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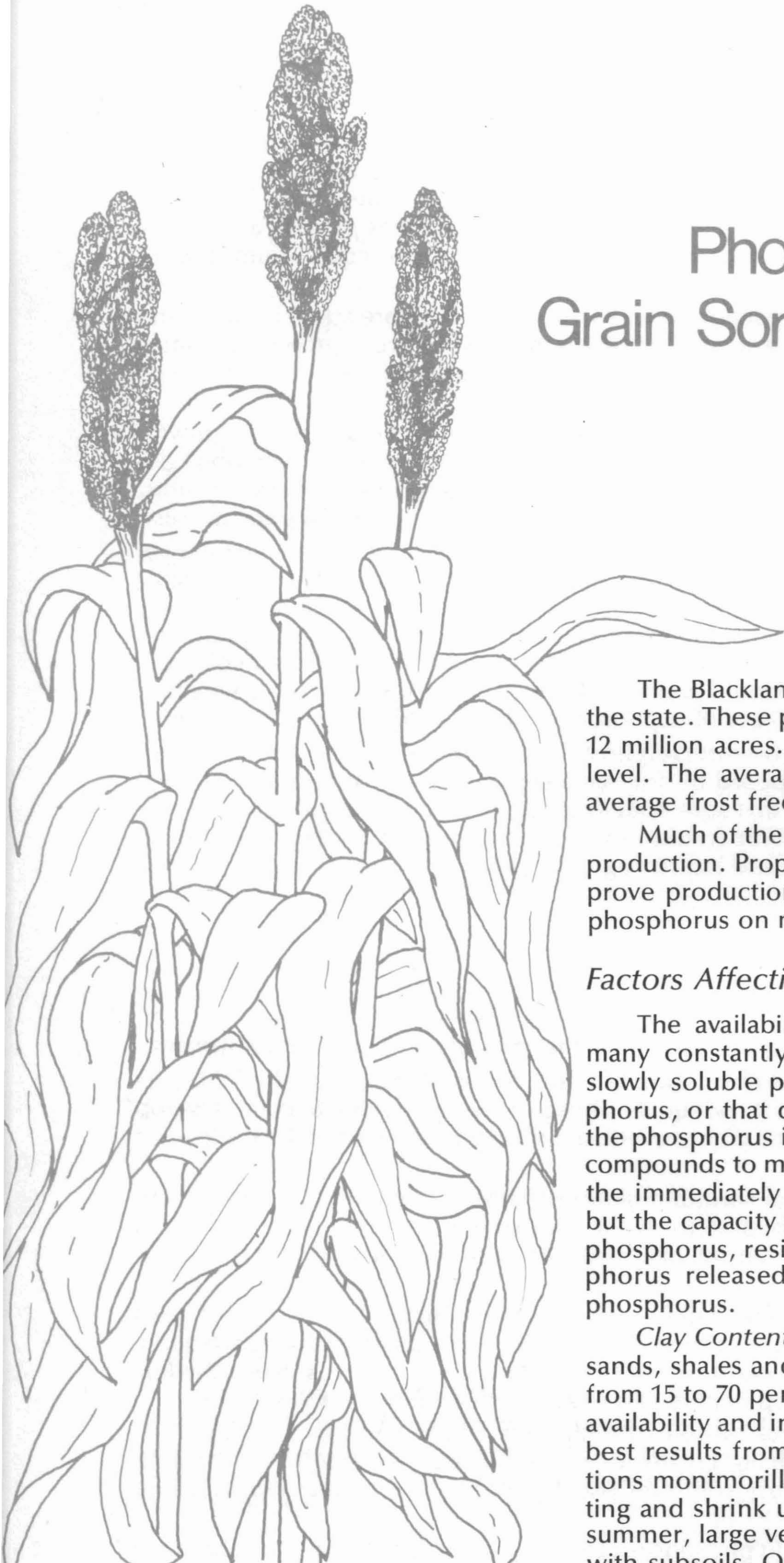


Phosphorus Fertilization for Grain Sorghum Production in the Texas Blacklands

*C. O. Spence and C. D. Welch**

The Blackland soils of Texas are of great economic importance to the state. These prairie soils are located in 52 counties and cover about 12 million acres. The elevation varies from 250-to 700 feet above sea level. The average annual rainfall varies from 30 to 45 inches. The average frost free period is from 230 to 280 days.

Much of the cultivated acreage in this area involves grain sorghum production. Proper phosphorus fertilization will enable farmers to improve production efficiency. This publication describes the effect of phosphorus on maturity, growth and yield of grain sorghum.

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 solution. In most soils the immediately available or equilibrium concentration is quite low, but the capacity to maintain the equilibrium is high because of native phosphorus, residual from past fertilization, recent fertilization, phosphorus released from organic decomposition and other forms of phosphorus.

Clay Content. Blackland soils were formed from marls, limy clays, sands, shales and chalks. They are alkaline 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 for best results from 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. Over a period of time this mixes with the phosphorus below the normal plow layer.

*Respectively, research and area Extension agronomist, Texas Agricultural Experiment Station and Texas Agricultural Extension Service, Sherman; and project leader in soil chemistry and Extension soil chemist, The Texas A&M University System.

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, most Blackland soils can store large amounts of "reserve" phosphorus that is gradually converted to available forms.

Lime, Free Calcium Carbonate or Caliche. Blackland 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 as a precipitate on the clay surface, which helps maintain a favorable 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 restricts 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 the plant growth should not affect the availability of phosphorus.

Temperature. Results from various 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. Therefore, cold spring weather adversely affects the release of phosphorus for the seedling grain sorghum plant. Second, plant absorption and utilization is affected by temperature. A higher level of available phosphorus is needed in a cold soil, especially in the seedling root zone. Since early planted grain sorghum often is exposed to cold weather, best results have been obtained by applying fertilizer phosphorus in a band with the seed at planting.

Organic Matter. In Blackland 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.

Effects of Phosphorus on Grain Sorghum

Phosphorus affects all parts of the sorghum plant, as well as the maturity and grain development.

The Root System. Phosphorus encourages the development of the root system, especially root hairs (the nutrient absorbers) early in the life of the plant. Adequate phosphorus also helps the plant develop an extensive brace root system, which enables the plant to withstand storms and carry a heavy load of grain without lodging.

The Stalk and Leaf Area. The seed of the grain sorghum plant contains only enough phosphorus to nourish the plant until it can develop a small root system. If the root system cannot pick up dissolved phosphorus the seedling will be stunted, and under adverse weather conditions it may turn purple or reddish purple.

Generally, the more leaf area a plant has the more dry weight it will produce. There is a great need for phosphorus early in the season when leaves are formed. The leaf area of a plant receiving adequate phosphorus will be greater than the leaf area of a plant receiving inadequate phosphorus. Since the leaf area manufactures food for the plant, leaf development is essential for maximum grain yields.

Maturity and Grain Development. Phosphorus hastens the maturity of the plant by enabling it to grow at a rapid and efficient rate. Rainfall is usually greater over the Blacklands early in the growing season. This early, rapid development enables the sorghum plant to utilize the natural rainfall more efficiently.

The seed of the grain sorghum plant is richer in phosphorus than any other part of the plant, because phosphorus is translocated from the other parts to the seed as the plants mature. At harvest, there are more pounds of phosphorus in the grain than in the remainder of the plant. Consequently, a good supply of available phosphorus is necessary for high grain yields.

Results of Phosphorus Studies

Numerous studies indicate that phosphorus should be placed with the seed or in bands. This reduces the amount of contact between the fertilizer and soil particles, and slows the rate of conversion to soil phosphorus. In recent tests, two techniques of phosphorus placement were studied. Phosphorus was placed in the seed furrow with the seed and banded 4 inches to the side and an inch below the seed. Effects on plant vigor as well as on grain formation were measured.

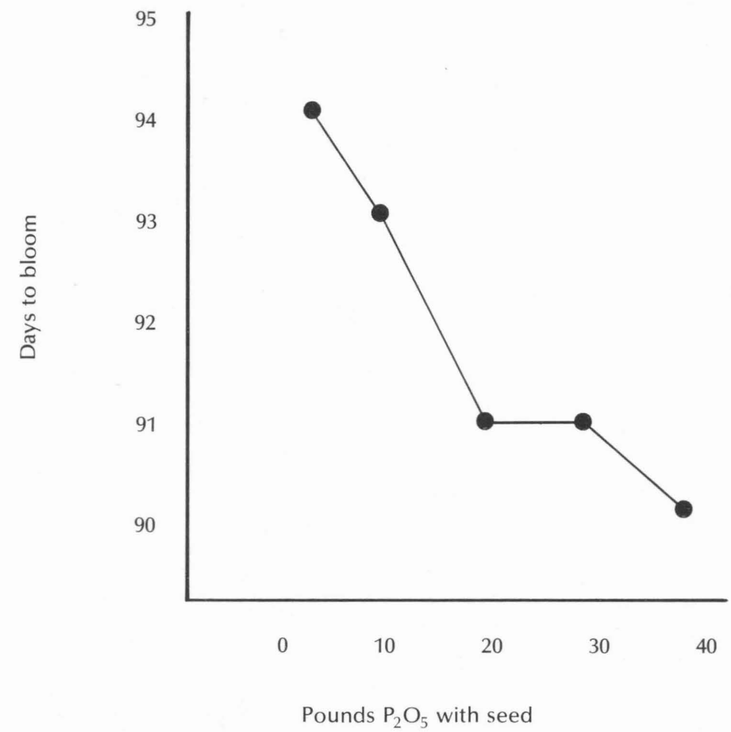
Seedling Vigor and Maturity. Phosphorus placed with the seed gave the seedling more vigor (Figure 1) and hastened maturity (Figure 2). This faster growth during the seedling stage made it possible to cultivate earlier, with better mechanical weed control. At nine locations, the average days to bloom was 90 for plots where phosphorus was placed with the seed. Where phosphorus was placed 4 inches to the side and 1 inch below the seed the average days to bloom was 94.

Fig. 1. Effect of phosphorus on seedling vigor.

60 lbs. P_2O_5 with seed at planting

No P_2O_5 with seed at planting

*Fig. 2. Effect of phosphorus applied with the seed on maturity of grain sorghum (average of nine Blackland locations).**



*All plots received a total of 60 pounds of P_2O_5. Varying amounts were applied with the seed so that the effect of placement could be measured.

Grain Yield. Phosphorus affects not only the development of the grain sorghum plant from seedling to bloom, but also the final yield of grain. In an effort to find out how much additional phosphorus the grain sorghum plant needed, rate of application studies were conducted at 34 locations in Blackland soils in North Central Texas. The average increase from 40 pounds of phosphorus (P_2O_5) was 847 pounds of grain per acre (Figure 3). The average increase from 80 pounds of phosphorus was 1006 pounds of grain per acre.

Phosphorus and Nitrogen Relationships. At 42 locations in the Blacklands, applied phosphorus increased yields 95 percent of the time and nitrogen increased yields 90 percent of the time. In rate and ratio studies the 1:1 ratio of nitrogen to phosphorus was the ratio most often needed. Rates in excess of 80-80-0 seldom increased grain yields. On a few soils that were very deficient in nitrogen the 2:1 ratio gave the greatest yield increase. Rates of nitrogen higher than 80 pounds per acre seldom increased grain yields. The 120-pound rate gave an average yield increase of only 5 pounds of grain over the 80-pound rate. The 160-pound rate averaged 15 pounds less grain per acre than the 80-pound nitrogen rate.

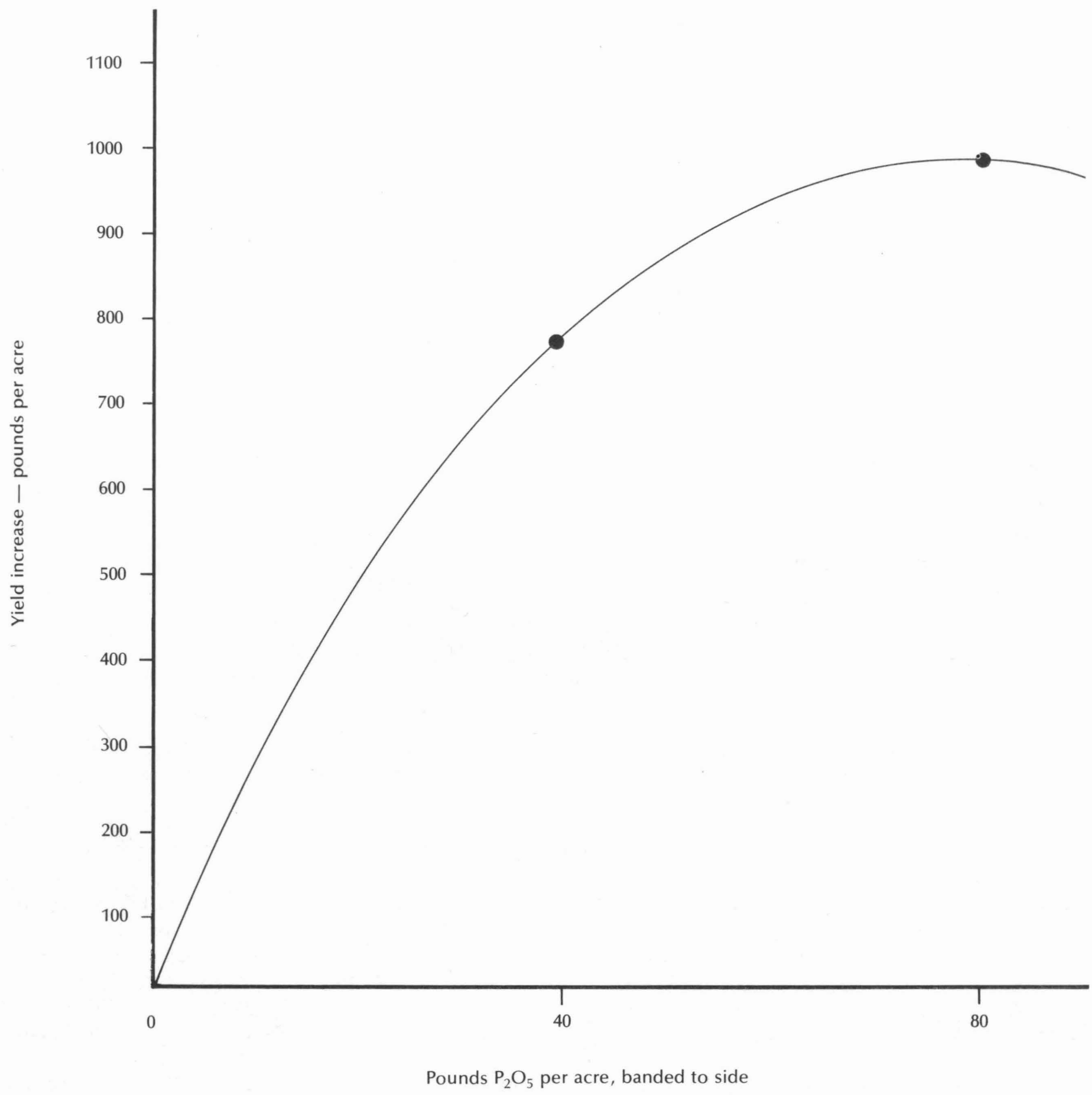
Crop rotations have a pronounced effect on the amount of additional nitrogen needed to produce a good yield of grain sorghum. More nitrogen is needed when grain sorghum is planted continuously, or when it follows crops that remove large quantities of nitrogen, such as sorghum silage or grass hay crops.

Supplying Available Phosphorus

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

Plant Residue and Organic Matter. 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.

Fig. 3. Average increase in yield of grain sorghum from phosphorus applications at 34 locations, North Texas Blacklands.



Conserving organic matter and adding fresh crop residues affect phosphorus availability. Organic matter decomposition increases the availability of both organic and mineral phosphorus. But phosphorus availability may drop temporarily during periods of rapid microbial activity, because the phosphorus becomes bound in various organic compounds within the bodies of the microorganisms. However, most of this phosphorus is released when the microbial tissue is decomposed. Therefore, adding large amounts of crop residues low in phosphorus and high in carbon, such as sorghum stubble, cotton stalks and straw, can temporarily immobilize soil phosphorus that normally would be available to plants. 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 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 after application, even though applied in a band. This means that residual phosphorus adds to the soil "pool" once regular fertilization begins. Most Blackland soils are very low in available phosphorus before cropping and fertilization begin.

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

Although the equilibrium concentration between soil phosphorus and dissolved or available phosphorus is generally low, the total amount released during a growing season depends on the capacity of a soil to maintain this equilibrium. Soil tests are aimed at including a portion of 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 ($PO_3^{\equiv}$). Since plants absorb the orthophosphate form, the polyphosphates must be converted to this form in the soil in order to be available to plants. Both give about equal results as sources of fertilizer phosphorus. Since the research has shown little difference in sources of phosphorus fertilizers, the rate, method and time of application are more important factors affecting early growth and yield of grain sorghum.

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