Research Reports

European Chafer Grub Feeding on Warm-season and Cool-season Turfgrasses, Native Prairie Grasses, and Pennsylvania Sedge

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SUMMARY. Six grass species representing vegetative and seeded types of native, warm-season and cool-season grasses, and pennsylvania sedge (*Carex pennsylvanica*) were evaluated in the greenhouse for resistance to root-feeding grubs of european chafer (*Rhizotrogus majalis*). Potted bermudagrass (*Cynodon dactylon*), buffalograss (*Buchloe dactyloides*), zoysiagrass (*Zoysia japonica*), indiagrass (*Sorghastrum nutans*), little bluestem (*Schizachyrium scoparium*), tall fescue (*Festuca arundinacea*), and pennsylvania sedge grown in a greenhouse were infested at the root zone with 84 grubs per 0.1 m² or 182 grubs per 0.1 m². The effects on plant growth, root loss, survival, and weight gain of grubs were determined. Survival rates were similar for low and high grub densities. With comparable densities of grubs, root loss tended to be proportionately less in zoysiagrass and bermudagrass than in other species. European chafer grubs caused greater root loss at higher densities. Grub weight gain and percentage recovery decreased with increasing grub density, suggesting a food limitation even though root systems were not completely devoured. Bermudagrass root weight showed greater tolerance to european chafer grubs; another mechanism is likely involved for zoysiagrass. Variation in susceptibility of plant species to european chafer suggests that differences in the ability of the plants to withstand grub feeding damage may be amenable to improvement by plant selection and breeding.

European chafer has become a serious pest in the eastern United States since its introduction in 1942 (Tashiro, 1987). Because it is particularly abundant in nonirrigated settings, european chafer damage is often catastrophic, requiring turf replacement. In recent

years, european chafer has become the dominant white grub pest in several states (Vittum et al., 1999). The adult stage of european chafer

does not injure plants and is most active just after sunset. Beetles emerge between mid-June and early July depending on the latitude and spring weather conditions. Adults remain active for 2 to 4 weeks, when they mate and deposit eggs in the soil below the plant canopy. Grub larvae hatch from eggs in July or early August and immediately begin feeding on roots. They continue feeding on the roots of turfgrass, meadow grasses, nursery plants, and field crops throughout the late summer and fall (Smitley, 1995; Tashiro, 1987). Feeding ceases during winter months and resumes again in March and April; pupation begins in late May. The most severe root-pruning injury occurs after the larvae reach their third and final instar in September, and may result in large patches of dead plants that turn to bare soil in the center. Damage to lawns may be compounded when foraging skunks, raccoons, or crows turn over infested turf. It has been reported that 10 to 15 grubs per 0.1 m² in a high-maintenance turf, or 4 to 5 grubs per 0.1 m² in a low maintenance turf are sufficient to cause noticeable damage (Smitley, 1998).

The most effective insecticides can provide excellent control, but only when applied to young grubs, in advance of visible damage. Such a strategy may be prohibitively expensive for low-maintenance turf. One of the best alternatives to insecticides is to establish plants that are tolerant of grub damage or resistant to european chafer grub feeding. The development of such tolerant or resistant turfgrass cultivars is an important objective for turfgrass breeding programs. Breeding for insect resistance is impeded by the lack of adequate methods for screening germplasm (Reinert, 1982). Screening for resistance to european chafer in the field is difficult because the infestations of insects are unpredictable and unevenly distributed. Screening trials

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Units

Units To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.0929	ft ²	m ²	10.7639
25.4	inch(es)	mm	0.0394
28.3495	oz	g	0.0353
28,350	oz	mg	3.5274 × 10 ⁻⁵
(°F - 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

may be easier in a greenhouse using potted plants or in a laboratory using small dishes with turf plugs or excised roots.

Little is known about turf resistance to white grubs, and at this time there is not a single registered turfgrass cultivar for which grub resistance is claimed (Potter et al., 1992; Reinert, 1982). Johnson-Cicalese et al. (1989) suggested that turfgrasses selected with aggressive growth habits exhibited less damage by insects. The dense rhizomes and stolons of zoysiagrass inhibited southern masked chafer female movement and egg laying (Hiatt and Potter, 1982; Potter, 1982). Potter et al. (1992) concluded that variation in susceptibility of turfgrasses to root-feeding grubs is probably affected more by differences in tolerance to feeding damage than by variation in suitability as food. In support of this conclusion, tolerance of tall fescue to european chafer grubs was reported in a previous study (Bughrara et al., 2003).

To date, no information has been reported on feeding of warm-season grass roots specifically by european chafer. However, bermudagrass, zoysiagrass, buffalograss, tall fescue, and pennsylvania sedge are being grown more frequently. With the increased use of these grasses has come the awareness of the potential problems caused by the european chafer grub. The objective of this research is to investigate six representatives of these turf types to determine the degree to which they may include traits for tolerance or resistance to european chafer feeding.

Materials and methods

The six grass species and pennsylvania sedge used in this research include bermudagrass, zoysiagrass, 'MOBUF' buffalograss, indiagrass, little bluestem, pennsylvania sedge, and 'KY-31' tall fescue. During the last week of July 2000, 15 pots (100 mm diameter $\times$ 125 mm deep) of each plant species were established in a greenhouse at Michigan State University, East Lansing. Turf cores removed from field plots were soaked overnight and washed several times with cold water to remove adhering soil. Excess moisture was manually expressed from the plug sample before the initial weight was obtained.

After washing and weighing, plants were placed in five groups of three, in order of increasing root volume; one plant from each group was then randomly assigned to be the control in the low- and the high-density grub treatments.

The plant cores were planted in individual plastic pots (6 inches in diameter, 10 inches deep) filled with sterilized sandy loam field soil (pH 7.1). Five replications of the three grub infestation levels (control, low density, and high density) were arranged on greenhouse benches in a randomized complete block design (a total of 15 pots per grass species and 105 pots in the entire experiment). Plants were potted and established in the greenhouse between 27 July and 4 Aug. Greenhouse temperatures ranged from 20 °C to 30 °C, and natural light was supplemented with sodium vapor lamps to provide a photoperiod of 16 h. The potted plants were watered daily, and clipped and fertilized weekly to maintain plant vigor. The irrigation regime was continued, but clipping was ended after the plots were infested with grubs.

Second and third instar european chafer were dug from two separate field sites (Lansing Airport and Michigan State University campus) on Aug. 8–10 and were transported to the greenhouse in plastic crispers with moist premixed soil. Grubs were introduced into pots on 19 Aug., 2 weeks after the plants were established in pots. The grubs were then counted and weighed as a group before putting them in pots. Subsamples of the grubs were weighed before the groups were randomly distributed to pots. On 19 Aug., each pot in the low-density treatment received six grubs and each pot in the high-density treatment received 12 grubs (33 or 66 grubs per 0.1 m²). By mid-September, plants in the european chafer-infested pots still appeared healthy, therefore the number of larvae per pot was increased, and watering was decreased to create drought stress. On 21 Sept., three more grubs were added to each pot in the low-density larva treatment, and eight grubs per pot were added to the high-density treatment. For most of the experiment, the total number of grubs per pot for the low-density treatment was nine and was 20 for the high-density treatment, corre-

sponding to densities of 49 and 110 grubs per 0.1 m², respectively. On 20 Oct., three more grubs per pot were added to the low-density treatment, and six grubs per pot were added to the high-density treatment, bringing the total grubs introduced per pot for the low-density treatment to 12 and for the high-density treatment to 26 (corresponding to densities of 84 and 182 grubs per 0.1 m²) for the final 3 weeks of the experiment. Grubs were placed on the soil surface within each pot, and any that did not burrow into the soil within 1 h were replaced. At the conclusion of the experiment (6–18 Nov.), surviving grubs were counted and weighed, roots were separated from shoots at the soil line, and roots and foliage from each pot were washed, dried, and weighed.

DATA ANALYSIS. The data were analyzed using the PROC MIXED procedure as a randomized complete block experiment (SAS, version 6; SAS Institute, Cary, NC). The statistical model included plant species, grub infestation levels, and their interaction as fixed factors. Interactions were examined between the grub density, plant species, and blocks as random factors.

Unequal variances among the plant species data were accounted for by using GROUP option in PROC MIXED. Measurements taken on the experimental units before grub infestation, such as initial root volume, root length, and plant weight, were considered as potential covariates to improve the accuracy of comparisons among the treatments (Milliken and Johnson, 2002). Root and foliage loss per surviving grub were calculated from root or foliage growth of the same plant species and pots. Root losses were compared among grub densities and plant species by using analysis of variance; means for the different plant species were separated by the Fisher's protected least significant difference test at $P = 0.05$.

Results

After 62 d in the greenhouse, some of the potted plant species in the low-density grub treatment began to wilt and die. The experiment was concluded when more than 50% of the plants died in some pots. Root growth (final root weight – root

weight of the control plant) differed significantly among plant species ($P < 0.0001$) and across different grub densities ($P < 0.001$). No significant interaction between these factors was observed, indicating that turfgrass species differed in their tolerance to grub damages. In the absence of grubs, based on dry root weight, bermudagrass grew the most roots (15.4 g), followed by tall fescue (10.6 g), zoysiagrass (8.6 g), pennsylvania sedge (8.1 g), indiagrass (3.5 g), buffalograss (3.2 g), and little bluestem (2.6 g; Fig. 1). In treatments infested with the low grub density, the mean root growth at the end of the experiment was: bermudagrass (10.6 g), zoysiagrass (6.6 g), tall fescue (6.1 g), indiagrass (4.0 g), and pennsylvania sedge (3.3 g) (Fig. 2). Little bluestem and buffalograss were severely damaged by grub feeding (0.4 and 0.6 g, respectively). In high-density treatments at the end of the experiment, the mean root growth for bermudagrass was 10.9 g, followed by zoysiagrass (6.9 g), tall fescue (4.5 g), and indiagrass (1.6 g; Fig. 1). Buffalograss, little bluestem, and pennsylvania sedge roots were severely damaged at 0.9 g, 0.4 g, and 0.6 g, respectively.

With the absence of grubs in the pots, foliar growth differed among plant species. 'KY-31' tall fescue showed the most growth at 11.1 g, followed by bermudagrass (10.6 g), zoysiagrass (9.2 g), pennsylvania sedge (8.4 g), buffalograss (4.9 g), little bluestem (3.8 g), and indiagrass (3.6 g; Table 1). Foliage growth was reduced for all plant species tested when european chafer grubs were present. The differences between the two treatments were not significant except that pennsylvania sedge lost 26.2% and 85% at low- and high-grub density, respectively (Table 1). Little bluestem lost 26.2% and 42% at low- and high-grub density, and zoysiagrass lost 13.0% and 23.9% for foliage growth at low- and high-grub density, respectively (Table 1).

Root loss from grub feeding differed greatly among the grass species ($P < 0.0003$). Buffalograss, pennsylvania sedge, indiagrass, and little bluestem suffered the greatest age of percent root loss (rate of root loss to the initial root growth) from grub feeding for low and high treatments (Table 1). The most severe root loss

Fig. 1. The dry root consumption by high european chafer grub densities. Little bluestem (LBS), buffalograss (BUF), indiagrass (IND), pennsylvania sedge (SED), 'KY-31' tall fescue (KY-31), bermudagrass (BER), and zoysiagrass (ZOY). 1 g = 0.0353 oz.

Fig. 2. The dry root consumption by low european chafer grub densities. Little bluestem (LBS), buffalograss (BUF), indiagrass (IND), pennsylvania sedge (SED), 'KY-31' tall fescue (KY-31), bermudagrass (BER), and zoysiagrass (ZOY). 1 g = 0.0353 oz.

(92.6%) was observed for pennsylvania sedge in the high-density grub treatment. Bermudagrass and zoysiagrass had the least amount of root weight lost from grub feeding regardless of grub density. The percentage of foliage lost was not different among turf types except for pennsylvania sedge, little bluestem, 'KY-31' tall

fescue, and indiagrass in the low-density grub treatments. They lost more foliage (69.4%–85.7%) from grub feeding damage to roots than did 'KY-31' tall fescue and zoysiagrass (20%–24%, Table 1).

To determine if the grass types tested have any additional resistance (beyond what is conferred from the

Table 1. Mean of root loss, percentage of root loss, and percentage of foliage loss of six grass species and pennsylvania sedge infested with two grub densities of european chafer and no grubs.

Species	No grub			Low grub density			High grub density			
	Root growth (g) ^z	Foliar growth (g) ^z	Root loss (g) ^z	Root loss (%)	Foliar growth (g) ^z	Foliage loss (%)	Root loss (g) ^z	Root loss (%)	Foliar growth (g) ^z	Foliage loss (%)
Bermudagrass	15.4	10.6	4.8	31.2	6.9	34.9	4.5	29.2	6.2	41.5
Buffalograss	3.2	4.9	2.6	81.3	1.6	67.4	2.4	73.4	1.5	69.4
Indiangrass	3.5	3.6	2.2	62.9	2.6	27.8	1.9	57.5	4.5	31.4
'KY-31' tall fescue	10.6	11.1	4.5	42.5	8.8	20.7	6.1	57.5	8.9	19.8
Little bluestem	2.6	3.8	2.2	84.6	2.8	26.3	2.2	84.6	2.2	42.1
Pennsylvania sedge	8.1	8.4	4.8	59.3	6.2	26.2	7.5	92.6	1.2	85.7
Zoysiagrass	8.6	9.2	2.0	23.3	8.0	13.0	1.7	19.8	7.0	23.9
LSD _{0.05} ^y	2.3	4.2	2.7	22.1	4.2	13.1	2.8	22.8	4.1	16.7

^z1 g = 0.0353 oz.

^yLSD_{0.05} = Fisher's protected least significant difference at $P = 0.05$.

size of the root system) to grub feeding, plants with a similar root weight need to be compared. This can be accomplished by plotting the root weight of control plants (not exposed to grubs) against the same turf types with grubs. When this is done, the grass species and pennsylvania sedges that are tested fall in a line going from those with the smallest root weight (little bluestem, buffalograss, and indiangrass) to those with the largest root weight (bermudagrass; Figs. 1 and 2). This reflects the tolerance that turf has to grubs based only on the weight of the roots, and the fact that european chafer root consumption is finite (Figs. 1 and 2). Figures 1 and 2 show that bermudagrass has more tolerance to european chafer consumption because it has a more massive root system than zoysiagrass, and may convey less susceptibility to grubs because of another mechanism. European chafer grubs in pots of zoysiagrass turf only consumed 22% of the root weight compared with

42% of the 'KY-31' tall fescue root weight and 59% of the pennsylvania sedge root weight, yet all of these grasses and pennsylvania sedges averaged a similar weight of roots in control treatments without grubs.

Grub survival differed among plant species ($P < 0.05$) and across grub densities ($P < 0.003$). The grub survival rate was higher in low-density treatments compared with the high-density treatments for all plant species except for little bluestem and indiangrass (Table 2). In high-density grub treatments, bermudagrass and 'KY-31' tall fescue had the highest rates of grub survival (Table 2). Mean survival of european chafer grubs across all plant species when they were initially introduced into pots with plants at low density was 44.5%.

Mean survival of grubs introduced at high density was 30.9% (Table 2). Zoysiagrass showed the least amount of root damage compared with other species (Figs. 1 and 2).

Discussion

Although all of the grasses and pennsylvania sedge species tested were suitable for feeding and growth of european chafer grubs, this study revealed some differences among grass and pennsylvania sedge species in the proportion of root weight lost from grub feeding. The average percentage of loss in root weight varied from 22% to 84%. In general, turf types with the largest root weight in the control treatments at the end of the test fared best because they could tolerate the most grub feeding without losing a high proportion of their root weight. Therefore, a large root weight, or rapidly growing roots, is a form of tolerance to scarab grubs feeding on turf roots. Any cultural practices such as irrigation, fertility, or raising the mowing height will promote more root growth and more tolerance to scarab grubs (Smitley, 1998). In our greenhouse, a test turf was grown under daily irrigation.

Table 2. Mean number of grub survival, grub weight gain, and percentage of grub recovery of six grass species and pennsylvania sedge infested with two densities of european chafer grub.

Species	Low grub density			High grub density		
	Grub survival (no. recovered)	Grub survival (%)	Wt gain ^z (mg) ^y	Grub survival (no. recovered)	Grub survival (%)	Wt gain ^z (mg) ^y
Bermudagrass	5.8	48.3	135.2	11.4	43.8	180.2
Buffalograss	4.4	36.7	158.3	6.6	25.4	201.6
Indiangrass	3.4	28.3	182.4	7.4	28.5	198.6
'KY-31' tall fescue	7.8	65.0	96.4	11.8	45.4	136.2
Little bluestem	5.4	45.0	128.7	5.2	20.0	183.7
Pennsylvania sedge	5.6	46.7	109.4	6.8	26.2	126.4
Zoysiagrass	5.0	41.7	144.2	7.0	26.9	177.3
LSD _{0.05} ^x	1.9	16.3	25.5	2.6	10.3	26.9

^zWeight gain is for the aggregate fresh weight of infested grubs.

^y1 mg = 3.5274×10^{-5} oz.

^xLSD_{0.05} = Fisher's protected least significant difference at $P = 0.05$.

Therefore, turf types that grow well under daily irrigation developed the largest root weights. It is reasonable to expect a similar type of response to turf growing outdoors under daily irrigation. However, turf response to dry conditions and drought stress may be very different. If the same turf types were grown outdoors under low maintenance conditions, the relative size of the root weights could be very different. Therefore, it is best to apply our test results to turf grown in irrigated sites, or sites with frequent precipitation.

Tolerance of zoysiagrass to white grubs has been previously observed. Braman and Pendley (1993) found that tall fescue and bermudagrass sustained greater root damage from white grubs than zoysiagrass. Our results suggest that cultivars of bermudagrass may be good candidates for resistance to european chafer and other scarab grubs except that the study was conducted in July at 20 °C to 30 °C, which is optimal for bermudagrass growth compared with other species.

Although our results show that the relative weight of turf roots is one form of tolerance to scarab grubs, other mechanisms are likely. Kain and Atkinson (1977) found that tall fescue in low maintenance pastures was tolerant to feeding damage from the new zealand grass grub (*Costelytra zealandica*). They attributed this tolerance to the physical structure and root biomass of tall fescue (Prestidge et al., 1985). Potter et al. (1992) also suggested that tall fescue tolerance to injuries caused by root feeding grubs is probably related more to its extensive, coarse root system instead of it

being an unsuitable nutrient source for grubs.

Recent research on the relative susceptibility of different turf types to scarab grubs (Bughrara et al., 2003; Potter et al., 1992; Prestidge et al., 1985) indicates some large differences among different turf species, and among cultivars within a species. This research needs to be expanded to allow the development of commercially available turf types that are resistant to grubs under low or high maintenance conditions.

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