Phosphorus fertilization and tillage effect on dinitrogen fixation in soybeans

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Summary  Tillage has been shown to affect the uptake of phosphorus (P) and yield of soybeans, [Glycine max (L.) Merr.], but there is little information concerning the effects of P fertilization on nitrogen (N₂) fixation in soybeans under no-tillage. Two field experiments were conducted in 1980 and 1981 to determine the effects of soil P on N₂ fixation under no-tillage, and to study the interaction of P fertilization and tillage of N₂ fixation, nutrient uptake, and yield of soybeans. In Exp. I, P was applied in 1977 at five rates up to 384 kg P ha⁻¹ and the effects of residual soil P were evaluated in 1980 and 1981 under no-tillage management. Nitrogen fixation rates, as measured by acetylene reduction assay, were significantly affected by soil P in Exp. I, but the assay proved to be a poor technique for estimating total plant N in these tests. Acetylene reduction rates and plant P increased rapidly as soil P increased from 2 to 20 mg kg⁻¹, with little additional increase above 20 mg P kg⁻¹.

In Exp. II, rates (0, 32, 64, and 128 kg P ha⁻¹) and time (fall, spring and fall plus spring) of P application were compared under conventional tillage and no tillage. However, plant P increased with increasing levels of applied P. Applied P had no affect on acetylene reduction rates but rates were greater for no-tillage than conventional tillage at the V9 and R5 stages of growth in 1981. Plant uptake of P was more efficient under no-tillage than under conventional tillage in 1980 and 1981. Application of 64 kg P ha⁻¹ under no-tillage resulted in equivalent plant P levels as the 128 kg P ha⁻¹ applied under conventional tillage.

Introduction

No-tillage management, which is often used in the Southeast with double-cropped wheat (Triticum aestivum L. em. Thell) and soybeans [Glycine max (L.) Merr.], may affect nitrogen (N₂) fixation in soybeans through changes in root morphology, accumulation patterns of soil nutrients, and improved soil moisture relationships. Kang and Yunasa and Maurya and Lal reported greater root densities with no-tillage than with conventional tillage in the upper few centimeters of soil. Phosphorus accumulates in the soil surface layer with no-tillage and Maurya and Lal reported greater root densities with no-tillage than with conventional tillage in the upper few centimeters of soil. Phosphorus accumulates in the soil surface layer with no-tillage and Maurya and Lal reported greater root densities with no-tillage than with conventional tillage in the upper few centimeters of soil. Phosphorus accumulates in the soil surface layer with no-tillage and Maurya and Lal reported greater root densities with no-tillage than with conventional tillage in the upper few centimeters of soil. Phosphorus accumulates in the soil surface layer with no-tillage and Maurya and Lal reported greater root densities with no-tillage than with conventional tillage in the upper few centimeters of soil. Phosphorus accumulates in the soil surface layer with no-tillage and Maurya and Lal reported greater root densities with no-tillage than with conventional tillage in the upper few centimeters of soil. Phosphorus accumulates in the soil surface layer with no-tillage and Maurya and Lal reported greater root densities with no-tillage than with conventional tillage in the upper few centimeters of soil. Phosphorus accumulates in the soil surface layer with no-tillage and Maurya and Lal reported greater root densities with no-tillage than with conventional tillage in the upper few centimeters of soil. Phosphorus accumulates in the soil surface layer with no-tillage and Maurya and Lal. The combination of greater root growth and P concentration in the soil surface can lead to greater P uptake under no-tillage as compared to conventional tillage.
Greater P uptake under no-tillage may affect N₂ fixation in soybeans because N₂ fixing nodules are a sink for fertilizer P. Phosphorus fertilization has been shown to increase nodulation and N₂ fixation in soybeans. Roy and Mishra reported an increase in grain yield, number of nodules, and nodule weight with P fertilization up to 39 kg ha⁻¹, but they noted a decrease with higher rates of applied P. DeMooy and Pesek observed a curvilinear effect of P on number, weight, and leghemoglobin content of nodules with maximum nodulation occurring at 200 to 250 mg P kg⁻¹. They concluded that P fertility plays a dominant role in optimizing nodulation of soybeans. Demooy et al. suggested a two-fold effect of P: a smaller direct effect on the host plant, and a larger indirect effect related to the high P requirement of nodule bacteria.

Here we describe two field studies determining the effects of residual soil P on N₂ fixation and yield of soybeans under no-tillage, and elucidating the interaction of P fertilization and tillage on N₂ fixation, nutrient uptake, and yield of soybeans.

Materials and methods

Two field experiments were conducted in the Piedmont region of central Georgia on a Cecil sandy loam soil (clayey, kaolinitic, thermic Typic Hapludults). Cecil soils are low in organic matter and high in Fe and Al oxides, resulting in a high P fixing capacity. Prior to the initiation of double-cropped wheat and soybeans in 1977, the experimental sites had been in continuous fescue for more than five years. Soybeans (var. Gay Soc) were planted with a fluted coulter, no-till planter in June of 1980 and 1981. Seeding rates were approximately 250,000 seeds ha⁻¹ in 66-cm rows. Both experiments were irrigated soon after planting to ensure plant emergence and establishment of an adequate stand. Supplemental irrigation was used during the growing season to ensure adequate plant growth.

Soil samples (10 cores per plot) were taken from the surface 15-cm prior to planting soybeans each year. Soil samples were air dried, crushed, and analyzed for P, K, Ca, Mg, Zn, Mn, and Cu by routine laboratory procedures following extraction with 0.05 N HCl and 0.025 N H₂SO₄. Soil pH was determined using a standard glass electrode in a 1:1 soil:water solution. Analyses for all elements except P were determined by atomic absorption or emission spectrophotometry, while P was determined colorimetrically. Soybean yields were determined by combine harvesting 5.2 m of the center two rows of each plot.

For Experiment I, P treatments were a one-time application of 0, 64, 128, 256, and 384 kg P ha⁻¹ in 1977. Nitrogen treatments applied to the wheat were 0, 22, 45, 67 and 90 kg ha⁻¹. Two additional treatments were included in each replication so that residual soil P and annually applied P could be compared. These annual treatments initiated in 1977 were surface applied by hand and consisted of: (A) 32 kg P ha⁻¹ applied each spring and 32 kg P ha⁻¹ applied each fall; and (B) 64 kg P ha⁻¹ applied in the fall only. Treatment arrangement was a 5 x 5 factorial in a randomized complete block with four replications and individual plot size was 6.1 x 6.1 m. Annual P fertilization treatments were based on initial soil P levels (6 kg P ha⁻¹) following recommendations from the Georgia Soil Testing and Plant Analysis Laboratory.

Treatments for Experiment II were also initiated in 1977. These treatments consisted of times P application of (fall only, spring only, and fall plus spring); method of application (incorporated and unincorporated); and rates of P (as triple superphosphate) at 0, 1/2, 1, and 2 times that recommended on the basis of the soil test. The recommended rate for fall plus spring applications (annual applications) was the amount recommended for wheat plus the amount recommended for