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The first section includes lecture notes of papers presented at the 1999 New Jersey Turfgrass Expo. Publication of the New Jersey Turfgrass Expo Notes provides a readily available

source of information covering a wide range of topics. The Expo Notes include technical and popular presentations of importance to the turfgrass industry.

The second section includes research papers containing original research findings and reviews covering selected subjects in turfgrass science. The primary objective of this section is to facilitate the timely dissemination of original turfgrass research for use by the turfgrass industry.

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UNDERSTANDING THE WHITE GRUB COMPLEX

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GENERAL WHITE GRUB BIOLOGY AND MANAGEMENT

White grubs are the root-feeding larvae of scarab beetles (Order: Coleoptera; Family: Scarabaeidae) that are pests of turfgrasses and pastures. At least 10 species are turfgrass pests in North America including native (masked chafers, black turfgrass atenius, May beetle, and green June beetle) and introduced (Japanese beetle, Oriental beetle, European chafer, and Asiatic garden beetle) species. As a group, white grubs are the most widespread and destructive turf insect pests in the cool-season and transition zones.

Signs of Infestation

The different white grub species are generally similar in habits, appearance, and the damage they cause. The primary damage is caused by the grubs which chew off roots close to the soil surface. In hot, dry weather, this can lead to quick loss of turf. All cool-season and many warm-season grasses are susceptible to white grubs. Early signs of a white grub infestation in turf include gradual thinning, yellowing, wilting in spite of adequate soil moisture, and the appearance of scattered, irregular dead patches. The patches increase in size and may join together until large turf areas are affected. Due to the tunneling and feeding activity of the grubs, infested turf feels spongy underfoot and can be pulled up easily, exposing the C-shaped white grubs. Secondary, and often more severe, damage can be caused by vertebrate predators

(birds, skunks, raccoons, moles, etc.) tearing up the turf to feed on the grubs. This damage may occur at grub densities well below the levels that would cause primary damage. The adult beetles do not cause damage to turfgrass but may be major pests of woody and herbaceous ornamentals.

Description of Life Stages

Adult. The adults are stout, oval beetles that range in length from 3/16 to 1 inch. The tibiae of the front legs have stout teeth on the outer margin that help the beetle to burrow in soil. The last three antennal segments are flattened and held together to form a distinct club that is larger in males than in females. Adults of different species differ in size, coloration, and habits; however, within the groups of masked chafers and May beetles, species differentiation is difficult.

Egg. The eggs are shiny, milky white, and oval, becoming swollen and more spherical as they absorb water from the soil.

Larva. Grubs of the various species are similar in appearance except for size, which ranges from 3/8 to 2 inches in mature grubs. The grubs go through three larval stages that look alike but differ significantly in size. The body of the grubs consists of a distinct brown head capsule with chewing mandibles, a thorax with three pairs of short, jointed legs, and a 10-segmented abdomen. Thorax and abdomen are whitish or cream colored, but the hind part of the abdomen often

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appears dark because of ingested soil and food in the gut. When feeding or resting, the grubs assume a typical C-shaped posture. Grubs can be identified to species by examining the raster (arrangement of spines and hair) on the underside of the last abdominal segment and the shape of the anal slit.

Pupa. The initially white pupa darkens with age and takes on the adult coloration shortly before adult emergence. Legs and wings are clearly visible but folded close to the body. The cast skin (exuvia) of the last larval stage may surround the pupa like a shroud (e.g., Japanese beetle, masked chafers) or is sloughed off and attached to the hind end of the pupa (e.g., European chafer).

Life History and Habits

The life stages consist of egg, three larval instars, pupa, and adult. Japanese beetle, Oriental beetle, European chafer, masked chafers, Asiatic garden beetle, and green June beetle have a 1 year life cycle and, as a group, are also referred to as the annual white grub complex. Adults emerge, mate, and lay eggs in mid-summer. The eggs are laid in the soil at a 1 to 5 inch depth and hatch in 2 to 3 weeks. The grubs grow quickly, molting twice, and by fall most of them are nearly full-sized 3rd instars. Declining soil temperatures in late fall force the grubs to move deeper in the soil where they overwinter. In spring they resume feeding for about 1 month. For pupation they move deeper in the soil. Adults emerge several weeks later. Damage caused by annual white grubs shows up in late summer and early fall (August and September) when the voraciously feeding 2nd and 3rd instars coincide with heat and moisture stress in the turf. Damage during the spring feeding period is less apparent because environmental conditions allow the grass to outgrow the loss of roots. Because of their different life cycles, the black turfgrass *ataenius* (usually more than one generation per year) and May beetles (1 to 4 years per generation) may also cause damage in June or July.

Management

Monitoring. Monitoring and sampling are essential for early diagnosis of grub problems. Grub populations can be monitored by taking soil plugs with a standard golf cup cutter or cutting uniformly sized squares with a flat-blade spade. The thatch and soil are then inspected to a depth of 3 inches. Samples should be taken in a grid pattern throughout the area to be examined. The workload can be reduced by concentrating sampling in high-risk areas. Observing adult activity can be helpful because sites with heavy beetle activity in June and July are more likely to have grub problems in late summer. Adult flight can be monitored using light traps for night flying scarabs, or scent traps for the Japanese beetle. Foraging activity of vertebrate white grub predators may indicate a white grub infestation. However, the presence of grubs should be confirmed through sampling, as the predators may also be after earthworms or other soil insects. Mapping and record keeping are helpful in tracking high-risk areas because the same sites are often reinfested in following years.

Early detection and proper timing are especially important when applying short-residual insecticides for curative treatments because these control agents work best against young grubs. If long-residual insecticides (e.g. imidacloprid, halofenozide) are used for preventive treatment, spot treatments targeted to sites where heavy beetle activity was observed earlier or to sites with a history of infestations are preferable over broadcast applications. It is rarely necessary to treat an entire lawn or fairway. Threshold density for causing visible damage varies with grub (see below) and grass species, and with the overall vigor and use of the turf.

Cultural control. Watering during peak beetle activity in mid-summer tends to attract egg-laying females and increases egg survival. Once the eggs have hatched, however, irrigation increases the tolerance of the turf to root feeding.

Effects of light to moderate grub infestations can often be masked by irrigation to alleviate stress, together with light fertilization to enhance recovery. Avoiding plants that attract the adults (food or shelter) along the turf areas reduces the reservoir of egg-laying adults. While no resistant cultivars are known, tall fescue is generally more tolerant of grub damage than other cool-season grasses.

Biological control. Naturally occurring predators, parasites, and pathogens are important in suppressing white grub populations and buffering outbreaks. These beneficial insects should be conserved whenever possible (e.g., spot-treat, avoid broad-spectrum insecticides). The entomopathogenic nematode *Heterorhabditis bacteriophora* can be very effective in grub suppression. Milky disease (*Paenibacillus* (formerly *Bacillus*) *popilliae*) occurs in many different strains. Only the strain that infects the Japanese beetle is commercially available. It can currently only be used for long-term inoculative control.

Chemical control. Mowing the turf and raking out the dead grass and thatch before treatment enhances insecticide penetration. Irrigation before application tends to bring the grubs closer to the surface, thus increasing efficacy. Treatments should be watered into the soil immediately with 0.5 to 1 inches of water. Granular formulations are more forgiving if post-treatment irrigation is delayed. If the thatch layer is thicker than 0.5 inch, dethatching before application should be considered. Curative controls work best when the grubs are small. The optimal time for preventative treatments (i.e., imidacloprid, halofenozide) is June to July.

IMPORTANT WHITE GRUB SPECIES IN THE NORTHEAST

Japanese Beetle (*Popillia japonica*)

Pest status. The Japanese beetle is considered the primary insect pest in turf in much of New England and the Mid-Atlantic states. Adults

are serious pests of ornamental and woody landscape plants. The grubs feed on all cool-season grasses, many lawn weeds, and other plants. Adults feed on more than 300 ornamental and woody landscape plants.

Distribution. Japanese beetles are established east of the Mississippi river except Florida, Mississippi, and Minnesota.

Distinguishing characteristics. Adult beetles (5/16 to 7/16 inch long) have a shiny metallic green head and body with darker green legs. The coppery-brown cover wings do not quite reach the tip of the abdomen. The side of the abdomen has tufts of white hair. The rastral pattern of the grubs includes two rows of short spines arranged in a V-shape. The anal slit is transverse.

Life history and habits. In the Mid-Atlantic states, the adults begin to emerge in early to mid-June (peak in early July). They are active during the day and quite conspicuous.

Management. Japanese beetles can be controlled as other white grub species. The damage threshold is 7 to 10 grubs/ft². In addition, egg-laying in adjacent lawn areas can be reduced by avoiding plants attractive to the adults (e.g., lindens, purple leaf plum, bracken, elder, grape, Indian mallow, mulitflora rose, sassafras, smartweed, and Virginia creeper). Trapping with pheromone traps is useful for monitoring but does not reduce adult populations.

Oriental Beetle (*Exomala orientalis*)

Pest status. The Oriental beetle is a pest of regional importance in the northeastern United States. In recent years it has become more abundant than the Japanese beetle in many areas. The grubs seem to prefer well-kept, open, sunny lawns with rich sandy loam and high moisture. Grubs feed on all cool-season grasses, strawberry beds, nursery stock, and potted plants. The adults feed on various ornamental plants but are not serious pests.

Distribution. The Oriental beetle is found in Connecticut, Maryland, Massachusetts, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, Virginia, and Hawaii.

Distinguishing characteristics. Adult beetles (3/8 inch long) are mostly straw-colored with variable black markings on the thorax and cover wings and a solid dark brown head. The larval raster includes two parallel rows of short, stout, inward-pointing spines. The anal slit is transverse.

Life history and habits. Adults are active from late June to August (peak in mid-July). Adults are mostly active around dawn.

Management. The Oriental beetle can be controlled as other white grubs. The damage threshold is 5 to 7 grubs/ft².

European Chafer (*Rhizotrogus majalis*)

Pest status. The European chafer may be the most serious white grub pest of home and low-maintenance lawns. The grubs feed on all cool-season grasses in turf and pastures, weeds, and on field, forage, and nursery crops.

Distribution. This insect is found in Connecticut, Delaware, Michigan, New Jersey, New York, Ohio, Pennsylvania, and Rhode Island.

Distinguishing characteristics. Adults are light reddish-brown (9/16 inch long) with a slightly darker head and pronotum. Fully mature grubs are just under 1 inch in length. The raster has two distinct, nearly parallel rows of small spines that diverge outwards at the tip of the abdomen. The anal slit is Y-shaped.

Life history and habits. The adults emerge in early June to mid-July (peak in mid-June to early July). They are nocturnal and active above 66°F. The grubs stop feeding later in fall and resume earlier in spring than other white grub species.

Management. European chafer grubs can be controlled as other white grubs but are less susceptible to many insecticides (including halofenozide) than Japanese beetle grubs. The damage threshold is 5 to 10 grubs/ft². Adults begin to fly at first bloom of hybrid tea and floribunda roses with peak flight at full bloom of common catalpa.

Masked Chafers (*Cyclocephala* spp.)

Pest status. Masked chafers are among the most destructive turfgrass pest in the Midwest and Northcentral United States, and in the transition zone. Areas in full sun, south-facing slopes, and areas with well-drained, moist soil high in organic matter are especially hard hit. The grubs feed on all cool-season grasses as well as decomposing organic matter.

Distribution. Masked chafer species occur throughout most of the continental United States.

Distinguishing characteristics. Adult beetles (7/16 to 1/2 inch long) are generally dull yellowish- to reddish-brown with a darker band across the head and eyes. Larvae of different species are indistinguishable. The raster consists of evenly spaced stout bristles without a distinct pattern.

Life history and habits. In the Mid-Atlantic states, the nocturnal adults are active in June to July, especially on warm, humid nights after rains. They are strongly attracted to light.

Management. Masked chafer grubs can be controlled as other white grubs but appear to be slightly less susceptible to imidacloprid. The damage threshold is 8 to 10 grubs/ft².

Asiatic Garden Beetle (*Maladera castanea*)

Pest status. The Asiatic garden beetle is a minor pest in turfgrass because the grubs feed deeper in the soil than other species (2 to 3 inches) and are less destructive than equal num-

bers of other similar sized species. This species can be a serious pest in nursery and vegetable crops. The grubs feeds on the roots of weeds, flowers, vegetables, and all cool-season turfgrasses.

Distribution. Asiatic garden beetles are distributed throughout Connecticut, Delaware, District of Columbia, Maryland, New Jersey, New York, Pennsylvania, South Carolina, and Virginia.

Distinguishing characteristics. Adults (5/16 to 7/16 inch long) are chestnut brown and velvety. The cover wings do not entirely cover the abdomen. Fully mature grubs are 3/4 inch long. They tend to remain somewhat lighter than other white grub species. A key characteristic is a single, transverse curved row of spines in the raster together with a Y-shaped anal slit. In addition, the maxilla has a whitish, enlarged, bulbous structure (or stipe).

Life history and habits. Adults fly from late June to October (peak in mid-July to mid August). They are nocturnal and active above 70°F. The adults are attracted to overgrown, weedy areas where they feed heavily on favored food plants such as goldenrod, ragweed, white clover, wild aster, and wild carrot. Eggs are often laid near favored food plants.

Management. Asiatic garden beetle grubs can be controlled as other white grubs but are not sensitive to halofenozide. In addition, eliminate adjacent weedy areas with food and shelter plants. The damage threshold is 18 to 20 grubs/ft².

Green June Beetle (*Cotinis nitida*)

Pest status. Damage is caused mostly through the burrowing and tunneling activity of the grubs and is most likely in soil with high organic matter and where manure-based fertilizers are used.

Plants attacked. Grubs feed on decomposing organic matter (e.g., thatch, compost, and

grass clippings). Adults feed on sugary foods (e.g., overripe fruit and tree sap).

Distribution. The beetle is widely distributed east of the Mississippi river as far north as Ohio, downstate New York, and Connecticut; common in the transition zones; introduced into southern California.

Distinguishing characteristics. In adult beetles (3/4 to 1 inch long), the upper side varies in color from dull brown with longitudinal green stripes to uniform, velvety green, while the underside is shiny, metallic green or gold. The grubs are larger, more robust, and more parallel-sided than other grub species. They have stubby legs, relatively short mouthparts, and move on their backs.

Life history and habits. Adults emerge in June to July (peak in mid-July) and are active during the day. Early instars tunnel horizontally in top 4 inches of soil. Older grubs tunnel vertically and deeper and push little mounds of loose soil out of tunnels. They often migrate (up to 65 ft) at night.

Management. Green June beetle grubs can be controlled as other white grubs. In addition, pyrethroid labeled for foliage-feeding insects in turfgrass can kill the grubs. The damage threshold is 5 to 7 grubs/ft². Treated grubs tend to die on surface. Composted yard-waste or use of manure-based fertilizers in spring or early summer may attract egg-laying females.

Black Turfgrass Ataenius (*Ataenius spretulus*)

Pest status. This insect can be a major pest on golf courses in parts of the Midwest, Northeast, and Mid-Atlantic states. Most damage occurs on golf course fairways and occasionally on greens, tees, and collars.

Plants attacked. The grubs commonly damage bentgrasses, annual bluegrass, and Kentucky bluegrass on golf courses.

Distribution. The black turfgrass atenioides is found in all states east of the Rocky Mountains and in California.

Distinguishing characteristics. The adults are small, shiny black beetles (3/16 to 1/4 inch long) with distinct longitudinal grooves on the cover wings. Mature grubs are 3/8 inch long. The grubs have two distinctive pad-like structures at the tip of the abdomen just in front of the anal slit and a scattered pattern of spines on the raster.

Life history and habits. In Ohio and further south, the black turfgrass atenioides has two generations per year. The overwintering adults begin emerging in late March. Egg laying begins in early May and continues until mid-June. The 1st generation of grubs is present from late May until early July, with damage typically showing up in June. The 2nd generation of adults emerges from late June to early July, laying eggs during July and early August. Damage from the 2nd grub generation appears in August and early

September. The winter generation adults emerge in September, mate, and fly back to the overwintering sites in surrounding wooded roughs or woodlots.

Management. In addition to using curative or preventive treatments against the grubs as in other white grub species, application of a short-residual insecticide when the overwintering beetles are migrating back to the turf in early spring can kill the females as they burrow into the soil to lay eggs. Damage threshold is 30 to 50 grubs/ft². The development of this insect is closely correlated with flowering dates of certain indicator plants which can be used for monitoring and timing of applications. 1st generation eggs are laid at full bloom of Vanhoutte spirea or horse chestnut; 1st generation larvae appear when multiflora rose is in full bloom, summer adults appear when summer phlox is in full bloom; and second generation eggs are laid when rose of Sharon is in full bloom. Adults can be monitored with black light traps.