SOIL FERTILITY TO AMELIORATE PLANT STRESS FROM ROOT FEEDING INSECTS

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ABSTRACT

Corn rootworms (*Diabrotica* spp.) are the most serious insect pests of maize (*Zea mays*) in the United States. Larval stages of these insects feed upon maize root systems causing plant lodging and grain yield reductions. Newly developed area-wide corn rootworm adult suppression methods, which reduce pesticide rates used against this pest complex by greater than 90 percent, do not completely eliminate rootworm populations. If maize producers had the option of using crop production practices that improve plant tolerance to rootworm larval feeding damage in conjunction with adult suppression methods, they could further reduce their reliance on soil insecticide applications. Because soil fertility can impact root system growth and development, it is possible that managed fertilizer applications could lessen the impact of rootworm larval feeding damage on root function. Research has shown that increased N fertilizer rates resulted in larger root system size and reduced lodging in rootworm damaged plants. Root systems were also larger under split-applied banded N (half applied at planting, half applied at cultivation) than under planting-time broadcast N. Lodging was reduced by split-applied banded N at low levels of infestation damage. These data suggest that N fertilizer management could play an important role in an integrated crop management strategy to improve plant tolerance to this important insect pest.

INTRODUCTION

The damage inflicted on maize root systems by the feeding activities of corn rootworm larvae can cause biological stress to the host plant. Reduced ability to absorb water and nutrients, reduced root hormone biosynthesis, and increased shoot lodging are important stresses that can cause grain yield reductions in root-damaged plants (Riedell, 1993). Because of the potential interactions between soil fertility and root system growth, it is possible that fertilizer management could reduce stress and improve plant tolerance to rootworm damage. If improved plant tolerance could consistently be achieved across environments, then perhaps fertilizer management could play an important role in an integrated crop management strategy to reduce grain yield loss to this insect pest. The objectives of this manuscript are to review pertinent information on rootworm larval damage and nutrient relations in maize, to present data which relates root system damage to plant physical and morphological characteristics, and to present preliminary data on fertilizer placement effects on plant tolerance to rootworm larval feeding damage.

ROOTWORM LARVAL FEEDING DAMAGE AND NUTRIENT RELATIONS IN MAIZE

Corn rootworm larvae, which feed exclusively upon roots of maize, pass through three

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subterranean developmental stages. First stage larvae are relatively small, but they perform an important role of establishment of the insect upon the host plant. Second and third stage larvae are progressively larger and more damaging to the root system than first stage larvae. Because one generation of insects occurs each year, the development of specific larval stages within the soil is relatively synchronized with the development of specific nodes of adventitious root axes (Branson, 1986). The fourth through sixth nodes of adventitious root axes sustain the most severe damage from corn rootworm larvae (Riedell, 1989). Larvae tunnel within the cortex and stele of the root axis. If extensive feeding damage occurs, the entire root axis will die. Under conditions of light to moderate feeding damage, many lateral "wound" roots will proliferate from the damaged root axis, leading to a foxtail appearance (Riedell and Kim, 1990).

Larval feeding activity typically begins when about 260 soil growing degree days are accumulated (early to mid June) and lasts until about 600 soil growing degree days (mid to late July)(Riedell and Evenson, 1993). A plot of nitrogen (N), phosphorus (P), or potassium (K) shoot concentration (Fig. 1, top) reveals that during the time of early larval feeding activity, both N and P

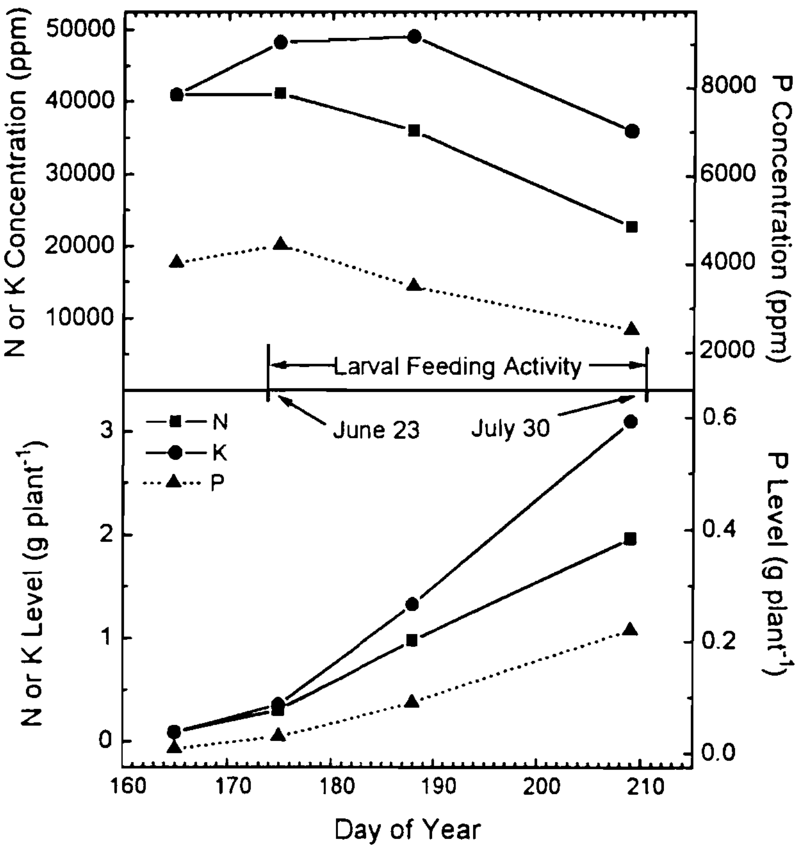

Fig. 1. Plots of N, P, and K concentrations and levels from maize plants grown under irrigated no-till field conditions at the Dakota Lakes Research Station near Pierre SD in 1993.

have reached their highest tissue concentration while K tissue concentration is still increasing. Plots of these data also reveal that the levels (on a gram per plant basis) of all three of these nutrients are accumulating in the shoots at near linear rates throughout the larval feeding damage period (Fig. 1, bottom). These graphs suggest that if root damage caused by rootworm feeding impairs root absorption of N, P or K, the concentration or level of these essential plant nutrients could be drastically less in shoots of rootworm damaged plants than in undamaged plants. This contention is partially supported by the work of Kahler et al. (1985) who found that K shoot tissue concentration was reduced by severe rootworm larval feeding damage. Spike and Tollefson (1989) provided indirect evidence that corn rootworm damaged plants were not as efficient in absorbing nitrogen from the soil as undamaged plants. This conclusion differs from that of Kahler et al. (1985) who found that shoot N concentration was not reduced in plants severely damaged by rootworm larvae. It appears that further work in the area of rootworm damage effects upon plant mineral nutrition is needed before a complete understanding of the interactions between soil fertility, root growth dynamics, nutrient absorption, and insect feeding damage is achieved.

SOIL FERTILITY FOR INCREASED PLANT TOLERANCE TO LARVAL DAMAGE

Vertical root pull resistance (Fig. 2) has been shown to be related to root systems size; the larger the size of the root system, the greater the force necessary to pull the root system from the ground (Ortman et al., 1968). Linear regression analysis of data using root damage rating as the

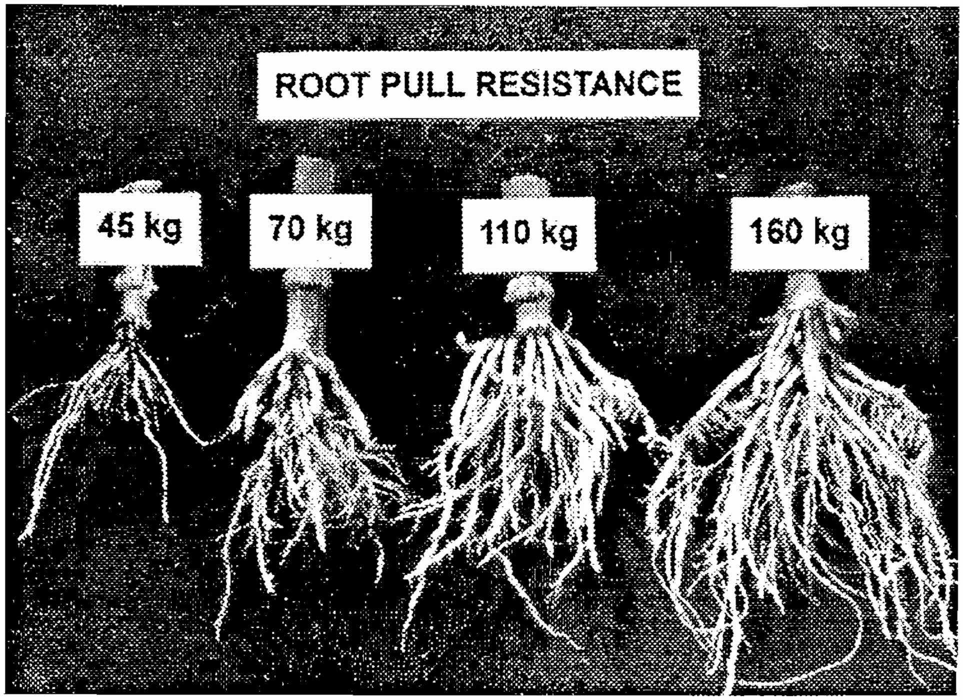

Fig. 2. Relationship between root system size and vertical root pull resistance in kg $plant^{-1}$. Plants were sampled when the majority of the rootworm larvae were in the non-feeding pupal stage of development by measuring the force necessary to pull the root systems from the ground using a fulcrum/milk scale apparatus as described in Ortman et al., 1968.

independent variable (Fig. 3) reveals a close association between root damage caused by corn rootworm larval feeding and root pull resistance, as well as between root damage and plant lodging. Greater root damage reduces root pull resistance and increases plant lodging. A close association between root pull resistance and lodging in rootworm damaged plants is present when root pull resistance is considered to be the independent variable (Fig. 4). Increased root system size leads to reduced lodging and higher yields in rootworm damaged plants. These observations support the idea that a large root system is the basis of plant tolerance to rootworm larval feeding damage (Branson, 1986).

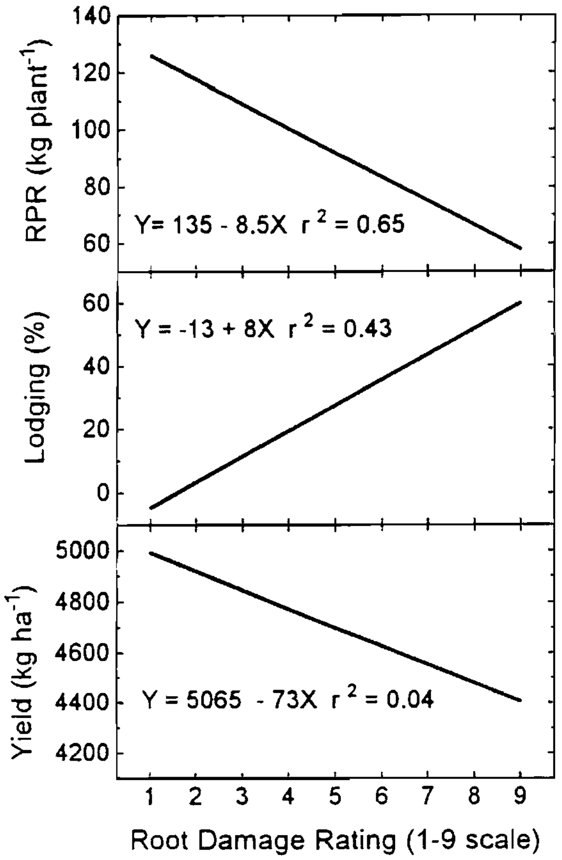

Fig. 3. Results of linear regression analysis of the effect of root damage rating on root pull resistance (top), percentage of plant lodging (middle), and grain yield (bottom). This data, obtained from Riedell and Evenson (1993), includes 3 levels of rootworm larval infestation, 3 levels of plant stand density, and 11 different plant genotypes.

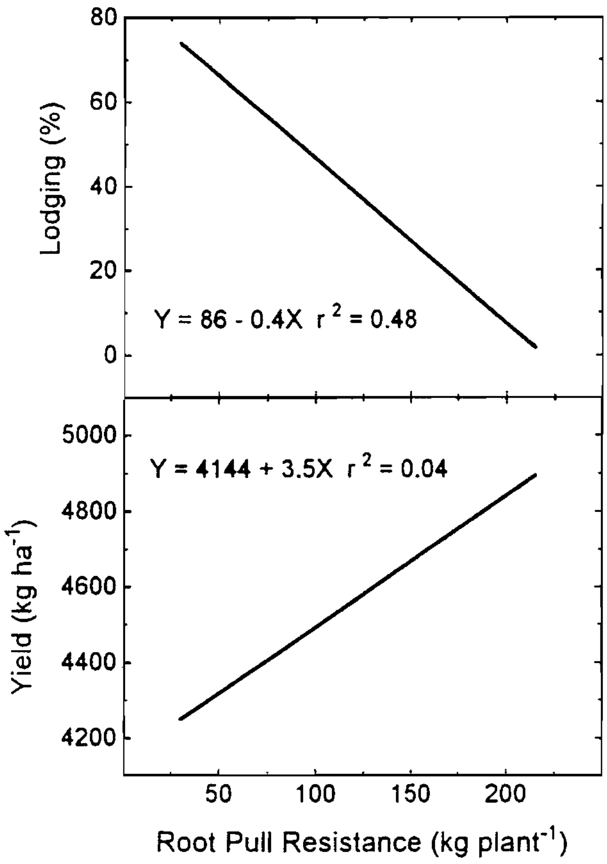

Fig. 4. Results of linear regression analysis of the effect of root pull resistance on plant lodging (top) and grain yield (bottom). Data set was the same as in Fig. 3. The PROC REG procedure in SAS (1988) was used in data analysis.

Kaspar et al. (1991) observed that maize root systems respond to zones of increased N fertility with increased root branching and greater numbers of small, higher order roots in the fertilized layers. The fact that increased N in specific zones of the soil can alter root system growth and morphology suggests that N fertilizer management could impact root system size which in turn could alter plant tolerance to rootworm larval feeding damage.

There are three aspects of N fertilizer application that could potentially impact root system size: N fertilizer rate, date of fertilizer application, and N fertilizer placement. Spike and Tollefson (1988) found that increasing N fertilizer rate (0, 168, 336 kg/ha urea applied before planting) increased the root system size (dry weight) and reduced lodging in rootworm damaged plants. In a study of split applications of N fertilizer (soil test recommended rates of broadcast liquid urea-ammonium nitrate applied at planting, or banded over-the-row liquid UAN half applied at planting and half applied at cultivation), Riedell et al. (1994) found that root systems were larger (increased root pull resistance) under banded N at the time of maximum rootworm damage than under broadcast N. Lodging was reduced by split-applied banded N at low levels of infestation damage. The reduced lodging seen in the fertilizer treatments from both of these studies was not accompanied, however, by reductions in yield loss in rootworm larval damaged plants.

Taken together, these results suggest that managed fertilizer application, coupled with the use of area-wide rootworm adult management protocols (Sutter and Lance, 1991) and large-rooted maize hybrids (Riedell and Evenson, 1993) would be a true step towards integrated pest management systems for limiting plant lodging and yield loss caused by a major maize insect pest.

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