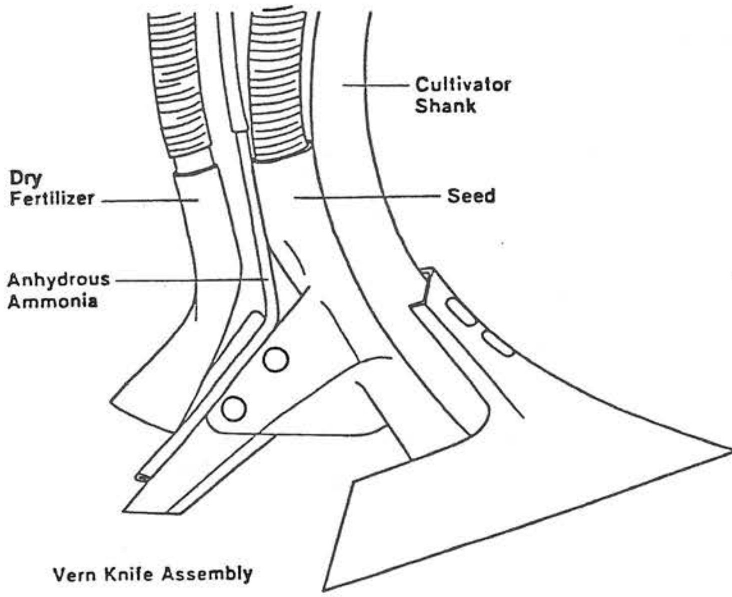

Fig. 3.

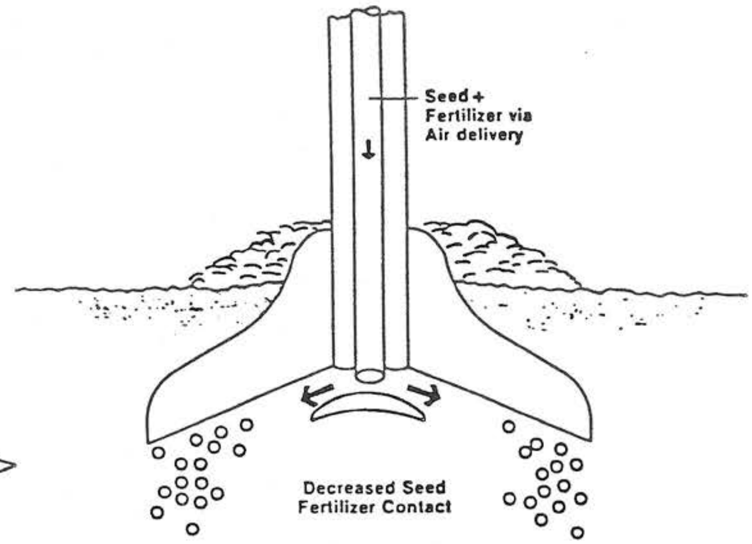

Fig. 4.

The design effectively separates seed and fertilizer in a fixed configuration with two rows of seed 5 to 7 inches apart on either side of the fertilizer band.

A similar, competing design, has a different ammonia tool mounting adaptable for both small grains and row crop seedings.

Air seeders are used in both no-till and conventional till seedings. The Vern knife performs especially well in prepared seedbeds with mellow free flowing surface soils. Cultivator sweep size and operating speeds determine the degree of weed control tillage achieved during seeding operations.

Fertilizer placement evaluations

Application of urea fertilizers to the soil surface with residues present is of concern because of the potential for nitrogen loss as ammonia. Recent research (3) has shown high urease activity in this environment with increased potential for ammonia loss. Since the potential for loss exists, one solution is to apply the fertilizer beneath surface residues. Equipment with this capability has been largely developed to provide subsurface fertilizer application in conjunction with seeding. The importance of properly designed equipment cannot be over emphasized.

Two North Dakota field studies evaluate no-till fertilizer placement. In Table 1 Deibert and his co-workers (1) evaluate results of a 4-year study on deep band vs. surface band placement of urea-ammonium nitrate on three tillage treatments. Placement treatments were in a band applied 4" deep in 12" spacings or dribbled on the surface band at the same spacing.

Table 1. Spring Wheat Yields* as Influenced by Tillage System and Fertilizer Placement - Minot, ND (1981-84).

Fertilizer Placement	No-till	Plow	Sweep	Avg.
	---------------	Bu/A	---------------	
Surface band	36.4	39.2	36.4	37.4
Deep band	38.7	41.8	38.6	39.7
Avg.	37.6	40.5	37.6	

*Sawfly damage in 1982 on no-till and sweep treatments.

Although the data suggest a trend toward increased yields with plowing and deep placement, the differences are not statistically significant. Sawfly damage to sweep and no-till plots in 1982 reduced yields. When this crop year is excluded, yield differences in Table 1 diminish further.

A great deal of speculation surrounds nitrogen loss from surface applications. Nitrogen uptake trends from the study, Table 2, like yield trends were not statistically significant. In the spring wheat production area 2.4-2.6 lbs of nitrogen needs to be available to the crop for each bushel of yield anticipated. Conclusions from the study are that well managed surface applications can be as effective as deep banding.

Table 2. Spring wheat nitrogen uptake* as influenced by tillage system and fertilizer placement - Minot, ND (1981-84).

Fertilizer Placement	No-till	Plow	Sweep	Avg.
	-------------	lbs/A	-------------	
Surface band	50	56	52	52
Deep band	52	58	54	56
Avg.	51	57	53	

*Sawfly damage in 1982 on no-till and sweep treatments.

Using air seeders, with cultivator sweeps as a seeding-fertilizer shoe, opportunity exists to increase band widths and decrease seed fertilizer contact (Figure 4). Using double disk openers on 6" spacings in a high moisture spring grain seedbed 30 lbs/A nitrogen applied with the seed is a practical upper limit. Table 3 reports results of a study by Deibert and his co-workers (2) where the seed-fertilizer contact band varied from 1 to 12 inches.

In this study yield decline did not occur in spring wheat seedings until about 35% stand loss occurred. The data demonstrates feasibility for application of all the nitrogen needed to grow a crop across much of the low rainfall production spring grain production area, at seeding time, by equipping an air seeder with the proper seeding shoe.

Table 3. Stand loss with air seeder dry fertilizer-seed placement.

Seed-Fertilizer Spread Pattern	Nitrogen Rate (lb/A)		
	0	40	80
Urea	-Relative stand count (%)-		
12"	100	85	70
6"	100	70	50
1"	100	25	5
Ammonium nitrate			
12"	100	97	97
6"	100	90	85
1"	100	80	65

Winter wheat research at the Central Great Plains Research Station, Akron, Colorado has shown results similar to those found in North Dakota (Table 4). There was a definite advantage to wide seed-to-fertilizer

Table 4. Effect of fertilizer source, rate, and application method on winter wheat yields, Akron, Colorado.

Phosphorus Source	Nitrogen Source	Nitrogen Balance Added	Total Fertilizer Rate N	Total Fertilizer Rate P_2O_5	Grain Yield BS[1/]	Grain Yield CS[2/]	Grain Yield DR[3/]
		lbs/A	lbs/A		-------bu/A------		
Check	--	--	-	-	22	36	21
UP	UAN	34	45	30	27	31	29
UP	UAN	79	90	30	13	18	38
MAP	UAN	39	45	30	30	23	--
MAP	UAN	84	90	30	45	30	--
DAP	UAN	33	45	30	31	10	--
DAP	UAN	78	90	30	11	15	--
UUP[4/]	-	--	45	30	40	38	31
UUP	-	--	90	30	14	35	33
UP	NH_3	34	45	30	31	--	--
UP	NH_3	79	90	30	18	--	--
MAP	NH_3	39	45	30	47	--	--
MAP	NH_3	84	90	30	33	--	--
DAP	NH_3	33	45	30	6	--	--
DAP	NH_3	78	90	30	1	--	--

1/ Blade seeder, liquid fertilizer applied 2 inches to the side of seed, dry with the seed, NH applied 5 inches to the side of seed.

2/ Chisel opener for seeding with liquid appied 3/4 inch directly below the seed and dry applied with the seed, NH application capabilities not available.

3/ Deep banded fertilizer 1.5 inches to the side and 2 inches below the seed.

4/ Experimental fertilizer from TVA.

separation distance when 90 lbs of N per acre was used regardless of fertilizer source or configuration distance. Source of fertilizer was also important with diammonium phosphate (DAP) in conjunction with either urea ammonium nitrate (UAN) or anhydrous ammonia (NH) resulting in greater yield decreases than monammonium phosphate (MAP) or urea phosphate (UP). The importance of separating seed from an ammonia source was evident when DAP was placed with the seed. These results emphasize the importance of equipment that can provide proper fertilizer placement for small grain production.

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FERTILIZATION OF NO-TILL WINTER WHEAT

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ABSTRACT

There is a growing trend towards the use of minimum and no-till production systems for dryland winter wheat in the Western Great Plains Region. More information is needed regarding management systems to optimize economic return. The proper management of plant nutrients is of main concern to this production system. This research project was initiated in 1983 to provide information concerning N and P fertilizer management. Each year, experiments were conducted at 3 locations over a range of environmental and soil conditions to determine optimum N and P rates, sources, and placements.

The N and P sources increased yield and N and P uptake similarly. Therefore, the non-traditional materials, urea-urea phosphates and liquid suspensions, appear to have an excellent potential as sources of N and P. The effect of placement on yield and N and P uptake was statistically significant. Banding the fertilizer below the seed or dribbling over the seed row after row closure resulted in greater N and P uptake and higher yields than surface broadcast placements. Since these two band placements produced similar grain yields, dribbling over the seed row would have the most potential for application to commercial production conditions since equipment modification would be less expensive than banding below the seed. A maximum rate of 30 lbs N/acre, as UAN, is suggested as a maximum N rate to be placed with the seed to avoid stand damage and reduction in yields.

OBJECTIVES

This research project was initiated in 1983 to provide information concerning N and P fertilizer management of summer fallow no-till dryland winter wheat in the Western Great Plains Region. The primary objectives of this project are threefold: 1) to determine the effect of rate and placement of various N and P fertilizer materials on N and P uptake, grain yield, and fertilizer efficiency, 2) to determine the potential use of urea-urea phosphate materials and UAN and APP 2% clay suspension fertilizer materials, 3) to determine rates of N which can be placed with the seed without stand damage and yield reduction.

MATERIALS AND METHODS

No-till dryland winter wheat sites under summer fallow production were located in Eads, Matheson and Platner, Colorado. Selected chemical characteristics of the soils at each site are shown in Table 1. The fertilizer sources, rates, and placements are shown in Table 2. Since no significant differences between fertilizer sources were observed in 1984, the discussion in this paper will be limited to the effects of rate and placement and rate of N with the seed.

Preplant broadcast applications were made by hand (granular materials) or with a CO_2 pressurized plot sprayer (liquid materials). Banded placements of solution materials were made at planting. Banding below the seed (BBS), approximately one half inch, and placement with the seed were accomplished utilizing the dual placement

Table 1. Soil characteristics for the three locations used for no-till, dryland winter wheat experiments, 1984-85

		Location	
	Eads	Matheson	Platner
Soil Type	Colby silt loam	Weld loam	Platner silt loam
Soil pH	7.8	6.8	7.1
O.M. (%)	1.2	1.4	1.1
AB-DTPA-P	0-1ft. 1.8	4.1	4.1
Nitrate ($ug\ g^{-1}$)	0-1ft. 10	17	13
	1-2ft. 7	5	6
	2-3ft. 5	4	4
	3-4ft. 4	4	2

Table 2. Fertilizer sources, rates, and placements used in no-till, dryland winter wheat field experiments, 1984-85.

Main Treatment Set

Sources
Urea, granular
DAP, granular
UAN, solution
APP, solution
UAN, 2% clay suspension
APP, 2% clay suspension
UUP, granular & solution
N:P ratios of 1:1 and 2:1

Rates
Nitrogen - 0, 30, and 60 lb N/acre
Phosphorus - 0 and 30 lb P_2O_5/acre

Placements
Broadcast (preplant)
Banded below seed (BBS)
Dribbled over seed (DOS)

N With Seed Treatment Set

Sources
UAN, solution
APP, solution

Rates
Nitrogen - 0, 20, 30, 40, 60 lb N/acre
Phosphorus - 30 lb P_2O_5/acre

Placements
Broadcast (preplant)
With seed

planter shoes. Dribbling over the seed (DOS) occurred by banding liquid fertilizer over the seed row after row closure, following the press wheel. Plots were 6' by 56' planted on 12 or 14 inch centers. A randomized complete block experimental design was used with four replications. The semi-dwarf variety Vona was planted at Platner and Matheson and the medium-height variety Sandy was planted at Eads during the last two weeks in September. Nutrient uptake was monitored by collecting tissue samples at the early tillering stage of growth in November and at the boot stage in May. Above ground biomass and total N and P uptake were determined at the boot stage and at harvest with uptake being partitioned between straw and grain at harvest.

There was no statistically significant location by treatment interactions, therefore we have combined treatments across locations in this report.

RESULTS AND DISCUSSION

There was a significant interaction of N rate by N placement on grain yield (Figure 1). At a N rate of 30 lbs N/acre broadcast, a yield of 52.8 bu was obtained, however, when the same N rate was dribbled over the seed or banded below the seed an increase in yield of 5 to 7 bu/acre was obtained. Only at the high N rate (60 lbs N/acre) does the broadcast placement approach the maximum yield obtained by 30 lbs N placed with the seed or dribbled over the seed. This significant N rate by placement interaction demonstrates that increased efficiency of N is obtained with these two band placements, broadcast being less efficient.

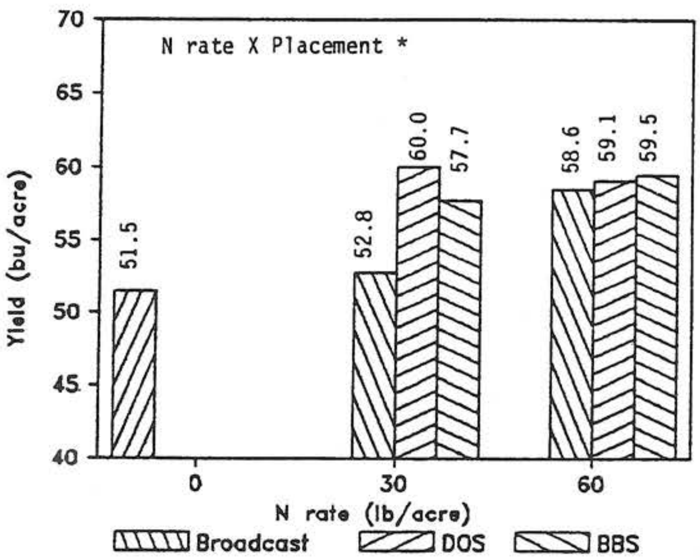

Figure 1. Effect of nitrogen (UAN) rates and placement on winter wheat grain yield, 1984-85. (averaged across phosphorus rates and locations)

Significantly higher P uptake and N uptake (Table 3) resulted from band application of P as contrasted to broadcast P. It is interesting to note the significant effect of P placement on N uptake. There was also a significantly higher yield from the banded P treatment (averaged across N rates) as contrasted to the broadcast P, with the yield advantage being approximately 4 bu/acre, which was significant at the .01 level.

The effect of N rate placed with the seed was not statistically significant for N and P uptake or grain yields (Table 3). However, a definite trend that was consistent at all locations for decreased P uptake, N uptake and grain yield was observed as N rate increased from 30 to 40 lbs N/acre. Our research in 1983-84 showed a substantial increase in stand damage and reduction in yield at the 80 lb N rate BBS, and none to 40 lb/acre. Therefore we conclude that a maximum rate of 30 lb N/A as UAN should be applied with the seed under dryland production systems in eastern Colorado.

Table 3. Effect of N (UAN) and P (APP) placement and rate with the seed on uptake and yield.

Treatment	Boot Stage P Uptake	Boot Stage N Uptake	Grain Yield
	lb P/A	lb N/A	bu/A
Placement[1/]			
P Broadcast	6.8	63	59
P Banded With Seed	8.4	72	63
Statistical Signif.	**	*	**
N Rate With Seed[2/]			
20 lb/A	7.0	64	62
30 lb/A	7.3	66	61
40 lb/A	6.1	59	56
Statistical Signif.	NS	NS	NS

1/ Averaged across N rates 20, 30 or 40 lb N with the seed, the remaining broadcast. Total fertilizer N = 60 lb/A. P rate = 30 lb P_2O_5/A .

2/ N source = UAN, total fertilizer N = 60 lb/A, remainder applied broadcast. P rate = 30 lb P_2O_5/A broadcast.

Since the effects of banded placement on grain yield are similar, we feel that dribbling the fertilizer over the seed row has greater potential under commercial production systems. Conversion of planting equipment to place liquid fertilizer materials in a band over the seed on the soil surface after row closure is much easier and less expensive than conversion to banding fertilizer with the seed. The problem of potential seedling damage due to close contact between the fertilizer material and the seed would also be eliminated.

ADDITIONAL SOIL FERTILITY RESEARCH PROGRAMS

P Solubility of Fertilizer Reaction Products. Objective: To identify and monitor P reaction product formation in dual N and P injection zones and determine its relationship to P availability to plants. Principal Investigators: D. Westfall and P. Grossl.

S cycling in Great Plains Agroecosystem. Objectives: To identify S cycling in agroecosystem as influenced by long-term tillage systems of dryland winter wheat. Principal Investigators: D. Westfall, P. Tracy, V. Cole, T. Elliott and G. Peterson.

Evaluation of Industrial By-products as Potential Fertilizer Materials: Objective: To evaluate the potential use of industrial by-products as sources of plant nutrients and identify toxic contaminant effects on plant and soil systems. Principal Investigator: D. Westfall.

N and P Requirement and Soil Test Correlation of Dryland Winter Wheat. Obectives: Determine the N and P requirement of wheat and demonstrate to farmers the benefit of proper fertilization with these nutrients. To develop soil test correlation information. Principal Investigators: D. Westfall, H. Follett, D. Whitney, J. Zupancic.

Spring N Fertilization/Soil Test Calibration of Dryland Winter Wheat. Objective: Develop soil test/plant tissue analysis procedures to guide producers in making spring top-dress applications of N. Principal Investigators: D. Westfall, K. Barbarick, R. Russell, B. Vaughan.

Urease Inhibitors to Increase N Efficiency. Objectives: Evaluate the effect of urease inhibitors on fertilizer N efficiency of corn. Principal Investigators: D. Westfall and W. Wood.

Application of Sewage Sludge to Dryland Winter Wheat. Objectives: Determine the N equivalency of sludge and its effect on production of dryland winter wheat. Principal Investigators: K. Barbarick, R. Lerch, D. Westfall, H. Follett.

Soil and Crop Management Systems. Objectives: Identify the N and P requirements of crop management systems designed to maximize water use efficiency. Principal Investigators: G. Peterson, D. Westfall, W. Willis, W. Wood, D. Smika.

Soil Test Laboratory Recommendation Comparisons. Objective: To evaluate the validity of various soil test laboratory fertilizer recommendations made from soil testing laboratories operating in Colorado. Principal Investigator: H. Follett

N Requirement of Millet. Objective: Determine N and P partitioning and nutrient needs of millet in relation to soil test parameters. Principal Investigators: G. Peterson, R. Rodriquez, D. Westfall.

P Fertilization of Alfalfa. Objectives: Determine the soil fertility requirements of alfalfa and their relationship to soil test levels. Principal Investigators: W. Schmehl and A. Fulton.

Maximum Economic Yield of Corn. Objective: Determine the growth and environmental parameters that control maximum economic yield for corn. Principal Investigator: S. Olsen.

N Fertilization of Potatoes. Objectives: To determine the effect of preplant N rate on tuber growth rate and to evaluate the interaction of plant population and N rate on advanced lines from the potato breeding program. Principal Investigator: M. Thornton

NITROGEN-TILLAGE INTERACTION FOR DRYLAND WHEAT IN WESTERN NEBRASKA

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ABSTRACT

A tillage experiment was initiated by C. R. Fenster on a previously cultivated Alliance silt loam near Sidney, Nebraska in 1969 in which the effect of no-till, stubble mulch (subtill), and plowed fallow upon soil properties, nitrogen cycling, and winter wheat production were compared. After more than ten years of these treatments, fallow tillage at this site generally had little or no effect upon soil bulk density. However, at most sampling dates, soil water content was greater and soil temperature lower for no-till soil than for plowed soil (subtill was usually intermediate). The cooler, more humid environment of no-till soil, coupled with an ample supply of carbonaceous residues in the upper 75 mm of soil, was associated with greater organic C and N contents, greater microbial biomass, and more potentially mineralizable N in no-till than in plowed or subtilled soil. Differences below the 75 mm soil depth were generally not significant. Plant growth and grain yields, averaged over all years, were not significantly affected by tillage method; however, uptake of labeled ammonium nitrate (applied at tillering) was usually slightly greater by the wheat crops on no-till than that on plowed or subtilled fallow. Likewise, during the following year and the second crop year, more labeled N was found as soil inorganic N and in wheat residues for no-till than for other treatments. About 28% of the original isotope applied to no-till wheat was recovered in the two grain harvests or remained in crop residues left in the field, compared to 22% for the plow and subtill treatments. No-till appears to conserve more N near the soil surface and enhances recycling of this N, when compared to plow or subtill fallow.

OBJECTIVES

No-tillage and reduced tillage for winter wheat production have gained in popularity in recent years, mainly because of potential for reduced production cost. We also know that reducing tillage decreases soil loss by erosion, and thereby conserves soil organic matter and maintains soil productivity. Other benefits from reducing tillage include reducing the rate of soil organic matter oxidization. Earlier research has shown that soil organic matter generally decreases with years of cultivation, and that this decline can be retarded by leaving crop residues on the surface (even where erosion is not a factor).

Objectives of this research were to document the above changes in soil organic matter and N conservation resulting from reduced tillage, and to define the soil environment that result from use of different tillage practices. By changing soil environment, we hypothesized that we also alter the rate and distribution of microbiological activity in the soil, and subsequently the recycling of soil and fertilizer N, and uptake of N by the wheat crop. This paper describes a field experiment in which data were collected to test this hypothesis.

MATERIALS AND METHODS

In 1969, C. R. Fenster (Fenster and Peterson, 1979) initiated an experiment on an Alliance silt loam near Sidney, Nebraska, which had been cultivated since 1920. Comparisons were made between plowed, stubble mulch (subtill), and no-till fallow on the production of winter wheat with and without 45 kg fertilizer N/ha applied at tillering to each wheat crop in a wheat-fallow sequence. The primary fallow-tillage (plow, subtill, or no-till) was made in April of the year of fallow (excessive weed growth the previous fall was prevented by use of herbicides if needed). Plowing and subtillage (large sweep machines) were limited to the 10-15 cm depth, and appropriate herbicides were applied to the no-till fallow (actual herbicides used varied, but they usually included paraquat, glyphosphate, 2, 4-D, and dicamba). Secondary tillage (rod-weeder) or spraying was employed as needed for weed control throughout the fallow period. Wheat was seeded the first week of September, and ammonium nitrate was surface broadcast at 45 kg N/ha near tillering in April. Wheat was harvested in July. Two sets of plots were established, one in crop and one in fallow each year.

In the 1978-1983 period, USDA-ARS scientists sampled these plots extensively to monitor soil water status (water content, infiltration, hydraulic conductivity), aeration (CO_2 production, air permeability, O_2 and nitrous oxide, and water-filled pore space), organic matter status (organic C and N, microbial biomass, microbial populations, plant root biomass and activity), and temperature regimes. These data were used collectively to help define the environment experienced by soil microorganisms and plant roots, and to determine how the soil environment was altered by tillage. In 1979 and 1980, N-depleted ammonium nitrate was applied (45 kg N/ha) to follow the fate of the fertilizer N through that crop, the next fallow season, and the second crop season.

RESULTS AND DISCUSSION

Some effects of tillage method on soil physical properties and soil water and aeration regimes are summarized by data in Table 1 (Mielke et al., 1984; Mielke et al., 1986). These data for May, 1980, are characteristic of those obtained at several other sampling dates during this study. Effects of tillage method on soil bulk density at this site were small, but the surface soil of no-tilled soil usually contained more water than that of plowed soil. This resulted in higher percent water-filled pore space (and less air-filled pore space) for no-till than for plow or subtill (Linn and Doran, 1984). Although water infiltration and conductivity were greater for no-till soil, air permeability was less because more soil pores were filled with water. Thus, the surface of no-tilled soil was wetter and cooler (usually by about 2 to 4°C) than that of plowed soil.

Table 1. Effect of fallow tillage method on soil water and aeration status at time of winter wheat tillering, Sidney, Nebraska.

Tillage Method:	No-Till		Subtill		Plow	
Soil depth (mm)	0-75	75-150	0-75	75-150	0-75	75-150
Bulk density, Mg m^{-3}	1.29	1.30	1.25	1.38	1.25	1.31
Water content, V/V	0.28	0.30	0.24	0.28	0.22	0.27
Water-filled pores, %	54.0	65.0	45.0	62.0	43.0	56.0
Hydraulic conductivity, mm h^{-1}	32.0	21.9	33.0	10.1	19.4	15.4
Water infiltration, mm h^{-1}	--- 61 ---		--- 52 ---		--- 50 ---	
Air permeability, pm^2	2.8	-	4.1	-	11.6	-

As a result of changes in the soil environment, populations of NH_4^+ - oxidizing and NO_2^- - oxidizing microorganism (Broder et al., 1984) in the surface of unfertilized no-tilled soil were only 54 and 78% respectively of that in plowed soil (Table 2). Fertilizing greatly increased populations of NH_4^+ - oxidizers but had little effect on relative population changes with tillage. Denitrifier populations were much greater in no-till than in plowed soil, and probably resulted from higher organic matter levels and more humid conditions. Soil NO_3^- N concentrations were slightly lower while potentially mineralizable N (PMN), total N, total C, and microbial biomass in no-till soil were somewhat greater than in plowed soil. Except for higher levels of PMN, N fertilization had little or no influence on these trends. These data suggest that the environment of no-till soil results in an accumulation of both total and labile N near the soil surface, but that rate of oxidization of these N pools is less in no-till than in plowed soil. These effects of tillage method on various soil N parameters could result from the cooler, less oxidative environment of the no-till soil, compared to that of the plowed soil (Power et al., 1984).

Table 2. Effect of fallow tillage method on microbial populations and N status of 0-150 mm soil depth at Sidney, Nebraska.

	Value for no-till / Value for plow	
	No N	With N
NH_4^+ - oxidizers	0.54	0.65
NO_2^- - oxidizers	0.78	0.80
Denitrifiers	13.0	1.9
NH_4^+ - N	1.22	0.95
NO_3^- - N	0.80	0.78
PMN	1.20	1.39
Total N	1.09	1.17
Total C	1.16	1.16
Microbial biomass	1.06	1.09

The effects of tillage on soil environment and subsequent microbial activity had relatively small effects upon uptake of the labeled N by the wheat (Table 3). Generally, labeled N uptake was slightly greater for no-till than for plowed or subtilled fallow -- at the end of the second cropping season, 28% was in plant material for no-till, compared to 22 and 21% for plow and subtill, respectively (Power et al., 1986). Also for no-till, somewhat more labeled N was present in the crop residue at all times than for the other tillage methods. After harvest of the first wheat crop, often slightly more labeled N was found in inorganic soil N for no-till than for other tillage methods.

Table 3. Labeled N in plant, crop residue, and inorganic soil N, as affected by fallow tillage method for winter wheat, Sidney, Nebraska.

	First Crop			Fallow		Second Crop		
	May	June	July	Oct.	April	Oct.	April	July
	----------- % of labeled N applied -----------							
				Plowed fallow				
Plant uptake +	15	28	12	0	0	0	4	1
Grain	0	0	16	16	16	16	16	21
Residues	0	4	6	5	6	1	2	0
Soil inorganic	42	16	7	4	2	0	0	0
				Subtilled fallow				
Plant uptake+	17	30	5	0	0	0	7	2
Grain	0	0	16	16	16	16	16	19
Residues	1	4	6	6	6	4	4	1
Soil inorganic	38	11	7	4	1	2	2	0
				No-till fallow				
Plant uptake+	20	28	7	0	0	0	8	4
Grain	0	0	18	18	18	18	18	22
Residues	5	9	16	19	11	8	6	2
Soil inorganic	33	9	4	7	4	2	2	2

+Excluding mature grain

Fallow tillage method generally had little significant effect on wheat dry matter production or grain yield (Table 4) during the crop-fallow-crop cycle studied (Power et al., 1986). Also, with a few exceptions, total N uptake by either of the two crops was not greatly affected by fallow tillage method. Likewise, uptake of labeled N was generally not affected by tillage method. For all fallow tillage methods, approximately 5% of the labeled N applied to the first wheat crop was taken up by the second wheat crop, suggesting that one would expect very little additional recovery of the labeled N in future wheat crops.

Table 4. Effect of fallow method on N-fertilized winter wheat growth, yield, and plant uptake of total and labeled N (average of the two sets of plots).

Fallow method	First crop May	First crop June	First crop July Straw	First crop July Grain	Second crop May	Second crop July Straw	Second crop July Grain
			A. Dry-matter production (Mg ha^{-1})				
Plow	2.40	6.73	4.48	2.19	3.82	4.42	3.37
Subtill	2.44	6.60	4.88	2.30	3.31	4.45	3.50
No-till	1.99	7.08	5.51	2.43	3.91	5.09	3.23
			B. Total N uptake (kg N ha^{-1})				
Plow	50.4	78.8	25.6	52.6	74.2	23.9	76.1
Subtill	48.3	82.6	27.0	54.5	66.2	16.2	75.8
No-till	48.1	81.0	35.0	49.6	71.1	21.6	70.4
			C. Labeled-N uptake (kg N ha-1)				
Plow	6.7	15.2	5.2	7.4	2.0	0.5	2.2
Subtill	7.7	13.6	2.4	7.1	3.1	0.7	1.6
No-till	9.0	12.6	2.9	8.1	3.5	0.8	1.7

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SULFUR FERTILIZATION OF WHEAT IN KANSAS

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ABSTRACT

Field experiments evaluating the effects of sulfur fertilization on wheat yields and quality were initiated in 1982 and have continued through 1985. Sulfur rates, sources, and methods of application as well as nitrogen rates have been evaluated on various soil types across Kansas. Results to date show an inconsistent yield response to sulfur, with all significant yield increases occurring on sandy, low organic matter soils. Two of three sandy locations reported have responded to sulfur application at some time during the course of this work. The addition of sulfur has consistently increased wheat tissue sulfur levels and, to a lesser extent, grain sulfur levels. Ammonium sulfate and ammonium thiosulfate performed similarly as sulfur sources. Surface banding on 10-inch centers and broadcasting were equally effective methods of sulfur application. Sulfur fertilization had little effect on grain protein levels, but tended to increase the levels of sulfur-containing amino acids.

OBJECTIVES

High-yielding, semi-dwarf, lodging resistant varieties and hybrids were grown on 70% of the 1985 Kansas wheat acreage. Top yields in official performance tests and on farmer fields have exceeded 100 bushels per acre the last two years. These high yields require more sulfur from the soil. In addition, the use of concentrated, high analysis fertilizers which supply no sulfur is the rule. Other factors that may aggravate the potential sulfur problem in Kansas include declining organic matter levels and the increasing popularity of conservation tillage, which slows breakdown of existing organic matter resulting in slowed release of sulfur.

Research in Kansas in the early 1970's showed inconsistent reponse to sulfur application on wheat. In recent years, there have been field reports of wheat yield response to sulfur. Other research is ongoing relating to the role sulfur has in quality aspects of wheat.

With all of these factors in mind, work was initiated in the fall of 1982 and is continuing with the objectives of evaluating the effects of sulfur fertilization including sulfur rates, sources, and methods of applicatoin on wheat yields and quality characteristics in Kansas.

MATERIALS AND METHODS

Experiment I. This dryland field experiment has been conducted at two locations; the Estel Wyatt Farm in Shawnee county, a Eudora silt loam - Sarpy sand complex (Fluventic Hapludoll, coarse, mixed mesic) and on the North Central Experiment Field in Republic county, a Crete silt loam (Pachic Argiustoll, fine, montmorillinific, mesic). Soil test information on these sites is in Table 1.

Table 1. Initial soil test results for experimental sites.

Location	Depth in.	pH	O.M. %	Available N ppm	Bray-1 P	Exchangeable K	Available S ppm
					------------lbs/A-------		
Wyatt Farm,	0-6	5.2	0.8	4	53	290	8
Exp. I and II	6-24	6.0	0.6	5	30	230	6
NC Field	0-6	5.6	2.6	16	57	500+	--
Exp. I	6-24	6.2	2.1	10	44	500+	--
Sandyland	0-6	5.7	0.7	4	45	270	6
Exp. II	6-24	6.3	0.5	7	--	---	10
Hewes Farm	0-6	7.0	0.5	12	32	370	6
Exp. II.	6-24	7.4	0.2	9	7	250	4

All combinations of nitrogen rates of 0, 60, and 120 pounds per acre and sulfur rates of 0, 15, 30, and 60 pounds per acre (urea and ammonium sulfate blends) were evaulated in randomized, complete block design studies with four replications. One-half of the N and S was applied preplant-incorporate and the remaining one-half was applied as a late winter topdress. Hard red winter wheat of the "Newton" variety was used, and excellent stands were obtained. If leaf diseases were assessed to be a potential problem, fungicide applications were made.

Tissue samples were taken at the early boot stage and analyzed for N and S. Grain yields were measured and individual plot grain samples were retained for moisture, protein, and mill and bake analyses.

Experiment II. This dryland field experiment was initiated in 1984 and has been run on three sites, on the Estel Wyatt Farm (adjacent to Experiment I), on the Sandyland Experiment Field in Stafford county, a Pratt loamy fine sand (Psammentic Haplustalfs, sandy, mixed, thermic), and on the Herb Hewes Farm in Gray county, a Pratt sand. Complete soil test results are in Table 1.

Sulfur rates of 0, 15, and 30 pounds per acre were used. Sulfur sources evaluated were ammonium sulfate (AS) and ammonium thiosulfate (ATS). AS and ATS applications were made as liquids either broadcast (through flat fan spray tips) or dribbled (surface-banded) on 10-inch centers as a late winter topdress. Nitrogen was balanced on all plots at 100 pounds per acre as ammonium nitrate.

Tissue and grain samples were taken as described for Experiment I.

RESULTS AND DISCUSSION

Experiment I. The effects of nitrogen and sulfur fertilization on wheat yields are summarized in Table 2. At the Shawnee county site (Wyatt Farm), only in 1984 did the addition of sulfur significantly increase yields. 1985 yields may have been affected by low pH and relatively high exchangeable Al^{+3} levels since the variety "Newton" is very susceptible to Al. This effect may have masked sulfur response as a visual response to sulfur was apparent during the growing season. On the higher organic matter soil in Republic county (North Central Field), sulfur fertilization has not significantly affected wheat yields. In 1983 and 1984, there appeared to be a trend toward higher yields with the addition of sulfur, but this trend reversed in 1985. The addition of nitrogen generally increased yields, and 120 lbs N/A produced significantly higher yields than 60 lbs N/A in three of the six site years.

Table 2. Effects of sulfur and nitrogen fertilization on wheat yields (Exp. I)

N	S	Grain yield, bu/A					
		Wyatt Farm, Shawnee Co.			North Central Field, Republic Co.		
lbs/A		1983	1984	1985	1983	1984	1985
0	0	55	20	40	39	18	28
60	0	61	30	54	61	28	47
60	15	62	34	52	58	31	42
60	30	63	34	51	61	30	45
60	60	60	37	47	64	37	46
120	0	61	42	51	66	37	45
120	15	58	42	50	73	44	42
120	30	65	46	52	69	38	36
120	60	59	50	51	70	36	43
	LSD (.05)	NS	6	6	12	7	8
Mean Values:							
N Rate	60	62	34	51	61	31	45
	120	61	45	51	69	39	42
	LSD (.05)	NS	3	NS	6	4	NS
S Rate	0	61	36	52	64	32	46
	15	60	38	51	65	37	42
	30	64	40	51	65	34	41
	60	59	43	49	67	36	44
	LSD (.05)	NS	4	NS	NS	NS	NS

The effects of nitrogen and sulfur fertilization on wheat tissue N and S levels and grain protein and S levels for 1985 are summarized in Table 3. 1983 and 1984 data are not shown, but results were very similar to the 1985 data shown. The

Table 3. Effects of sulfur and nitrogen fertilization on wheat tissue and grain composition, 1985. (Exp. I)

N	S	Wyatt Farm, Shawnee Co.				North Central Field, Republic Co.			
		Tissue		Grain		Tissue		Grain	
lbs/A		%N	%S	%Protein	%S	%N	%S	%Protein	%S
0	0	1.99	.08	11.0	.10	1.26	.07	10.5	.08
60	0	2.36	.10	12.4	.11	2.00	.14	11.1	.08
60	15	2.25	.15	11.8	.12	1.83	.12	11.0	.09
60	30	2.09	.15	11.6	.12	1.87	.13	11.1	.08
60	60	2.26	.18	12.3	.13	1.87	.13	11.4	.09
120	0	2.46	.10	13.2	.11	2.23	.15	12.5	.10
120	15	2.40	.14	13.4	.12	2.32	.20	13.0	.10
120	30	2.47	.15	13.3	.12	2.26	.23	13.1	.11
120	60	2.60	.21	13.2	.14	2.38	.28	13.0	.11
	LSD (.05)	0.15	.04	0.6	.01	0.22	.05	0.5	.01
Mean Values:									
N Rate	60	2.24	.14	12.0	.12	1.89	.13	11.2	.09
	120	2.48	.15	13.3	.12	2.30	.21	12.9	.10
	LSD (.05)	0.10	NS	0.4	NS	0.12	.03	0.3	.01
S Rate	0	2.41	.10	12.8	.11	2.11	.14	11.8	.09
	15	2.32	.14	12.6	.12	2.07	.16	12.0	.09
	30	2.28	.15	12.5	.12	2.06	.18	12.1	.09
	60	2.43	.19	12.7	.13	2.13	.20	12.2	.10
	LSD (.05)	NS	.04	NS	.01	NS	.04	NS	.01

addition of sulfur significantly increased tissue S levels and, to a lesser extent, grain S levels even though grain S levels were generally 0.12% S or lower. Sulfur fertilization had non-significant effects on tissue N levels and grain protein content. The addition of nitrogen increased tissue N levels and grain protein at both locations and at the Republic county site consistently increased tissue S levels.

Preliminary mill and bake data indicate little effect from sulfur fertilization but low flour protein levels have been a problem on getting meaningful mill and bake results. Amino acid analysis show higher levels of the sulfur-containing amino acids, methionine and cystine, when sulfur is added; but levels of these amino acids were not deficient on the sulfur check plots.

Experiment I was put out on another sandy location in Finney county in 1985, and no repsonse to sulfur was noted, however, yields were severely depressed by hot, dry conditions during early grain fill.

This experiment will be repeated at several locations in 1986.

Experiment II. Yield results from experiment II, which evaluated S rates, sources, and methods of application are reported in Table 4. Sulfur fertilization

Table 4. Effects of sulfur rates, sources, and methods of application on wheat yields. (Exp. II)

			Grain yield, bu/A				
			Wyatt Farm Shawnee Co.		Sandyland Field Stafford Co.		Hewes Farm Gray Co.
S lbs/A	S Source	Method of Application	1984	1985	1984	1985	1985
0	---	---	45	47	57	32	45
15	ATS	B'cast	51	55	58	37	43
30	ATS	B'cast	48	51	57	36	38
15	AS	B'cast	53	50	55	38	42
30	AS	B'cast	55	51	57	37	42
15	ATS	Dribble	50	50	56	39	38
30	ATS	Dribble	54	49	61	37	42
15	AS	Dribble	55	52	60	39	41
30	AS	Dribble	53	52	58	37	42
LSD (.05)			NS	NS	NS	3	NS
Mean Values:							
S Rate	15		52	52	57	38	41
	30		53	51	58	37	41
LSD (.05)			NS	NS	NS	NS	NS
S Source	ATS		51	51	58	37	40
	AS		54	51	57	38	42
LSD (.05)			NS	NS	NS	NS	NS
Method of Application		B'cast	52	52	57	37	41
		Dribble	53	51	59	38	41
LSD (.05)			NS	NS	NS	NS	NS

significantly increased grain yields at the Sandyland Field in Stafford county in 1985, although no response was noted in 1984. The response to sulfur was significant even though yields were reduced by hot, dry conditions during early grain fill. Even though not statistically significant, yields increases of from 3 to 10 bushels in 1984, and 2 to 8 bushels in 1985 were noted with sulfur fertilization at the Wyatt location in Shawnee County. An additional site was evaluated in 1985 (Hewes Farm, Gray Co.) and sulfur fertilization had little effect on grain yields at this location.

ATS and AS have performed similarly as sulfur sources at all locations. Likewise, both methods of sulfur application have performed equally well.

The effects of sulfur rates, sources, and methods of application on tissue S content, grain protein levels and grain S content are summarized in Table 5. The results shown are for 1985 only as 1984 and 1985 results were similar.

The addition of sulfur fertilizer tended to increase wheat plant tissue S levels and, to a lesser extent, grain S levels but these increases were not always significant. Grain S levels remained below 0.12% even when sulfur was applied.

There were no significant differences between sulfur sources or methods of sulfur application with respect to tissue or grain S content or grain protein levels.

Table 5. Effects of sulfur rates, sources, and methods of application on wheat tissue and grain composition, 1985. (Exp. II)

			Wyatt Farm Shawnee Co.			Sandyland Field Stafford Co.			Hewes Farm Gray Co.		
S	S	Method of	Tissue	Grain		Tissue	Grain		Tissue	Grain	
lbs/A	Source	Application	%S	%Pro.	%S	%S	%Pro.	%S	%S	%Pro.	%S
0	---	-----	.14	14.3	.10	.05	12.1	.08	.11	13.8	.10
15	ATS	B'cast	.15	13.7	.09	.12	11.9	.10	.13	14.0	.11
30	ATS	B'cast	.14	13.8	.10	.17	11.8	.10	.13	14.3	.11
15	AS	B'cast	.17	14.3	.10	.14	11.8	.10	.13	14.3	.10
30	AS	B'cast	.18	14.2	.11	.18	11.6	.11	.12	14.0	.11
15	ATS	Dribble	.17	14.6	.10	.15	11.8	.10	.13	14.2	.11
30	ATS	Dribble	.18	14.1	.10	.18	11.8	.12	.14	14.0	.10
15	AS	Dribble	.15	14.2	.09	.14	11.9	.10	.13	14.2	.11
30	AS	Dribble	.21	13.9	.10	.19	12.1	.11	.13	14.1	.11
LSD (.05)			NS	NS	NS	.03	NS	.01	NS	NS	NS
Mean Values:											
S Rate 15			.16	14.2	.09	.14	11.8	.10	.13	14.2	.11
30			.18	14.0	.10	.18	11.8	.11	.13	14.1	.11
LSD (.05)			NS	NS	NS	.02	NS	.01	NS	NS	NS
S Source ATS			.16	14.1	.09	.15	11.8	.10	.13	14.1	.11
AS			.18	14.2	.10	.16	11.8	.10	.13	14.2	.11
LSD (.05)			NS	NS	NS	NS	NS	NS	NS	NS	NS
Method of		B'cast	.16	14.0	.10	.15	11.8	.10	.13	14.2	.11
Application		Dribble	.18	14.2	.10	.16	11.9	.11	.13	14.1	.11
LSD (.05)			NS	NS	NS	NS	NS	NS	NS	NS	NS

Experiment II was conducted at another sandy site in Seward county in 1984 and no significant effects due to sulfur rate, source, or method of application were noted. This data is not reported, however, since yields were affected by a hailstorm.

Experiment II is being repeated at several locations in 1986. By gathering enough site years of data on several different soil types, we hope to be able to better predict where sulfur responses are likely in Kansas.

NITROGEN INTERFERENCE WITH P-UPTAKE FROM DUAL N-P BANDS

by J.T. Harapiak & N.A. Flore[2]

ABSTRACT

Soft wheat seeded at two different dates following fertilizer application indicated that the fertilizer response pattern to dual deep banded N-P fertilizer can be modified by the length of time the bands are allowed to incubate in the soil prior to seeding. Higher rates of nitrogen in freshly applied dual N-P bands can initially interfere with crop uptake of phosphate. The benefit of including a "starter" phosphate application was greater where the dual N-P bands had been recently applied. The application of starter phosphate resulted in a yield reduction where the dual N-P bands had been allowed to incubate in the soil for three weeks prior to seeding.

OBJECTIVES

Recent studies conducted in Alberta (Harapiak and Flore, 1984) have indicated that higher rates of nitrogen (urea) can at least temporarily, interfere with plant uptake of fertilizer phosphate from dual N-P bands. This research established that if the bands were allowed to incubate in the soil for a period of three weeks, phosphate uptake from the bands was considerably improved. Manitoba based research (Flaten and Racz, 1984) has indicated that a reduction in early P uptake could be attributed to high NH_3 concentrations within the dual N-P band. These initially toxic concentrations would delay root proliferation and therefore P uptake from the core of the dual N-P band. It is also probable that toxic levels of nitrate accumulated in the bands as a direct result of the elevated levels of pH and free ammonia within the bands (Tisdale et al., 1985; Goyal & Huffaker, 1984). Some preliminary research has also suggested that the addition of potash to an N-P band may further aggravate initial P uptake (Harapiak and Penney, 1984).

Based on these research findings, it was decided in the spring of 1982 to establish an experiment using irrigated soft white wheat (Fielder) to demonstrate the practical implications of allowing N-P bands to incubate for a period of three weeks on P-uptake from dual N-P bands and the need for starter phosphate.

MATERIALS AND METHODS

The source of nitrogen was urea (46-0-0) which was applied at a rate of 120 kg/ha of N. The source of phosphate was monocalcium phosphate (0-45-0) which was applied at a rate of 40 kg/ha of P_2O_5. The nitrogen was either broadcast (incorporated) or deep banded using a narrow knife opener. The bands were applied at a spacing of 12" and at a depth of 5". The phosphate was applied either broadcast or deep banded together with the nitrogen or else placed directly in the seedrow. In one treatment, a split application of phosphate was evaluated. Potash was applied as potassium chloride (0-0-62) at the rate of 30 kg/ha of K_2O.

The test site was located near Rockyford in the dark brown soil zone on an alluvial lacusterine parent material. The texture of the surface soil was a heavy loam. Soil samples submitted to the Alberta Soil and Feed Testing Laboratory for routine analysis indicated that nitrate-nitrogen levels were very low (12 lbs/acre in the

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0-24" depth). Available phosphate levels (Miller & Axley) in the surface layer were rated as being low (ie. 15-20 lbs available P per acre). The available K levels for the surface layer ranged between 450-600 lbs per acre which would be considered adequate. The pH of the surface layer was 6.5 and increased to 7.5 (6-12") and 7.9 (12-24") with depth. There was no free lime in the surface layer.

A split-plot design was utilized in that two identical randomized block (six replicates) experiments were established side by side. All of the fertilizer treatments were applied on May 1, 1982. One plot was seeded on the same day, while the other plot was seeded on May 21. The surface soil temperature (0-4") was 46°F and 51°F respectively for the two seeding dates. The wheat was seeded at a rate of 2 bushels/acre.

Harvested grain samples were submitted for N and P analysis using conventional wet chemistry methods. Grain samples were also submitted for moisture, N and P analysis by NIR methods.

RESULTS AND DISCUSSION

Grain Yields

The average grain yield data that was collected in this research trial is summarized in Table 1. The top yields that were achieved in the treatments that received deep banded fertilizer. For nitrogen alone, in terms of grain yield increase due to fertilizer, the banding advantage amounted to 10-20%. This is quite a respectable gain in fertilizer use efficiency considering that these trials received adequate amounts of irrigation water. For the N-P treatments, the banding advantage amounted to 5-50%. On average, the 120 kg/ha of nitrogen that was applied appeared to result in yield increase of approximately 50 bushels/acre. The application of 40 kg/ha of phosphate only resulted in an additional average yield increase of 6 bushels/acre. On average, there was no response to the application of potash fertilizer although there was a trend suggesting a potash response at the early seeding date.

Table 1. Influence of Fertilizer Treatment* and Seeding Date on Yield of Irrigated Soft White Wheat (WCFL, 1982)

Placement Treatment*	Date of Seeding: May bu/ac	May t/ha	May 21 bu/ac	May 21 t/ha	Average bu/ac	Average t/ha
1) Check	20.7	1.39 b	26.9	1.81 d	23.8	1.60 d
2) N B'cast	70.0	4.71a	69.9	4.70 c	70.0	4.70 c
3) N B'cast + P	76.4	5.14a	74.5	5.01 bc	75.4	5.08abc
4) N Band	75.2	5.06a	77.6	5.22 bc	76.4	5.14abc
5) N Band + P	79.4	5.34a	83.1	5.59abc	81.2	5.46ab
6) N-P B'cast	73.3	4.93a	71.2	4.79 c	72.2	4.86 bc
7) N-P Band	76.3	5.13a	92.8	6.24a	84.6	5.68a
8) N-3/4P Band + 1/4P	80.0	5.38a	83.3	5.60abc	81.6	5.49ab
9) N-P-K Band	80.1	5.39a	86.7	5.83ab	83.4	5.61a
10) N-P Band + K	81.3	5.47a	86.2	5.80ab	83.8	5.64a
Average	71.3	4.79	75.2	5.06a	73.2	4.93

Means followed by same letter are not significantly different (Tukey's P=0.05).
Fertilizer applied May 1, and + indicates portion drill-in applied at seeding.
*N = 46-0-0, 120 kg N/ha, P = 0-45-0, 40 kg P_2O_5/ha, K = 0-0-62, 30 kg K_2O/ha.

There was no statistically significant difference between the mean yields for the two different seeding dates. Although there was a significant response to fertilizer for the first seeding date, there were no significant differences among the fertilizer treatments. For the second seeding date, there was no significant difference among the nitrogen banded treatments that received some type of phosphate or phosphate plus potash application.

It is obvious that deep band placement of both nitrogen and phosphate (ie. dual application) was a very effective treatment for the second seeding date. This was quite different for the early seeding date where a drill-in or a split application of phosphate combined with deep banded nitrogen was more effective than a dual deep band application of N & P. This trend would suggest that for the early seeding date, the large amount of nitrogen in the N-P bands could in fact, have initially hindered uptake.

Researchers in Manitoba (Flaten and Racz, 1984) suggested that a reduction in response to P could be associated with low P uptake due to toxic levels of NH_3 within the bands. Based on recent reviews of nitrogen fertilizer behaviour (Tisdale et al., 1985; Goyal & Huffaker, 1984) it is quite probable the accumulation of toxic levels of nitrite within the dual N-P bands shortly after application may have also been a contributing factor to the reduced response to phosphatre applied in dual N-P bands at the early seeding date. The accumulation of nitrite is favoured by elevated pH levels and the presence of free ammonia. It is known that both of these conditions exist within a band following the application of urea. The fact that the later seeded crop responded effectively to phosphate in dual N-P bands would suggest that the bands had become somewhat detoxified with time. This type of response pattern is in keeping with the improved crop uptake of phosphate from N-P bands with time that has been reported based on isotope labelled phosphate trials (Harapiak and Flore, 1984).

The dual N-P band treatment appeared to be very effective for the second seeding date. However, the fact that this particular treatment out yielded similar treatments that contained potash may indicate that the high yields recorded for this treatment may have been an anomaly and could actually be 4-6 bushels per acre high. A potash response on these soils for the early seeding date could possibly be explained by the slightly colder seedbed at the time of planting.

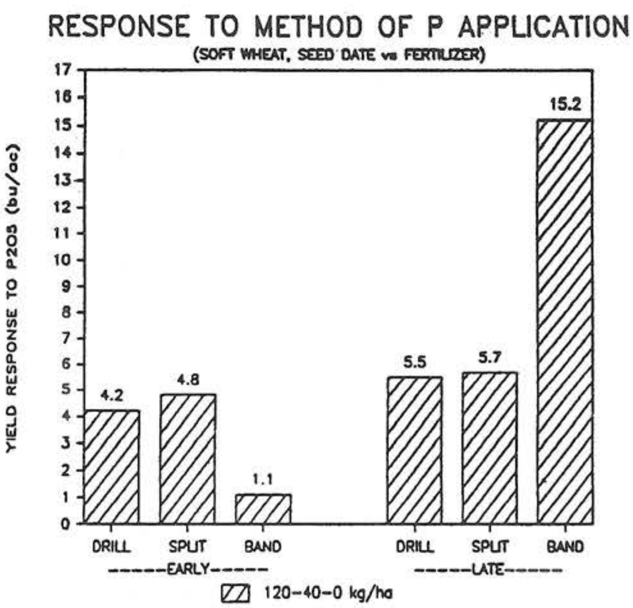

Fig.1. Grain response of irrigated soft white wheat to three methods of phosphate application at two seeding dates (May 1 and May 21) in plots treated with deep banded nitrogen (applied May 1).

The increase in grain yield due to method of phosphate application for the N-P fertilizer treatments that received deep banded nitrogen is summarized in Fig. 1. The results indicate quite clearly that the time of fertilizer banding relative to the time of seeding is an important factor to consider for situations where all of the required phosphate is to be deep banded in combination with a higher rate of nitrogen. Best results will be achieved if the N-P bands are allowed to incubate in the soil for a period of 3 weeks prior to seeding. Alternately, the N-P bands could be fall applied to avoid the problem of nitrogen interference with P uptake.

Nitrogen Uptake

The nitrogen uptake data is summarized in Table 2. The data is presented based on analysis conducted using conventional wet chemistry methods as well as the NIR technique. The statistical analysis was conducted on the latter method simply

Table 2 Influence of Fertilizer Treatment* and Seeding Date on Nitrogen Uptake in Soft White Wheat Grain Based on Conventional and NIR Analysis (WCFL, 1982).

Placement Treatment*	Nitrogen Uptake (kg/ha) May 1 Conventional	NIR	May 21 Conventional	NIR	Mean Conventional	NIR
1) Check	24.6	23.4 b	29.9	28.4 d	27.2	25.9 d
2) N B'cast	68.2	69.5a	64.1	67.8 c	66.2	68.6 c
3) N B'cast + P	76.4	71.9a	67.5	72.8 bc	72.0	72.4abc
4) N Band	77.9	72.6a	75.2	79.7abc	76.6	76.2abc
5) N Band + P	81.2	81.7a	78.7	84.8abc	80.0	83.2ab
6) N-P B'cast	71.7	69.3a	66.7	71.6 bc	69.2	70.4 bc
7) N-P Band	77.4	73.9a	91.6	94.2a	84.5	84.0a
8) N-3/4 P Band + 1/4P	82.9	78.1a	81.9	87.3ab	82.4	82.7ab
9) N-P-K Band	82.8	77.4a	81.4	85.7abc	82.1	81.6abc
10) N-P Band + K	81.7	77.3a	83.6	88.2ab	82.6	82.8ab
Average	72.5	69.5 b	72.1	76.0a	72.3	72.8

Means followed by the same letter are not significantly different (Tukey's P = 0.05).
*Fertilizer applied May 1 and + indicates portion of drill in applied.
N = 46-0-0, 120 kg N/ha P = 0-45-0, 40 kg P_2O_5, K = 0-0-62, 30 kg K_2O/ha

because these results were available at an earlier date. The average protein contents based on conventional and NIR analysis were quite comparable (9.27% and 9.29% respectively), although the differences between average values for a given seeding date were somewhat larger.

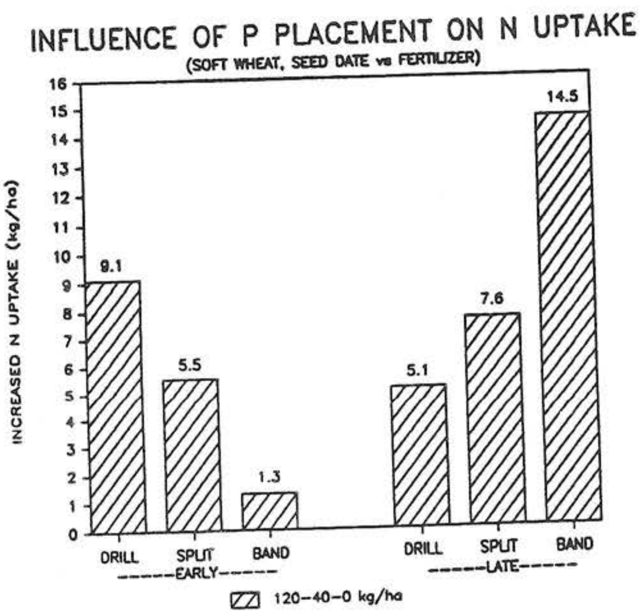

Fig.2. Influence of three methods of phosphate placement and two seeding dates (May 1 and May 21) on enhancing N uptake in grain of irrigated soil and white wheat from plots treated with deep banded nitrogen (applied May 1).

In terms of increased N uptake due to the application of fertilizer, band treatments were more effective than comparable broadcast treatments (44.6 vs 55.2 kg N/ha). The average banding advantage relative to comparable broadcast treatment amounted to 24%. The average N uptake values for the first seeding date were significantly lower than the average N uptakes achieved for the second seeding date.

Although all fertilizer treatments for the first seeding date resulted in a significant increase in N uptake (ie. average N uptake increased by 51.2 kg/ha), there were no significant differences among the fertilizer treatments. The highest N uptake for the first seeding date resulted with deep banded nitrogen and seedrow of applied phosphate.

For the second seeding date, the application of fertilizer increased the average

N uptake by 52.9 kg/ha. The highest N uptake was achieved by the dual banded (N-P) treatment although there were no significant differences among any of the treatments to which all, or at least a portion of the fertilizer was applied by deep banding.

The data summarized in Figure 2 indicates the contrasting influence that method of P placement had an increasing N uptake depending on seeding date for the treatment where nitrogen was applied by deep banding. For the early seeding date, placing all of the phosphate directly in the seedrow was the most effective method of increasing N uptake in the grain portion of the irrigated soft wheat crop. At the later seeding date, placing all of the P directly in the seedrow was less effective than either a split application or placing all of the P in a deep band in combination with the nitrogen.

Phosphate Uptake

The phosphate (P_2O_5) uptake data is summarized in Table 3. The results of both methods of P analysis are tabulated although statistical analysis was only conducted on the P analysis by the NIR method. The average phosphate content (% P) of all the grain samples amounted to 0.32% by the conventional method compared to 0.28% for the NIR method. It would appear that the P analysis by the two methods did not agree as closely as did the N analysis.

In terms of increased P_2O_5 uptake due to the application of fertilizer, band treatments were more effective than comparable broadcast treatments (20.0 vs 23.0 kg P_2O_5/ha). This amounted to a banding advantage of 15%.

Table 3 Influence of Fertilizer Treatment* and Seeding Date on Phosphate Uptake in. Soft White Wheat Grain Based on Conventional and NIR Analysis (WCFL, 1982)

Placement Treatment*	Phosphate (P_2O_5 Uptake (kg/ha)					
	May 1		May 21		Mean	
	Conventional	NIR	Conventional	NIR	Conventional	NIR
1) Check	13.6	9.0 b	15.6	12.4 d	14.6	11.2 d
2) N B'cast	34.3	29.3a	33.5	30.6 bc	33.9	30.0 c
3) N B'cast + P	37.1	31.7a	33.9	34.1abc	35.5	32.9abc
4) N Band	36.2	31.0a	34.8	32.8 bc	35.5	31.9abc
5) N Band + P	37.7	33.8a	37.3	36.2abc	37.5	35.0ab
6) N-P B'cast	36.1	29.7a	33.7	31.6 bc	34.9	30.6 bc
7) N-P Band	37.7	31.5a	40.0	40.2a	38.8	35.8a
8) N-3/4 P Band + 1/4P	39.4	33.9a	37.8	37.0abc	38.6	35.4ab
19) N-P-K Band	39.2	34.3a	38.7	37.3ab	39.0	35.8a
0) N-P Band + K	38.9	33.3a	39.5	37.7ab	39.2	35.5a
Average	35.0	29.8 b	34.5	33.0a	34.8	31.4

Means followed by the same letter are not significantly different (Tukey's P = 0.05).
* Fertilizer applied May 1 and + indicates portion of fertilizer drill in applied.
N = 46-0-0, 120 kg N/ha P = 0-45-0, 40 kg P_2O_5, K = 0-0-62, 30 kg K_2O/ha.

Although all of the fertilizer treatments had a significant effect on increasing uptake of P_2O_5, there were no significant differences among the fertilizer treatments for the first seeding date. For the N-P treatments, the highest P_2O_5 uptake was achieved where phosphate was included in the seedrow. Potash containing treatments also tended to record higher P_2O_5 uptake values. Average phosphate uptake values were significantly lower for the early seeding date.

For the second seeding date, the highest P_2O_5 uptake was achieved by the dual (N-P) deep band application although these values were not significantly different from any other treatment to which phosphate had been applied except for the case in which the phosphate was broadcast applied.

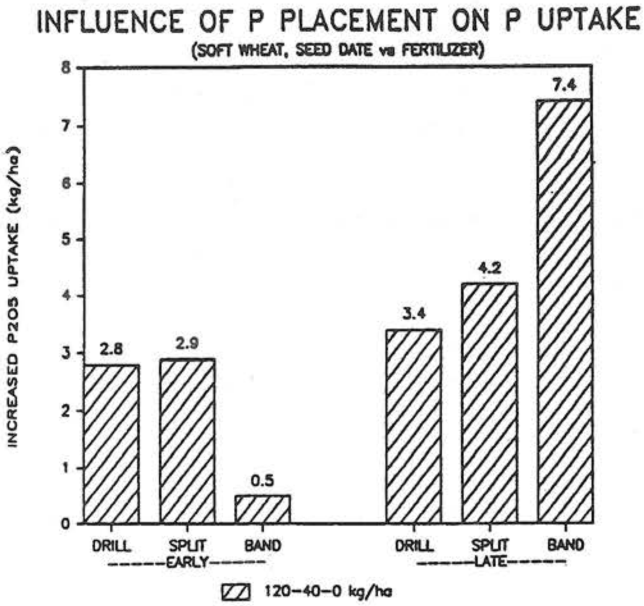

Fig.3. Influence of three methods of phosphate placement and two seeding dates (May 1 and May 21) on enhancing P_2O_5 uptake by grain of irrigated soft white wheat from plots treated with deep banded nitrogen (applied May 1).

The data sumarized in Figure 3 clearly demonstrates that there were large differences in the trends between the options available for phosphate application when nitrogen was applied by deep banding. For the early seeding date, placing all of the phosphate in a deep band in combination with the nitrogen appeared to be least effective in terms of increasing P_2O_5 uptake in the grain portion of the irrigated soft wheat crop. For the second seeding date, placing all of the phosphate directly in the seedrow was not as effective in terms of increasing P_2O_5 uptake in the grain portion of the crop as was a split application of phosphate or placing all of the phosphate in a deep band in combination with the nitrogen (ie. dual banding). It should be re-emphasized that for the second seeding date, the bands were allowed to incubate in the soil for a period of 3 weeks prior to the crop being seeded.

CONCLUSIONS

The information collected from this study demonstrates that when the required N & P are applied in common bands, high concentrations of nitrogen within the bands may initially interfere with fertilizer P uptake for the bands. This interference is only a potential problem as rates of nitrogen approach 100 lbs N/acre in bands applied at a 12" spacing. Since band concentration is also a function of band spacing, increasing the spacing between the bands to 18" could potentially result in poor crop uptake of P from a dual band at a rate approaching 70 lbs N/acre.

While application of compact bands is desirable in the fall of the year to slow the rate of nitrification, more diffuse bands may be desirable for spring application. Application of the bands three weeks prior to seeding can markedly reduce N interference with P uptake from dual bands (Harapiak and Flore, 1984), presumably due to the "mellowing" or detoxification of the high ammonia concentrations within the bands (Flaten and Racz, 1984). Nitrite accumulation within the band may also contribute to reduced P uptake (Tisdale et al., 1985; Goyal and Huffaker, 1984).

The need for application of starter phosphate fertilizer directly in the seedrow to overcome a potential short-term inability of the crop to extract phosphate from dual N-P bands will be most important if the soils are cold, soil moisture levels are favourable at the time of planting and soil phosphate levels are low (Harapiak and Penney, 1984).

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INNOVATIVE CROPPING SYSTEMS FOR SASKATCHEWAN

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ABSTRACT

This paper provides a brief overview of some of the components of the Innovative Acres Program being carried out in Saskatchewan. Initial emphasis of the program has been snow management as a means of extending rotations through increased soil moisture storage. Chemical summerfallow, winter wheat and annual grain legumes have become important components of the rotations being studied in the drier portions of the province, the Brown and Dark Brown soil zones. In the moister areas, Black and Gray soil zones, emphasis has been placed on achieving maximum yields through optimum use of fertilizers, herbicides and pesticides. Soil building crops such as alfalfa, clovers and annual grain legumes are seen as increasing components of crop rotations in these areas.

OBJECTIVES

The Innovative Acres Program was initiated in the autumn of 1981 with the objective of maximizing productivity and maintaining soil quality through water efficient farming practices.

METHODS

Cropping systems using innovative management techniques have been established at 39 locations throughout the province. These systems are cooperatively developed with participating farmers and regional agricultural committees. In each case the innovative cropping system, established on a 20-ha parcel is compared to an adjacent 20-ha parcel utilizing the regular farming system in the district. The comparisons made between the innovative and regular parcels have been based on a detailed soil survey and the establishment of transects along which twelve benchmark sampling sites are positioned. These sites represent upper, mid and lower topographic positions in the landscape. Neutron moisture casings are installed to a depth of 130 cm at each of the benchmark sites to measure soil water storage and crop use. Soil samples for fertility analysis and subsequent nutrient recommendations in addition to samples for yield are taken along the transect in the area adjacent to the moisture measurement sites. The Innovative treatments include: investigations of the effects of fall stubble management on the retention of snow water, the use of legumes for underseeding or as a partial summerfallow, chemical summerfallow when necessary, and the use of optimum fertilizer applications. Replicate plots were established at a number of the sites to provide more information on fertilizer management, nitrogen fixation by grain legumes, variable rate fertilizer application and crop residue management. At each of the locations individual farmers also included field strip demonstrations on management practices of local interest.

RESULTS AND DISCUSSION

Stubble Management

The manipulation of snow cover by fall stubble management offers the greatest potential for increasing plant available water on the Canadian prairies. Under good management each extra cm of water available to the growing wheat crop increases grain yield by about 100 kg ha^{-1}. Currently only about one-third of the fall and winter precipitation is stored as plant-available water; the remainder is lost as blown snow, runoff and drainage.

The Innovative Acres Program has monitored four fall management practices; 1) standing stubble, 2) standing stubble with snow strips, 3) fall cultivated stubble and 4) fallow. The snow catch strips were created by a swather attachment which leaves strips of taller stubble but harvests the heads. The data presented in Table 1 summarizes the results of 3 years of study of 100 fields.

Table 1. Differences in overwinter soil water storage between different fall stubble management systems.

Management System	Extra soil water gained (cm)			
	Upper Slope	Mid Slope	Lower Slope	Field Average
Standing stubble over fallow	2.5	3.6	6.3	3.4
Standing stubble over fall cultivated stubble	2.1	2.1	0.5	1.7
Stubble and trap strips over standing stubble	1.0	0.6	1.9	0.9

The studies indicate that leaving stubble standing in fall, in conjunction with herbicide treatment to control winter annuals, increases plant available water by approximately 2 cm. An additional 1 cm of snow water recharge can be attained by leaving snow catch strips in standing stubble.

Measured yield gains on fields showed that on the average an additional 280 kg ha^{-1} of wheat grain was produced where stubble was left standing. The major yield gains occurred on the mid-slope positions which represent the largest area of the field. The data presented in Table 2 shows the comparison of wheat yields for paired stubble and fall cultivated stubble with similar fertilizer treatments.

The results of the study indicate that fall stubble management has the potential to increase grain yields in the drier regions of the province. Differential height swathing or straight combining provides for good snow catch, and if used in conjunction with winter wheat and a flexible cropping system, can result in increased production in the Brown and Dark Brown soil zones. More research is required in the wetter areas of the province and on the problems associated with snowmelt infiltration.

Chemical Summerfallow

Chemical fallow has been a small but growing component of the Innovative Acres Program. It is particularly adaptable to the Brown and Dark Brown soil zones where it may compete favorably to conventional tillage fallow in terms of cost. If done properly, chemical fallow has been found to increase soil moisture storage in addition to providing cover and thus reducing erosion (Table 3).

Table 2. Measured yield gains by slope position for standing stubble vs. fall cultivated stubble (1983 and 1984, average of 6 sites).

Slope position	Wheat Yield ($kg\ ha^{-1}$)		Yield Increase ($kg\ ha^{-1}$)	W.U.E. ($kg\ cm^{-1}$)
	Stubble	Cultivated Stubble		
Upper	1915	1735	175	194
Middle	2390	1990	400	270
Lower	2290	2150	140	100

Table 3. Soil moisture comparisons for chemical and regular summerfallow.

	Soil water gain (cm)	
	Chemical fallow	Regular fallow
Harvest - Spring (9)	5.3	5.0
Spring - August (9)	-1.0	-0.3
August - Spring* (5)	3.8	3.6
Total Gain (5)	8.0	7.1

*Four of the fields were seeded to winter wheat

The levels of NO_3^--N in chemical fallow fields are generally lower than in tilled fallow systems and extra fertilizer nitrogen inputs are often required to maximize yield. The data presented in Table 4 summarizes measured changes in NO_3^--N levels.

Table 4. Comparison of NO_3^--N levels for chemical and regular fallow systems.

	Changes in NO_3^--N ($kg\ ha^{-1}$)	
	Chemical fallow	Regular fallow
Spring '83-Fall '83 (5)	+73	+101
Fall '83-Spring '84 (4)	-55	-62
Spring '83-Spring '84 (4)	+18	+39

Partial Legume Fallow

Annual grain legumes are currently being grown in partial fallow systems as an alternative to either chemical or conventional summerfallow. Crops such as lentils are planted in the spring, and if moisture conditions are favorable for growth the crop can be maintained for its seed yield, desiccated to provide coverage for direct seeding of winter wheat, or worked in the next spring to provide green manure for the spring seeded crop. This system not only provides erosion control but offers the potential for a possible cash crop in addition to the benefits associated with biological nitrogen fixation.

N_2 Fixation by Annual Grain Legumes

The objective of this research is to quantify N_2 fixation and the yield of grain legumes as affected by rhizobial inoculation, cultivar and soil-climatic zone. Two cultivars of lentils, field peas and fababeans have been used in these studies. Inoculation was found to increase yields at nearly all sites with average yield increases of 24% for lentils, 35% for peas and 59% for fababeans. Estimations of N_2 fixation by ^{15}N isotopic dilution indicate that greater than 50% of the nitrogen in the grain legumes is due to fixation (Table 5).

Table 5. Estimation of N_2 fixation by grain legumes (Foam Lake 1984).

	^{15}N isotopic dilution		By difference
	% N derived† from fixation	N fixed (kg/ha)	N_2 fixed (kg/ha)
	Lentils		
Eston	54.6	44.1	20.7
Laird	31.7	27.3	6.1
	Peas		
Tara	59.9	78.3	72.0
Trapper	58.8	70.8	61.7
	Fababeans		
Aladin	52.3	20.3	0
Outlook	58.9	16.2	0

† $1 - \frac{\%\ ^{15}N \text{ excess fixing plant}}{\%\ ^{15}N \text{ excess non-fixing plant}}$

SOIL FERTILITY RESEARCH BEING CONDUCTED BY THE SASKATCHEWAN INSTITUTE OF PEDOLOGY

1. Sulphur and its relationship to carbon, nitrogen and phosphorus in a climotoposequence of Saskatchewan soils (J.R. Bettany, J.W.B. Stewart).

2. Natural sulphur isotope abundance variations applied to the study of the soil S cycle (J.R. Bettany).

3. Nature and forms of sulphur in boreal forest soils (J.R. Bettany, D.W. Anderson).

4. The soil S cycle (J.R. Bettany, J.W.B. Stewart).

5. Nitrogen-sulphur interactions in soils (J.W.B. Stewart, J.R. Bettany).

6. Micronutrients in Saskatchewan soils (J.W.B. Stewart, J.J. Germida).

7. Nitrogen fertilizer management for winter wheat (E.H. Halstead, D.B. Wilkinson, E. de Jong).

8. N_2 fixation in annual grain legumes (D.A. Rennie, E.H. Halstead, E. de Jong).

9. The effect of potassium chloride on the root rot of cereals (E.H. Halstead).

10. Investigations of the efficiency of large broadcast applications of fertilizer phosphate over an eight-year period (J.W.B. Stewart, J.L. Henry).

11. The agricultural use of potash (J.L. Henry).

12. The reserves and labile pool of potassium in agricultural soils (L.M. Kozak, P.M. Huang).

For additional information on these projects, please refer to the Saskatchewan Institute of Pedology's Twentieth Annual Report (1984-85) or contact the scientists involved.

ZINC SOURCES AND THEIR RELATIVE EFFECTIVENESS FOR CROPS

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ABSTRACT

Zinc fertilizers are widely used in the Great Plains region. Choice of Zn source depends upon intended method of application, relative agronomic effectiveness, price per unit of Zn, compatability, and convenience in application alone or with other fertilizer. Relative agronomic effectiveness of Zn sources should be determined by applying several Zn rates throughout the response range in replicated field experiments. Periodic soil tests for available Zn are suggested when Zn deficiency is suspected, or to check for Zn accumulation in soils which already are being fertilized with Zn. Published Zn recommendations are available in every State in this region. The grower selects Zn sources and determines Zn rates after consulting with his fertilizer dealer and the appropriate extension and industry representatives. Everyone involved is obligated to see that the best information is made available to the grower.

ZINC USE

Zinc fertilizer use in the Great Plains region (West North Central and Mountain States) has increased from 5,810 tons (elèmental basis) in 1968, the first year that such data was obtained, to 19,490 tons in 1984 (16). This increase in Zn use has resulted from increased awareness of Zn needs, use of soil tests for Zn, and published Zn recommendations for one or more crops in the region.

ZINC SOURCES

The most common Zn fertilizers are $ZnSO_4$ and ZnO, although Zn oxysulfates (ZnO products partially acidulated with H_2SO_4), inorganic Zn complexes, and several synthetic chelates and natural organic complexes also are used (14). Industrial by-products containing Zn also have been used as Zn fertilizers in increasing amounts during the past decade although they have been marketed for more than 25 years. Sources of these by-products are spent acids from the galvanizing industry, battery production facilities, and other industries. Ammoniation of spent acids containing Zn results in neutral products supplying N and S as well as Zn. Baghouse dusts and flue dusts from Zn smelters and other industries also are sources of Zn. Use of certain industrial by-products as fertilizers allows their beneficial disposal, depending on whether or not their constituents may have harmful side effects (13).

Some industrial by-products also may contain heavy metal contaminants, such as Cd, Ni, and Pb. Concentrations of these heavy metals in the by-products usually are low. Therefore, their application rate to soil also would be low, especially in Zn fertilizers. For example, application at a rate of 5 lb/acre of Zn as $ZnSO_4 \cdot H_2O$ (36% Zn) containing 100 ppm of Cd would result in a Cd application rate of 0.001 lb/acre. Concentrations of Pb in some industrial by-products range from 1 to 5%, so the Pb application rate would be proportionately higher.

APPLICATION WITH MIXED FERTILIZERS

Zinc fertilizers can be applied with mixed NPK fertilizers by incorporating them during the manufacturing process, bulk blending with granular fertilizers, coating granular fertilizers, or by mixing with fluid fertilizers just before application to soil (12). Foliar sprays of soluble Zn sources also are applied for some crops, pecan trees, and some other fruit and vegetable crops (2).

Zinc sources can be uniformly distributed throughout NPK fertilizers by incorporation during manufacture. Because the Zn source is in intimate contact with fertilizer components under conditions of high temperature and moisture, the rate of chemical reactions which may influence the immediate plant availability of some Zn sources is enhanced. Residual availability of this applied Zn may not be affected, however.

Application of Zn sources with bulk-blended fertilizers is very popular because of the ease with which grades may be changed to meet specific crop needs in a given field. Granular Zn products which match the particle size of the NPK components are needed to minimize the possibility of segregation during handling and application.

Coating Zn fertilizers onto granular fertilizers greatly reduces the possibility of segregation but results in increased costs. Liquid binders are required as coating agents. Water, oils, waxes, and some fertilizer solutions have been used as binding agents. Some oils bleed through fertilizer bags. Other binding agents are unsatisfactory because they do not maintain the coating during handling. This results in segregation of the powdered Zn sources from the granular NPK components. Fertilizer solutions are preferred as coating agents because the fertilizer grade is not decreased appreciably.

Applying Zn sources with fluid fertilizers also allows the fertilizer dealer and the grower to be flexible. Because solubility or compatibility of Zn sources with solution or suspension fertilizers is required, selection of Zn sources is important.

SOLUBILITY AND PARTICLE SIZE EFFECTS

Agronomic effectiveness of Zn sources is partially related to their solubility. Highly soluble Zn fertilizer, such as $ZnSO_4$, will dissolve soon after soil application, and Zn will diffuse from the application site into the surrounding soil. The volume of soil affected by applied Zn is related to the solubility of Zn fertilizers per unit of applied Zn. Since plant uptake of Zn depends upon root interception of Zn-affected soil, Zn uptake from applied fertilizers should be related to the volume of soil affected by the fertilizer.

Particle size also may affect agronomic effectiveness of Zn fertilizers. Decreased particle size results in increased numbers of particles per unit of applied Zn. Therefore, more soil should be affected by Zn if the fertilizer is uniformly applied. Decreased particle size also increases the specific surface of a fertilizer. This should increase the dissolution rate of fertilizers with low water solubility, such as ZnO.

Importance of particle size to the relative agronomic effectiveness of $ZnSO_4$ and ZnO was demonstrated in a greenhouse study (1). Two Zn sources of three particle sizes were mixed with a Zn-deficient soil. Corn forage yields and Zn uptake were similar with fine (-100 mesh) $ZnSO_4$ and ZnO. While granular (-10+14 and -16+20 mesh) $ZnSO_4$ was somewhat less effective than fine $ZnSO_4$, granular ZnO with the same particle size ranges was completely ineffective during the six-week growth period. Response of corn to Zn also was related to level of water-soluble Zn in several fertilizers (3). Greater crop response was slight to fertilizers with levels of water-soluble Zn greater than 50% of the total Zn, depending on the fertilizer. The level of water-soluble Zn and its immediate agronomic effectiveness also decreased with increasing degree of ammoniation when added as $ZnSO_4$ to phosphate fertilizers (10). However, applications of Zn with ammoniated phosphate fertilizers should provide residual Zn for crops.

SOURCE EVALUATIONS

Agronomic effectiveness of a Zn source is the degree of crop response per unit of applied Zn. Field experiments using two or more non-zero rates of each Zn source are needed to best determine the relative agronomic effectiveness of several Zn sources. An excellent example of such an experiment is summarized in Table 1. Five Zn sources each were banded with 10-34-0 at rates of 0.1, 0.3, 1.0, and 3.0 lb/acre of Zn. Effectiveness of Zn sources, based on average corn yields over all Zn rates, decreased in the order: ZnEDTA, $ZnSO_4$, $Zn(NO_3)_2$-UAN, Zn-NH_3 complex, and ZnO, but average yields only ranged from 132 to 143 bu/acre.

TABLE 1. Response of Corn to Zn Sources Banded with 10-34-0 to a Nebraska soil, pH 7.6. (5,6).

Zn source	Zn applied, lb/acre: 0	0.1	0.3	1.0	3.0	Avg.
	yield, bu/acre					
--	62					
ZnEDTA		138	139	155	141	143
Zn-NH_3 complex		118	138	134	140	133
$ZnSO_4$		132	141	131	144	137
ZnO		124	124	134	144	132
$Zn(NO_3)_2$-UAN		131	131	142	141	136
(average)		129	135	139	142	

Relative agronomic effectiveness of Zn sources varied widely with Zn rate. For example, ZnEDTA was much more effective than ZnO and the Zn-NH_3 complex at the lowest Zn rate, but all sources were equally effective at the highest Zn rate (Table 1). Other conclusions possibly could be drawn by examining data at the other Zn rates. Obviously, more than one Zn rate in the response range is needed for an objective evaluation of the merits of one Zn source as compared with another. Despite the greater effectiveness of ZnEDTA, other Zn sources might be more economical even if higher Zn rates were required.

Data from three papers are given as examples of crop response to two or more Zn sources. In Michigan several Zn sources each were banded with 6-24-12 fertilizer for pea beans on a Zn-deficient soil (7). Yields were increased by ZnEDTA, ZnNTA, and powdered ZnO at both locations. Granular ZnO and a Zn frit were not effective at either location, and yields with $ZnSO_4$ were only slightly higher at one location. In Virginia several rates of Zn as ZnEDTA and $ZnSO_4$ were broadcast and incorporated for corn (15). Results showed that yields were significantly increased with both Zn sources at both locations. Unfortunately, these Zn sources were not applied at the same Zn rate so no direct comparison could be made. ZnEDTA was more effective with band than with broadcast application at one location. Both ZnEDTA and $ZnSO_4$ were equally effective with seed applications for corn, but higher $ZnSO_4$ rates were required for band or broadcast applications (9). In another study, several Zn sources applied with suspension fertilizers were compared in a greenhouse experiment (11). Effectiveness of the Zn sources decreased in the order: ZnEDTA, Zn-citric acid, $ZnSO_4$, ZnO, and $ZnCl_2$. Meaningful values of relative agronomic effectiveness of Zn sources cannot be determined from greenhouse results, but such studies give some indications of expected effectiveness under field conditions.

Numerical values of the relative agronomic effectiveness of Zn sources are sometimes used. These numbers are the ratios of the pounds per acre of Zn needed by one Zn source to produce the same yield increase that one lb/acre of another source would produce. Because ZnEDTA generally requires the lowest Zn rate, the ratios of Zn generally are compared with ZnEDTA set at one. The relative effectiveness of ZnEDTA as compared with $ZnSO_4$ or ZnO generally has been found to range between 2.5 to 5.0, although ratios as high as 10 have been reported. Many of these values have been obtained from experiments where similar Zn rates were not always used. Therefore, it was not possible to know if lower rates of the less effective Zn source could have resulted in similar yields. Again, multi-rate field experiments are needed to best determine the relative effectiveness ratios. Results from greenhouse experiments should not be used to give these ratios, as greenhouse conditions do not closely simulate those in the field. While relative effectiveness of Zn sources is important, other factors to consider are cost per unit of Zn, compatability with other fertilizers, and convenience in application alone or with other fertilizers.

RESIDUAL EFFECTS OF ZINC

Residual effects of applied Zn should be considered in making Zn recommendations. Several states have reported increases with time in soil test levels for Zn. This buildup of Zn has resulted in reduction of the recommended Zn rate for crops after Zn has been applied for a number of years. Many states are reporting that the incidence of Zn deficiencies has decreased significantly with time. While crop responses to applied Zn still are reported, the magnitude of such increases is not as great as it was 10 to 20 years ago.

Because available Zn levels increase in soils after repeated applications, Zn soil test results should be continually monitored, and recommended Zn rates should be decreased as soil Zn levels increase. If not, Zn levels could be reached that would cause toxicities in some sensitive crops, although such toxicities have not been reported.

ZINC RECOMMENDATIONS

Recommendations for Zn applications in the States of the Great Plains region are summarized in Table 2. Soil tests for Zn by university soil testing laboratories generally are made only on request in these States. The main soil test methods for Zn are the DTPA (8) and AB-DTPA (4) procedures, although several other procedures also are used. Interpretation of Zn levels extracted by DTPA is: 0 to 0.5 ppm--low, 0.51 to 1.0 ppm--medium (marginal or moderate), and > 1 ppm--adequate.

Because the AB-DTPA procedure extracts more Zn from soils, the interpretation of Zn levels is: 0 to 0.9 ppm--low, 0.91 to 1.5 ppm-medium, and > 1.5 ppm--adequate.

Corn and dry beans are the main crops grown in the Great Plains region which are fertilized with Zn. Several other crops, however, including sorghum, sudan, potatoes, soybeans, flax, and pecans also are fertilized with Zn. Methods of application, soil pH level, and irrigated conditions affect the recommended Zn rates in some States.

Each state has published Zn recommendations. Fertilizer dealers and growers should consult with extension specialists and industry representatives if there are specific questions. Appreciation is given to those who provided information for this Table.

TABLE 2. Summary of zinc soil tests and recommendations - Great Plains Region

State	Extractant	Zn recommendation[a]		
		Crop	Zn rate, lb/acre	
			low Zn	marginal Zn
Colorado	AB-DTPA	Corn, dry beans, sorghum, sudan, potatoes	5 (10)	0 (5)
Kansas	DTPA	corn	8-10 (8-10)	2-5 (2-5)
		sorghum, soybeans, dry beans	2-5 (8-10)	0 (2-5)
Montana	DTPA	corn, dry beans	5 (10)	0 (5)
Nebraska	0.1 N HCl[b]	corn, dry beans	5-8 (5-8)	3-5 (3-5)
	DTPA[c]	corn, dry beans	10-15 (10-15)	5-10 (5-10)
New Mexico	DTPA	corn, sorghum, alfalfa, wheat	(7.5-15) (5-10)	(1-7.5) (1-5)
North Dakota	DTPA	corn, flax, dry beans, potatoes	10-15	10-15[d]
Oklahoma	DTPA	corn	2-5	
		pecans	foliar spray	
South Dakota	DTPA	corn	10 (5)	
Texas	DTPA	corn, sorghum, pecans	1	
Wyoming	AB-DTPA	corn, dry beans, potatoes	5 (10)	0 (5)

a/ Values in parenthesis are Zn rates for irrigated crops.

b/ For acid soils

c/ For calcareous soils (pH > 7.3)

d/ Broadcast rate recommended for a trial basis only, banded rate should be 2 lb/acre.

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NITRAPYRIN EFFECTS ON MINERAL COMPOSITION OF IRRIGATED WHEAT

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ABSTRACT

Application of nitrapyrin affected the plant tissue levels of only a few nutrient elements in a given year for a given stage of growth. Nitrapyrin increased the K/(Ca + Mg) rates of wheat only at Feekes Stage 2 in 1983 and did not appear to greatly influence the grass tetany potential of wheat forage during the two years of the study.

OBJECTIVES

Nearly 500,000 acres of wheat are grown annually in New Mexico consisting of 40% of the total cropped land in the state. Although most of the wheat is grown for grain, irrigated wheat acreage also provides winter grazing for livestock and a significant source of cash flow for the grower. Nitrogen fertilization of wheat is a commonly accepted practice in wheat production but nitrification inhibitors in combination with fertilizer N have not yet been widely accepted. Recent research (Mathers, et al., 1982) in the Southern Great Plains indicates that using nitrapyrin may increase the incidence of grass tetany in livestock grazing on wheat.

The objective of this study was to measure the effects of nitrapyrin on the elemental concentrations of wheat with particular emphasis on K, Ca and Mg but also with interest in other primary, secondary and micro-nutrient elements.

MATERIALS AND METHODS

This study was initiated in October, 1982 on a Reagan loam soil (fine, carbonatic, thermic Typic Calciorthid) at the NMSU Ag Science Center near Artesia, New Mexico. Plots 20 feet wide by 40 feet long were laid out in a split plot design with 5 replications. Treatments included an unfertilized check and N rates of 30, 60 and 90 lbs N as urea per acre. A blanket application of 26 lbs P, 33 lbs K and 5 lbs Zn and 33 lbs P, 33 lbs K and 2 lbs Zn were made on the basis of a soil test in 1982 and 1983, respectively, prior to application of N treatments. The nitrapyrin was impregnated on the urea at an 0.5 lb/A a.i. rate by mixing a commercial formulation with 8, 33 or 58 ml ethanol for the urea quantities of the respective N rates. The nitrapyrin mixture was poured over the urea sample in a rotating drum and mixed for 5 minutes to ensure coating of the fertilizer granules. Both impregnated and untreated urea were then spread by hand on the respective plots and immediately disced in to a depth of 4 inches.

Centurk wheat was planted at a rate of 60 lbs/A using a grain drill. The wheat was irrigated up in 1982 but due to adequate soil moisture, no fall irrigation was necessary in 1983 to ensure emergence and early growth.

Plant samples were collected six weeks after stand emergence (Feekes Stage 2), 18 weeks after stand emergence (Feekes Stage 4), at boot stage (Feekes Stage 10) and at soft dough stage (Feekes Stage 10.7 to 10.8). The samples were washed after collection, dried at 70^{o}C for 72 hours, and ground to pass a 1 mm screen. The samples were then digested by an HNO_3 - $HClO_4$ procedure and analyzed by ICP-ES. Grain yield and protein data were also collected.

RESULTS AND DISCUSSION

Table 1. Significance of nitrapyrin effects on elemental composition of Centurk wheat at Feekes Stage 2.

Element	1983	1984	Average
N(%)	ns	ns	ns
P(%)	ns	ns	+
K(%)	ns	ns	+
Ca(%)	**	ns	ns
Mg(%)	**	ns	*
B(ppm)	ns	ns	ns
Zn(ppm)	ns	ns	ns
Fe(ppm)	ns	ns	ns
Mn(ppm)	ns	ns	ns
Cu(ppm)	ns	+	ns

+, *, ** Significant at the 10%, 5% and 1% levels, respectively.

ns - Not significant.

The significant effects of nitrapyrin on elemental composition of wheat at Feekes Stage 2 are reported in Table 1. Tissue calcium and magnesium were significantly reduced by nitrapyrin application in 1983 with respective decreases of 0.43% to 0.39% calcium and 0.16% to 0.15% magnesium for untreated and nitrapyrin treated plots. Copper concentration in the wheat decreased from 9.6 ppm to 9.1 ppm with nitrapyrin treatment in 1984. For the averaged two year data, phosphorus was decreased from 1.92% to 1.85%, and magnesium was decreased from 0.18% to 0.17% with nitrapyrin treatment.

Table 2. Significance of nitrapyrin effects on chemical composition of Centurk wheat at Feekes Stage 4.

Element	1983	1984	Average
N(%)	ns	ns	ns
P(%)	*	ns	ns
K(%)	+	ns	ns
Ca(%)	ns	*	*
Mg(%)	ns	ns	*
B(ppm)	ns	ns	ns
Zn(ppm)	ns	ns	ns
Fe(ppm)	ns	+	ns
Mn(ppm)	+	ns	ns
Cu(ppm)	ns	*	*

+, * Significant at the 10% and 5% levels, respectively.

ns - Not significant.

Significant effects of nitrapyrin on elemental composition of wheat at Feekes Stage 4 as reported in Table 2. Phosphorus and manganese in the tissue significantly increased from 0.23% to 0.24% and 162.8 ppm to 167.5 ppm, respectively, due to nitrapyrin in 1983. Tissue potassium decreased from 3.27 ppm to 3.15 ppm. In 1984, nitrapyrin significantly decreased tissue concentrations of calcium, iron and copper from 0.43% to 0.41%, 156 ppm to 151 ppm, and 11.8 ppm to 10.0 ppm, respectively. Significant reductions of 0.39% to 0.38% for calcium, 0.16% to 0.15% for magnesium and 11.0 ppm to 10.0 ppm for copper were observed for the averaged two year data.

Table 3. Significance of nitrapyrin effects on selected elemental ratios of Centurk wheat at Feekes stages 2 and 4.

Elemental ratio	1983		1984		Average	
	Stage 2	Stage 4	Stage 2	Stage 4	Stage 2	Stage 4
K/Ca + mg	**	+	ns	ns	ns	ns
P/Fe	ns	ns	+	ns	+	ns
P/Zn	ns	*	ns	ns	ns	*
P/Mn	ns	ns	ns	ns	ns	ns
P/Cu	ns	ns	ns	**	ns	*

+, *, ** Significant at the 10%, 5% and 1% levels, respectively.

ns - Not significant.

Significant nitrapyrin effects on selected elemental ratios are reported in Table 3. The K/(Ca + Mg) ratio is of major concern to stockmen due to relationship to grass tetany. In 1983, this ratio significantly increased with nitrapyrin treatment at Feekes Stage 2 and significantly decreased at Feekes Stage 4. No significant differences were observed in 1984 or in the averaged data. However, the K/(Ca + Mg) ratios for all treatments for both years were generally 2.2 or greater and have potential for causing grass tetany (Grunes, 1973; Grunes, et al., 1970). Nitrapyrin significantly increased P/Zn at Feekes Stage 4 in 1983 and again for the two-year average P/Fe was significantly increased by nitrapyrin application at Feekes Stage 2 in 1984 but decreased for the averaged data. It also significantly increased P/Cu at Feekes Stage 4 in 1984 and for the averaged data.

Application of the nitrapyrin generally decreased grain yield although grain protein remained the same or increased very slightly. Yield decreases were generally due to lodging of the wheat.

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SOIL FERTILITY RESEARCH

PROJECT: Fertilizer Management for Alfalfa.

RESEARCH LEADER: L. J. Cihacek, NMSU Ag Science Center, Artesia, New Mexico.

OBJECTIVES: (a) To evaluate effects of phosphorus fertilizer sources on alfalfa forage yield; (b) To evaluate effects of potassium fertilizer sources on alfalfa forage yield; (c) To evaluate effects of a combination of phosphorus and zinc on alfalfa forage yield; (d) To evaluate the effect different soil test recommendations on alfalfa forage yield; (e) To evaluate effects of phosphorus fertility rates and time of application on alfalfa forage yield; and (f) To evaluate method of phosphorus fertilizer placement on alfalfa forage yield.

PROJECT: Nitrogen Management S.E. New Mexico.

RESEARCH LEADER: L. J. Cihacek, NMSU Ag Science Center, Artesia, New Mexico.

OBJECTIVES: (a) To evaluate plant growth regulators on wheat grown under high nitrogen environments; (b) To evaluate long term effects of N application on cotton lint yield and quality and residual profile N; and (c) To update N fertilizer recommendations for wheat.

PROJECT: Crop Culture.

COOPERATORS: C. E. Barnes and L. J. Cihacek, NMSU Ag Science Center, Artesia, New Mexico.

OBJECTIVE: To evaluate effects of irrigation and nitrogen variables on corn grain and forage yields.

PROJECT: Effects of Irrigation, Row Spacing and Nitrogen on Lint Yield of Cotton.

COOPERATORS: C. E. Barnes and L. J. Cihacek, NMSU Ag Science Center, Artesia, New Mexico

OBJECTIVE: To examine effects of irrigation level, row spacing and N rate on optimizing cotton lint yield and lint quality.

EFFECT OF NEWLY AND PREVIOUSLY APPLIED NITROGEN ON YIELD AND RECOVERY OF NITROGEN BY BARLEY

A.O. Ridley and J.M. Tokarchuk
University of Manitoba

ABSTRACT

Nitrogen was applied to 4 consecutive crops of barley planted on an Almasippi LFS at MacGregor and Snowflake CL at Purvis, Manitoba. Rates of N applied were 0, 34, 68, 101, 134 kg ha^{-1} using urea fertilizer. In the fifth crop year no nitrogen was applied to monitor the effect of residual N on yield, N-uptake and protein content of barley.

Yields of barley varied between years, but were generally greater at MacGregor than at Purvis. In the fifth crop year yields of barley at MacGregor were increased by residual N from the 68, 101 and 134 kg $N.ha^{-1}$ plots. At Purvis residual N from all previously applied treatments increased yield. Protein content of grain, and total N uptake by the crop was also increased by residual nitrogen. Indication of residual N effect on crop growth could be predicted from NO_3-N analysis of soils taken before the residual N monitoring crop was planted.

OBJECTIVES

Nitrogen fertilizer applied to soils is seldom completely recovered by crops in the year of application. Analysis of the above ground portion of cereal crops in Manitoba indicates that crop recovery is often as low as 30 to 60%. The fate of unused N has not been determined. It may be permanently lost through volatilization, leaching or denitrification. It may also remain in the soil as unused fertilizer N or be immobilized, and thus be available for future crops. With the high rates of nitrogen now being applied to crops annually, residual N could be an important source of nitrogen and affect both crop yields and quality.

The objectives of this study were to determine the effect of repeated applications of nitrogen fertilizer on barley yields and quality and to determine the residual effect of previously applied nitrogen.

MATERIALS AND METHODS

A field experiment was established on two soil types in Manitoba in 1978: (1) Snowflake CL at Purvis (Orthic Black Chernozem developed on mixed glacial till) and (2) Almasippi LFS at MacGregor (Carbonated Rego Black Chernozem developed on deltaic sand). The experiment consisted of 15 treatments in randomized block design with 5 replicates. Plots were 7 m x 3.2 m and treatments were placed on the same plots for 4 years. In the fifth crop year, no N was applied to monitor residual effect. Barley (c. Conquest) was planted each year at 100 $kg.ha^{-1}$. Phosphorus fertilizer was applied with the seed on all plots at 18 $kg.P.ha^{-1}$ using 0-0-60, mixed with the phosphorus.

Nitrogen treatments included rates, times and methods of application of N. In this paper, only the rate treatments are reported and are an average of banded and broadcast methods of application since analyses indicated that there was no significant difference between the methods. The rates of N were: 34, 68, 101 and 134 $kg.ha^{-1}$ using urea 46-0-0, and a control.

RESULTS AND DISCUSSION

The two soil types were selected to provide comparisons of results from two common but different soils in Manitoba. Almasippi LFS is characterized by having a coarse texture and is saturated to the surface in spring. It also has free lime at the surface. These conditions could cause loses of N by denitrification and volatilization. Snowflake CL is characterized by having a medium texture and moderately good drainage, but is not calcareous. Losses by denitrification and volatilization would not be expected to be as severe as for Almasippi LFS.

Regression analyses was conducted on barley yields for both sites and all crop years. Lines of best fit for the data are shown in Figure 1A and 1B.

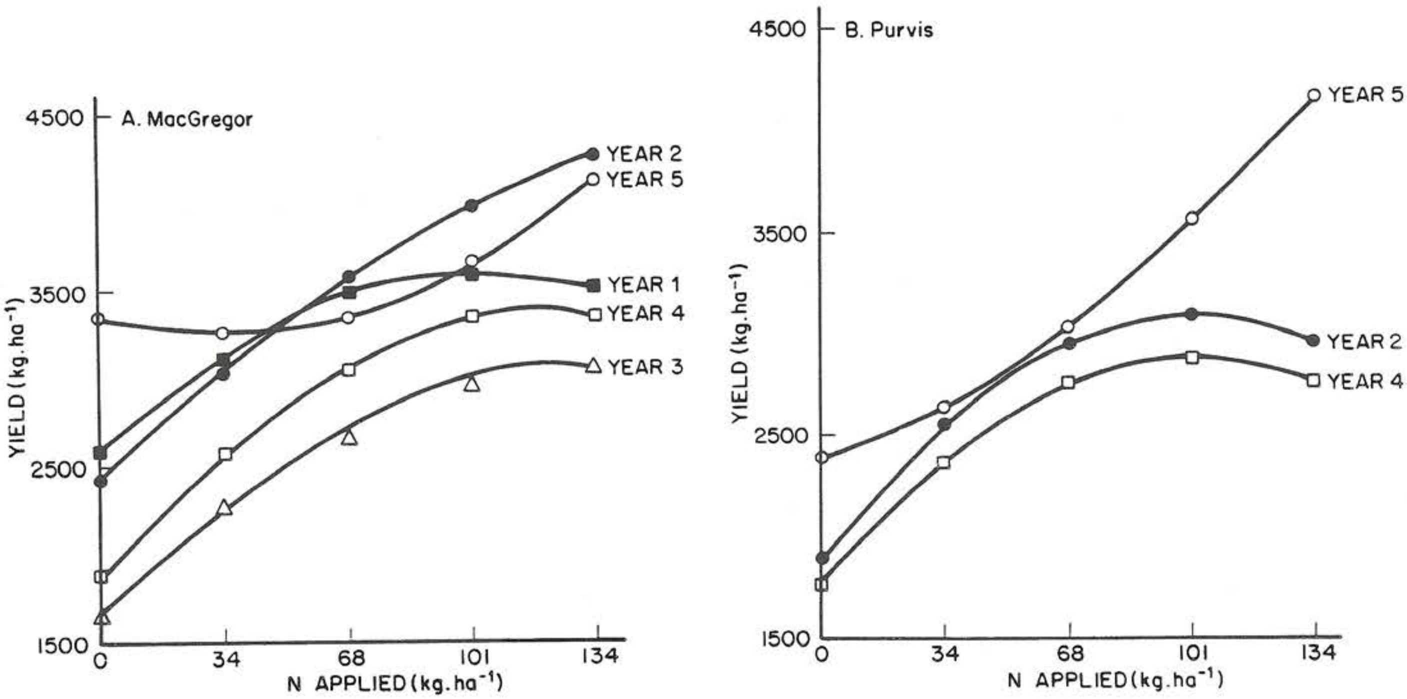

Figure 1. Effect of newly and previously applied N on yields of barley at A. MacGregor and B. Purvis.

The r^2 values calculated were: MacGregor: 0.53; 0.79, 0.70; 0.70; 0.45 for years 1978 to 1982 respectively, and Purvis: 0.63; 0.69; 0.80 for 1979, 1981 and 1982 respectively. All r^2 values are highly significant. Barley was not harvested at Purvis in 1978 because of hail damage to the crop, and in 1980 because of poor crop emergence.

At MacGregor, crop yields were increased by the application of urea-N for that crop, at rates of N up to 101 kg.ha^{-1} in years 1, 3 and 4. In year 2, the highest rate of N applied (134 kg.ha^{-1}) was not sufficient to produce maximum yields. In crop year 5 (1982) no N was applied, however, yields were very high. This was attributed to an exceptionally good growing year in Manitoba. Examination of crop yield statistics for the province showed that yields of wheat in 1982 were 7.6% higher than the previous high. Despite the high yields where no or low rates of N were applied in previous years (Figure 1), yields were even greater where high rates of N were applied.

At Purvis, crop yields were increased by the application of urea-N for the crop at rates of N up to 101 $kg.ha^{-1}$ in years 2 and 4. (Crops were not harvested in years 1 and 3). In crop year 5 (1982) no N was applied, however, yields were greater than those obtained with the application of N to the crop in previous years. This, similar to MacGregor, was attributed to an exceptionally good growing year. Yields, however, were highest on plots where N had been applied in previous years, indicating a response to residual N. Response to residual N was considerably greater at Purvis than at MacGregor and may be due to fertilizer application in the first 4 crop years, but no crop harvest in 2 of the years.

Nitrogen uptake in the above ground portion of the barley crops, and grain protein contents were increased by high rates of previously applied N at both sites (Table 1). At MacGregor, N uptake from the no N applied plots was slightly greater than when low rates of N had previously been applied. This is consistent with a high protein content (10.1%) and high yield. At Purvis both nitrogen uptake and percent protein in grain increased directly with increasing rates of previously applied nitrogen.

Table 1. Total N uptake in above ground portion of barley crop and crude protein content (%) of grain in 5th crop (1982).

Previously applied N	N uptake		% protein	
($kg.ha^{-1}.year^{-1}$)	MacGregor	Purvis	MacGregor	Purvis
0	68	41	10.1	9.4
34	63	48	10.1	9.5
68	63	53	9.9	9.5
101	77	78	10.9	11.1
134	87	103	11.5	12.6

Soil analysis for NO_3-N was conducted on samples taken after the fourth crop (Table 2). At MacGregor, the amount of NO_3-N found at 0-60 cm depth was greater in

Table 2. Soil nitrate-N content in September 1981 prior to cropping in the final year.

Previous Applied N	Soil Nitrate-N ($kg.ha^{-1}$)			
($kg.ha^{-1}.year^{-1}$)	MacGregor		Purvis	
	0-60 cm	0-120 cm	0-60 cm	0-120 cm
0	39	59	27	33
34	24	31	30	44
68	26	40	37	54
101	34	52	52	76
134	33	72	99	138

the control plot than in any of the previously fertilized plots. Measured at 0-120 cm depth, the control plot NO_3-N was also greater than any other treatment except when 134 $kg.ha^{-1}$ of N had been applied. Examination of single plot data from each replicate showed that 2 out of 10 samples taken from the controls were much higher in NO_3-N, N-uptake and yield than in the other eight samples. No reason for this was evident. If these two samples were omitted from the analyses, data would have been similar to that obtained from the 34 kg $N.ha^{-1}$ treatment. Thus the control data for MacGregor may be considered high. At Purvis, soil NO_3-N content was increased consistently with increasing rates of N previously applied when measured at both the 0-60 cm and 0-120 cm depth. It is assumed that this NO_3-N remained available for the fifth crop and was thus partially responsible for the residual N response obtained. Additional N required to account for both high yield and protein obtained presumably came from mineralization of immobilized fertilizer N.

Residual nitrogen effect on barley yields were greater at Purvis than at MacGregor. Protein content and N-uptake were also greater than at MacGregor, but only at the highest rate of previously applied N. It is not clear if this is due to soil type differences whereby N was lost from the Almasippi soil at MacGregor or if the two unharvested crops resulted in more available N at Purvis.

ADDITIONAL SOIL FERTILITY RESEARCH IN THE DEPARTMENT OF SOIL SCIENCE, THE UNIVERSITY OF MANITOBA

Effect of soil erosion on soil productivity.

1. Yield, potassium uptake and potassium use efficiency of barley affected by soil magnesium.
   Yields of barley decreased with increases in the Mg content of soils. High concentration of Mg in soils had only minor effects on K uptake. Yield reductions on high Mg soils appears to be due to lower plant availabilities of Zn, Fe and/or Mn in these soils. G.J. Racz.

2. Maximum production research with wheat.
   Field experiments were conducted for several years to determine P and K requirements and methods of application for maximum yields of wheat. Soils deficient in P and K required a large application of P and K initially, and small amounts annually thereafter. Soils medium to high in P and K produced high yields with only small annual amounts applied with the seed. R.J. Soper.

3. A study of N-fixation by lentils, soybeans and fababeans.
   Early maturing varieties of soybeans required supplemental N over that supplied by the soil or by dinitrogen fixation. In reducing days to maturity, some N_2 fixation capacity of soybeans was lost. Lentils were found to be poor fixers of dinitrogen and normally don't fix enough N_2 for plant requirements. Lentils have also been found to be dependent on mychorizae for nutrition. Fababeans have the capacity to fix all nitrogen required. R.J. Soper.

4. Dual N-P placement.
   The movement and solubility of P in dual bands as affected by the kind of nitrogen fertilizer and soil type is being studied. Uptake of P from dual bands by various crop species is being evaluated in environmental cabinet and field studies. G.J. Racz.

5. Effect of copper and zinc fertilizers on yield and chemical composition of wheat grown on coarse textured soils.
Micronutrient contents of crops grown on coarse textured soils in Manitoba are often depressed when N and P fertilizers are applied at heavy rates. Fertility studies with Cu and Zn are being conducted to determine methods of application that will overcome detrimental effects of high rates of phosphorus. J.M. Tokarchuk.

6. Mechanisms of denitrification. Oxygen transport and denitrification in soil profiles.
The magnitude of fertilizer and native soil nitrogen loss by denitrification processes is investigated. Soil temperature, oxygen and biological activity within the profile are used to estimate the denitrification. C.M. Cho.

7. Determination of energy requirements, production potential and economics of winter and spring wheat under zero and conventional tillage practices employing intensive fertilizer management.
Field studies are being conducted at two sites. In the first crop year, winter wheat survived at only one of the sites, but yields at that site exceeded 5 $tonnes.ha^{-1}$. Spring wheat under zero and conventional tillage yielded between 4.5 and 4.7 $tonnes.ha^{-1}$. Economic evaluation is being conducted on a large data base assembled by the Department of Agricultural Economics. Models generated will be tested with the field data. A.O. Ridley and D.F. Kraft.

8. Effect of soil erosion on soil productivity.
Erosion was simulated by physically removing various portions of the Ap horizon of several soils. Losses in productivity were measured by crop growth. The extent to which these losses could be overcome by nutrient application was assessed. C.F. Shaykewich.

9. Effect of organic matter on soil properties and crop yields.
Two types of crop residue; cereal straw containing 0.6% N; and alfalfa hay containing 3.4% N were added at the equivalent rate of 50 tonnes per hectare to pots in a growth chamber. Results obtained by the addition of residues are bing compared with those obtained with the use of mineral fertilizers. R.A. Hedlin.

10. Management of sandy soils.
Manitoba contains large areas of coarse textured soils. These are often low in fertility and subject to erosion. Various tillage practices (including zero tillage) are being investigated in addition to nutrient requirements for maximum yields. G.J. Racz and J.M. Tokarchuk.

CONSERVATION TILLAGE-CROP PRODUCTION SYSTEMS FOR THE NORTHERN GREAT PLAINS

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ABSTRACT

Conservation tillage (minimum-till and no-till) crop production systems have not been developed for the northern Great Plains. For the most part, the emphasis of previous soil and water conservation research has been on studying two-factor interactions of which tillage and soil fertility, tillage and water conservation, soil fertility and crops, are examples. Recent advances in computer technologies now makes it possible to accommodate analyses for assessing the interaction and significance of many factors and research approaches. We have established a long-term field-plot size experiment on 63 acres to study multifactor variables involving cropping systems, conservation tillage, soil fertility, and cultivar variables in a single study. The experimental design, procedures and operational logistics for conducting this type of complex field scale experiment and the data sets being collected by the various research disciplines involved will be discussed.

INTRODUCTION

Soil erosion is recognized as a serious threat to man's well-being, and in some areas of the world, to his very existence. Although substantial advances have been made in erosion abatement, losses in areas of the United States continue to exceed the rate of soil renewal. In the northern Great Plains, soil losses to wind and water erosion exceeds 5 tons per acre on about 50% of the 28 million acres of cropland and exceeds 9 tons per acre on about 21% of it. Cost-effective minimum-till and no-till conservation tillage systems, adaptable to the region and if adopted by producers, potentially would reduce soil losses by wind and water erosion by, conservatively, 50%.

Crop residue management is a major factor in erosion control. Left on the soil surface, residues reduce wind speed and thereby wind erosion, and act as a barrier to water runoff and absorb impact energy imparted by falling rain and thereby reduce water erosion. The greatest deterrent to erosion is a vegetative cover, dead or alive, on the soil surface. Simultaneously, residues affect water conservation by suppressing water evaporation rate and effecting retention of precipitation (including snow) where it falls. In essence, the focal point of dryland agricultural research in semiarid and subhumid regions is to save as much water as possible from precipitation and use it as efficiently as possible for crop and livestock production. Conservation of soil and conservation of water are inseparable.

For the most part, the emphasis on previous soil and water conservation research has been on studying two-factor interactions such as tillage (residue and management) and soil fertility, tillage and water conservation, soil fertility and crops etc. The advent of computer technologies now makes it possible to accommodate systems analyses for assessing the interaction and significance of many factors, and therefore paves the way for a team research approach to conservation problems.

Current information on conservation tillage systems in the northern Great Plains is essentially limited to no-till production of winter wheat. Information is lacking for spring-sown cereal grain and oilseed crops. Soil erosion hazards of spring-planted crops, especially oilseed crops (sunflowers, safflower), is high compared to winter wheat because of the longer idle period between crops, particularly when summerfallow is used and because oilseed crops produce less crop residue.

OBJECTIVES

The research goal is to develop efficient and cost-effective conservation tillage (residue management) practices with emphasis on methods of increasing precipitation storage efficiency, improving crop residue management for erosion control, and using available soil water most efficiently. In addition, this systems experiment provides opportunities for multidisciplinary research in such areas as associated disease, insect and weed problems, N and P cycling, biotic and abiotic soil property changes, and soil productivity-crop response relationships.

PROJECT DESCRIPTION

The field research is conducted on a 63-acre site on Williams loam (fine-loamy, mixed, Typic Argiboroll) with a 2 to 4% southeasterly slope. The experimental variables in three replications are all combinations of (1) two cropping sequences; spring wheat-fallow and spring wheat-winter wheat-sunflowers [main blocks (450 x 240 ft.)], (2) three conservation tillage treatments; conventional tillage, minimum tillage, and no-till [main plots (150 x 240 ft.)], (3) three fertilizer nitrogen rates; 0, 20, and 40 lbs N/ac for crop-fallow and 30, 60 and 90 lbs N/ac for continuous cropping sequence (subplots 150 x 80 ft.) and (4) two cultivars, standard (check) and current "best" (sub-subplots, 75 x 80 ft.).

The experimental area had been in spring wheat in 1982 and in 1983 it was, the first year of the lease, uniformily cropped to sunflowers. We applied 1 lb/ac active ingredient (ai) of Treflan[1/] granular herbicide using a granular applicator mounted on an undercutter sweep which served as the first tillage. This was followed by a tandem disk operation ahead of planting. The site also received 40 lbs N/ac from ammonium nitrate before disking. The sunflowers yielded about 1500 lbs/ac and used all available soil water to a depth of 5 feet. The minimum soil water depletion point for the experimental site averaged 11.5% $\pm$ 0.5 by volume weight or 1.67 inches of water for each 1-foot increment to a depth of 5 feet. Therefore, the total soil water content at the minimum depletion point for the 5-foot soil profile is 8.4 inches. This value will serve as the base upon which available soil water and crop water use will be calculated in future years.

In the fall of 1983, we took soil samples (9 samples per main block) from the 0 to 3, 3 to 6, and 6 to 12 inch depths and by 1 foot increments from 2 to 5 feet for soil analysis to provide the base data for chemical and physical soil properties before treatment variables were initiated. Bicarbonate soluble P ranged from 8 to 12 ppm. We applied a uniform broadcast application of 40 lbs P/ac from concentrated superphosphate in October 1983. Soil test P in the 0 to 6 inch depth when sampled in the spring of 1984 ranged from 18 to 26 ppm. Soil NO_3-N averaged 46 lbs N/ac to a depth of 5 feet.

In 1984, we established the crop-fallow cropping sequence by planting spring wheat after sunflower in one block and fallowing a sunflower block. For the spring wheat-winter wheat-sunflower sequence, spring wheat was planted in the spring wheat

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[1/] Trade names of herbicides and farm equipment used in this report are given for the benefit of the reader and does not constitute endorsement or a recommendation of the product by USDA-ARS.

and winter wheat blocks and spring barley was planted in place of sunflower to void planting sunflower two years in a row in the same block.

By the 1985 crop season all cropping sequences, tillage treatments, N rates, and cultivar variables were in place. The conventional tillage treatment consists of using the undercutter sweep as needed between crop sequences and using a tandem disk once just ahead of planting. The minimum tillage treatment consists of using the undercutter only once or twice between crop sequences and using chemical weed control as may be needed thereafter. The no-tillage treatment consists of only herbicide spray operations as may be needed. A description of all tillage and spray operations being used in the two cropping sequences are shown in Table 1. Our tillage treatments may also be defined in terms of target crop residue levels at planting when the previous crop was spring wheat or winter wheat as follows: conventional tillage, 30% or less crop residue on the soil surface; minimum tillage, 30 to 60% residue cover; and no-till, 60% or greater crop residue cover. Therefore, we do not have a fixed number of tillage and/or spray operations but rather a system of tillage, plus spray and spray-only operations as may be needed for weed control and for obtaining target residue maintenance levels. Our combine is equipped with both a straw spreader and a chaff spreader. This spreads the straw and chaff over the width of the header.

The major soil fertility variable in this study is N rates, since P was uniformly applied at a one-time high rate to maintain available P at an adequate level for many years. All N rates are broadcast in the spring ahead of planting for the spring-planted crops and as a topdressing in late April for winter wheat. Soil samples are taken by 1-foot increments to a depth of 5 feet in the fall after harvest and again in early spring before planting to determine soil water and soil NH_4-N and NO_3-N contents. These data, along with total plant N in grain and straw, will provide the base data for determining the most optimum and cost-efficient N rates needed.

We hypothesize that interactions of crop cultivars and the tillage-nitrogen variables are important. Therefore, we are using a standard, or most popular, cultivar of a particular crop grown in the area as the check cultivar. The other cultivar is chosen for its expected, or known, improved performance in no-till cropping systems. Additionally, we are currently testing 5 to 10 cultivars of winter wheat and spring wheat in other no-till studies on large field scale basis to determine "best" cultivars for use in this study. Similar studies are being conducted on sunflower cultivars.

The major measurements being taken include: soil water at harvest, at soil freeze-up, and in the spring; residue quantity at harvest, in the spring, after planting, and periodically during fallow; plant population; plant growth and development; snow retention or trapping; soil physical properties (soil aggregate stability, bulk density, soil texture, etc.); soil test N and P; crop yield and quality; weed populations; plant pathogens and epidemiology; insect populations; soil and atmospheric environmental data; and crop canopy and residue spectral reflectance data. Long-term variables under investigation include changes in physical and chemical soil properties, N and P cycling and nutrient balance, and soil organic carbon.

Our goal is to use "best" management and cultural practices for each conservation tillage-cropping system. The planting equipment is very important for it is critical that the same plant population be attained in all treatments within each crop. Therefore we use the same drill for a given crop across all tillage variables. The Bettenson (Melroe) double disk no-till drill is used for planting spring wheat, a 8010 Haybuster no-till drill is used for planting winter wheat, and a 8000 IHC no-till 4-row unit planter is used for sunflower. These drills are capable of establishing a good plant population in crop residue levels up to 3000 lbs/ac.

The Haybuster undercutter with granular herbicide applicator is the principal tillage implement used in both conventional- and minimum-till systems. The 16-foot machine is equipped with 32-inch sweeps, and decreasing blade angle from toe to heel which permits consistent shallow depth (2-inch) operations. A 14-foot tandem disk is used ahead of planting in the conventional-till plots. Our sprayer was developed to perform as a ground-speed driven, pump injection system so that quantity of herbicide and water can be accurately regulated along with droplet size to provide optimum weed control. At the present time we are using Glean at 1/4 oz ai/ac, Roundup plus 2,4-D at 0.4 lb and 0.4 lb ai/ac, respectively, for long-term weed control in the no-till spring wheat-fallow sequence. In the spring wheat-winter wheat-sunflower sequence we are using Roundup + 2,4-D for grassy and broadleaf weeds on the no-till spring or winter wheat plots. For sunflowers we are using Treflan TR10 granules for conventional- and minimum-till sunflower production. For no-till sunflowers, we are currently experimenting with a fall application of Surflan at 1.25 lbs ai/ac plus a spring burn-down application of Roundup plus 2,4-D just before planting. We also applied Furadan insecticide at 1/2 lb ai/ac in the sunflower seed row to assist in insect control in all tillage systems. Broadleaf weeds within the spring wheat or winter wheat plots are controlled with a herbicide mixture of Brominal and 2,4-D ester each at 6 oz ai/ac.

The large size of the field plots in this study provide many advantages to the various research disciplines involved. (1) The plots are large enough, particularly the tillage (150 x 250 ft.) and N rate by tillage plots (150 x 80 ft.), to accommodate independent sampling sites for soil water and soil nutrients, plant growth and yield, weed populations, insect populations, plant and atmospheric sampling for pathogenic activities, etc. (2) The relatively large plot size provides additional border areas between treatments which can be used to reduce the confounding effects of one treatment on another in relation to plant pests (disease, insect and weed problems) associated with a given treatment. (3) This field size experiment also provides a potential for correlating spectral signatures from hand-held and satellite-mounted sensors with dry matter, crop yield and crop residue measurements to aid in land resources assessments of soil production and protection. (4) Since we are using field-size commercially available farming equipment for all operations, the applicability and acceptance of the results by producers has been enhanced appreciably.

Table 1. Description of tillage and spray operations used in the cropping sequences.

Cropping sequences	Conventional till	Minimum-till	No-till
Crop-Fallow			
Fallow	Undercut (3-4 times)	Undercut (2 times), spray	Spray (2 times)
Crop	Disk at planting	Spray at planting	Spray at planting
SpWH-WWh-Sunflower			
Spring wheat after WWh	Undercut at harvest Disk at planting	Undercut at harvest Undercut at planting	Spray at harvest Spray at planting
Winter wheat after SpWh	Undercut at harvest Disk at planting	Undercut at harvest Undercut at planting	Spray at harvest Direct planting
Sunflower after WWh	No fall treatment Undercut in spring† Disk at planting	No fall treatment Undercut w/TR10‡ in spring† Undercut at planting	Fall spray (Surflan)‡ Spray at planting (Glycophos.)‡

†Undercut early spring about 4 weeks ahead of planting sunflowers.

‡Trade names of herbicides and farm equipment are given for the benefit of the reader and does not constitute endorsement or a recommendation of the product by USDA-ARS.

CHLORIDE RESEARCH UPDATE

Paul E. Fixen, Assistant Professor,
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ABSTRACT

Spring wheat experiments conducted at 24 sites in eastern South Dakota over a 4-year period resulted in grain yield increases at 10 sites and documented foliar disease suppression at 5 sites. Yield response to KCl was, in all but one case, due likely to the Cl in the KCl. Yield responses were influenced by soil Cl level, applied N level, and variety. Broadcast and drill applied KCl were equally effective.

GREAT PLAINS RESEARCH

In the last three or four years, research activity on chloride has increased in several states due in part to the positive responses to Cl reported on winter wheat in the Northwest. The following is a brief summary of current studies compiled from responses obtained from letters sent recently by the author to the Plains States.

Iowa (Killorn et al.) Soybeans - Yield decrease from Cl addition.

Kansas (Claassen et al., Hooker) W. Wheat - Nonsignificant response to Cl at 3 sites, 1984-1985; (Granade et al.) Soybeans - Nonsignificant response to Cl (declining trend).

Montana (Engel) Take-all infected spring wheat - Yield increase due to NaCl if anhydrous ammonia was N source, not with sodium nitrate as N source.

North Dakota (Goos et al.) 1982-1985 Spring Wheat (4 sites) - No yield increases, 2 sites showing trend for common root rot suppression.
Barley (10 sites) - Yield increase at 2 sites, common root rot suppression at 7 sites.
Winter Wheat (6 sites) - No yield increases, Tanspot decrease at 2 sites.
Durum (4 sites) - No yield increases, common root rot suppression at 1 site.

Contact individual researchers for details on these studies. The remainder of this paper deals with ongoing studies in South Dakota.

OBJECTIVES

Experiments on Cl have been conducted in South Dakota since 1982 with the following objectives:

1. Determine the frequency of Cl response by spring wheat.
2. Determine the influence of Cl additions on root and foliar disease incidence and plant water relationships.
3. Compare the effectiveness of broadcast and seed placed KCl.
4. Determine the influence of soil Cl level, N level and cultivar on wheat response to added Cl.

METHODS

Experiments on hard red spring wheat have been conducted at 24 locations in Eastern South Dakota since 1982. Soils at experimental sites have been medium textured Borolls and Ustolls ranging from 6.2 to 7.4 in pH. All sites tested very high or high in ammonium acetate extractable K. Nearly all experiments had 6 replications in randomized complete block designs. The Cl source was KCl (0-0-60) in all cases except where $CaCl_2$ and KNO_3 were used to separate K and Cl responses. The variety used was Butte except where variety was a factor in the experiment. Plant parameters measured included grain yield, plant Cl concentration at heading, root and foliar disease ratings and plant water potential components at selected sites. Routine soil analysis plus water extractable Cl was determined in one foot increments to a depth of 4 feet.

RESULTS AND DISCUSSION

Frequent responses have occurred to KCl addition in these experiments. Grain yield increases have occurred at 42% of the sites tested while foliar disease suppression was detected at 21% of the sites (Table 1). Comparison of KCl, KNO_3 and $CaCl_2$ was made at 7 locations of which 5 responded to K or Cl. In all but one case, KCl response was due to Cl not K (Table 2). At one site that tested 280 lbs/A of NH_4OAc extractable K, a response to both K and Cl was measured.

Plant K concentration has generally been unaffected by KCl addition while Cl concentrations have been doubled (Table 3). This is evidence that responses at sites where no $CaCl_2$ treatment was included were also due to Cl.

Factorial experiments of broadcast KCl rates and 0 or 33 lbs KCl/A applied with the drill in seed contact have been conducted at 6 sites where yield responses were measured. Four of the sites are summarized in Fig. 1. No "starter" benefit was measured at any site and the effectiveness of broadcast-incorporated KCl and seed placed KCl was similar. However, the KCl rate required for maximum yield frequently exceeded the rate that could be safely applied with the seed.

Soil Cl contents to 2 feet and plant Cl concentrations were highly correlated in these studies (1982-1984, 85 analysis not completed at this writing). Approximately 3/4 of the variability in plant Cl was explained by soil Cl content (Fig. 2). Yield increases were measured when whole plant Cl concentration at heading of check plots dropped below 0.15% (Fig. 3).

The responsiveness of 4 varieties was compared at 4 locations in 1984-1985. Yield response occurred at 3 sites (Table 4). The varieties varied considerably in responsiveness with Marshall responding at all 3 sites, Butte and Oslo at 2 sites and Guard showing no KCl response. Marshall had the lowest average yield without KCl but the highest yield with KCl (Table 5).

An N x KCl interaction study conducted in 1985 revealed a significant effect of applied N on KCl response. Response to KCl was 9.6, 6.6 and 2.5 bu/A at N rates of 0, 120 and 240 lbs N/A respectively (Soil NO_3-N = 53 lbs/A-2').

The yield increases measured at responsive sites have been very economical (Table 6). The average return per $ invested on KCl was $3.71.

Table 1. Frequency of spring wheat response at Cl sites, in South Dakota. 1982-1985.

Year	Number of Sites: Total	Yield Increase	Disease Suppression	Yield Incr. or dis. sup.
1982	3	2	0	2
1983	3	2	0	2
1984	8	2	1	2
1985	10	4	4	5
Total	24	10	5	11
Percent	100	42	21	46

Table 2. Spring wheat yield response to KCl and $CaCl_2$ in Eastern South Dakota at responsive sites, 1983-1985.

Treatment[1/]	Site: 83A	83L	84N	84S	85S	Average
	bu/A					
Check	29	34	73	45	65	49
KCl	36	39	80	51	69	55
$CaCl_2$	36	39	78	51	68	54

1/ 167 lbs KCl/A in 1983 and 120 lbs KCl/A in 1984-1985; $CaCl_2$ at equivalent Cl rate.

Fixen et al., 1986a.

Table 3. Influence of KCl fertilization on wheat plant K and Cl concentrations.

Treatment	Plant Concentration[1/]: K	Cl
	%	
Check	3.2	0.35
+ KCl[2/]	3.2	0.74
Change	0.0	0.39

1/ Whole plant at heading: average of 13 sites, 1982-1984.

2/ Varying rates of KCl.

Fixen et al., 1986a.

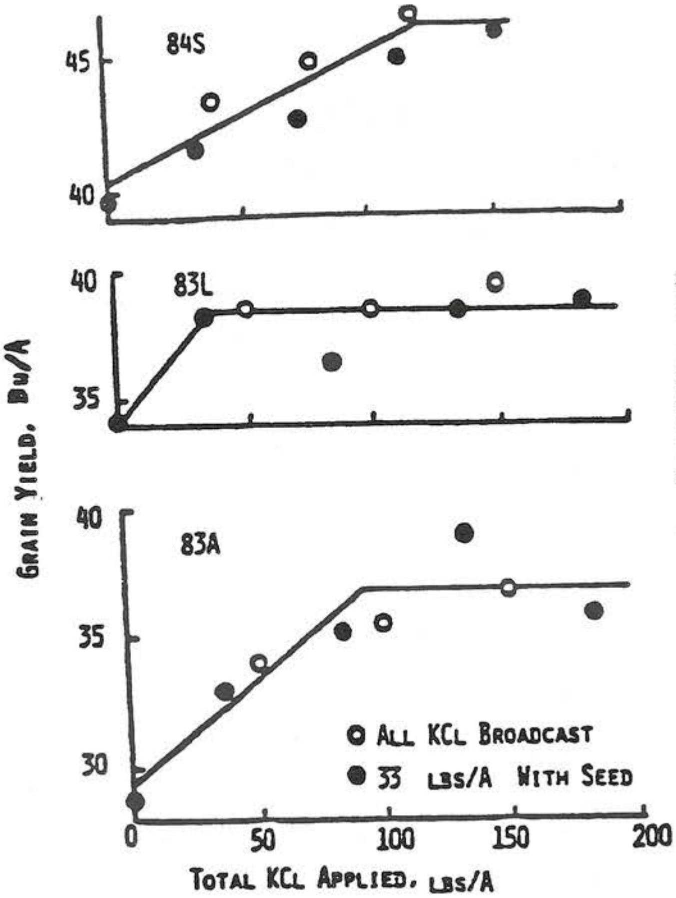
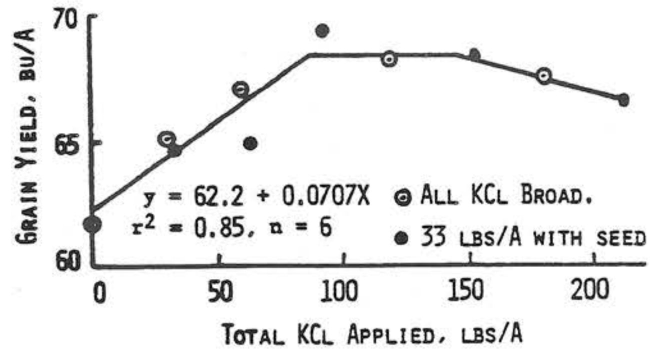


Fig. 1. Wheat grain yield response to KCl rate and placement, 1983-1984. (Fixen et al. 1986a).



Grain yield response to seed placed and broadcast KCl, 85S.

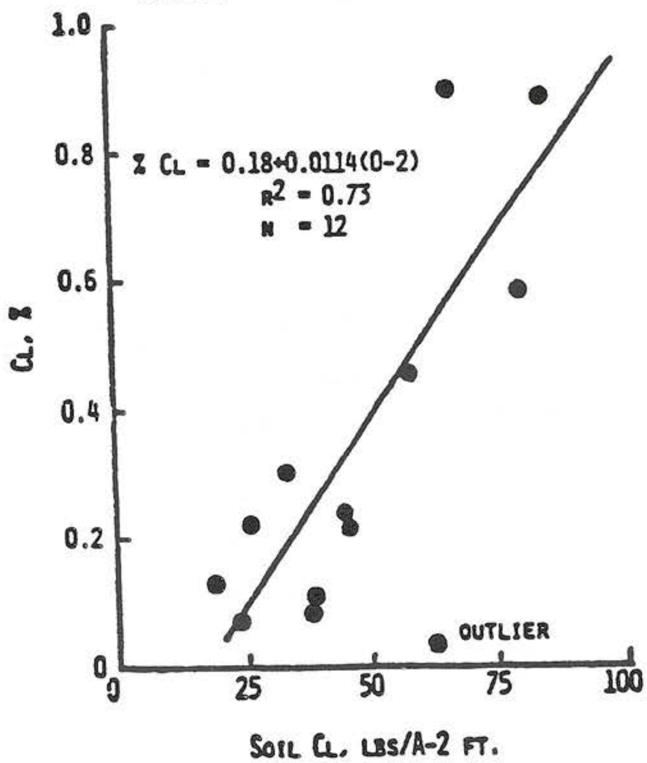


Fig. 2. Influence of soil chloride to a 2 foot depth on plant chloride concentration, 1982-1984. (Fixen et al. 1986b).

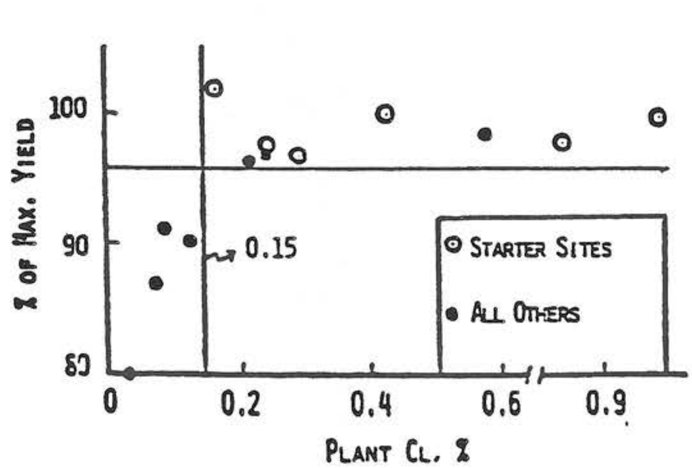


Fig. 3. Cate-Nelson analysis of plant Cl concentrations.

Table 4. Influence of spring wheat variety on yield response to KCl fertilization in South Dakota.

Variety	Site 84N	Site 84S	Site 85S	Average Response
	bu/A1/			
Marshall	4.2	7.7	9.2	7.0
Butte	0.0	5.3	6.1	3.8
Oslo	3.0	4.9	1.0	3.0
Guard	0.4	-0.9	-0.3	-0.3

1/ Difference between 120 lbs KCl/A and 0 lbs/A.
Fixen et al.

Table 5. Average grain yield of four spring wheat varieties, with and without KCl.

Variety	KCl, lbs/A 0	KCl, lbs/A 120	Response
	bu/A		
Marshall	58.3	65.3	7.0
Butte	60.5	64.3	3.8
Oslo	60.0	63.0	3.0
Guard	60.3	60.0	-0.3

Average of 3 site-years in Eastern South Dakota, 1984-1985.
Fixen et al.

Table 6. Rate of KCl required at responsive sites for maximum spring wheat yield in Eastern South Dakota, 1982-1985.

Site	KCl Response1/	Rate Required	Return per $ invested2/
	bu/A	lbs/A	$
82H	5	86	2.91
82A	5	84	2.98
83A	7	92	3.80
83L	4	33	6.06
84S	6	121	2.48
85S	6	88	3.41
85B	5	77	3.25
85D	5	135	1.85
85W	4	30	6.67
Avg.	5	83	3.71

1/ Variety = Butte. 2/ Calc. at $3.50/bu wheat and $0.07/lb KCl.
Fixen et al., 1986a and unpublished data.

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ONGOING SOIL FERTILITY RESEARCH IN SOUTH DAKOTA

1. Nitrogen management as influenced by tillage systems in Eastern South Dakota (3 sites).
   Objectives: 1) Determine the influence of tillage on the N fertilizer requirements of corn, wheat, and oats under South Dakota growing conditions. 2) Compare topdressed N to knifed N for common tillage systems. 3) Gather calibration data for the NO_3 soil test.

2. Influence of water stress and tillage on nutrient uptake by corn (line source - 1 site, 3 other field sites, greenhouse).
   Objectives: 1) Determine the influence of moisture stress on the nitrogen level in the soil and in plant tissue required for maximum yield. 2) Determine the influence of moisture stress and tillage on tissue concentrations of the essential elements and resulting DRIS indices.

3. Management of urea fertilizers for reduced-till winter wheat (3 sites).
   Objectives: 1) Compare conventional granular urea, coarse granular urea, broadcast UAN, and dribbled UAN. 2) Determine the influence of timing on nitrogen use efficiency for the materials being tested.

4. Phosphorus management as influenced by tillage systems in eastern South Dakota (3 sites).
   Objectives: 1) Determine the influence of tillage systems on the optimum soil test P level for corn and oats. 2) Determine the optimum P fertilizer placement for common tillage systems as influenced by soil test P level. 3) Determine the influence of tillage systems on the chemistry and availability of P fertilizer residues.

5. Residual effects of fertilizer phosphorus on an Eagan silty clay laom (1 site).
   Objectives: 1) Determine the effects of residual fertilizer phosphorus on crop yields. 2) Monitor changes in soil test P as phosphorus is removed by crop growth.

6. Zinc requirements of corn and flax in eastern South Dakota (1 site).
   Objectives: 1) Determine the soil Zn requirements of corn and flax as influenced by P placement. 2) Determine the influence of $ZnSO_4$ additions on DTPA extractable Zn in the persistence of such treatments. 3) Compare the Zn requirements of common flax varieties.

7. Soil Testing Lab. Recommendation Comparisons (2 sites).
   Objective: Compare soil test recommendations from several laboratories and evaluate their effect on crop yields and profitability.

8. Nitrogen mineralization Studies (20 sites).
Objective: Determine if several soil nitrogen availability indices are related to nitrogen uptake by small grain.

INCREASING P EFFICIENCY-RESIDUAL P

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ABSTRACT

Two cropping systems were studied to determine the effect of different methods of phosphorus (P) fertilizer application on residual P value. In eastern Nebraska on a Pawnee clay loam, grain sorghum yields were significantly higher following P fertilizer that was knifed (dual placed) compared to where fertilizer was either seed applied or broadcast on a previous wheat crop. The knife method of application resulted in a residual value of between 30 and 50% of a new application depending on rate of application. The increased residual value of the knife method of application was probably the result of placement below the tillage depth where limited soil-fertilizer mixing occurred. However, in a wheat-fallow experiment in western Nebraska on a Keith silt loam, method of P application did not affect the residual value of previous fertilizer P applications on wheat even though rate of application did significantly increase wheat yields in the wheat crop following fallow. The increased time from application in the first crop through fallow to the next wheat crop was apparently too long. Knifed bands apparently reached an equilibrium with the surrounding soil and lost the advantage observed from knifed P in the wheat-sorghum system.

OBJECTIVES

The objective of this study was to compare the residual phosphorus (P) effectiveness of different methods of P application in two different cropping systems.

METHODS

Two cropping systems were studied to evaluate how methods of P application affect residual or carryover P. The systems were a wheat-sorghum system and a wheat-fallow system. In the wheat-sorghum system, four levels of P (11, 22, 34 kg P/ha with check) were applied with the wheat seed, broadcast, and knifed as a dual application in 1982. Wheat was harvested and yields determined in 1983. In the spring of 1984, sorghum was planted in the 2.4 m x 9 m plots and P was applied in the row at planting and knifed in prior to planting on plots that received no P in the previous wheat crop. P was applied at rates of 11, 22, 34 kg P/ha. All broadcast P was incorporated by disking and field cultivating prior to planting. Both wheat and sorghum was harvested on an area of 1.86 m^2. Study was located on a Pawnee clay loam in Saunders County Nebraska. Soil had a Bray and Kurtz No. 1 (B&K) P soil test of 4 mg/kg.

The wheat-fallow study was located in Perkins County Nebraska on a Keith silt loam with a B&K soil test of 8 mg/kg. This wheat study was established in 1982. Treatments included broadcast (spring and fall) seed, and knifed (spring and fall) applications of P with three rates of application (11, 22, 34 kg P/ha with check). The plot area was fallowed in 1983-84 and seeded to wheat in the fall of 1984 to determine residual P value of different methods of P application.

RESULTS AND DISCUSSION

It has been known for some time that P fertilizer effectiveness can be increased substantially by banding methods of application. In Nebraska, research has shown that applying P with the seed of wheat is up to four times more effective than broadcasting and that this ratio of effectiveness is related to the amount of available P in the soil. Dual placement or knifed P has been found to be equally as effective as seed application. Since farmers generally prefer not to apply fertilizer P at planting time, knifed P has been increasing in popularity. Since knifed P bands are not disturbed by normal tillage one might expect their residual value to be greater than broadcast P or shallow applied bands that are mixed with the soil by tillage.

Wheat-Sorghum Experiment

Wheat grain yields in 1983 were significantly increased by applied P in Saunders County by nearly 2 Mg/ha. The knife and seed methods of application resulted in equal grain yields while both methods produced significantly higher yields than obtained by broadcasting P. Broadcasting P on this low P soil was not effective. Only at the highest rate of 34 kg P/ha were yields increased above check yields. The result was that P fertilizer uptake efficiencies were very low averaging only 5% (across rates) when broadcast compared to an average of 33% for seed application and 29% for the knife application.

Although wheat fertilizer P uptake was high for the knife and seed methods of application, grain sorghum (planted in the spring of 1984) yields were significantly increased from the residual only when P was knifed applied (Figure 1). There was no residual effect of the 1982 P treatments for either the seed or broadcast treatments. While not significant, seed application at the low rate seemed to have a negative residual effect. At the 11 kg/ha application rate, wheat removed 46% of the applied fertilizer P when seed applied. This may account for the trend for decreased grain yield at the 11 kg/ha seed rate since this treatment yielded 1.2 Mg/ha more wheat than the check.

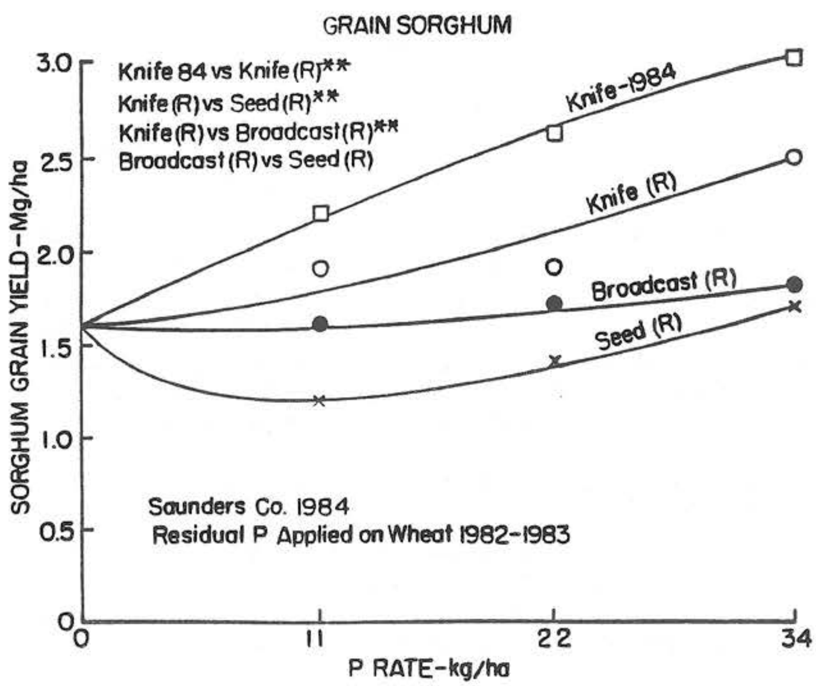

Figure 1. Effect of different methods of P application on residual P as determined by grain sorghum following fertilized wheat. Saunders County, NE. 1984.

The residual P effect from the knife treatment was equivalent to about 15 to 17 kg P/ha when applied at the 34 kg P/ha rate (Figure 1). This resulted in a total fertilizer efficiency for both the wheat and sorghum crops of 33% or a 4% increase due to residual. Total fertilizer P efficiency was not increased by growing sorghum where P was seed or broadcast applied since there was no residual effect with these methods of application.

While wheat fertilizer efficiencies averaged about 30% in 1983 with either seed or knife applications, grain sorghum averaged only about 10% when row or knife applied in 1984. While wheat was much superior to sorghum in terms of P fertilizer uptake, sorghum produced 2.5 times more grain for each kg of P uptake.

While no soil samples were taken, it is believed that the knife method of P application resulted in more residual P because the band application was placed below the tillage depth. The seed bands and broadcast methods of application resulted in complete mixing with the soil and loss of P availability.

Wheat-Fallow-Wheat Experiment

Wheat grain yields in 1983 were significantly affected by methods of application. Seed and knife methods of application significantly increased grain yield compared to broadcast. Wheat was again planted in 1984 to test the residual P affect of previous treatments. While wheat grain yields were significantly increased in 1985 as the original P application rates increased, method of P application did not affect the residual value of applied P. While no significant effect of method of application was found, contrast comparisons showed that the knife (spring) application had greater residual value at the high rate of application (34 kg P/ha). This indicates that time was probably a critical factor in why knifed P did not affect residual value. It is not likely that tillage during fallow was deep enough to disturb the knifed P bands which were applied at a depth of 15 cm.

NEBRASKA SOIL FERTILITY PROJECTS

Chemical Aspects of Phosphorus Movement and Availability to Plants in Sandy Soils - R. C. Sorensen.

Studies concerning the factors which affect the extent of movement of phosphorus containing constituents in sandy soils, including soil particle size, soil pH, associated chemical components and organic matter content.

Potassium Chemistry of Micaceous and Feldspathic Soils in Nebraska - Dennis L. McCallister.

To identify the chemical and mineralogical fractions in a group of Nebraska soils which control their potassium supplying capability.

Increasing Fertilizer Nitrogen Use Efficiency in West Central Nebraska - G. W. Hergert.

Build a data base on nitrogen mineralization and evaluate residual nitrates to improve current nitrogen recommendations and to determine the extent of temporal and spatial variation of nitrate in farmers fields.

Fertilizer Utilization Efficiency in Central Nebraska - Richard Ferguson.

Project includes nitrogen efficiency and loss mechanisms such as ammonia volat lization, nitrate leaching, immobilization and denitfification in conventional and conservation tillage systems.

Increasing the efficiency of P fertilization - D. H. Sander

This project includes various field and greenhouse studies designed to increase the efficiency of P fertilizers by studying the effect of method of application, timing of application, soil test correlation and calibration, source effectiveness, and variety and hybrid interactions.

Soil nutrient cycling as influenced by crop rotation and residue management - Daniel Walters, R. A. Olson, C. Shapiro.

To evaluate the influence of residue type, quality and placement on nutrient cycling in both monoculture, and rotated cropping systems. Emphasis is placed on N and P cycling.

Cultural and Nutrient Investigations for Crops in Western Nebraska - Frank Anderson.

Project involves the determination of N, P, K and micronutrient needs of western Nebraska crops on both dryland and irrigated soils.

Improving Fertilizer Efficiency in Northeast Nebraska - Charles Shapiro.

Studies involve various aspects of increasing fertilizer efficiency such as the value of starter fertilizers, methods of nitrogen and phosphorus application in both conventional and conservation tillage systems, and an evaluation of both nitrogen and phosphorus sources.

Evaluating the Cause of and Correcting Chlorosis - E. J. Penas and R. A. Wiese.

Investigations primarily involve the factors affecting chlorosis in soybeans as affected by varieties, soil characteristics and different material and application methods for correcting chlorosis.

Evaluating Plant Nutrient Needs and Product Quality - Delno Knudsen.

Objectives include providing chemical, physical and biological analyses of soil, plant and water samples for various ARD projects; improve soil testing correlations and calibrations for Nebraska conditions; adapt analytical techniques, procedures and instrumentation as appropriate.

RATE LIMITING PROCESSES OF PHYTOAVAILABILITY OF POTASSIUM ON MONTANA SOILS

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Montana State University

ABSTRACT

Throughout Montana crops have frequently responded to K fertilizers on soils testing "high" in NH_4OAc-extractable K^+. It is hypothesized that this response is a true plant nutrient response, and that K^+ diffusion is the major rate-limiting process for K^+ availability in these soils. Analyses of soil solution extracts obtained by immiscible liquid displacement, in conjunction with previously reported crop and water use data, are used to estimate amounts of K which could be derived from alternative processes (primarily mass flow). Results further support the hypothesis that most K^+ must reach the plant root via diffusion. Fertilizing with K increases soil solution concentrations of K^+ so that increasing proportions of the crop requirement can be met through mass flow, thus decreasing the demands on diffusion.

OBJECTIVES

A decade of field research with K fertilizers on major crops of Montana has shown a high frequency of crop yield response even though most of the soils are high in soil test extractable K^+ (Skogley, 1976; Skogley and Haby, 1981). We hypothesize that this response is primarily a true response to K as a yield-limiting nutrient, and that K^+ diffusion is the rate-limiting process under our cropping conditions. In this presentation I will review literature and reasoning which led us to this hypothesis, and present more data to support it.

RESULTS AND DISCUSSION

Chloride Involvement - First, I want to dispel the suggestion that what we are measuring is primarily a response to Cl in the fertilizer. Many of our field experiments were conducted with both KCl and K_2SO_4 as comparative sources of K. Although this was done mainly to determine the need for supplemental S, the data can also serve to indicate whether or not crop responses to Cl may have occurred. Table 1 presents a summary of results from 17 experiments where a yield increase from K fertilizers was measured, and where both sources of K were included.

Table 1. Comparison of small grain yield response to KCl and K_2SO_4 fertilizers in Montana field experiments, 1972-1983.

- Number of Experiments -					
Where KCl and K_2SO_4 were compared, and a grain yield response occurred*		Where K_2SO_4 response was ≥KCl response	Where KCl response was >K_2SO_4 response	Where K_2SO_4 response was >KCl response	Where response to both occurred and additional response to one @ higher rate
Winter wheat	= 12	10	2	1	2**
Spring wheat	= 1	1	0	0	0
Barley	= 4	3	1	1	0
Totals	17	14	3	2	2

* All yield responses were significant above the 90% confidence limit.
** One additional response to KCl; one to K_2SO_4.

In a few instances there was apparently a yield response to KCl which did not occur with K_2SO_4, but in over 80% of the experiments, yield response occurred to both sources of K fertilizer.

Another reason we feel that Cl is not the primary factor is that its benefits have generally been implicated in various disease severity relationships (Christensen, et al., 1982). Levels of disease in most of our field plots have been insignificant. Most of these were on dryland sites. At a few irrigated sites where diseases (mainly "take-all" complexes) were present, disease severity ratings indicated a trend toward greater severity when K_2SO_4 was applied, as compared to KCl, but the lowest level of disease was always recorded when no fertilizers at all were applied. We also found no relationship between the severity of disease and crop yield.

Rate-Limiting Processes for K^+ - A number of processes have been identified which can influence the amount of K^+ which will reach the plant root surface where it is "available" for absorption. Plant "uptake" mechanisms or metabolic processes could also limit the quantity of K absorbed. However, studies by Barber (1985) suggest that ion uptake mechanisms probably do not normally become rate-limiting for plant K nutrition. Plant root factors of major importance are rate of growth and proliferation. As the root grows and proliferates, it presents an increasing demand for K, and an increasing ability to respond to this demand.

Root Proliferation - Careful measurements by a number of researchers indicate that the roots of annual crops occupy something less than 1% of the total soil volume in which they are growing (see for example Barber, et al., 1962). The amount of K^+ coming in contact with the plant root via this process is consequently a small proportion of the plant's demand.

Mass Flow - When plant roots absorb water and lose it through transpiration, they set up a convective flow of soil solution toward the root. Any dissolved K^+ in the soil solution will be carried to the plant root in this manner. If the concentration of K^+ in the soil solution is high enough, this process can account for moving the plant's K requirement to the root.

Barber (1985) presents results from saturation extracts of numerous soils and calculates the contribution from mass flow. Over a range of 200 to 600 kg of water per kg of dry plant tissue, and assuming a K requirement of 4%, his results suggest that as little as 2 to 5% of the total plant K demand may be met in this fashion. On a few soils with unusually high soluble K^+, most of the demand could be met.

To develop an estimate of the contribution of mass flow in soils of our region, I will compare results of field measurements of water use by winter wheat grown near Bozeman, and soil solution concentrations on extracts obtained through immiscible liquid displacement (ILD) (Mubarek and Olsen, 1976). The ILD data should more accurately represent the soil solution concentrations than do saturation extracts because the ILD extracts are taken at soil moisture conditions of 1/3 and 1 bar tension.

Results of the experiment conducted near Bozeman indicate a crop yield of 3300 kg ha^{-1} (50 bu A^{-1}) on an Amsterdam silt loam soil which was adequately fertilized with N and P (Brown, 1971). The soil had a nearly full profile of stored soil water at seeding, and the growing season was described as "good." Total water use (evapotranspiration) was 28 cm (11 inches), and some water was removed from the profile to a depth of 183 cm (6 ft). This converts to 2.8×10^6 kg of water ha^{-1}. The total dry weight of the crop would be 3300 kg ha^{-1} (grain), plus the straw, plus the root mass. McNeal, et al. (1971) report a harvest index (grain/grain + straw) of about 40% for small grains in this area, so the total weight of grain plus straw in Brown's experiment would be approximately 8250 kg ha^{-1}. Measurements of root mass of small grains have not been made in these studies, but reports summarized by Troughton (1962) provide a mean weight for winter wheat roots of 2600 kg ha^{-1}. Using this value, the total plant dry weight for this experiment would be approximately 10,850 kg ha^{-1}.

Determining the K demand for a crop is not readily accomplished, because the actual K requirement may greatly exceed the values obtained for K removal. Peak demands for K occur before crop heading (Gasser and Thorburn, 1972), and only 50 to 60% of the plants' maximum K accumulation may remain at maturity (Gregory, et al., 1979). Considering these facts, it may be reasonable to assume that a certain K^+ concentration of plant tissue must be maintained, at least during some stage of development, for all final plant dry matter produced. Based on data summarized by Beaton and Sekhon (1985), an estimate of 4% K^+ for healthy, vigorous, non-stressed plants may be reasonable. Based on this estimate, the total K "demand" for the crop in Brown's experiment would be approximately 430 kg ha^{-1}.

Results of soil solution analysis of K^+ in ILD extracts for samples of soil which had received 0, 100, or 400 kg K ha^{-1} are presented in Table 2. Data for NH_4OAc-extractable K^+ are included. The soil was the same as that on which Brown conducted his experiment (Amsterdam silt loam), but only the surface 15 cm sample was used. Samples were incubated at the indicated moisture and temperature conditions for periods up to 14 days, and results are averaged over 36 observations each.

Table 2. Soil solution concentration of K^+ in ILD extracts and NH_4OAc-extractable K as influenced by K additions, temperature, and soil moisture on 0-15 cm layer of Amsterdam silt loam. Bozeman, MT. 1985.

Added K kg ha^{-1}	K^+, m mole L^{-1} (ppm)			
	5°C		20°C	
	1 Bar	1/3 Bar	1 Bar	1/3 Bar
0	1.25 (48.7)	1.01 (39.4)	1.54 (60.2)	1.24 (48.3)
100	1.85 (72.2)	1.57 (61.5)	2.15 (83.9)	1.83 (71.7)
400	4.87 (190.1)	4.16 (162.7)	5.62 (219.6)	4.51 (176.6)
	NH_4OAc-Extractable K^+, c mol kg^{-1}			
0	1.22	1.23	1.31	1.34
100	1.50	1.51	1.51	1.55
400	2.01	2.08	2.08	2.04

Using these soil solution concentrations for K^+, the total amount of K^+ which would be present in (and presumably moved to the plant root by) the water used during the growing season would be 135 to 169 kg K^+ ha^{-1} at 0 added K fertilizer. This is approximately 30 to 40% of the total plant demand as derived earlier. When K was added at a rate of 100 kg ha^{-1}, the concentration of K^+ in the soil solution increased to where maximum K^+ derived from mass flow would be 172 to 235 kg ha^{-1}, or 40 to 55% of the total crop demand. At the highest rate of K addition (400 kg ha^{-1}), more than enough K was present in the soil solution so that the entire plant K demand could be accounted for by mass flow. Colder soil temperatures would reduce mass flow contributions and drier soil conditions might increase it, based on ILD extract concentrations. However, mass flow is undoubtedly reduced as soil moisture tensions exceed 1 bar and as water viscosity effects at near 0°C are considered.

Several errors may be inherent in this approach, but they are probably at least partially counter-balancing. Perhaps the total plant K demand is inflated, but then so is the amount of mass flow. Total water use includes that water lost from the soil surface through evaporation, and this water would not deliver K^+ to the plant root. Also, surface soils in this region normally have at least twice as much extractable K^+ as do samples from the 15 to 30 cm soil depth. Lower soil depths are even less well supplied. The water use data indicated that plant roots were extracting water from as deep as 183 cm (6 ft) soil depth. Considering these facts, the estimates of the contribution of mass flow to the crop K demand are probably at least good "ball-park" estimates.

Data for NH_4OA-extractable K^+ (Table 2) indicate the fact that we are dealing with a soil which would normally be considered very high (about 475 ppm K^+) by soil test standards. In other field experiments on the same soil type, and very near the one reported by Brown, we have recorded crop responses to applied K fertilizers during some years, and on soils testing at least this high in extractable K^+.

Diffusion - These results further support the suggestion by Barber and others that much of the K requirement of crops must reach the plant root through diffusion. We have previously reported on rates of K^+ diffusion in many soils of our region, and on soil, weather, and site characteristics which influence diffusion (Schaff and Skogley, 1982; Skogley and Schaff, 1985). Results help explain why responses to K fertilizer in the field are highly season-dependent, because the rate of K diffusion in a given soil is highly influenced by temperature and moisture conditions. It is obvious also that the contribution of mass flow toward meeting plant demands for K are influenced by these same factors (and in the same direction).

The rate of K^+ desorption from non-K fixing clays (such as those predominating in Montana soils) is quite rapid (measured in minutes), and is not likely to be a rate-limiting process (Sparks and Huang, 1985). Current studies also indicate that these soils are highly buffered, and that as K^+ is depleted from the soil solution by plant uptake, replacement from exchangeable K^+ is quite rapid and efficient.

SUMMARY

Theoretical and experimental evidence abounds to explain why the contemporary soil tests for K do not perform well for the purpose of predicting crop response to K fertilizers under many soil and climatic conditions. It is not necessary to invoke indirect effects (such as those of Cl^-) to understand and/or explain this apparent anomoly.

Underestimation of the true magnitude of crop demands for K, which differs greatly from that amount of K actually removed by a mature crop, is perhaps part of the problem. Relative contributions of mass flow and diffusion of K^+ to the roots of crops can vary tremendously, both when dealing with widely different soils, but also as conditions change within one soil. In a typical, normally high-K soil of our area, calculations indicate that more K^+ must be moved through diffusion than that which will move to the plant root by mass flow.

Fertilization with K helps overcome the (sometime) inability of these soils to supply adequate available K in two ways. First, soil solution concentrations of K^+ are increased by fertilization. Increased soil solution K^+ means that proportionately greater percentages of the K^+ demand can be accounted for through the mass flow mechanism, thus reducing the relative demand for K^+ diffusion. At the same time, K^+ diffusion is driven by the concentration gradients between the bulk soil solution and that adjacent to the plant root surface (which is presumably near zero). Thus, the rate of K^+ diffusion is simultaneously increased. Second, the amount of K^+ adsorbed on the soil exchange complex is increased. This increases the soil K buffer capacity and allows it to maintain higher levels of supply over more extended periods of the growing season.

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ECONOMICS OF A ONE-TIME PHOSPHORUS FERTILIZER APPLICATION[1]

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ABSTRACT

Grain yield and protein data from a soil fertility study initiated in 1967 and continued through 1983, on a Williams loam with a $NaHCO_3$ soil test P level of 6 ppm, was evaluated to determine the potential economic benefits of a one-time P fertilizer application under conditions of varying fertilizer N levels. Fertilizer N (0, 40, and 80 lb N/acre) was applied each crop year, except two, as main plots. Fertilizer P (0, 20, 40, 80, and 160 lb P/acre) was applied one time, at study initiation, as subplots in a split-plot design. Fertilization and interest costs, tax credit, and crop price were used to estimate the net dollar return from N and P fertilization. The most economical treatment was the one-time application of 80 lb P/acre plus 40 lb N/acre each crop year. This treatment returned a net of $18/acre per crop above that of the check plot when averaged over 11 crops and was profitable starting with the second crop. Generally, net returns increased as the level of initial P fertilizer application increased at all N rates. Premium payments for grain protein in hard red spring wheat in the northern Great Plains can potentially pay for 50 to 75% of the fertilizer N added.

OBJECTIVES

Wheat yields in the northern Great Plains are generally increased by P fertilization on soils testing "very low" and "low" in plant-available P, as has been demonstrated by numerous studies. Few of these studies have considered the economic benefits resulting from the positive effects of residual P fertilizer on crop yields. The current emphasis on the need for higher fertilizer rates to optimize grain yields necessitates that the short- and long-term economic impact of these fertilizer applications be evaluated. Recently, Halvorson and Black (1985a and 1985b) completed a long-term (17 years) residual P fertilizer study. Halvorson et al. (1986) also completed an economic analysis of this same P study. The objective of this paper is to present a brief summary of the yield and protein data and economic analysis presented in the above referenced studies.

MATERIALS AND METHODS

Grain yield and protein data were collected from 1967 to 1983 from 11 crops of a N and P fertilizer study conducted on a glacial till Williams loam

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near Culbertson, MT. After the 6th crop in a crop-fallow sequence, the plots were annually cropped through 1983. Although safflower and barley were grown during the annual cropping phase of the study, they had yields in terms of pounds/acre equivalent to wheat. Therefore, to keep the analysis in wheat equivalents, the yields of safflower and barley were calculated based on 60 lb/bu grain test weight. However, only the protein data from the 8 wheat crops are included in this analysis.

Ammonium nitrate (0, 40, and 80 lb N/acre) was applied broadcast each crop year as main plots in a split-plot design, except to the 7th and 8th crops which were safflower and barley, respectively. By the end of the 6th crop-fallow cycle, residual NO_3-N had accumulated in the root zone of the 40 and 80 lb N/acre fertilizer treatments (Halvorson and Black, 1985c), and therefore, no additional N was applied to the 7th and 8th crops. Fertilizer P was applied only once, at initiation of each plot series in 1967 or 1968. The fertilizer P (0, 20, 40, 80, and 160 lb P/acre) was broadcast and incorporated with a disk to a depth of about 3 inches. All other tillage operations during the study were performed to a depth of 2 to 3 inches. This analysis represents the average results from these duplicate sets of plots.

The economic factors considered in this analysis included crop and fertilizer price, fertilizer application costs, protein premiums, federal income taxes, and real interest rates. A grain price of $3.30 was used because this is the average U.S. loan price for hard red spring wheat. A fertilizer cost of $0.47/lb P and $0.23/lb N with a broadcast application cost of $2.44/acre was used for the first year. All subsequent N fertilizer applications were assumed to be anhydrous ammonia ($0.16/lb N) with an application cost of $4.20/acre. A 6.25% real interest or discount rate was used, which is a 10.25% nominal interest rate minus a 4.00% inflation rate. A tax advantage was calculated assuming a 50% tax bracket for the 1st crop year and a zero percent tax bracket for crop-years 2 through 11. Protein premiums were calculated assuming a zero premium at 12% protein and a $0.46/bu premium at 17% protein with a linear relationship between this protein range, based on a 16-year average of protein premiums paid in North Dakota.

RESULTS

The average cumulative grain yield increase over that of the no fertilizer treatment for the 11 crops, used as the data base in this economic analysis, is shown in Table 1. The treatment with the greatest cumulative yield above that of the check was the single application of 160 lb P/acre plus the addition of 80 lb N/acre each crop year, except as noted. Following the 6th crop, the cumulative yields for the zero N plots showed little change and tended to decrease slightly during the annual cropping phase of this study.

Table 1. Wheat grain yield of the check treatment each crop year and cumulative yield above check with each additional crop year for the various N and P treatments.

Treatment		Crop year										
N	P	1	2	3	4	5	6	7	8	9	10	11
lb/acre		Check yield, bu/acre										
0	0	31	18	35	23	32	20	17	32	24	18	15
		Cumulative yield above check, bu/acre										
0	0	0	0	0	0	0	0	0	0	0	0	0
0	20	6	7	8	9	14	16	17	16	17	16	14
0	40	7	12	16	18	25	27	31	30	30	29	28
0	80	8	13	19	22	32	38	42	40	41	39	38
0	160	10	18	27	31	41	48	52	51	53	49	50
40	0	-2	-1	1	1	6	4	10	7	12	23	28
40	20	7	14	15	15	23	23	33	34	40	52	56
40	40	12	20	26	30	44	50	59	59	65	78	86
40	80	12	24	36	45	65	79	88	91	98	112	119
40	160	13	27	39	48	70	87	96	100	110	125	133
80	0	-2	-0	1	0	8	7	17	17	21	33	42
80	20	7	11	15	15	26	28	38	38	43	55	61
80	40	10	18	28	31	46	53	63	65	70	84	93
80	80	11	25	38	45	64	77	86	86	93	109	118
80	160	12	27	42	50	69	89	100	103	114	132	142

The cumulative net returns above fertilizer costs, discounted at a rate of 6.25% but without any tax credits, are shown in Table 2. Without N fertilization, the 20 and 40 lb P/acre treatments were profitable in crop-yr 1, 80 lb P/acre in crop-yr 2, and 160 lb P/acre in crop-yr 3. The 40 lb N/acre treatment without fertilizer P was not profitable. With 40 lb N/acre each crop year, the 20 and 40 lb P/acre treatments were profitable in crop-yr 1, and the 80 and 160 lb P/acre treatments in crop-yrs 2 and 3, respectively. The 80 lb N/acre treatment without fertilizer P was not profitable. With 80 lb N/acre each crop year, the 40 and 80 lb P/acre treatments were profitable in crop-yr 2 and the 160 lb P/acre treatment in crop-yr 3. The 20 lb P/acre treatment did not become profitable until crop-yr 7 at the 80 lb/acre N rate. These data show that a good balance in both N and P is needed to achieve optimum economic returns. The one-time application of 80 lb P/acre plus 40 lb N/acre each crop year resulted in the highest average estimated net income, $18/acre per crop year above that of the check treatment.

On the assumption that a farmer had a high income situation in one year that extended him into the 50% tax bracket, we calculated an estimated net return with the tax savings. Without N fertilization, all P treatments were profitable the first year except 160 lb P/acre, which became profitable in crop-yr 2. The 40 and 80 lb N/acre treatments without P fertilization did not show a profit at any time. All treatments receiving fertilizer P showed a net profit in crop-yr 1 when 40 or 80 lb N/acre were added each crop year, except for the 160 lb P/acre plus 80 lb N/acre treatment which showed a profit in crop-yr 2. When considering the tax benefit, the 160 lb P/acre plus 40 lb N/acre treatment had the greatest long-term net profit above that of the check plot with an average net profit of $21/acre per crop year. Using this scenario, the tax savings could contribute greatly to the long-term net profits and make the economic returns to N and P fertilization even more profitable.

Table 2. Cumulative net dollar return above check plot for the various N and P treatments with each additional crop year with a 6.25% discount rate but without tax considerations.

Treatment N	Treatment P	Crop year 1	2	3	4	5	6	7	8	9	10	11
lb/acre		$/acre										
0	0	0	0	0	0	0	0	0	0	0	0	0
0	20	8	10	12	17	29	34	36	35	36	34	32
0	40	2	18	30	33	53	58	67	65	65	62	60
0	80	-14	1	20	27	53	68	76	73	75	71	69
0	160	-46	-20	7	17	42	60	69	67	71	65	66
40	0	-17	-23	-30	-39	-32	-45	-31	-37	-34	-17	-14
40	20	4	12	8	-0	12	3	27	29	37	54	54
40	40	8	25	33	34	63	69	88	90	98	116	124
40	80	-9	18	45	59	103	129	149	156	166	187	194
40	160	-43	-11	15	32	80	115	133	142	158	181	189
80	0	-28	-38	-49	-66	-60	-73	-51	-52	-51	-36	-30
80	20	- 9	-10	-16	-29	-14	-22	1	2	4	18	21
80	40	- 7	3	15	10	37	40	63	67	70	87	95
80	80	-23	4	27	34	68	89	108	109	117	137	144
80	160	-57	-25	3	10	47	83	107	115	131	155	164

The protein concentration in the grain generally decreased with increasing level of P fertilization for all N treatments. However, grain protein was increased significantly by N fertilization. The average (16 wheat crops) value of the protein per crop year above that of the check treatment is shown in Table 3. Without N fertilization, increasing the rate of P fertilization resulted in a greater net loss per acre because of the lower protein concentration in the grain than that of the check treatment. With N fertilization, the average value of protein per acre increased with increasing rate of P fertilization as a result of an increase in grain yield above that of the check. The 80 lb P/acre plus 80 lb N/acre treatment had the greatest estimated average return per wheat crop ($7.43/acre) due to protein premium. This increase in grain value due to N fertilization can potentially pay for 50 to 75% of the N applied.

Table 3. Average value of the grain protein above that of the check plot per wheat crop for the various N and P treatments.

N Rate	Fertilizer P Added, lb P/acre 0	20	40	80	160
lb/acre	$/acre				
0	0.00	-0.36	-0.27	-0.51	-1.38
40	3.51	4.06	4.24	4.67	4.96
80	4.70	5.29	6.48	7.43	7.43

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USDA-ARS SOIL FERTILITY RESEARCH AT AKRON, COLORADO

The purpose here is to briefly outline the soil fertility research projects being conducted by USDA-ARS and cooperators at the Central Great Plains Research Station at Akron, Colorado.

PROJECT TITLE: Effect of N and P fertilization on water-use efficiency by winter wheat, barley, and corn in the Central Great Plains.
Objective: Determine the effects of N and P fertilization on crop yield, quality, and water-use efficiency using reduced tillage under irrigated and dryland conditions.
Personnel: Ardell D. Halvorson and C. A. Reule.
Location: Central Great Plains Research Station, Akron, CO.

PROJECT TITLE: Effect of N source, placement, and rate on dryland winter wheat yields in a no-till system.
Objective: Determine the effectiveness of several N sources for use in no-till production systems and the best method of managing these N sources to obtain optimum economic returns.
Personnel: Ardell Halvorson, USDA-ARS, and Hunter Follett, CSU.
Location: Northeast of Platner, CO.

PROJECT TITLE: Management of N fertilizer for dryland winter wheat in reduced tillage systems.
Objective: Determine the N needs of crops grown in an annual cropping reduced-tillage system and the best placement method for N fertilizer in this system.
Personnel: Ardell Halvorson and C. A. Reule.
Location: Central Great Plains Research Station, Akron, CO.

PROJECT TITLE: Effect of time and rate of N fertilizer application on soil profile NO_3-N distribution and crop yield and quality.
Objective: Determine the best time to apply fertilizer N for optimum winter wheat production and quality. Nitrogen is applied at 4 rates in early November, mid-May, mid-July, and mid-September during the fallow period, and top dressed to the wheat in mid-March.
Personnel: Ardell Halvorson and C. A. Reule.
Location: Northwest of Otis, CO.

PROJECT TITLE: Management of P fertilizer for dryland winter wheat in reduced tillage systems.
Objective: Determine the most efficient method of P placement for optimum economic yields and the value of residual fertilizer P for future wheat production.
Personnel: Ardell Halvorson, USDA-ARS, Akron, CO and John Havlin, Kansas State University, Manhattan, KS.
Location: Peetz, CO, and Scottsbluff, NE.

PROJECT TITLE: Crop rotation and N fertilization for efficient water use.
Objective: Determine the potential of producing economical dryland corn or sorghum yields following winter wheat in a wheat-corn-fallow rotation using reduced tillage systems. The N fertilizer requirements for optimum crop production and efficient water use are being evaluated.
Personnel: Ardell Halvorson, USDA-ARS, and John Shanahan, CSU.
Location: Central Great Plains Research Station, Akron, CO.

PROJECT TITLE: Reduced tillage/nutrient management for winter wheat production on eroded soils.
Objective: Nitrogen and P rate and application method for winter wheat production on soils where up to 46 cm of top soil has been removed in relation to the use of no-till, reduced-till and conventional stubble mulch tillage systems is being studied.
Personnel: Darryl E. Smika, USDA-ARS, Akron, CO.
Location: Central Great Plains Research Station, Akron, CO.

SAMPLING SOIL BY DEPTH FOR ALFALFA: ITS POTENTIAL

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ABSTRACT

Bayard fine sandy loam, Greyback gravelly loam, and Lost Wells sandy clay loam which receive pH 8.0 irrigation waters were sampled at 30 cm intervals to 90, 120 or 180 cm, respectively one to three years after treatment. Sewage sludge, steer manure, cheese plant effluent, and 0-45-0 were used to supply phosphorus up to 300 kg/ha. Recommended, 2x recommended, 3x recommended, and 4x recommended amounts of irrigation water with an SAR less than 2 were applied. Sodium bicarbonate extractable phosphorus was measured on all soil samples.

The sodium bicarbonate P values decreased as depth increased on all treatments on all soils. Relative available phosphorus contents at specific soil depths were very similar for all soils. The relative P values were regressed on the respective soil depths and the r^2 values reported. A graph was constructed with one line for each of four sampling depths showing the percent that their relative phosphorus amount was of the cumulative phosphorus amounts for each succeeding depth in the profile. Using the soil depth, the sample depth, the soil P test value, and information from this graph, it is possible to obtain a good estimate of the amount of available phosphorus in the profile for alfalfa.

INTRODUCTION

A soil testing system for phosphorus should measure the appropriate soil phosphorus concentrations and enough other soil characteristics so that a valid phosphorus fertilizer recommendation can be made for a specific alfalfa crop management system. Most fertility specialists would have similar interpretations for the various subsidiary conditions, but nearly all are tied to the phosphorus measurement of the upper six inches of soil. However, alfalfa is one of the deeper rooted crops with a high phosphorus requirement. The other crops in the irrigated rotation tend to do their phosphorus feeding at more shallow depths which makes the surface soil phosphorus test more reliable for them. A suitable phosphorus testing system for alfalfa should verify those soil horizons where test values correlate well with any graded series of treatments that change phosphorus levels of the soil.

EXPERIMENTAL CONDITIONS

The soils being considered in this study were sampled to 90 cm at Torrington, 120 cm at Thayne, and 180 cm at Riverton. The minimum pH in any horizon was 7.5, while the pH of the irrigation waters was 8.0. The drainage condition ranged from moderate to well with intermittently perched water tables attainable in some irrigation seasons at one site. All sites have been used for irrigated alfalfa production, but not all were supporting alfalfa during the phosphorus sampling period. The mean annual air temperatures in degrees Celsius were 3.7 at Thayne, 5.6 at Riverton, and 8.9 at Torrington.

The irrigation waters were readily available when needed at all lcoations. The sodium adsorption ratio (SAR) values were 2 or less at all sites. The irrigation season specific conductance extremes over all sites were from 15 to 75 mS with no greater spread than 50 mS for any site (USGS, 1974). Surface irrigation techniques were used at Riverton and Torrington while sprinklers were used for weekly effluent applications at Thayne. The irrigations at Torrington were initiated when 50% of the available moisture remained in the surface horizon and continued until field capacity was reached. At Riverton, 10% and 50% of available moisture remaining were used for initiating irrigation -- with three of the 50% initiation plots receiving the following amounts of water -- replacement only, two times replacement, or four times replacement (Delaney, et al., 1978). The weekly effluent sprinkler applications at Thayne were 3 to 4 times the replacement water requirements depending on season (Borrelli, et al., 1978).

The combination of alkaline soils and alkaline waters containing 75 to 200 mg HCO_3L^{-1} applied at 45 to 60 cm per irrigation season was able to move phosphorus deepter in the profile (Delaney, et al., 1978). This feature was accentuated in all the trials by large applications of phosphorus containing materials (sewage effluent, sewage sludge, steer manure, 0-45-0) or by applying water in amounts on some treatments that exceeded the evapotranspiration and leaching requirements (Borrelli, et al., 1978) (Delaney, et al., 1978).

RESULTS

Sodium bicarbonate extractable phosphorus (Olsen and Sommers, 1982) was evaluated at the end of the growing season at Torrington, before spring growth and after the last forage harvest at Thayne for two years, and at the end of the third alfalfa growing season at Riverton. Mean values for three replications at Torrington and four replications at Thayne and Riverton were recorded in Table 1.

Table 1: Sodium bicarbonate extractable P (mg kg^{-1}) for locations, soil depths and treatments shown.

Location[1]	Soil depth cm.	KgP/ha from sewage sludge 0	106	212	318	KgP/ha from steer manure 0	95	190	285
Torrington	0-30	6.8	23.2	58.2	41.8	7.1	15.7	39.3	43.6
(Bayard fine	30-60	3.6	12.9	32.5	44.3	4.3	11.7	24.3	21.1
sandy loam)	60-90	5.0	3.9	10.7	7.5	3.6	7.5	7.5	8.9

		Sequential Kg effluent P added by sprinkler/ha: 0 Spring 1976	+34 Fall 1976	+89 Spring 1977	+31 Fall 1977
Thayne	0- 30	16	34	65	89
(Greyback	30- 60	9	16	17	32
gravelly	60- 90	4	7	13	21
loam)	90-120	5	4	13	5

		112 Kg P/ha as 0-45-0 applied 3 years before these final samples: Limited H_2O	Recommended H_2O	2 X Rec. H_2O	4 X Rec. H_2O
Riverton	0- 30	18.0	14.1	9.4	12.8
(Lost Wells	30- 60	3.6	5.9	6.5	4.0
sandy clay	60- 90	2.4	3.9	3.4	3.4
loam)	90-120	2.0	6.2	5.9	5.3
	120-150	3.6	2.8	5.6	7.2
	150-180	2.4	4.4	2.5	4.0

[1]Replications: Torrington 3, Thayne and Riverton 4.

In order to make the desired comparisons, the following conversion were performed on the P concentration data for each soil treatment:

Depth, cm.	Line 1.	Depth, cm.	Line 2.
30	$(P_{0-30} \div P_{0-30})100=$		
60	$(P_{0-30} \div P_{0-60})100=$	60	$(P_{0-60} \div P_{0-60})100=$
90	$(P_{0-30} \div P_{0-90})100=$	90	$(P_{0-60} \div P_{0-90})100=$
120	$(P_{0-30} \div P_{0-120})100=$	120	$(P_{0-60} \div P_{0-120})100=$
150	$(P_{0-30} \div P_{0-150})100=$	150	$(P_{0-60} \div P_{0-150})100=$
180	$(P_{0-30} \div P_{0-180})100=$	180	$(P_{0-60} \div P_{0-180})100=$

Depth, cm.	Line 3.	Depth, cm.	Line 4.
90	$(P_{0-90} \div P_{0-90})100=$		
120	$(P_{0-90} \div P_{0-120})100=$	120	$(P_{0-120} \div P_{0-120})100=$
150	$(P_{0-90} \div P_{0-150})100=$	150	$(P_{0-120} \div P_{0-150})100=$
180	$(P_{0-90} \div P_{0-180})100=$	180	$(P_{0-120} \div P_{0-180})100=$

Then the resulting data for the respective lines was used to calculate semilogarithmic regression lines using the centimeters depth as the linear component and the calculated percentages in the logarithmic component. More than one location was involved in each line shown in Figure 1. The equations obtained for each line follow:

Line 1. $y = 107.96 \times 10^{-0.00281x}, \quad r^2 = 0.72$

Line 2. $y = 138.34 \times 10^{-0.00236x}, \quad r^2 = 0.84$

Line 3. $y = 166.97 \times 10^{-0.00247x}, \quad r^2 = 0.86$

Line 4. $y = 168.28 \times 10^{-0.00192x}, \quad r^2 = 0.80$

Table 2: Extreme r^2 values for the effect of sampling depth on the proportions of profile $NaHCO_3$ P determinations.

	Thayne			Torrington			Riverton		
Depth, cm.	Best	Worst	Combined	Best	Worst	Combined	Best	Worst	Combined
0-30	0.98	0.87	0.84	0.99	0.83	0.85	0.99	0.94	0.73
0-60	0.99	0.94	0.91			0.61	0.99	0.97	0.82
0-90			0.67				0.99	0.95	0.78
0-120							0.99	0.94	0.81
0-150									0.91

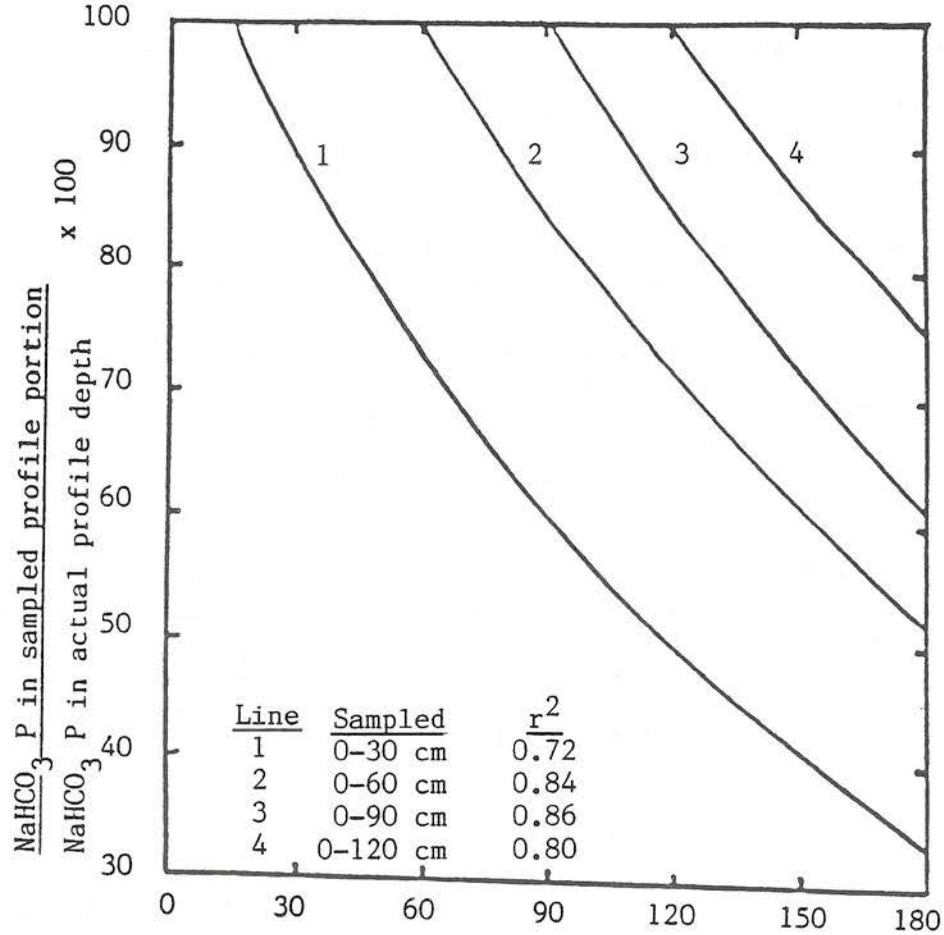

Figure 1: Effect of sampling depth on proportion and reliability of profile $NaHCO_3$ P determinations.

DISCUSSION

The test results shown in Table 1 demonstrate a decrease in phosphorus concentration as profile depth increases fo all treatments at all locations. An evaluation of the consistency of this decrease was desired. It was believed that the variety of phosphorus materials and rates applied with the range of water rates and climatic conditions present would cover any possible conditions found in production fields from which growers would be sending samples to the soil testing laboratory. If this decrease in phosphorus concentration with depth was definable in a generalized way, then how could the relationship with sampling depth be used in evaluating the available phosphorus content of the soil for agronomic management for alfalfa?

Regressions of the transformed P analysis data on soil depth for individual treatments within soils as shown in Table 2 can have relatively high r^2 values with some spread as treatments differ. Combining all treatments data by sites or for all sites had similar effects on the resultant r^2 values (Table 2) (Figure 1). The all--sites combination possesses higher r^2 values for the 0-60 cm or the 0-90 cm sampled profile portion than for the 0-30 cm or the 0-120 cm sampled layers (Figure 1).

The relationships between the phosphorus content of sampled soil portions and the distribution of available phosphorus throughout the profile as shown in Figure 1 seem to be quite stable for the sites studied. To use this information in a soil testing and phosphorus fertilizer recommendation program for alfalfa, it will be necessary to have a reasonable estimate of the effective rooting depth for the site. Soil survey information and experience with the area can be helpful, but irrigation induced perched water table behavior can complicate the situation. Spot check probing may be required to find the effective rooting depth for certain production fields. With reasonable rooting depth information in hand, the user can choose a soil sampling program.

For example: The distribution of available phosphorus in the 120 cm profile is 50% in the 0-30 cm layer, 20% in the 30-60 cm layer, 15% in the 60-90 cm layer and 15% in the 90-120 cm layer. Pulling samples by horizon or interval to the full 120 cm depth would allow the analyst to provide a complete list of the chemically available phosphorus for the profile. Time, expense, and surficial soil variability tend to discourage this approach. However, laboratory analyses for phosphorus from shallower samples could be converted to profile estimates by use of multiplying factors--i.e. 2 for 0-30 cm sample or 1.43 for 0-60 cm sample or 1.1 for 0-90 cm sample. The r^2 values for the 30, 60, and 90 cm samples were 0.72, 0.84, and 0.86, respectively (Figure 1).

The soil testing laboratory supervisor can really have the analyses performed and operate the recommendation system in a timely fashion if the soil history questionnaire or information sheet is complete. Sampling and rooting depths could be missing. Pursuit of this missing information can be time consuming or fruitless so use of default options with attendant footnotes might become standard alternate practices. System design by the specialist will be critical for the fact of the profile phosphorus distribution to be beneficial to the grower.

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PHOSPHORUS ECONOMICS ON DRYLAND WINTER WHEAT

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ABSTRACT

Phosphorus fertilizer trials on dryland wheat were initiated in 1984 on 13 cooperating farms from northern Oklahoma through western Kansas to eastern Colorado. Soil test P ranged from very low to high with most soils in the low to very low range. Treatments consisted of six P rates from 0 to 75 lb P205/A as 10-34-0, preplant dual applied with anhydrous ammonia, under a sweep plow. Treatments were replicated three or four times at each location. Significant positive yield responses were detected at four of the nine locations harvested. On low testing soils,66% of the sites responded to P. Yields leveled out in the 45 to 60 lb P205/A range.

Regression analysis of the yield data from the P responsive sites generated the following yield prediction equation:

Grain Yield = 38.8bu/A + 0.332 (P205 rate) - 0.0026 (P205 rate)**2

The maximum yield potential P fertilization rate determined from this equation was 63.8 lb P205/A. Based on $3.00 wheat and $0.27/lb P205 fertilizer, the maximum profit would have been generated at 46.5 lb P205.

OBJECTIVE

Substantial university man-hours have been expended in the High Plains since 1965 evaluating wheat response to phosphorus fertilization and efficient methods of applying P. Thompson (1979) summarized data showing significant wheat yield responses on 40% of 99 western Kansas dryland sites over a 15 year period. Sixty-two percent of sites testing low to very low in soil P responded to P with an average 16% increase in yield over N only fertilization. Data from these studies indicated that 46lb P205/A may be required on soils testing low to avoid limiting yields. There would appear to be substantial acreage of potentially P responsive dryland wheat. Yet, Kansas stastics show that only 40% of the harvested wheat acreage over the entire state in 1983 received any phosphorus fertilizer. (66th Report Kansas Agriculture, 1983). Fertilizer use stastics for Colorado in 1984 indicated 2 lb P205/A applied to wheat (Hargett and Berry, 1985).

A series of sites in western Kansas and eastern Colorado were established to demonstrate the potential economic return from phosphorus fertilization and enhance farmer interest in P use on dryland wheat.

METHODS AND MATERIALS

A total of 13 farmer-cooperator field locations were selected with the assistance of Servi-Tech, Inc., fieldmen in the summer of 1984. Site information as complete as could be verified is provided in Table 1.

TABLE 1 FIELD SITE LOCATIONS, SELECTED SOIL, AND VARIETY INFORMATION

Location	P Soil * Test ppm P	Soil Type	Variety
Woods Co.,Ok	63.0	Reinach vfsal	Wings
Trego Co.,Ks-I	9.0	Hastings sl	Bounty 205
Trego Co.,Ks-II	8.5	Hastings sl	Bounty 205
Sherman Co.,Ks	18.5	Ulysses sl	Larned
Ford Co.,Ks	9.9	Harney sl	Unknown
Greeley Co.,Ks	10.8	Ulysses sl	Rocky
Wallace Co.,Ks	11.3	Keith sl	Uknown
Gray Co., Ks	21.0	Richfield sl	TAM 105
Kit Carson Co.,Co	7.0	Unknown	Unknown

Sites deleted because of nonexistent or poor stands;
Grant Co.,Ks Ford Co.,Ks-II Kiowa Co.,Co Cheyenne Co.,Co
* Mehlich II P soil test procedure.

Treatments as indicated in Table 2 were arranged in a randomized complete block design with four replications at all locations, except Trego II, which had only three replications.

TABLE 2 TREATMENTS EMPLOYED AT ALL LOCATIONS

Treatments	
Lb N/A	Lb P205/A
0	0
80	0
80	15
80	30
80	45
80	60
80	75

Phosphorus, as 10-34-0, was dual-applied with anhydrous ammonia, preplant, on 12" centers under a sweep plow. The sweep was also operated through the no-fertilizer control plots. The sites were planted by the respective cooperating farmers. Four locations were abandoned because of dry fall soil conditions that resulted in poor stands and/or severe weed competition in the spring. The remaining nine locations were harvested with a small plot combine.

RESULTS AND DISCUSSION

TABLE 3 GRAIN YIELD RESULTS AT NINE HARVESTED LOCATIONS IN 1985.

Treatment lb N/A	Treatment lb P205/A	Woods Co., OK	Kit Carson Co., CO	Trego-I Co., KS	Trego-II Co., KS	Sherman Co., KS	Ford Co., KS	Greeley Co., KS	Wallace Co., KS	Gray Co., KS
		Yield (Bu/A)								
0	0	36.6	22.4	32.2	41.4	74.4	27.3	57.7	49.4	25.0
80	0	39.5	25.4	59.5	48.1	82.2	29.6	52.0	47.3	20.2
80	15	38.5	33.6	56.0	49.6	76.7	30.7	56.2	58.4	21.1
80	30	37.6	33.6	57.0	52.7	75.9	35.4	57.3	61.4	22.5
80	45	41.3	38.1	54.0	52.8	81.7	39.1	53.1	59.8	24.6
80	60	40.6	37.0	53.0	53.6	64.3	38.2	57.1	62.4	22.4
80	75	42.5	37.6	54.5	55.0	65.9	41.1	57.6	63.4	22.9
LSD .05	TRT	ns	3.9	5.7	ns	11.6	3.7	3.3	4.5	ns
	FAC	ns	4.2	ns	ns	12.7	3.4	3.1	3.9	ns
Coef Var %		17.0	8.2	6.5	10.2	11.3	6.3	3.1	4.4	11.3

A significant positive yield response to the phosphorus fertilizer application was detected at four of the nine sites. Grain yield response appeared to plateau at somewhere between 45 and 60 lb P205/A on the responsive sites. Available soil P levels at these locations were all in the low range varying from 7 to 10.8 ppm P in the surface 6 inch.

Yield data from the four locations showing significant positive P responses was combined after a chi-square variance test indicated homogeneous variances over these locations. Regression analysis of the pooled yield data produced the response curve shown in Figure 1. The P fertilizer rate producing the point of maximim yield was calculated as follows:

$$P\ rate = (-0.332 / 2*(-0.0026)) = 63.8\ lb\ P205/A$$

Using this same regression equation and assuming a \$3.00/bu wheat price and \$0.27/lb P205 P fertilizer, the P rate for maximum profit was determined by the following:

$$P\ rate = (\$0.27/\$3.00)-0.332 / 2*(-0.0026) = 46.5\ lb\ P205/A$$

Using the same regression equation, the nomograph in Figure 2 is presented to aid in determining the maximum profitable P fertilization rate at various wheat and fertilizer prices. Note that Figure 2 is based on one year's data and applies to low or very low P testing soils only.

Phosphorus application method costs are compared in Table 4 in gallons of diesel fuel per acre. Dual N-P costs assume that the farmer will sweep three times for weeds and wheat with fertilizer applied with the last sweep operation. The Drill method includes three sweep operations with NH3 applied in the last pass and P banded at seeding. Broadcast P assumes phosphorus applied as a separate operation and NH3 applied with the last sweep operation.

TABLE 4 COSTS OF VARIOUS TILLAGE SYSTEMS 1/

Tillage System		Cost Gal. Diesel/A
Dual N-P Band		
	Harvest	1.38
	Sweep 2x	1.30
	Sweep + NH3 + APP	.65
	Disc	.70
	Drill	.35
	Insect - Herbicide	.20
	Total	4.58
Drill Band		
	Harvest	1.38
	Sweep 2x	1.30
	Sweep + N3	.65
	Disc	.70
	Drill	.35
	Insect - Herbicide	.20
	Total	4.58
Broadcast P		
	Harvest	1.38
	Sweep 2x	1.30
	Sweep + NH3	.65
	Broadcast P	.42
	Disc	.70
	Drill	.35
	Insect - Herbicide	.20
	Total	5.00

Sources
1/ Kuhlman (1977); Doane's Agri. Report (1985); Schrock (1985)

Costs are similar with both the Dual N-P and Drill methods, however, considerable time is saved at planting with the Dual N-P method as the fertilizers are applied with a tillage operation. Broadcast P may save farmer time if the P is custom applied, however, there is a large volume of data that shows there could be some agronomic advantages to N and P applied in a dual band compared to broadcast P alone on soils testing low or very low.

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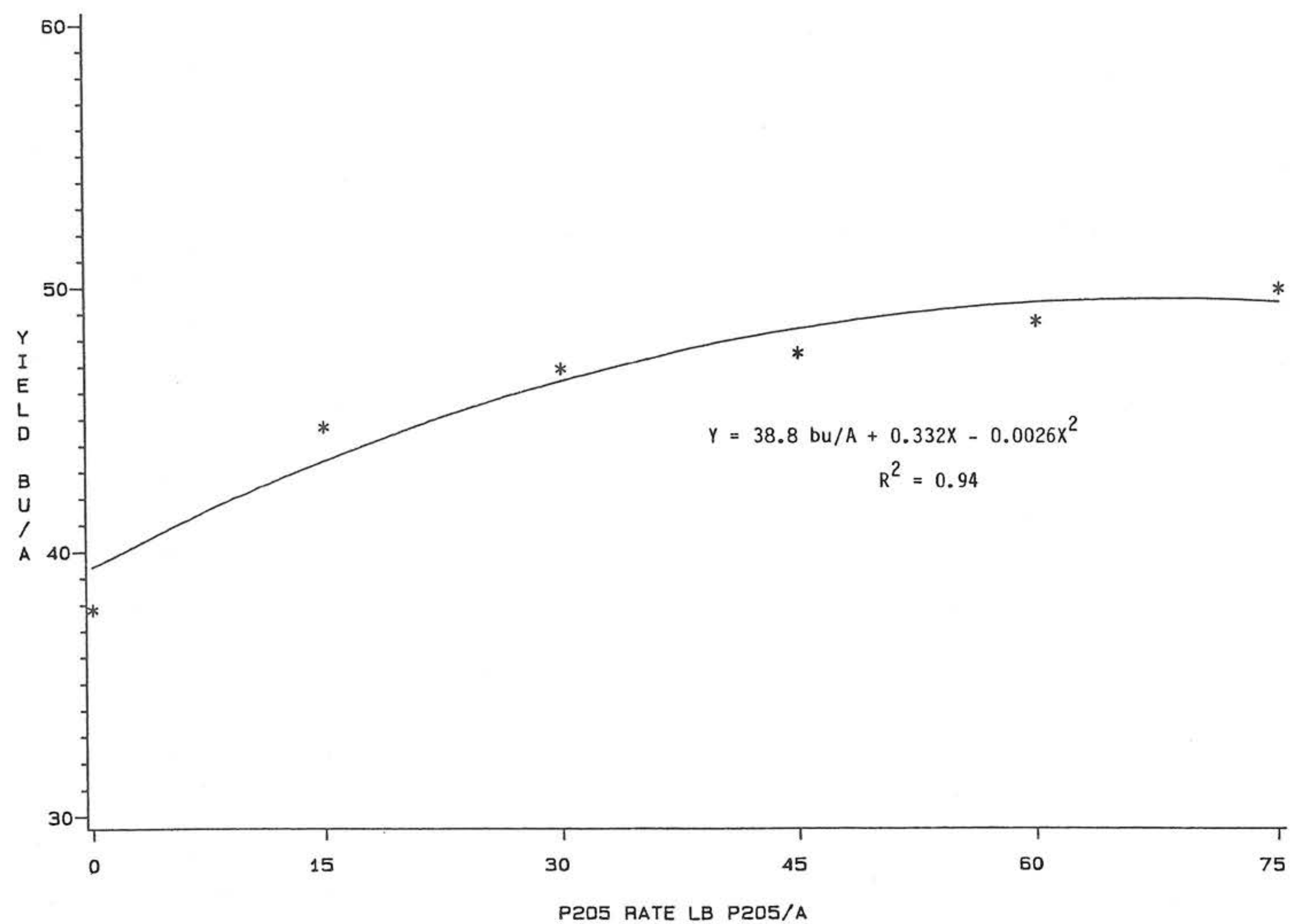

Figure 1. Regression of Pooled Yield Data From Sites at Kit Carson County, CO; Ford, Greeley, and Wallace County, KS, on P_2O_5 Rate Applied

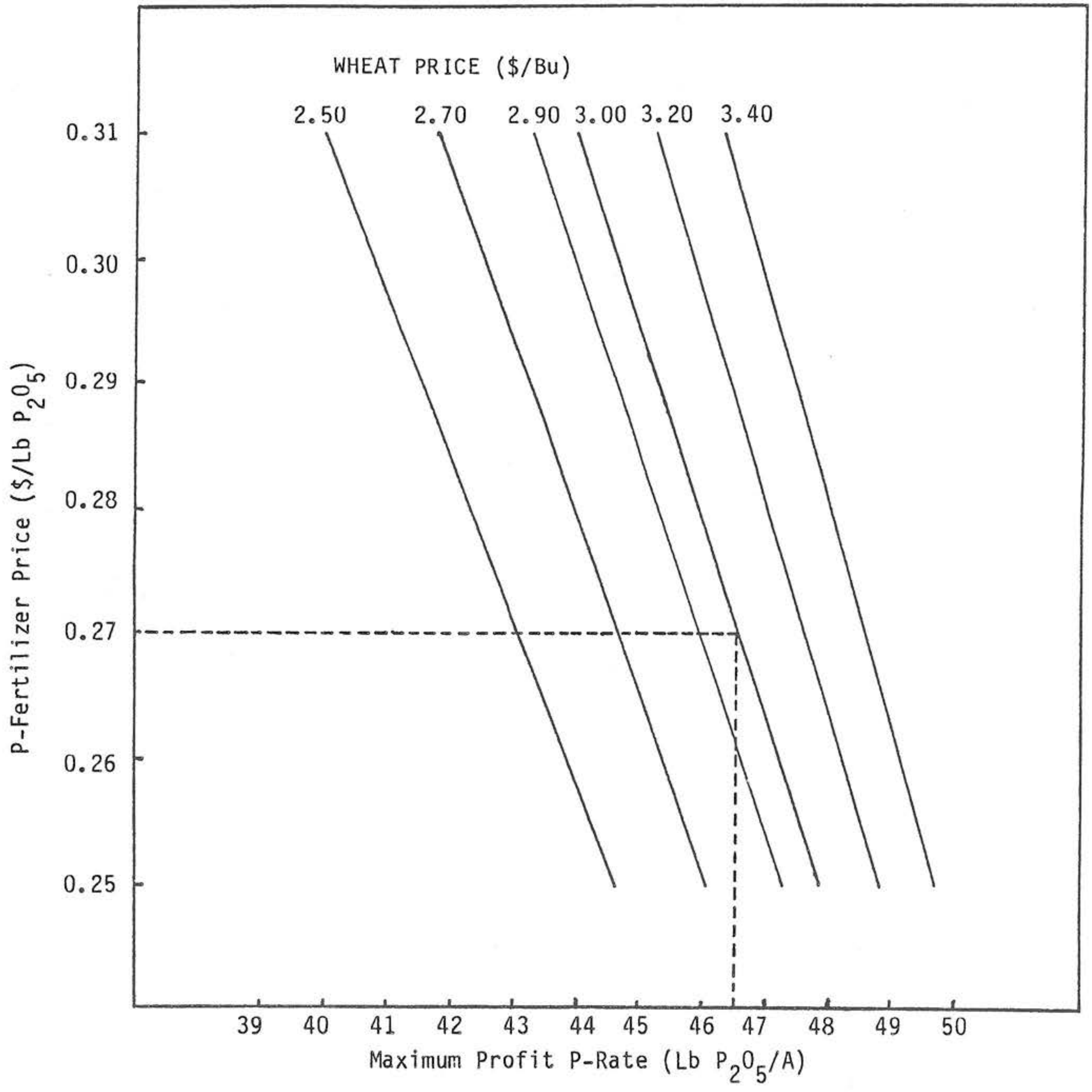

Figure 2. Nomograph of Maximum Profitable P-Fertilizer Rate at Various Wheat and Fertilizer Prices

NITROGEN FERTILIZER MANAGEMENT FOR ALBERTA

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ABSTRACT

Field experiments were conducted in the southern, central, and north-central parts of Alberta to identify inefficiencies in presently used N fertilizing practices and the differences in barley responses to methods of N application designed to circumvent these inefficiencies. Broadcast methods of N addition were found to be less effective than deep-banded or nested N. When broadcast, ammonium nitrate produced greater barley yields than urea. When banded, no differences were observed in crop response between the fertilizers tested showing that method of application of N did not result in significant N losses in the central and north-central areas. Overwinter losses were reduced if N addition was conducted late in the fall.

OBJECTIVES

Much of the research in the Canadian prairies has been directed towards identifying the inefficiencies of present N fertilization practices and determining how to circumvent the problems. Consequently, much of the research effort has been focussed on fertilizer forms and methods and time of addition (1,2,3,4). This paper summarizes some of the work done in recent years by some of the soil fertility researchers in Alberta.

MATERIALS AND METHODS

Since this is a summary paper, it would be difficult to provide the methods used in each of the experiments separately. In general, all the experiments reported here were conducted using field plots, and in most cases using scaled down field machinery. Where novel application methods were used, hand application of fertilizers was performed. Rates, times and methods of addition varied between the experiments and in most cases were some of the parameters studied in the experiments. Commercial grades of N fertilizers were used in all cases.

RESULTS AND DISCUSSION

Comparison of yield increases resulting from broadcast application of urea and ammonium nitrate in the spring are shown for irrigated land in the southern part of the province (Fig. 1). Broadcast ammonium nitrate was more effective than broadcast urea, except at high levels of addition. In central Alberta without irrigation, when the fertilizers were broadcast and incorporated to a depth of 10 to 12 cm, yield increases were greater than with a broadcast application without incorporation (Table 1). There were slight or no yield differences between the two N fertilizers when broadcast and incorporated into the soil, but when broadcast without incorporation, urea was less effective in increasing barley yield than ammonium nitrate. Under dry conditions, differences between fertilizers were minimal because water, not N, was limiting crop growth.

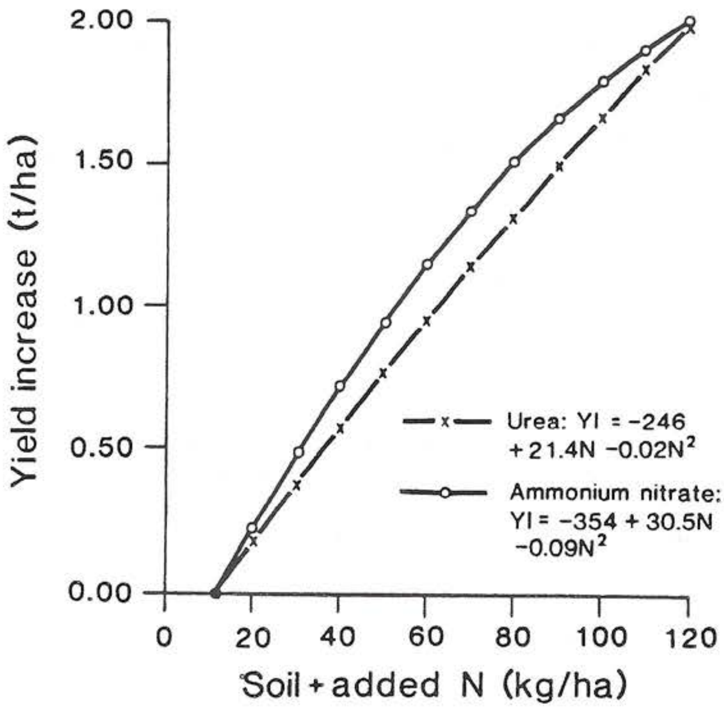

Fig. 1. Barley yield response to spring broadcast N fertilizer in southern Alberta -data from 7 exp. x 5 reps.

Table 1. Yield increase of barley from spring-applied urea and ammonium nitrate in central Alberta**

Method of application*	Yield increase (kg/ha)	
	Urea	Ammonium nitrate
Broadcast	990	1200
Broadcast and incorporated (10-12 cm)	1280	1340

*56 kg N/ha applied.
**Average of 4 experiments X 4 reps.

Research in southern Alberta has shown that banding of N fertilizers 15 cm below the surface has tended to eliminate differences in fertilizer effectiveness. For example, anhydrous ammonia, urea, and ammonium nitrate additions resulted in similar yields. Furthermore, the yield increases obtained were greater than those obtained with broadcast forms added at the same rates. The relative yield increases from N application by banding and broadcasting are shown in Fig. 2. If the spring broadcast curve in Fig. 2 is considered to be the response curve for the standard method of adding N fertilizer, then the spring-banded curve clearly shows that yields can be increased by banding the same N rate.

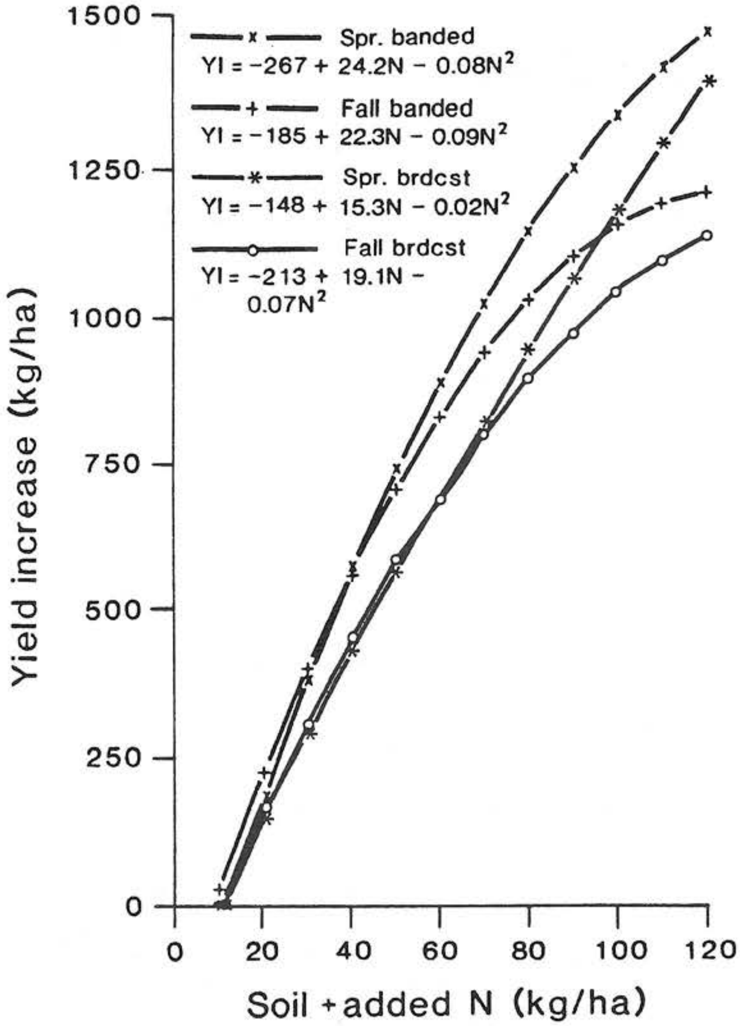

Fig. 2. Barley yield responses to N fertilizer banded and broadcast in spring and fall in southern Alberta.
-data from 7 exp. x 5 reps.

Fig. 2 also shows the yields obtained from fall application of N in the southern part of Alberta. Basically, it shows that at low to moderate rates of N addition, little if any reduction in yield was observed relative to the spring-applied treatment. At higher levels of N addition, the fall curves tail off. Care must be used in interpreting these curves since the fall-applied N was added very late in the season (soil temp. <5^{o}C). Earlier fall application can result in 20-30% losses of N over the winter, particularly in the more northern parts of Alberta where precipitation is greater (Table 2). Substantial amounts of mineral N have been shown to be lost from fall-applied urea when it was incorporated into soil in field experiments in north and north-central Alberta. Consequently, fall-applied treatments gave lower yields of grain than did similar applications of urea in spring. Delaying applications from early fall to late fall increased yields relative to the earlier application. The relative efficiency of fall- vs. spring-applied urea was approximately 30% for urea applied in late September and approximately 70% for urea applied in late October under these conditions.

Placing urea in concentrated "nests" (spot application) has also been shown to increase grain yields and N uptake efficiency (Table 2). The yields from fall-applied bands or nests were greater than from fall-applied broadcast-and-incorporated urea but were still lower than those obtained from spring-applied treatments in the north and north-central parts of the province.

Table 2. Effect of N placement on barley grain yield increase in central Alberta#

Method of application*	Time of application	Yield increase (kg/ha)
Broadcast and incorporated	fall**	830
Banded (5-cm depth 46 cm apart)	fall	1140
Nested (1 spot in 46x46) cm area, 5-cm depth)	fall	1480
Broadcast and incorporated (10-12 cm)	spring	1710

#Average of 20 experiments x 4 reps.
*N added at 56 kg N/ha.
**Fall application between Sept. 27 and Oct. 23.
#Average of 20 experiments x 4 reps.

Other data show fall banding to be the most effective method for applying fertilizer in years with less than ideal seedbed moisture supply (Table 3). This kind of response to N fertilizer is common to southern Alberta, but is also found throughout the province where the seedbed moisture is low and the young plants continue to be stressed by lack of moisture for several weeks. The young plant roots make little contact with the shallowly incorporated fertilizer, but are able to contact the deeper banded N more easily.

Table 3. Relative performance of fall- and spring-applied N fertilizer in situations where seedbed moisture conditions are less than optimal

Method of application*	Barley yield increase (kg/ha)	
	Fall	Spring
Broadcast and incorporated**	672	717
Banded	907	806

*N added at 56-67 kg N/ha as 34-0-0 or 46-0-0.
**Incorporated to a depth of 5-7 cm.
Seedbed prepared by cooperating farmers with standard farm equipment.
Average of 15 experiments x 3 reps.

Our research shows that there are two main separate mechanisms which reduce the effectiveness of N fertilizers in Alberta: 1) winter or early spring loss of fall-applied N by denitrification or occasionally by leaching; and 2) stranding of broadcast or shallowly incorporated spring-applied N in dry surface soil layers. Band placement greatly helps both situations. The choice of fall or spring application depends on the area and the soil moisture levels.

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ONE-PASS PNEUMATIC FERTILIZING-SEEDING WITH VARIOUS N SOURCES AND N RATES

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ABSTRACT

Fertilizer rate, fertilizer source and spreader type influenced the degree of stand reduction and final yield obtained when spring wheat was planted in a one-pass operation utilizing a pneumatic fertilizing-seeding unit. Greatest stand reduction occurred when fertilizer and seed were placed in a single row and least when spread over a wide 12-inch band. Fertilizer rates above 40 lb N/acre increased the degree of stand reduction and lowered yield response unless SCU or AN were used as fertilizer sources. Stand reduction followed the sequence U $\geq$ U + DAP > U + UP $\geq$ UUP > AN > SCU with respect to source. Once stand reduction exceeded 35 percent, delays in crop maturity occurred and no yield response was obtained from the fertilizer applied. Crop maturity was delayed as much as 7 days with single row placement. Maturity was affected least when seed and fertilizer were spread in a wide band. AN and SCU sources caused the least stand reduction, the lowest tillering, thus the least effect on maturity compared to other sources.

OBJECTIVES

The expansion of reduced tillage in wheat production areas has raised questions relative to fertilizer management because normal fertilizer practices currently used under conventional tillage are not always compatible with high residue conditions. Such questions have directed new research emphasis in areas of fertilizer placement and fertilizer sources.

Pneumatic equipment attachments to tillage implements were developed for seeding and fertilizing in the same operation thus eliminating or reducing the number of field operations. Direct application of fertilizer with small grain seed, especially urea base fertilizers, can cause extreme germination damage when N rates exceed 20 lb/acre. This low N rate will not meet the requirements for producing maximum wheat yields and may require additional operations to supply the total fertilizer needs. The seed germination problem can be overcome to some degree with pneumatic seeders by dispersing the seed and fertilizer with deflectors on the tillage equipment. This tillage-seeding-fertilizing method and associated deflector or spreaders also provides greater mixing and distribution in the soil for less direct fertilizer-seed contact to reduce germination damage. Although some seed germination damage may occur, no specific rate limits have been established for this tillage-seeding-fertilizing management option.

The amount of seed germination damage, although controlled by soil properties, fertilizer rate and degree of soil mixing, can be modified by fertilizer source. Studies with "acid-based" urea-urea phosphate (UUP) fertilizers indicated that higher rates of these materials may be applied with the seed and cause less damage than with combinations of urea and/or ammonium phosphate (1). The decreased germination damage was associated with the capacity of the acid phosphorus to inhibit damage by retarding urea hydrolysis, neutralizing the products of urea hydrolysis and thus reducing free ammonia which damages the seed. Sulfur coated urea (SCU) a source that utilizes slow-release characteristics also showed promise as another approach to keep salt levels and free ammonia below damaging levels.

These new ideas and experimental materials need to be field tested to determine feasibility and/or establish recommendations for these fertilizer management practices in reduced tillage. The objectives of this study were to [1] determine the effects of various experimental N sources and rates on wheat seed germination with one-pass pneumatic seeders using various spreader types and [2] compare rates of experimental fertilizer materials with commercially available sources on seed germination, plant growth, nutrient uptake and yield.

MATERIALS AND METHODS

A field study was conducted to evaluate sources and rates of nitrogen fertilizer material applied with wheat seed at planting in a one-pass operation. A Wil-Rich pneumatic fertilizer-seeder unit on a 24-foot chisel plow with 12-inch spacing and an International 5288 tractor with dual rear wheels was utilized. Seeded plots were 100 feet long with data collected from the center 50 foot section. Four spreader types (attached to the chisel shanks) that distributed the seed and fertilizer in various patterns (shown in the diagram) were used. Spreader types A, B and C used 12-inch sweep shovels and various deflectors to achieve the desired pattern. Type D was achieved with a narrow spear point (no-till shoe) that placed seed and fertilizer in a single row. The study was conducted on a Bearden silty clay soil, previous crop soybeans, with three replications in a randomized complete block design with spreader types as 6-foot wide subplots. Plant counts, a measure of seed germination damage, and other growth parameters were collected from 2 by 2 foot squares randomly selected in the plot area after planting. Yields were determined after harvesting the mature grain from a 50 foot long area with a small plot combine. Preliminary information and results on this study were previously reported (2,3).

RESULTS AND DISCUSSION

Spring wheat stand reduction (Table 1) as influenced by fertilizer source, fertilizer rate and spreader type using an air seeder unit in a one-pass operation varied with treatments imposed but was fairly consistent across years. Stand reduction increased as the rate of N increased from 40 to 80 lb/acre irrespective of source. The greatest reduction occurred with U or U + DAP, least with AN or SCU and intermediate with experimental UP and UUP. Spreader type had the greatest influence on degree of stand loss. When all fertilizer was placed in a narrow band with the seed (Type D) reductions from 60 to 90 percent were obtained with U, U + DAP and U + UP. Reduction was only 20 to 30 percent when AN or SCU were applied. Spreading the fertilizer and seed over a 12-inch band (Type B and C) caused minimal stand losses of 15 to 30 percent with U, U + DAP and U + UP and only 0 to 10 percent with AN and SCU. The UUP caused stand reductions in the 5 to 20 percent range. Spreader type A (6-inch spread) had less stand reduction than type D, but higher than B or C. Excessive stand losses (greater than 35 percent) occurred with type A when rates exceeded 40 lb N/acre with the U, U + DAP, U + UP sources.

The stand reductions were compensated for by increased tillering (data not shown) but the increase also influenced crop maturity. The number of days to heading (Table 2) were recorded in 1985 and showed, on the average, a 1 to 4 day delay with all sources except SCU. The greatest delay, in some cases a week delay, occurred when all fertilizer was applied with the seed in one row (Type D). A delay in maturity was realized with the wide spread only when N rates exceeded 40 lb N/acre. In some cases, the wheat crop headed out earlier than the check, especially when SCU or AN were applied.

The relative change in yield, associated with both stand reduction and maturity, is summarized in Table 3. A consistent yield reduction was observed with spreader

Table 1. Spring wheat stand reduction as influenced by fertilizer source, fertilizer rate and spreader type in a one-pass pneumatic fertilizer-seeding. North Dakota.

Fertilizer				Spreader Type				
Source[1/]	Rate	N + P	Year	A	B	C	D	Ave.
	lb/acre			percent[2/]				
U	40	0	1984	32	21	11	76	35
			1985	13	5	22	77	29
			Ave.	22	13	16	76	32
	80	0	1984	47	36	26	90	50
			1985	63	25	28	87	51
			Ave.	55	30	27	88	50
AN	40	0	1984	1	0	0	11	3
			1985	2	0	8	24	9
			Ave.	2	0	4	18	6
	80	0	1984	16	0	10	33	15
			1985	44	20	13	36	28
			Ave.	30	10	12	34	22
SCU	40	0	1984	10	0	0	12	5
			1985	16	5	10	37	17
			Ave.	13	2	5	25	11
	80	0	1984	15	3	0	5	6
			1985	15	14	3	43	19
			Ave.	15	8	1	24	12
U + DAP	40	17	1984	27	22	18	57	31
			1985	16	7	12	70	26
			Ave.	22	14	15	63	28
	80	17	1984	58	35	35	77	51
			1985	68	38	39	96	60
			Ave.	63	36	37	86	56
U + UP	40	17	1984	18	6	18	61	26
			1985	0	0	8	47	14
			Ave.	9	3	13	54	20
	80	17	1984	43	20	25	82	42
			1985	54	33	28	82	49
			Ave.	48	26	26	82	45
UUP	40	17	1984	10	0	0	7	4
			1985	37	19	12	74	36
			Ave.	24	10	6	40	20
	80	17	1984	22	13	4	56	24
			1985	31	27	13	86	39
			Ave.	26	20	8	61	32

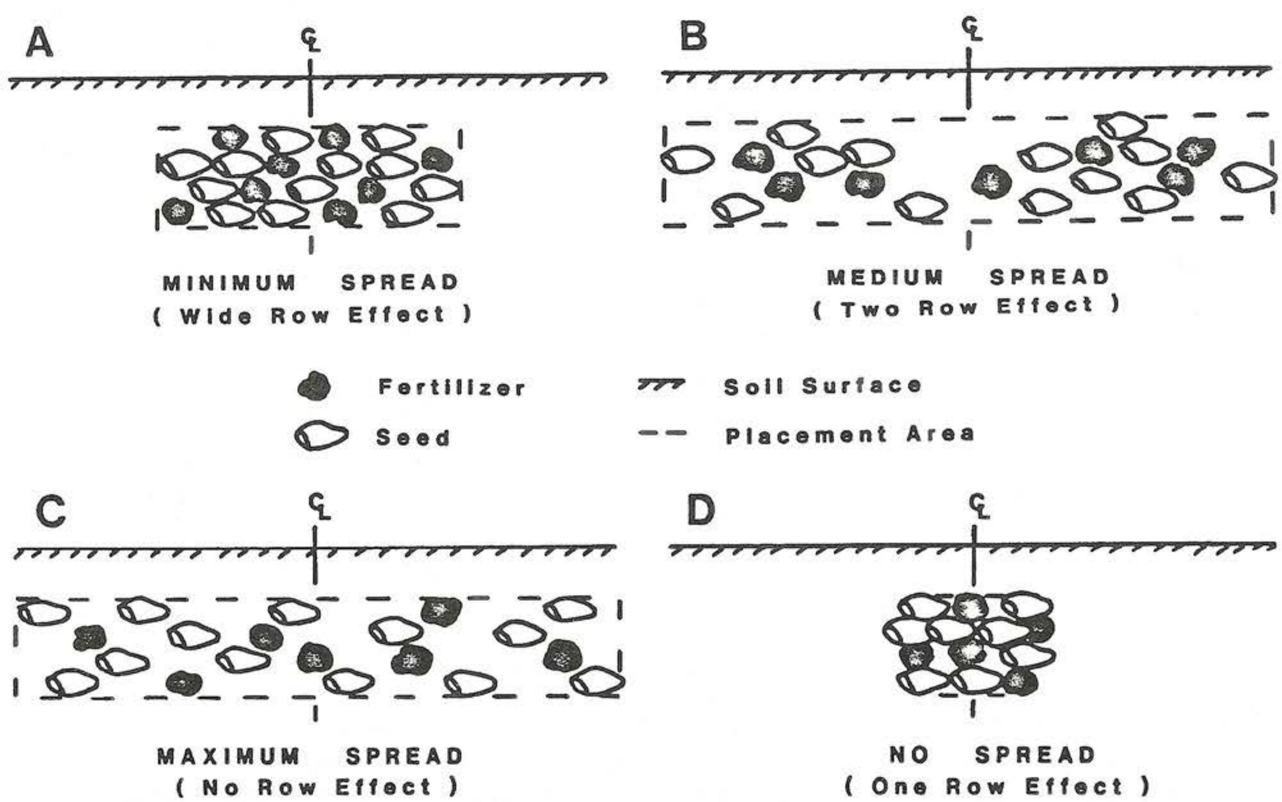
1/ Urea (U), ammonium nitrate (AN) and diammonium phosphate (DAP) were obtained from commercially available sources. Urea phosphate (UP), urea-urea phosphate (UUP) and sulfur coated urea (SCU) are experimental materials furnished by TVA-National Fertilizer Development Center.

2/ Relative change with respect to the check treatment with no fertilizer applied.

Table 2. Number of days to heading of spring wheat as influenced by fertilizer source, fertilizer rate and spreader type in a one-pass pneumatic fertilizer-seeding. North Dakota 1985.

Fertilizer			Spreader Type				
Source[1/]	Rate	N + P	A	B	C	D	Ave.
	lb/acre		number of days				
Check	0	0	69	65	65	66	66
U	40	0	70	67	67	72	69
	80	0	71	67	67	73	70
AN	40	0	68	64	64	70	67
	80	0	68	65	64	71	67
SCU	40	0	71	64	64	65	66
	80	0	69	64	64	67	66
U + DAP	40	17	68	64	64	72	67
	80	17	71	68	66	73	69
U + UP	40	17	67	64	64	71	66
	80	17	69	65	65	73	68
UUP	40	17	70	65	65	72	68
	80	17	70	68	67	73	69

[1/] Urea (U), ammonium nitrate (AN) and diammonium phosphate (DAP) were obtained from commercially available sources. Urea phosphate (UP), urea-urea phosphate (UUP) and sulfur coated urea (SCU) are experimental materials furnished by TVA-National Fertilizer Development Center.



PNEUMATIC SEEDER
FERTILIZER - SEED DISTRIBUTION
12-INCH SHOVEL SPACING

Table 3. Spring wheat yield change as influenced by fertilizer source, fertilizer rate and spreader type in a one-pass pneumatic fertilizer-seeding. North Dakota.

Fertilizer				Spreader Type				
Source[1/]	Rate	N + P	Year	A	B	C	D	Ave.
	lb/acre			percent[2/]				
U	40	0	1984	21	21	32	-24	13
			1985	12	18	27	-28	7
			Ave.	16	20	30	-26	10
	80	0	1984	2	16	17	-51	-4
			1985	-38	14	11	-55	-17
			Ave.	-18	15	14	-53	-10
AN	40	0	1984	9	17	24	14	16
			1985	27	34	42	15	29
			Ave.	18	26	33	14	22
	80	0	1984	25	28	25	0	19
			1985	25	26	34	0	21
			Ave.	25	27	30	0	20
SCU	40	0	1984	1	20	11	7	10
			1985	14	26	30	25	24
			Ave.	8	23	20	16	17
	80	0	1984	16	29	31	18	23
			1985	21	41	38	23	31
			Ave.	18	35	34	20	27
U + DAP	40	17	1984	21	23	26	-10	15
			1985	31	40	46	-6	28
			Ave.	26	31	36	-8	22
	80	17	1984	13	26	25	-76	-3
			1985	14	31	42	-78	2
			Ave.	14	28	34	-77	0
U + UP	40	17	1984	9	26	24	-9	12
			1985	31	31	39	7	27
			Ave.	20	28	32	1	20
	80	17	1984	12	13	18	-50	-2
			1985	26	37	44	-37	18
			Ave.	19	25	31	-44	8
UUP	40	17	1984	33	37	31	14	28
			1985	14	32	32	-12	16
			Ave.	24	34	32	1	22
	80	17	1984	14	31	30	-33	11
			1985	25	36	42	-27	19
			Ave.	20	34	36	-30	15

1/ Urea (U), ammonium nitrate (AN) and diammonium phosphate (DAP) were obtained from commercially available sources. Urea phosphate (UP), urea-urea phosphate (UUP) and sulfur coated urea (SCU) are experimental materials furnished by TVA-National Fertilizer Development Center.

2/ Relative change with respect to the check treatment with no fertilizer applied.

type D with U or U + DAP (both N rates) and with U + UP and UUP at the 80 lb N/acre rate. A yield increase was obtained with type D when AN at 40 lb N/acre rate and SCU at both N rates were applied. A yield increase was obtained with all sources and rates except 80 lb N/acre U with spreader type A. No yield reductions were observed with spreader type B and C, irrespective of rate or source. It is interesting to note that the maximum yield increase with SCU was obtained only at the higher rate (80 lb N/acre). Although yield response varied with source and rate, generally no yield response was obtained once stand reduction exceeded 35 percent. Thus the selection of fertilizer source and degree of spread influenced the response obtained on this silty clay soil. Responses obtained on other soils may be similar but may vary with soil properties like texture, moisture and pH.

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FERTILIZER PLACEMENT EFFECTS ON YIELD AND NUTRIENT CONTENT OF WINTER WHEAT IN OKLAHOMA

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ABSTRACT

Efficient fertilizer applications are essential to achieve maximum economic yield. Many different fertilizer application methods are being used in wheat production systems in Oklahoma. Methods include broadcast, band, topdress, placement under V-blades and behind thin knives, dribble, split application, and varying combinations of methods that are compatable with clean-, reduced-, and no-till systems. Increases in yield and nutrient uptake have been primarily due to N and P fertilization. Differences in yield and nutrient uptake due to method of fertilizer application have varied with soil nutrient availability indices and favorableness of the growing season.

Depressed market prices for wheat, increased production costs and declining land values have resulted in low profit margins and renewed interest in efficiency of placement of fertilizers in winter wheat production systems.

Leikam et al. (1983) showed that dual injection bands of N and P 15 to 20 cm deep increased grain yield of winter wheat and increased P concentration in leaf tissue. Maxwell et al. (1984) reported increased dry matter production and P concentration in plants grown in rows directly over dual injection bands compared to plants in rows 13 to 25 cm away from the band. Westerman and Edlund (1985) reported the positive effect of increased grain yield due to deep placement of N and P in bands diminished with continued fertilization in the same plots and at the end of the 4 yr study broadcast applications were more efficient. Band application of P with seed at planting was shown to be a very efficient method of application many years ago. More recently, other methods such as fertilizer placement under the V-blade, and dribble applications have been receiving attention. Therefore, the objective of this paper is to discuss the effect of different methods of fertilizer placement on yield and nutrient content of winter wheat.

Additional index words: Triticum aestivum L., Anhydrous ammonia, ammonium nitrate, UAN, ammonium polyphosphate, broadcast application, dual placement, dribble, banded with seed.

MATERIAL AND METHODS

Wheat experiments involving methods of fertilizer placement, and fertilizer sources and rates have been conducted at numerous locations throughout the state. Soils pH at these locations ranged from 5.0 to 7.5 and soil test P availability indices ranged from 9 to 48 μg P g^{-1} of soil using Bray and Kurtz No. 1 (1:20) extraction. Soil available N levels ranged from deficient to adequate.

Plots were harvested for grain yield using a modified Gleaner combine and subsamples of grain were taken and analyzed for N and P.

RESULTS AND DISCUSSION

Comparisons of broadcast vs. deep band application of N, P, and N plus P effects on grain yield and nutrient uptake are shown in Table 1. Data reported are means averaged over 3 to 4 years at each location. Fertilizers were applied to the same plots annually. Three locations with varying available nutrient indices were selected for the study; Altus (N-deficient and P-adequant), Stillwater (N-deficient and P-deficient), and Haskell (N-adequate and P-deficient).

Nitrogen fertilization increased yield and N uptake in grain at Altus but P fertilization had no effect. There were no differences in mean yield and N uptake in grain due to method of application. However, in the first year of the study, broadcast application of ammonium nitrate disked in preplant resulted in higher yield and N uptake in grain than obtained with anhydrous ammonia applied behind thin shank knives with 45 cm spacings (data not shown). The first year of the study at Altus was dryer throughout the growing season than subsequent years. Apparently under moisture stress conditions, deep band application of N in 45 cm intervals is less efficient than broadcast application.

Nitrapyrin had no effect on yield or nutrient uptake in grain during the 4 yr study at Altus.

Yield and uptake of N and P in grain averaged over years were increased with P fertilization at Stillwater, but there were no differences due to method of application. An adjacent N, P, K experiment on the same soil indicated a yield response to applied N. During the initial year of the study, there was a substantial increase in early forage growth when N and P were dual injected behind thin shanked knives in comparison to broadcast applications. The increase in forage growth also resulted in higher yield and N and P uptake in grain. However, with continued fertilization in the same plots with subsequent years, the positive effect of fertilizer in deep bands diminished, and broadcast applications were more efficient.

At Haskell, the increase in yield and N uptake in grain was due to p fertilization. There were no differences in 3 yr average yields or nutrient uptake due to method of applications. However, broadcast applications were more efficient than deep band applications in later years of the study. Nitrapyrin had no effect on yield and nutrient content of winter wheat.

Table 1. Fertilizer application method effects on grain yield and nutrient uptake averaged over years.

Source and method[†]	Rate N	Rate P	Rate NI	Yield[‡]	Uptake N	Uptake P
	-------	-------	-------	kg·ha^{-1}	-------	-------
Altus[§]						
Check	0	0	0	2050 a	44 a	11 a
AA - KF	112	0	0	2850 b	81 b	15 a
AN - BC + APP - BC	112	30	0	2870 b	74 b	16 a
AN - BC + APP - KF	112	30	0	2970 b	77 b	16 a
AA - KF + APP - BC	112	30	0	2730 b	82 b	16 a
AA - KF + APP - KF	112	30	0	2840 b	81 b	15 a
AA - KF + APP - KF + NI - KF	112	30	0.56	2760 b	81 b	15 a
No. of years in avg.				4	3	3
Stillwater						
AA - KF	112	0	0	1820 a	47 a	5 a
AN - BX + APP - BC	112	30	0	2430 b	58 b	8 a
AN - BC + APP - KF	112	30	0	2380 b	59 b	8 a
AA - KF + APP - BC	112	30	0	2380 b	59 b	7 a
AA - KF + APP - KF	112	30	0	2280 b	59 b	9 a
No. of years in avg.				4	4	4
Haskell						
Check	0	0	0	1680 a	42 a	5 a
AA - KF	112	0	0	1670 a	42 a	4 a
AN - BC + APP - BC	112	30	0	2450 b	59 b	7 a
AN - BC + APP - KF	112	30	0	2180 b	53 b	7 a
AA - KF + APP - BC	112	30	0	2510 b	64 b	7 a
AA - KF + APP - KF	112	30	0	2160 b	54 b	7 a
AA - KF + APP - KF + NI - KF	112	30	0.56	2170 b	58 b	7 a
No. of years in avg.				3	3	3

[†] Anhydrous ammonia (AA), ammonium nitrate (AN), ammonium polyphosphate (APP), and nitrapyrin (NI) were used as sources. Methods of application were knifed (KF) and broadcast (BC). All broadcast applications were disked in preplant.

[‡] Numbers in columns followed by the same letter within locations are not significantly different using LSD (0.05).

[§] Bray and Kurtz No. 1 (1:20) soil test P indices were 48, 10, and 9 μg P g^{-1}, respectively for Altus, Stillwater, and Haskell.

Table 2. Effect of methods of P fertilization on grain yield averaged over two years.

Rate† N	Rate† P	Method	Yield‡ Stillwater	Yield‡ Haskell
---kg ha^{-1}--			---------kg ha^{-1}----	
0	0		2020	1560
112	0	N B'Cast	2700	1720
112	10	N + P B'Cast	2450	2170
112	20	N + P B'Cast	2660	2130
112	10	N B'Cast; P banded w/seed	2660	2150
112	20	N B'Cast; P banded w/seed	2640	2130
112	0	N Knife preplant	2915	1915
112	10	N + P Knife preplant	2790	2250
112	20	N + P Knife preplant	2710	2130
112	0	N Dribble disked-in	2660	1800
112	10	N + P Dribble disked-in	2580	2260
112	20	N + P Dribble disked-in	2630	2360
112	0	N V-blade	2750	1660
112	10	N + P V-blade	2560	2210
112	20	N + P V-blade	2880	2280
LSD (0.05)			410	380

†APP (10-15-0) expressed as elemental P and UAN (28-0-0) were used as fertilizer sources.

‡Bray and Kurtz No. 1 (1:20) soil test P indices were 36 and 15 μg P g^{-1} for Stillwater and Haskell, respectively.

Data from another set of experiments designed to compare effects of methods of P fertilization on yield of winter wheat are shown in Table 2. Grain yields were not affected by method of P fertilization at two locations that varied markedly in soil test P indices. Phosphorus fertilization increased grain yield at Haskell, but there were no differences among broadcast, banded with seed, dual placement behind thin shanked knives, dribble or dual placement of N and P under the V-blade.

Varying methods of N and P fertilization have not resulted in substantial increases in grain yield and nutrient content of winter wheat in Oklahoma. Largest increases in grain yield have been the result of applying deficient nutrients in proper amounts based on calibrated soil tests.

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APPENDIX
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