occur and normal mowing procedures would remove infected leaves. The use of fungicides for diseases of this type could be substantially reduced or eliminated.

Initial studies with aminooxyacetic acid (AOA) have provided some positive results. AOA blocks the enzymatic conversion of S-adenosyl-L-methionine (SAM) to 1-aminocyclopropane-1-carboxylic acid (ACC) in the biosynthetic pathway of ethylene in higher plants. This action ultimately reduces the total ethylene produced. Leaves of inoculated plants showed elevated levels of endogenous ethylene at 24, 48, 72, and 96 hr after inoculation; peak endogenous ethylene production occurred at 48 hr (1000 u1 1^{-1}). Plants inoculated and treated with AOA (10^{-3}M) produced less endogenous ethylene at all sampling times than untreated inoculated plants. At 48 hr, the leaves of inoculated plants treated with AOA produced 642 μl l^{-1} of endogenous ethylene compared to 1000 μl l^{-1} produced by untreated inoculated plants.

Chlorophyll loss was initiated after peak endogenous ethylene production (48 hr) and became progressively more severe with time. Chlorophyll content of leaves of untreated inoculated plants was 57 percent of that in healthy control leaves at 96 hr after inoculation; chlorophyll content of leaves of AOA treated and inoculated plants was 81 percent. The decrease in endogenous ethylene in infected leaves of AOA treated plants clearly decreased the chlorophyll loss associated with the disease. No phytotoxic effects were observed to be associated with AOA.

These initial observations are encouraging and suggest that manipulation of symptom expression (yellowing) by leaves infected with *B. sorokiniana* may be feasible. Several additional substances that interfere with ethylene biosynthesis, or with the mode of action of ethylene, will be examined during the next year.

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Biological Control of Turf Pests: Isolation and Evaluation of Nematode and Bacterial Pathogens

White grubs are chronic and often serious problems for golf course and other turfgrass managers throughout the United States. In the Eastern States, the Japanese beetle alone is responsible for over $230 million in control and turf replacement costs. Turf managers are seeking alternatives to the conventional chemical insecticides now available for grub control due to concerns about effectiveness, groundwater contamination, chemical trespass, and adverse effects on nontarget organisms. The development of effective and reliable biological control agents will provide options for use in managing turf pests. Two groups of organisms, insect parasitic nematodes (microscopic worms) and bacteria, have shown promise in controlling a variety of insects. A team of federal and university researchers in Ohio, New Jersey, and California are searching for new isolates of nematodes and bacteria with increased effectiveness against white grubs in turf.

Initial efforts have been placed on the isolation of new strains of insect parasitic nematodes from golf courses and other turf areas. In New Jersey, nearly 300 sites across the state have been examined and more than 50 new isolates have been collected. Representatives from the two major genera of insect parasitic nematodes have been recovered. New strains of a nematode originally isolated from Japanese beetle larvae in the 1930's were found. Field tests demonstrated that new strains of two different species of nematodes were more effective than strains now used in commercial production, and were as effective in controlling Japanese beetle larvae as a chemical insecticide standard. Efforts in Ohio and California have resulted in the isolation of new strains of both genera of insect pathogenic nematodes from soil, as well as from natural field infections of white grubs. Strains from grubs may be adapted to these hosts and offer promise for controlling these pests.

Efforts to identify bacterial pathogens of white grubs have located the organism responsible for causing "amber disease" in New Zealand. These bacteria are commercially available there, but their strains have no effect on white grubs in the USA. We have isolated several bacteria from the Japanese beetle in Ohio and New Jersey, and from masked chafer larvae in California on media that is selective for the amber disease organisms. One isolate from California has been identified as similar to the New Zealand bacteria, thus indicating real promise for finding effective bacterial pathogens in the United States. Additional iso-

lates of both nematodes and bacteria will be obtained in the future, and the effectiveness of all isolates against white grubs will be established.

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Damaged Thresholds, Risk Assessment, and Environmentally Compatible Management Tactics for White Grub Pests of Turfgrass

The objectives of this project are to: 1) field test a pheromone-based risk assessment system for predicting white grub densities, 2) evaluate the compatibility of turfgrass insecticides with beneficial predators, and 3) establish damage thresholds for white grubs on cool-season turfgrasses.

For the first objective, an inexpensive trap system, which could be easily used by golf course superintendents, was developed and field tested. Female masked chafers produce a volatile sex pheromone that is highly attractive to night-flying males. In 1990, we placed sticky traps at 30 sites in the roughs surrounding three fairways at the Lexington Country Club, Lexington, KY. The traps were baited with 3 female-equivalents of the pheromone extract, and set out on the turf surface to capture beetles. We repeated this procedure on two nights, July 3 and July 9. In early August, we returned to the golf course and took 12 turf core samples at each site. Grubs were returned to the laboratory where they were identified and counted. We plotted and analyzed the data to determine if there was a predictive relationship between the trap captures of adults and subsequent grub populations.

While we had hoped for a strong correlation between the number of adult beetles caught and the subsequent grub density, no such relationship was evident in the golf course test. We could not predict the local grub population based on pheromone trap captures. Our efforts on this project will now be mainly directed at identifying the chemical sex pheromone. This would enable large quantities of synthetic pheromone to be produced at relatively low cost. The pheromone could be formulated in dispensers which discharge it slowly over a period of several weeks, making extended trapping more practical.

The second objective of the project is to determine the importance of predators in reducing populations of pest insects in turf, and to identify those turfgrass insecticides that are least disruptive to this process. Improper timing of insecticide applications, or use of certain insecticides that are particularly harsh on predators, could result in peak resurgences because of interference with natural predation on eggs and other life stages of pest species. Large plots (0.25 acre) of Kentucky bluegrass were treated in June 1991 with either carbaryl, isazofos, cyfluthrin, or left untreated. Impact of the insecticides on predators was monitored with pitfall traps for up to 10 weeks post-treatment. Eggs of the Japanese beetle and pupae of the fall armyworm were implanted into the treated plots at 1 and 3 weeks after treatment, and the incidence of natural predation that occurred in 48 hours was determined. Last fall, grub populations were sampled in treated and untreated plots to determine if the June treatments could indirectly affect grub populations by eliminating predators.

Preliminary counts suggest that all of the insecticides resulted in significant reductions in predator abundance. Their effects, however, were not equally severe, and analysis of the full data set is expected to reveal significant differences in impact on beneficial insects. Initial results document the high rate of predation in the control plots (more than 50%) and is the first experimental verification that predators are important in natural regulation. There were high rates of predation on fall armyworm pupae in all plots, including those treated with insecticides. Perhaps the most striking and significant result from these 1991 studies was the finding that fall grub populations were significantly higher in some pesticide treated plots than in untreated control plots.

The third objective is to quantify relationships between grub density, root damage, foliar growth, and aesthetic quality of different cool-season turfgrasses to establish damage thresholds for making management decisions. Interactions between grass species, grub species, and management tactics on the expression of grub feeding injury will be measured. Large, replicated plots of Kentucky bluegrass, creeping bentgrass, hard fescue, perennial ryegrass, and endophyte-infected and endophyte-free tall fescue were established in 1989. In spring 1991, we implanted 12 galvanized