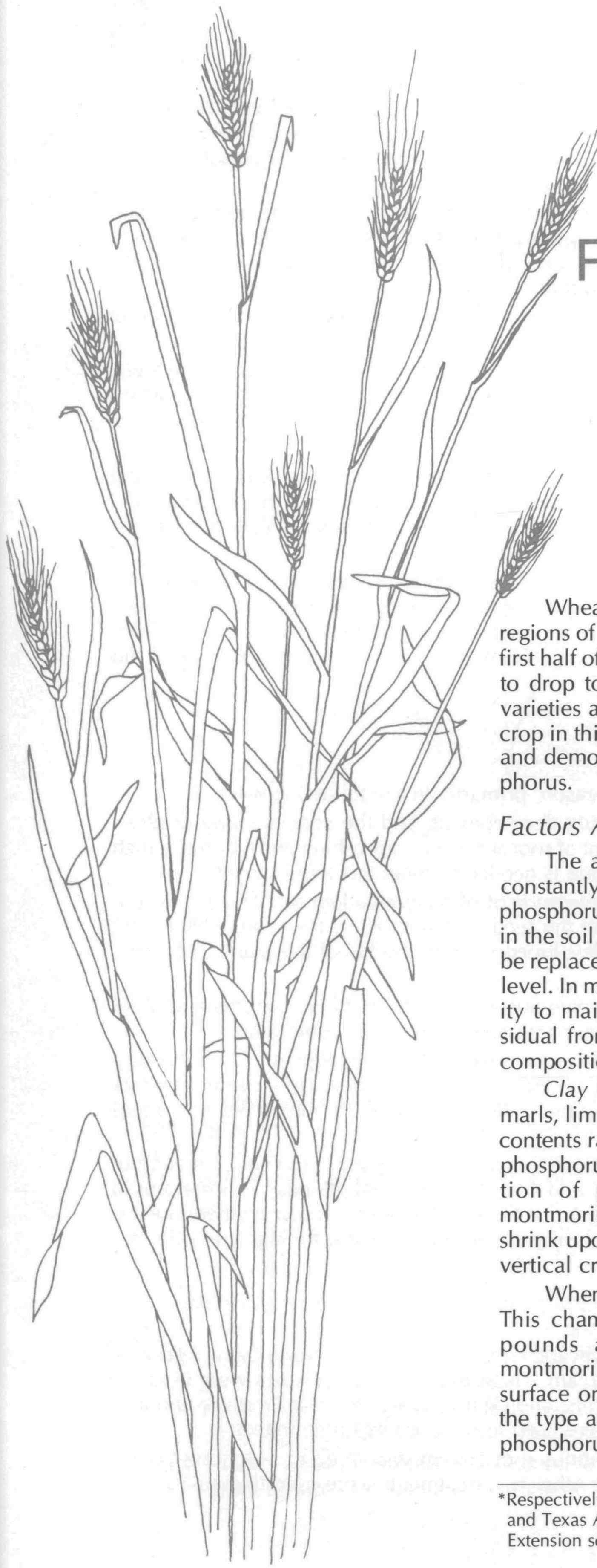

Phosphorus Fertilization for Wheat Production on Blackland and Grand Prairie Soils

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Wheat has been an important crop in the Blackland and Grand Prairie regions of North Central Texas since the land was first settled. But during the first half of this century, a decline in soil fertility caused average wheat yields to drop to about 10 bushels per acre. Now, with fertilization, improved varieties and other production practices, wheat is once again an important crop in this area. Improved fertilization has resulted from Extension research and demonstration efforts. One important factor has been the use of phosphorus.

Factors Affecting Phosphorus Availability

The availability of soil and fertilizer phosphorus is affected by many constantly changing factors. An equilibrium exists between slowly soluble phosphorus compounds in a soil and available phosphorus, or that dissolved in the soil water. As plants absorb some of the phosphorus in solution, it can be replaced from the slowly soluble compounds to maintain the equilibrium level. In most soils the equilibrium concentration is quite low, but the capacity to maintain the equilibrium is high because of native phosphorus, residual from past fertilization, recent fertilization release from organic decomposition and other sources.

Clay Content. Blackland and Grand Prairie soils were formed from marls, limy clays, sands, shales and chalks. They are alkaline soils with clay contents ranging from 15 to 70 percent. The amount and type of clay affect phosphorus availability and influence the rate, method and time of application of phosphorus fertilizers. Under these alkaline conditions montmorillonite clays have formed. Such clays swell upon wetting and shrink upon drying. Under extreme drying, common during summer, large vertical cracks form which allow the surface soil to mix with subsoils.

When fertilizer phosphorus is applied it is changed to soil phosphorus. This change generally involves the formation of new phosphorus compounds as precipitates on the surfaces of clay particles. Since montmorillonite clay particles are very small, there is a large amount of surface on which phosphorus compounds can be precipitated. Therefore, the type and amount of clay in soils affect the chemistry and availability of phosphorus.

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Lime, Free Calcium Carbonate or Caliche. Blackland and Grand Prairie soils usually contain "free" calcium carbonate which reacts with fertilizer phosphorus to form compounds that are less soluble and more slowly available than the original compounds in the fertilizer. These alkaline soils have pH values from 7.5 to 8.3; hence, slowly soluble calcium phosphates predominate. However, these phosphates provide a favorable soil reserve and help maintain the equilibrium level of phosphorus available to plants.

Soil Compaction and Reduced Aeration. Compaction reduces the amount of pore space between the clay and other soil particles. Plant roots need air, and any condition that restricts root growth to a small volume of soil reduces the total amount of phosphorus to which plant roots are exposed. Therefore, less phosphorus is available to plants in compacted or poorly aerated soils.

Moisture. Since water fills the soil pores, too much water reduces aeration and causes conditions unfavorable for root growth. A reduction in root activity affects the uptake of plant nutrients, including phosphorus. Microbial decomposition of plant residues releasing phosphorus is reduced in extremely wet or extremely dry soils. Soil moisture in the range needed for plant growth should not affect the availability of phosphorus.

Temperature. Results from numerous research studies show that temperature affects the availability of phosphorus and its use by plants in two important ways.

First, the microbial decomposition of organic matter which releases phosphorus increases with temperature. Since wheat is a "cool season" crop, less available phosphorus from organic matter is released during wheat growth than during growth of a "warm season" crop. This adds to the importance of phosphorus fertilization for wheat.

Second, the absorption and utilization of phosphorus is affected by temperature. A higher level of available phosphorus is needed as the temperature decreases, especially in the seedling root zone. Since the temperature is decreasing during the wheat planting season, best results have been obtained by applying fertilizer phosphorus with or near the seed.

Organic Matter. In Blackland and Grand Prairie soils, much of the reserve phosphorus is found in the organic matter. As plant residues and organic matter are decomposed by soil microorganisms, phosphorus is released and becomes available to plants. Research shows that soils high in organic matter can continue to supply available phosphorus over a period of years. With fertilization, the soil organic matter is higher in phosphorus, and this contributes to maintaining and improving crop yields.

How Phosphorus Affects Wheat

Phosphorus affects the growth of wheat throughout the season, primarily in the following ways.

Seedling Development. Phosphorus is essential for seedling development, and the concentration of phosphorus is high in seedling tissue. Because of the limited amount of root surface for absorbing phosphorus, a high concentration of available phosphorus in the seedling root zone is needed to meet this requirement.

Adventitious Roots. Phosphorus encourages the rapid development of adventitious roots. This is the root system that develops from the crown of the plant and not from the seed. The number of tillers the wheat plant produces is dependent on the number of adventitious roots developed early in the life of the plant. Therefore, phosphorus fertilization is needed at planting.

Fall Growth and Winter Hardiness. Wheat plants that receive adequate amounts of phosphorus and other nutrients make good fall growth, are winter hardy and can overcome adverse weather conditions.

Number of Tillers. The number of tillers is determined early in the growth of the wheat plant. Tillers develop from the root crown and determine the number of seed heads. If the plant does not develop an extensive root system by January, the number of tillers will be reduced. Phosphorus affects the plant's ability to develop a root system, which in turn affects tillering.

Maturity and Seed Production. Phosphorus hastens the maturity of small grain plants. The concentration of phosphorus is higher in the seed than in other parts of the plant, and there are more total pounds of phosphorus in the grain than in the straw. Phosphorus is translocated from vegetative tissue to the seed at maturity; therefore it is important to have an adequate supply of available phosphorus throughout the growth cycle for high grain yields.

Results of Phosphorus Studies

Field experiments were conducted in Cooke, Collin, Fannin and Grayson Counties in North Central Texas to determine the effect of phosphorus placement on the wheat plant. Three placement techniques were used: (1) drilled with the seed; (2) drilled half way between the seed drills; and (3) broadcast on the soil surface and then harrowed into the soil. Vegetative growth and grain yields were used to measure treatment effects.

Vegetative Growth. The fall development of the adventitious root system was three to five times greater where phosphorus was banded with the seed than where the other two treatments were used (Figure 1).

80 lbs. P_2O_5 with seed | 80 lbs. P_2O_5 broadcast

January | January

March | March

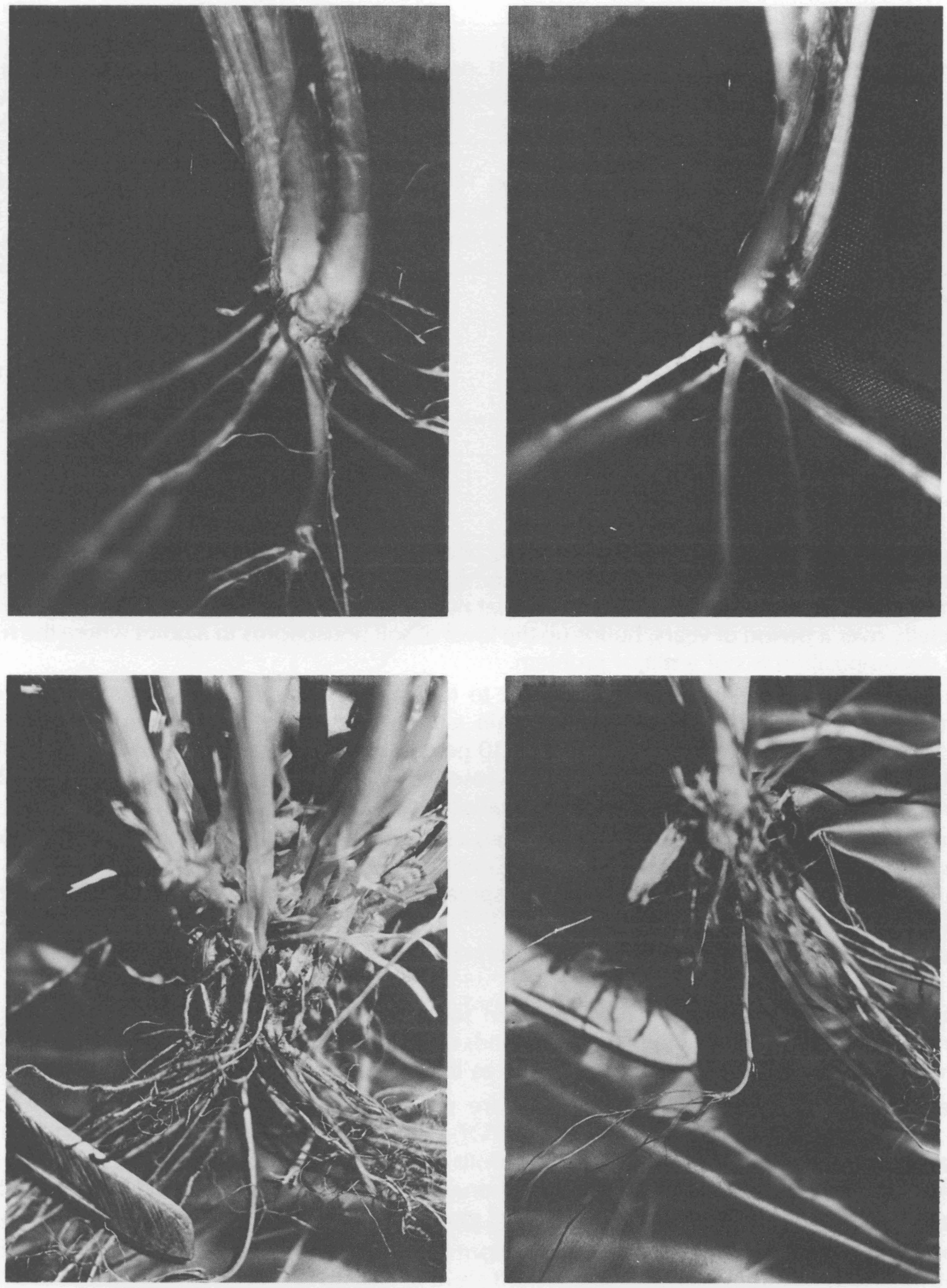

Fig. 1. Adventitious root system development as affected by phosphorus placement and time.

Phosphorus from the broadcast and banded half way between seed drill applications was not available soon enough to produce early winter pasture. The amount of phosphorus in leaves of plants that had received 80 pounds of phosphorus broadcast was 0.09 percent. In contrast, the amount of phosphorus in leaves of plants that received 80 pounds of phosphorus banded with the seed was 0.25 percent. Leaf samples were taken 50 days after planting. Plant growth observations indicate that the plant did not pick up enough phosphorus from the broadcast and banded between seed drill treatments to affect growth until 60 to 90 days after planting.

Demonstrations show that phosphorus placed with the seed produces two to three times as much winter pasture as the other methods of application on soils very low in available phosphorus. An example of the increase in fall growth is shown in Figure 2.

No phosphorus

40 lbs. P_2O_5 with seed at planting

Fig. 2. Effect of phosphorus on winter growth of wheat.

There is greater contrast in growth from phosphorus placed with the seed when the temperature is lower. This indicates that the wheat plant cannot convert sugar to starches as efficiently under low temperatures without readily available phosphorus.

If the seedling wheat plant is deficient in phosphorus, the potential number of tillers is reduced. Some farmers attempt to compensate for a lack of tillering due to phosphorus deficiency by increasing the seeding rate from 60 pounds to 120 pounds per acre. When phosphorus is placed in the seed furrow, 60 pounds of seed is adequate to insure development of enough tillers to make normal yields (Figure 3).

80 lbs. P_2O_5 broadcast

80 lbs. P_2O_5 with seed

Fig. 3. Effect of phosphorus placement on number of tillers.

Grain Yields. Yield is measured as vegetative growth for grazing and harvested grain. Both the rate and method of applying phosphorus affect these yields.

Rate and ratio studies were conducted at 48 locations to determine the rate of phosphorus needed for efficient wheat production. Phosphorus and nitrogen are both necessary. The ratio most often needed was a 1 to 1 ratio of nitrogen and phosphorus. When wheat followed grain sorghum or other crops that are heavy nitrogen users, a 2 to 1 ratio was best. Fall applied nitrogen was needed when wheat followed crops that use large amounts of nitrogen.

Phosphorus fertilization increased grain yields 91 percent of the time on Blackland soils and 79 percent of the time on Grand Prairie soils. The average increase was 12 pounds of grain for each pound of P_2O_5 up to 40 pounds per acre. The next 40 pounds of P_2O_5 increased yields at the 6-pound rate for each pound of applied P_2O_5. The relationship between applied phosphorus and increased grain production is shown in Figure 4.

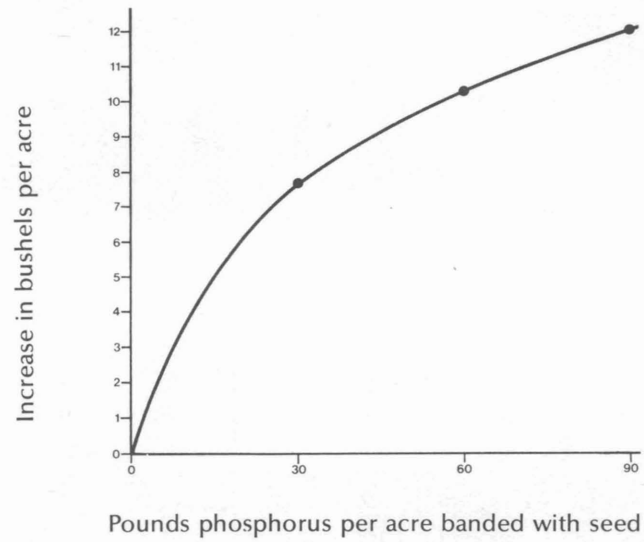

Fig. 4. Average increase in wheat yields from various rates of phosphorus at 48 locations during 17 years.

In summary, the most efficient utilization of phosphorus is achieved when it is banded with the seed. Banding between seed drills is the next most efficient method, and broadcasting on the soil and then harrowing is the least efficient. It has been possible to double or triple the yield of grain with efficient phosphorus and nitrogen management. The largest increases were obtained from soils low in available phosphorus (Table 1).

Supplying Available Phosphorus

Plants obtain phosphorus from several sources, primarily from plant residue and organic matter decomposition, mineral soil phosphorus and fertilization.

Plant Residue and Organic Matter. The phosphorus cycle is similar in some respects to the nitrogen cycle. For maximum release of plant nutrients, organic matter should decompose in the presence of oxygen and moisture. In a clay soil, therefore, decomposition should take place near the soil surface.

Conserving organic matter and adding fresh crop residues affect phosphate availability. Organic matter increases the availability of both native and fixed phosphorus. But phosphorus availability may drop temporarily during times of rapid microbial development. The phosphorus becomes bound in various organic compounds

*Table 1. Average Effect of Phosphorus Placement at Fourteen Locations on Yield of Wheat During a Four-Year Period**

County	Number Locations	No Fertilizer	How Phosphorus Was Applied: Drilled Between Seed Drills	Broadcast on Surface and Harrowed	Drilled With Seed
Collin	3	24.8	32.2	31.8	36.6
Cooke	4	16.6	32.1	30.8	33.5
Grayson	4	16.4	30.3	29.4	31.4
Fannin	3	12.8	27.4	26.9	28.9
Average		17.6	30.5	29.7	32.6
Increase Over no Fertilizer		-0-	12.9	12.1	15.0

*Yields in bushels per acre with uniform nitrogen rate

within the bodies of the microorganisms. Most of this phosphorus is released in time as inorganic phosphorus. Large amounts of crop residues low in phosphorus and high in carbon, such as sorghum and cotton stalks and straw, can temporarily immobilize soil phosphorus that normally would be available to plants. However, fertilization, especially over a period of years, builds up the level of soil phosphorus to a point where the reduction due to microbial decomposition is not a major problem.

Soil Phosphorus. Although plants respond well to fertilizer phosphorus applied with the seed, research shows that on soils low in phosphorus plants obtain a high proportion of their requirement from the soil phosphorus "pool." Studies also show that less than 30 percent of fertilizer phosphorus is used by the first crop. This means that residual phosphorus adds to the soil reserves or "pool" once regular fertilization begins. Most Blackland and Grand Prairie soils are very low in available phosphorus.

The rate at which fertilizer phosphorus is converted to soil phosphorus depends on several factors, including the surface contact between the soil and fertilizer. Confining the fertilizer to a band reduces this contact and slows down the rate of conversion, as compared to spreading the same amount of phosphorus throughout the soil.

Soil phosphorus does not move very much, which contributes to the effect of row applications on seedling growth.

Although the equilibrium concentration between soil phosphorus and available phosphorus is generally low, the total available during a growing season depends on the ability of a soil to maintain this equilibrium. Soil tests are aimed at measuring the phosphorus "pool" as the soil's capacity to supply available phosphorus.

Fertilizer Phosphorus. Phosphorus fertilizers are produced in two common chemical forms, orthophosphates (HPO_4^{-}, $H_2PO_4^{=}$) and polyphosphates ($PO_3^{\equiv}$). Plants absorb the orthophosphate form, and the polyphosphates are converted to this form in the soil. Both give essentially equal results as sources of phosphorus. Since research has shown little difference in phosphorus fertilizers, the rate, method and time of application are more important factors affecting early growth and grain yields from wheat.

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