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High Phosphorus Applications Influence Soil-available Potassium and Kentucky Bluegrass Copper Content

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Abstract. **The objectives of this study were to determine the effects of high P applications on 'Baron',Kentucky bluegrass *(Poa pratensis* L.) turf quality, chlorophyll content, soil test levels of P and K, and foliar nutrient concentration. In this 5-year field study, P was applied at 0,22,43,86,172, or 258 kg·ha^{-1}·year^{-1} using triple superphosphate (210 g P/kg) in single-applications in May. Phosphorus applications did not affect overall yearly quality, chlorophyll content, or soil pH, but increased available soil P and reduced available soil K and Cu concentration in clippings.**

Turfgrass establishment requires adequate amounts of P for root growth and other developmental processes (Goss, 198 1). Watschke et al. (1977) showed that P near the soil surface is needed for optimum establishment. However, Powell (1977) demonstrated that continued growth depends on P uptake from the underlying soil by newly produced roots that are capable of exploring new soil volume. Phosphorus use by Kentucky bluegrass is high compared with that by other turfgrasses (Beard, 1973). Turner and Waddington (1982) reported that on soils with <30 mg P/kg, establishment was improved with P applications, but not on soils with 78 mg P/kg. Kentucky bluegrass can grow on soils having P levels as high as 1700 kg·ha^{-1} with few visible detrimental effects (Juska et al., 1965). The effects of high soil P levels on the availability of other nutrients in the soil and their uptake by grass plants is unclear.

Soil mobility of P is limited. The orthophosphate ion is readily adsorbed on silicate clays, such as kaolinite, and reacts with Al, Fe, and Mg to form insoluble compounds (Tisdale and Nelson, 1966), thus potentially reducing availability of these nutrients. Continued use of heavy P fertilization may also affect nutrient uptake. Hall and Miller (1974) showed that incorporating increasing P levels into the soil surface affected the foliar concentration of essential nutrients of Kentucky bluegrass in various linear and curvilinear relationships. Incorporating increasing amounts of P into the soil significantly decreased foliar N, K, Cu, and Zn, and increased P, Mg, and Na concentrations. No data were given concerning the effect of P on the soil availability of these nutrients.

Although it has been suggested that tissue analysis may be a more accurate indicator of fertilizer needs (Davis, 1969), fertilizer recommendations for turfgrasses are based primarily on soil tests (Turgeon, 1985). Soil from established turfgrass sites should be tested every 3 to 4 years for accurate fertilizer recommendations (Turgeon, 1985). If P is routinely applied without tissue or soil tests, overapplication may occur. The objectives of this study were to determine the effects of high P levels applied over an extended period on turfgrass quality, chlorophyll and nutrient concentration of the foliage, and soil availability of P and K.

The 5-year field experiment was conducted from 1983 to 1987 at the Iowa State Univ. Horticulture Research Station located ≈13 km north of Ames, Iowa. The design was a randomized complete block with six P treatments, including 22,43,86, 172, and 258 kg P/ha per year from triple superphosphate (210 g P/kg) applied in single applications during May. There were three replications. The 'Baron' Kentucky bluegrass had been established in Fall 1979 on a Nicollet (fine-loamy mixed mesic Aquic Hapludoll) soil, initially containing (in mg·kg^{-1}) 23,000 organic matter, 12 P, 47 K, and 950 Ca, with pH 7.1 and 69% base saturation. Plots were mowed as needed at 6.5 cm, with clippings returned, and irrigated to avoid stress. All the plots received 195 kg N/ha per year from urea (450 g N/kg) applied in four equal applications in April, June, September, and November. Potassium chloride (500 g K/kg) was applied uniformly at 49 kg K/ha per year in late summer during the first 4 years.

Turf quality was rated monthly throughout the growing season (April to November) beginning in July 1983 by using a scale where 9 = highest quality, 6 = acceptable, and 1 = lowest. Clipping samples were collected four times from July to Oct. 1983, 1984, and 1985, and six times from July to Sept. 1986. Data were collected on fresh weight, and chlorophyll analysis was performed as described by Wilkinson and Beard (1974). Clipping and soil samples were also taken once in Fall 1987 for foliar and soil analyses. Clippings were freeze-dried and sent to the Tissue Analysis Laboratory, Ohio Agricultural Research and Development Center, to be analyzed for N, P, K, Ca, Mg, Mn, Fe, B, Cu, Zn, Al, and Na. Nitrogen was determined by micro-Kjeldahl techniques, and all other foliar analyses were performed by a direct-reading emission spectrophotometer. Available soil P and K were analyzed by the Soil Testing Laboratory, Iowa State Univ., using Bray P_1 and ammonium acetate methods, respectively (Walsh, 1971). All data were subject to analysis of variance, and response models were chosen from Landsberg (1977) to regress clipping P and Cu concentrations and soil exchangeable P and K concentrations in response to P treatments. Model estimates were derived iteratively.

Phosphorus applications did not affect yearly quality means in any of the five years of the experiment. Of the 34 months when quality ratings were taken, significant differences occurred in only 5 months (Aug. 1983, Oct. and Nov. 1985, Apr. 1986, and May 1987). These differences were generally due to low quality ratings in control plots and improved quality ratings in all treated areas regardless of P level. Phosphorus applications did not affect chlorophyll content in any of the 14 sampling dates. Fresh clipping weight increased slightly in plots treated with the highest P level in 1983. No other clipping yield differences were present.

Phosphorus applications resulted in increased clipping P concentration up to 172 kg P/year. Control plots exhibited average clipping P (dry weight) concentrations of ≈ 3300 mg P/kg, whereas average clipping P concentrations were nearly 5000 mg·kg^{-1} at 172 kg P/year (Fig. 1). Kneebone and Pepper (1981) showed that clipping P concentration of perennial ryegrass *(Lolium perenne* L.) increased with increased P application, but the concentration was reduced substantially when increased N rates were applied. Smith et al. (1985) showed that the critical leaf P concentration for a 10% reduction in dry matter of perennial ryegrass was ≈ 2100 mg P/kg. Critical soil test P levels for grasses have not been clearly established. Waddington et al. (1978)

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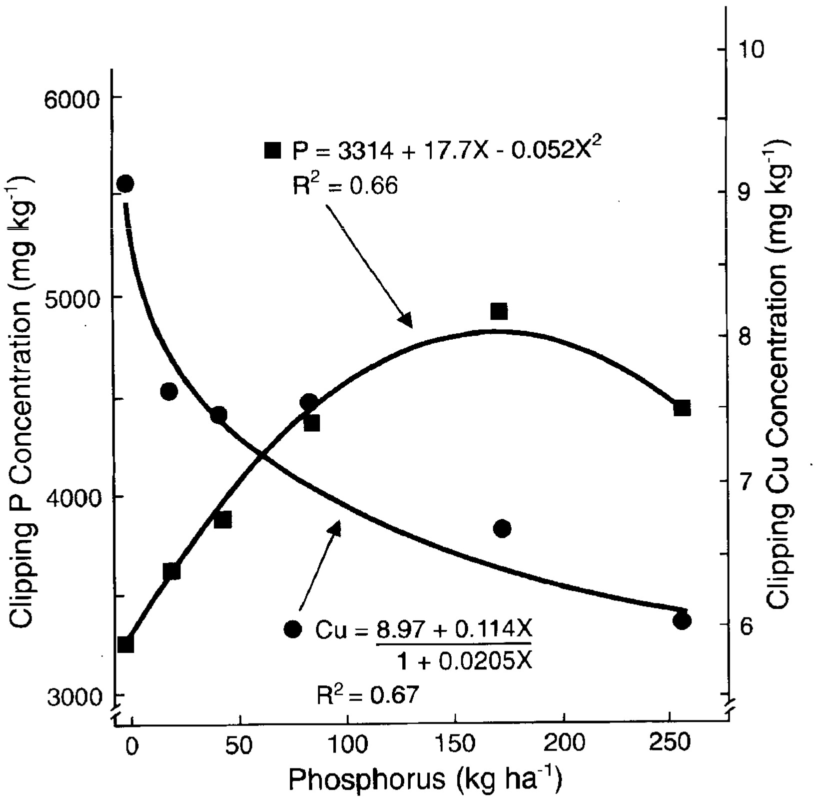

Fig. 1. Clipping P and Cu concentrations in Kentucky bluegrass in response to yearly P applications over 5 years. Each point represents the mean of three replications.

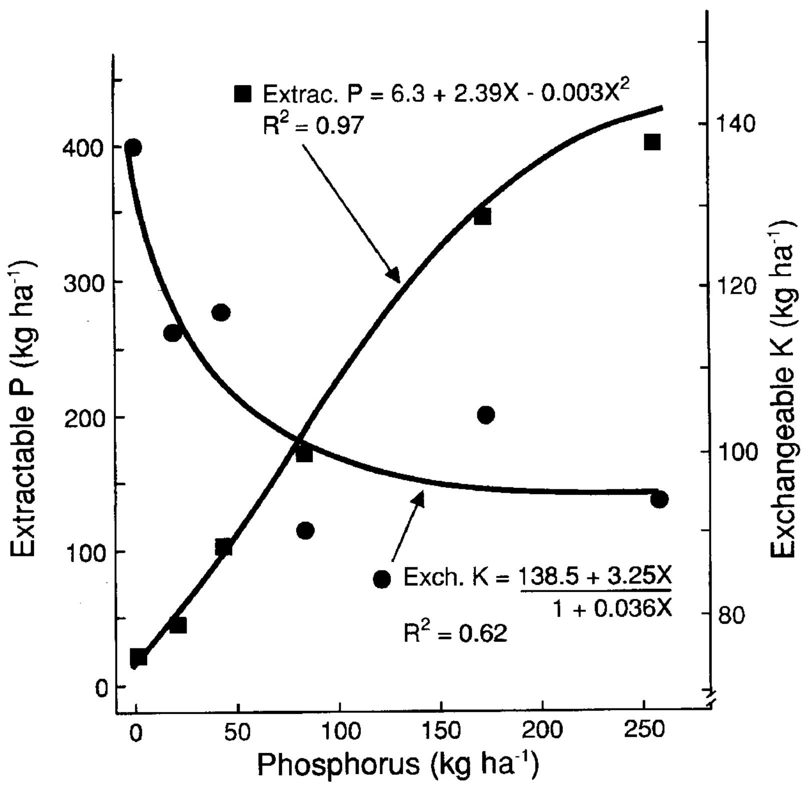

Fig. 2. Soil extractable P and Kin response to yearly P applications to Kentucky bluegrass over 5 years.

showed that tissue P concentration in 'Penncross' creeping bentgrass *(Agrostis palustris* Huds.) was not greatly affected by P applications when soil P was >24 mg·kg^{-1}, although Sartain and Dudeck (1982) reported that perennial ryegrass responded positively to P applications when the soil contained 82 mg P/kg.

As the clipping P concentration increased, the clipping Cu concentration decreased (Fig. 1). Hall and Miller (1974) also demonstrated a similar reduction in foliar Cu of Kentucky bluegrass when increased P levels were incorporated into the soil. Available soil Cu may have become limited because insoluble compounds formed when Cu reacted with the orthophosphate anion; a similar reaction occurs with Fe and Mg (Tisdale and Nelson, 1966). Copper concentrations found in the clippings, however, were still within the 5–10 mg·kg^{-1} range found in higher plants (Salisbury and Ross, 1978). No other nutrients analyzed from clippings were significantly affected by P treatment. These results differ from those of Hall and Miller (1974), who showed that concentrations of several other elements in tissue were reduced at high P levels. These discrepancies may be due to differences in soil type between the two studies, or to the longer duration of this study, which may have allowed the other elements to stabilize and equilibrate with high soil P levels.

Control plots (no added P) averaged ≈25 kg extractable P/ha. After 5 years of P applications, plots receiving 258 kg P/ha per year averaged nearly 400 kg extractable P/ha (Fig. 2). As soil extractable P increased, the concentration of exchangeable K decreased.

The reason for the strong relationship between applied P and exchangeable K in soil is uncertain. There was no relationship between applied P and tissue K concentration, and there was no large yield increase to account for the additional K use by the grass. This result indicates that high P concentrations may have some effect on the testing procedure for soil K. Phosphorus can bind with Kin minerals such as taranakite [$H_6K_3A1_5(PO_4)\cdot 8H_2O$], which could affect available Kin the plant and would likely affect chemically extracting K from the soil.

Overapplications of P from the continued use of P-containing fertilizers may increase the need for applied K. With respect to nutrient uptake, Adams (1980) concluded that there was little evidence to establish a P × K interaction in the plant other than the cation–anion balance. When a positive P × K interaction existed, Dibb and Thompson (1985) emphasized keeping applied P levels in balance with K for maximum yield. Christians et al. (1979) demonstrated the need to keep P in balance with both K and N for maximum quality and growth of Kentucky bluegrass and creeping bentgrass.

Our research shows that overapplication of P may lead to reduced Cu uptake and reduced available K needed for grass growth. Further studies are needed to investigate the effects of high P levels on soil test extractions and on the availability of other elements to turfgrasses.

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