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Effect of phosphorus fertilizer distribution in the band on grain yield and P uptake of winter wheat and corn

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EFFECT OF PHOSPHORUS FERTILIZER DISTRIBUTION IN THE BAND ON GRAIN YIELD AND P UPTAKE OF WINTER WHEAT AND CORN

by

Bahman Eghball

A DISSERTATION

Presented to the Faculty of
the Graduate College in the University of Nebraska
in Partial Fulfillment of Requirements
For the Degree of Doctor of Philosophy

Major: Agronomy

Under the supervision of Dr. Donald H. Sander

Lincoln, Nebraska

September, 1987

TITLE

Effect of Phosphorus Fertilizer Distribution in the Band on Grain Yield and P Uptake of Winter Wheat and Corn

BY

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EFFECT OF P FERTILIZER DISTRIBUTION IN THE BAND ON GRAIN YIELD AND P UPTAKE OF WINTER WHEAT AND CORN

Bahman Eghball, Ph.D.

University of Nebraska, 1987

Advisor: Dr. Donald H. Sander

Phosphorus fertilizer distribution in the band is affected by band spacing, P application rate, and fertilizer P particle size. Twelve experiments were conducted over four years (1983-1986) to evaluate the effect of different factors influencing P fertilizer distribution in the band on grain yield and P uptake. From 1983 to 1985, five field experiments were conducted to determine the effect of P fertilizer particle size on grain yield and P uptake of winter wheat (Triticum aestivum, L.); in 1983, 1984 and 1986 four field experiments were conducted to determine the effect of band spacing of dual-placed N and P fertilizers on grain yield and P uptake of corn (Zea mays, L.); a "Field Pot" experiment was conducted in 1984 and 1985 to evaluate the effect of P fertilizer distance and distribution in the band on corn P uptake and dry matter production; and in 1986, effect of band spacing , P application rate, delivery tube size and traveling speed during application with a standard squeeze pump was evaluated on distribution of P fertilizer solution in the applied band.

The results indicate that phosphorus fertilizer particle size significantly affected grain yield and P uptake of winter wheat. Optimum particle size was about 0.025 mg which is much smaller than P fertilizer particle sizes farmers normally use (about 20 mg). Great surface area of applied P fertilizer at particle sizes smaller than optimum, and also noncontinuous distribution of large particles in the applied band

limited the efficiency of these particle sizes. Band spacing of dual-placed N and P fertilizers affected utilization of both nutrients. Effect of band spacing on N and P effectiveness were opposite in that applied P was more effective while N was less effective as the band spacing decreased. Distance that P fertilizer was applied from plants was important only at early stages of growth. Phosphorus uptake increased as spacing between injection points in the applied band increased. This was because as injection point spacing increased, the P target size (two dimensional surface of P affected soil exposed to the root system) increased, resulting in greater root-fertilizer contact. It was also found that P fertilizer solution is distributed as droplets in the band at low P application rates and narrow band spacings. Distance between droplets reduced probability of root-P fertilizer contact and decreased P fertilizer effectiveness.

While many factors influence P fertilizer efficiency, results indicate that P fertilizer distribution is a significant factor affecting efficiency in that it influences the probability of root-fertilizer contact.

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ABSTRACT

Five field experiments were conducted over three years (1983-85) to evaluate the effect of P fertilizer particle size on winter wheat (*Triticum aestivum* L.) yield and P uptake. In 1983, an introductory experiment indicated that P fertilizer particle size could greatly affect P fertilizer efficiency. Studies in 1984 and 1985 confirmed these observations. In these studies ammonium polyphosphate (11-24-0, N-P-K) at five particles of 0.0002, 0.0009, 0.025, 0.93 and 22 mg were applied at P rates of 8.4, 16.8 and 25.2 kg P ha^{-1} on four different soils. Wheat grain yields were increased significantly by applied P on all four soils. However, grain yields were affected by P fertilizer particle size primarily on the two soils where yield increases from applied P were greatest. Maximum grain yield occurred at approximately the intermediate particle size studied (0.025 mg), although optimum particle size was dependent on P rate. As the P rate increased particle size became less of a factor influencing P fertilizer efficiency. The low effectiveness of particle sizes smaller than optimum probably resulted from increased soil-P fertilizer contact, while effectiveness of larger particles were reduced by lack of adequate root contact. Wheat grain yield at the 8.4 kg ha^{-1} P rate was actually 0.31 Mg ha^{-1} less for the 22 mg particle compared to the 0.025 mg particle on the two most P responsive soils. Calculations indicated that the 22 mg fertilizer particles had an average distance of 2.8 cm from one another in the band area, compared to 0.003 cm or a continuous band for the 0.025 mg particles. Phosphorus uptake and other yield components generally paralleled the results with grain yield. While optimum fertilizer size

probably ranges from 0.025 to 1 mg per particle, the optimum size in these experiments was less than the 20 mg particle size reported for farm fertilizers.

INTRODUCTION

Particle size of P fertilizer influences the utilization of applied P in two ways. First, it affects the distribution of fertilizer in soil which has been shown to be an important factor in effectiveness of applied P (1,17). Second, it determines the effective surface area and therefore the reactivity of P fertilizer with soil which affects availability (9). Increasing particle size of P fertilizer increases P concentration in the soil solution of the treated zone after the excess P has diffused away (4). The extent of movement from the application point is proportional to the rate of P application (12).

Distribution of fertilizer particles in the soil is directly related to the rate of application and influences the probability of roots encountering P fertilizer (2). Nonuniform distribution is important because presence of P in one zone and absence in another may affect root distribution, P uptake and total dry matter production (18). When P application is restricted to part of the soil volume, roots in the P treated soil may differ in growth rate and morphology from roots in untreated soil (1). Rate of root growth is much greater in fertilized than unfertilized soil because roots may stop growing in unfertilized soil after a short time (6). For greater effectiveness of applied P it is essential to place the P fertilizer where root-fertilizer contact is the highest.

Some research has been reported on the effect of particle size of phosphorus fertilizer of different water solubilities on plant growth (11,14,15,16). Because most presently used P fertilizers have high water solubility, distribution of applied P may be an important factor

affecting fertilizer effectiveness when banded. Eghball and Sander (7) showed that when band applied with a squeeze pump, the P fertilizer solution is placed as droplets of different sizes varying in distance from each other. Distance between droplets increases as application rates are reduced or band spacings become closer. The authors suggest that this may be a factor influencing the effectiveness of banded P at low application rates compared to broadcasting at the same rate.

Little research has been done on the effect of particle size on the distribution of applied P in the band or if particle size of applied P fertilizer affects crop yield and fertilizer P efficiency. The objective of this research was to determine the effect of P application rate and P fertilizer particle size on the yield and yield components of winter wheat (*Triticum aestivum* L.).

MATERIALS AND METHODS

Five experiments were conducted across Nebraska over a three year period (1983-85). An introductory experiment was conducted on a Crete sicl (Pachic Argiustoll) in eastern Nebraska in 1983 (Table 1). Phosphorus fertilizer as ammonium polyphosphate (11-24-0, N-P-K) was applied as particles weighing 2.56, 1.28, 0.64, 0.32 grams per particle and as a powder obtained by grinding the fertilizer particles. The fertilizer particles were arranged on an application belt and placed with the wheat seed in 30 cm rows at a rate of 16.8 kg P ha^{-1}. The calculated distance between particles in the applied band were 15.0, 30.0, 60.0 and 120.0 cm for 0.32, 0.64, 1.28 and 2.56 gram particles, respectively.

Experiments were established in western Nebraska at two locations in 1984 and 1985 on four different soil types (Table 1). In these experiments smaller particles were utilized because particles used in the 1983 experiments were too large. Phosphorus fertilizer (11-24-0) particles of 22, 0.93, 0.025, 0.0009 and 0.0002 mg, prepared by Tennessee Valley Authority, were applied at application rates of 8.4, 16.8 and 25.2 kg P ha^{-1}. Fertilizer P was placed directly with the wheat seed in 30 cm rows by means of an application belt. Particle weight for the first three sizes was determined by weighing and for the two smallest particles was calculated based on sieve opening and density of the fertilizer (1.75 Mg m^{-3}). Sieve opening was used to approximate an average particle diameter. Centurk winter wheat was seeded in 30 cm rows at a rate of 50 kg ha^{-1} with a standard hoe drill in all years.

A randomized complete block experimental design with five fertilizer P particle sizes and four replications was used in 1983. In 1984 and 1985, a randomized complete block design with five replications was