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Dichondra Pests In Southern California

by

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This article has several objectives: To review the common dichondra pests and their control, to discuss two new pests, and to present some of our personal observations and opinions on insecticides and pest control. It should be remembered that it is natural to find many insects and other small arthropods in dichondra. Only a few of these cause serious damage, some are beneficial, and others are pests only if they become too numerous. Since symptoms of injury from insects and other pests often are not clear cut and are easily confused with troubles caused by diseases and poor cultural conditions, the presence of injurious pests should be confirmed before insecticides are applied.

We believe that insecticides should be applied only when a pest is present in sufficient numbers to cause damage. Also with respect to pest control, we cannot overemphasize the importance of proper fertilization and good cultural practices. Healthy, vigorous dichondra will outgrow the effects of many infestations. However, when it is in poor condition, damage may be more severe and recovery following insecticide treatment is slower.

Cutworms. Cutworms are rather fat-bodied caterpillars ranging in length from 1 to 2 inches when fully grown (Fig. 1). They are usually dull-colored, greenish, gray, brown or blackish, and often with spots or longitudinal stripes. They feed on the leaves and crown, and may cut off young plants at the ground level. While an established lawn may support quite a population of cutworms without showing much damage, new dichondra may be severely damaged. Cutworms usually feed at night and hide during the day in holes, under debris, or beneath the mat of organic matter at the surface of the soil. The adults are mostly dull or somber-colored moths. Only the caterpillars are injurious.

Injury is most likely to occur during the summer and early fall months, and has been most severe in the warm inland areas. Probably the greatest difficulty in controlling cutworms is in recognizing a serious infestation before the lawn is badly damaged. A lawn may support many small cutworms without showing much damage. However, as the caterpillars approach full size, the amount of food they consume increases enormously, and the lawn may be injured seriously in a period of 2 or 3 days. Also the large caterpillars are more difficult to kill with insecticides than the small ones.

To prevent cutworm damage, a close check of the lawn should be kept during the summer and early fall. For vigorous, well established dichondra it is not necessary to apply an insecticide unless there are more than 2 or 3 cutworms per square yard. Young dichondra, especially at the seedling stage, is much more susceptible to damage and should be treated if more than an occasional cutworm is found. From the standpoint of cutworm damage, new lawns should be seeded before May or after September. This avoids having the dichondra in its most susceptible stage during the peak of cutworm activity.

To determine if cutworms are present, sections of the lawn can be flooded at night, or the pyrethrum test can be used. In the latter, mix one tablespoon of a commerical pyrethrum preparation (containing 0.5 to 1 per cent pyrethrins) in a gallon of water, stir thoroughly and apply with a sprinkling can at the rate of one gallon of the mixture per square yard. Pyrethrum irritates the caterpillars and brings them to the surface. Several areas in the lawn should be tested. If the lawn already shows signs of damage, the mixture should be applied to green areas in and around the damaged sections.

Control of cutworms. DDT and toxaphene are effective against cutworms. Preparations designed especially for cutworms in turf and dichondra and containing one or both of these materials are available. The new carbamate insecticide, Zectran, is very effective against cutworms and is preferred by us. All of these materials should be applied according to the manufacturer's directions. Zectran is sold under the name of DOW "Snail, Slug 'N Bug Killer " and when applied as directed for slugs (see below) will also reduce populations of snails, springtails, millipedes, sowbugs and pillbugs.

Flea beetles. Flea beetles (Coleoptera: Chrysomelidae) are a new pest of dichondra and were first brought to our attention in 1962 by Mr. Gene Harper of the Agricultural Commissioner's Office of San Bernardino County. The species has been identified as *Chaetocnema magnipunctata* Gentner. In San Bernardino County infestations have been found in the city of San Bernardino, Loma Linda, Redlands, Fontana and Highland. In 1963 a number of dichondra lawns in the City of Riverside were severely damaged. We have also had reports of damage in Los Angeles County.

The adult flea beetles (Fig. 2) are black and very small, about 1 mm (1/25 of an inch) long. They feed on the upper surface and skeletonize the dichondra leaves.

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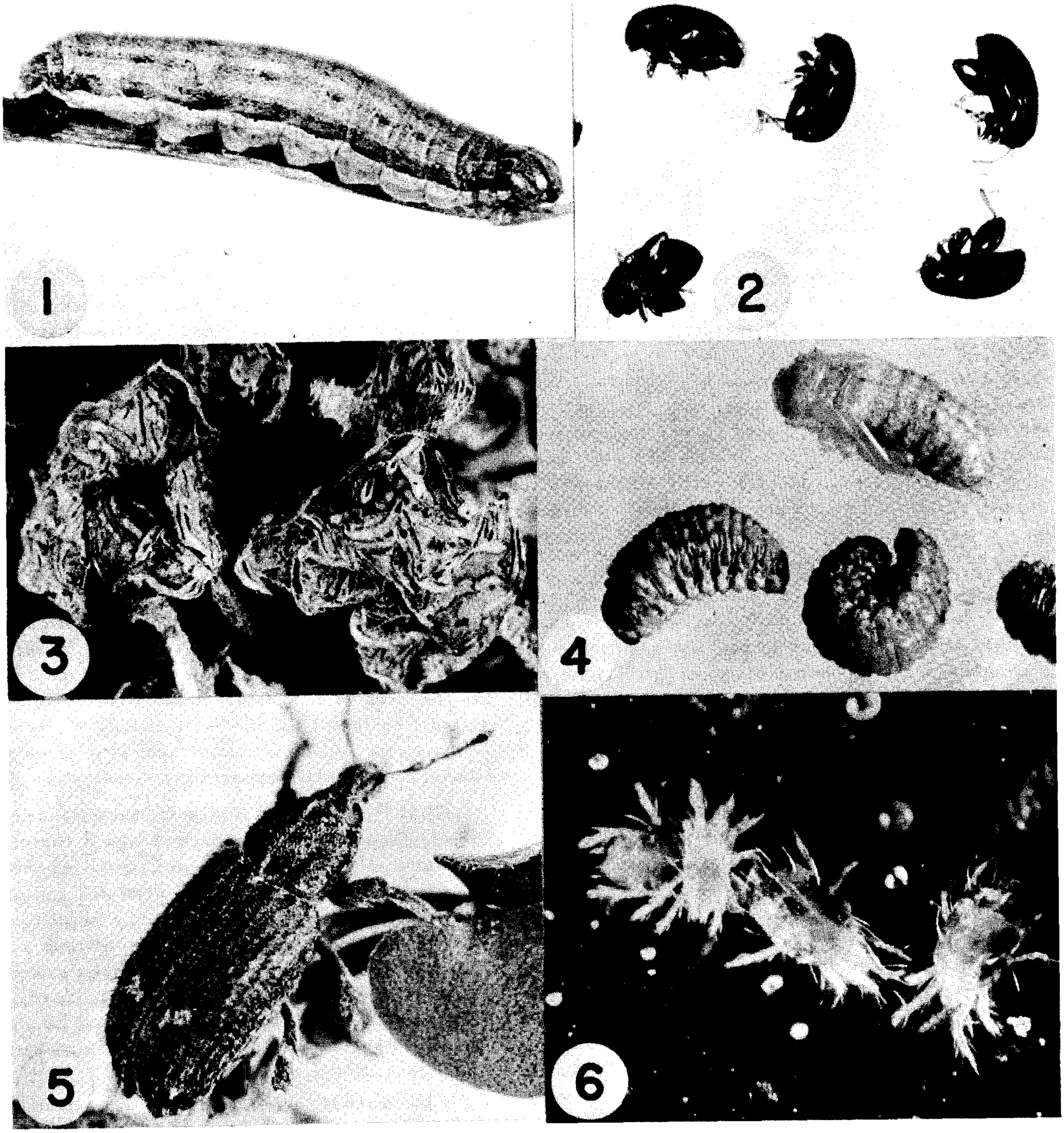

Fig. 1. The armyworm, *Pseudaletia unipuncta* (Haw.).
Fig. 2. Flea beetles, *Chaetocnema magnipunctata* Gentner.
Fig, 3. Two dichondra leaves (enlarged) showing flea beetle damage.
Fig. 4. Grubs (larvae) below, and pupa above, of vegetable weevil.
Fig. 5. The vegetable weevil, *Listroderes costirostris obliquus* (Klug).
Fig. 6. Spider mites, *Tetranychus sp.*

NOTE: The photographs in this article are not according to scale.
See text for approximate size of the pests.

When enough of the leaf is eaten away the leaf turns brown. The injury (Fig. 3) is very characteristic and can readily be seen with an ordinary magnifying or reading glass. The damage at first appears to be localized or spotty and since the beetles are so small most people assume the damage is due to lack of water or fertilizer burn. Usually it is not until the lawn is severely damaged that they suspect or associate the damage with an insect.

Very little is known about the life cycles of most flea beetles. With dichondra it appears that damage is most likely to occur during the warm months – from May through October. Observations on one lawn in Riverside indicate that in the summer a generation may be completed in approximately a month. The grubs (larvae) probably develop in the soil and feed on the roots. However, significant damage has not been observed until the adults emerge and begin feeding on the leaves.

Control of flea beetles. Spray the lawn with DDT or one of the preparations containing DDT and designed for cutworms. Apply at the rate given on the label for cutworms and use enough spray to thoroughly wet foliage and the surface of the ground.

Lucerne moth. This is another new pest of dichondra and damage to lawns has been reported during the last several years in the San Gabriel, Monrovia, Arcadia area. While clover and other legumes are preferred, the larvae will feed on dichondra and grasses. The larvae are slender, spotted caterpillars very similar in appearance to lawn moth larvae but a little larger, the full grown caterpillars being about an inch long. While lawn moth larvae are relatively sluggish, lucerne moth larvae wriggle actively when disturbed. The adults have a wing spread of an inch or slightly more. The hind wings are gray and the fore wings are mottled gray brown with two pairs of indistinct dark spots. Damage to dichondra has occurred mainly in the summer and early fall months.

Control of the lucerne moth. DDT and Sevin do not appear to be very effective against lucerne moth larvae. Since we have not had an opportunity to do any experimental work with this pest we can only make a suggestion as to control. Zectran is suggested as the material most likely to control this pest. Use it at the rate of 3 pints of the emulsion per 100 gallons of water (1 tablespoon per gallon). At lower rates it has been reported to be ineffective.

Vegetable weevil. In recent years the vegetable weevil has become a pest of increasing importance in dichondra in southern California. Damage is most likely to occur during the winter and early spring months, and probably is accentuated by the fact that growth of dichondra is slow during this period. With heavy infestations, damage is severe and recovery is slow.

Grubs of the vegetable weevil (Fig. 4) are small, green, legless larvae about 3/8 of an inch long. They hide in the soil during the day and feed on the foliage at night. The adult weevils (Fig. 5) cannot fly so infestations are usually localized.

To prevent damage from the vegetable weevil, frequent examinations of the lawn are necessary during the winter and early spring. The grubs and adult beetles are most easily found at night when they are feeding. If more than an occasional grub or beetle is found the lawn should be treated.

Control of the vegetable weevil. Malathion, dieldrin or Zectran sprays are effective against the vegetable weevil. If specific directions for the vegetable weevil are not given on the label, use malathion at the rate given for mealybugs and scale insects, dieldrin at the rate given for thrips and weevils and Zectran at the rate given for snails and slugs. Apply enough of the spray to thoroughly wet the plants and the surface of the soil.

Mites. Damage to dichondra lawns may result from infestations of the two-spotted spider mite or closely related species. These mites (Fig. 6) are about 1/50 of of an inch long, globular in shape, and reddish, yellowish or greenish in color. They feed by sucking the plant juices, the first symptom of injury being a speckling of the leaves. This is followed by a yellowing or bronzing effect and the drying up of the leaves. The mites spin fine webs and with large populations the plants may be heavily webbed with large masses of mites in the webs.

Other mites may be associated with dichondra but normally are not injurious.

The oxalis mite is a bright red color and is approximately the size of the two-spotted spider mite but with longer legs. It feeds only on oxalis, causing a yellowing or bleaching of the leaves which makes the oxalis more noticeable. The clover mite feeds on clover, grasses, weeds and various other plants and shrubs. It differs somewhat in appearance and habits from other spider mites. The adults are about 1/30 of an inch in length with long front legs. The legs are amber or orange-colored and the body may vary from reddish-brown to a greenish color. The clover mite may invade homes when large populations build up in adjacent areas.

Control of mites. Spider mites damaging dichondra can be controlled with Kelthane or Dimite sprays applied according to the manufacturer's directions. It is important that the applications be thorough and that the undersides of the leaves be wet by the spray. For effective control, at least two applications about two weeks apart are required. Control of the clover mite by home owners is difficult and it is recommended that a commercial pest control operator be hired.

Slugs and Snails. These are common pests of dichondra lawns. Control is difficult since there usually is a continual migration of these pests from other areas. The common brown garden snail can be controlled with baits containing metaldehyde. Baits are less effective against slugs. Both snails and slugs can be controlled with Zectran sprays but repeated applications are necessary. Use Zectran (Dow Snail, Slug 'N Bug Killer) at the rate given on the label. Areas where slugs and snails tend to congregate should be thoroughly drenched with the spray.

Miscellaneous pests. Ants may invade homes or cause unsightly mounds in lawns. They can be controlled with

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chlordane, dieldrin or diazinon (Spectracide) applied according to the manufacturer's directions. Earwigs, springtails, millipedes, sowbugs and pillbugs are common inhabitants of lawns. They are pests only when they become very numerous since their normal food is decaying organic matter. When necessary they can be controlled with sprays of diazinon, malathion or Zectran. Gnats and small flies may also breed in dichondra lawns. The adults may be a nuisance in patios and yards, and may enter homes. The larvae or maggots feed on decaying organic matter. Spraying the dichondra with diaxinon or malathion may give relief.

The use of organic fertilizers – blood meal, fish, activated sludge and similar products are conducive to the buildup of large populations of earwigs, springtails, millipedes, sowbugs and pillbugs. They also attract gnats and provide more favorable breeding conditions.

Application of insecticides. Do not apply insecticides to dichondra needing water. Make a light application of fertilizer, if needed, and water well before treatment. Apply the insecticide when the foliage is dry and do not water again until necessary. Use enough spray to thoroughly wet the foliage and the surface of the ground. Do not spray when the temperature is above 90° F.

Caution! All insecticides are poisonous. Carefully follow the precautions on the label. Do not allow children or pets to play on treated lawns for 5 days. Keep insecticides in their original containers and out of reach of children, irresponsible persons and pets.

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Reviving Old Putting Greens

by Chester L. Hemstreet and Fred Dorman

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As Americans' leisure time increases, the traffic on golf greens has multiplied. This increased usage, together with the players' demand for a more lush turf or greater green surface resilience, points up the problem of "old greens."

Attempts to increase turf vigor and green resilience have increased long-standing problems of diseases, poor root systems, and low water penetration rates. Increased irrigation to soften a putting green surface may leave water on greens, seriously reduce the air available to roots, scald foliage in the summer, and increase soil compaction.

Faced with these problems, the manager of an old putting or bowling green turf may ask, "Shall I replace the turf at a cost of $1800 to $2500 per green, or attempt temporary or permanent turf rejuvenation methods?" Since many turf management budgets are not sufficient for the replacement of more than one or two greens a year, he may have to consider old and new methods of turf rejuvenation.

Factors in "Old Green" Turf Failure

Turf failures may be the result of various turf management procedures or the lack of equipment to prevent the development of these problems. The surface layers on old greens may present turf managers with a serious problem. Alternate layers of soil and organic material on old greens may build up 4 to 6 inches deep, and will reduce the movement of water through the surface soil.

A combination of the following usually is responsible for surface layering:

1. Topdressing with a finer or coarser textured material than the parent soil
2. Burying thatch and mat under thick layers of top-dressing materials
3. Poor mixing of thatch and top-dressing material due to insufficient brushing and verticut operations
4. Uneven applications of top-dressing
5. Inadequate thatch removal
6. Rapid removal of thatch (scalping)
7. Failure to aerify adequately
8. Insufficient use of mower brush
9. Overwatering which eliminates soil air needed to break down buried organic materials
10. Soil compaction from foot traffic

Some of the above problems can be attributed directly to improper use of special equipment already available to

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the golf course superintendent.

Thatch can be kept down by a program of brushing and verticutting. To reduce surface layering, select top-dressing material of the right texture and use a verticut machine to mix it with the thatch and mat. Machine aerification can reduce the adverse effects of many years of layering. However, these procedures may not be adequate to rejuvenate old greens completely.

GREEN REJUVENATION PROGRAM IN SAN BERNARDINO COUNTY - 1961-1962

During the winter of 1961, the Arrowhead Country Club in San Bernardino requested assistance in its program of putting green replacement and repair. Of immediate concern were two 35-year-old greens with typical characteristics of old-green maladies: Surface soil stratification, compaction, impaired root penetration, unhealthy root system, and an anaerobic soil condition sufficiently severe to develop a strong odor after exposure of plugs to air for 20 to 30 minutes. One green was replaced by scalping off the undesirable 6 inches of soil surface – the other, Green No. 4, was selected for a test of a promising green rejuvenation technique – “deep aeration.”

Water penetration tests conducted on Green No. 4 in November of 1961, with standard 6-inch diameter infiltrometers, indicated the nature of this problem. With Seaside bentgrass in place, the water penetration race averaged 1/16 inch per hour; with thatch and mat removed, the penetration rate averaged 1/4 inch per hour; after complete removal of the stratified top 4 to 6 inches of the green surface, the parent soil was found to have an average penetration rate of approximately 2 inches per hour.

Test Prepamtions. To eliminate thatch during the period of this test, Green No. 4 was verticut on December 19, 1961, and January 19, 1962. Two-thirds of the length of the green was reserved for the “deep aeration” treatment; the other third, approximately 21 feet, was saved as a control area. The test area was split lengthwise; the west portion was treated by placing 3/4-inch-diameter holes on 2-inch centers to a depth of 6 inches with Oakfield soil tubes. Similar holes in the east portion of the green were placed on 4-inch spacings.

A notched 20-feet-long 1 x 6 inch board was used as a template, to assure reasonable hole spacing accuracy. Approximately 26 man-hours of labor were necessary to hand-aerify 1000 square feet of surface during the 2-inch spacing treatments.

Cores were picked up with a square-ended shovel. Aerifier holes were filled (vertically mulched) with a sandy top-dressing mixture containing 25 per cent redwood sawdust, plus all major and minor nutrients. The top-dressing material was added soon after holes were completed. Air-dried material was used to facilitate filling the holes completely. The green was irrigated twice, given a light top-dressing of fine sand similar to char used in the UC mix, then “squeegeed” smooth. Green No, 4 was put into play April 12, but appeared to be adequately healed by April 9 or 10.

Next, the entire green was aerified with rotary spoon-type equipment. The holes were left open, to facilitate movement of irrigation water into the areas between the “deep aerified” holes. Visual observations of foliage and root health were made and compared to adjacent greens of similar age and condition.

Results

A striking increase in resilience of this putting green was detected immediately after the hand-aeration holes were completed. Heavy irrigations were no longer necessary to supply injured roots with adequate moisture and increase green surface resilience.

Water infiltration tests conducted during the summer of 1962 indicated a considerable increase over the pre-treatment rates. Prior to the deep aeration treatments, there was excessive water accumulation on the surface of Green No. 4 after approximately 1/4 inch of water was applied – a 20 to 30 minute irrigation. For periods up to 5 hours, the soil surface would yield water when walked on after 1/2 inch of water was applied. After treatment, casual or excessive water accumulation appeared only in the control or untreated area, and on a 3 or 4 square foot area in the northwest portion of the green where slope was a problem.

Even though adequate green surface drainage was effected and root growth increased from a depth of 3 to 4 inches to 6 to 7 inches in the deep aerified holes, tensionmeter readings indicated the root zone from 2 to 6 inches seldom was dried out below the maximum amount of water that soil would hold. During this period, the greens on this course were watered daily.

Terminal Infiltration Tests. These tests, conducted on Green No. 4 in January 1963, gave the following infiltration rates from an average of seven replications: The area with deep aerifier holes 2 inches apart averaged 2.5 inches per hour over a period of approximately 3 hours. That area with holes 4 inches apart averaged 1.6 inches per hour during the same period of time. The control area averaged 1.07 inches per hour.

These figures are not suggested as the true infiltration rate of the green surface, but as relative rates of water infiltration between treatments and control. This infiltration study followed nearly 4 months of manipulating the quantity and frequency of irrigation, to determine over a period of time how little water could be applied and yet avoid serious drought injury to the turf.

It is believed that this long period of minimum water application increased the air in the soil and allowed the layers of partially decomposed organic matter (old buried thatch) to decompose. Upon investigation of these layers in January of 1963, it was apparent that the jelly-like nature of these layers had been changed to one of a granulated texture.

Irrigation Frequency Manipulation. Tensiometer readings taken during the summer at 2- 4-, and 6-inch depths indicated a surplus of water was being applied. During the period from September 1 to October 9, Green No. 4 was irrigated only on Tuesday, Thursday, and Saturday, using a total of approximately .854 inch per week. Be-

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tween irrigation applications, especially on warm days, "dry spots" (hydrophobic areas) developed. Treatment with a commercial wetting agent, at maximum concentrations recommended by the company, materially reduced the number of dry spots during the interval between water applications.

Since these dry spots apparently limited the ability of the greenskeeper to lengthen the time between irrigation applications, a piston-type aerifier machine was used on the entire green.

From October 9 to November 23, the green was irrigated only-when visual observations of the turf and tensiometer readings indicated that irreparable damage could be incurred from further withholding of water. During each irrigation, sufficient water was applied to wet the green soil to a depth of 6+ inches. During this period, the average weekly irrigation water application was approximately .5 inch. In one instance, water was withheld for approximately 7 days, and in another, for approximately 10 days.

From November 24 to December 12, approximately .1 to .2 acre inch of water was applied at a time – just enough to wet the upper portion of the root zone. When the 6-inch-deep tensiometer readings and turf color indicated the approach of a serious moisture deficit, the entire root zone was completely rewetted. Average weekly water applications during this period totaled approximately .3 acre inch.

DEEP AERATION (VERTICAL MULCHING) CONCLUSIONS

Large-diameter deep-aerifier holes placed through the surface of an "old" bentgrass green successfully provided adequate surface drainage. This treatment materially increased the overall rate of water infiltration and the resilience of the green surface soil for a period of 12 to 18 months after treatment.

This deep aeration or vertical mulch procedure, plus irrigation water application control, increased root activity at deeper soil depths and decreased root density at the shallower depths. The deeper root system, and possibly the hardening of the turf from reduced water applications, resulted in less turf injury when the interval between irrigations was lengthened, thus reducing the total amount of water applied and time spent in application.

CONTROLLING DRY SPOTS ON GOLF GREENS – 1963

Since the 1962 tests with wetting agents and machine aerification failed to completely eliminate all "dry spots" under any feasible irrigation schedule, and because several treatments were applied together, we followed this work with a replicated test on another green, to relate the occurrence of the hydrophobic areas to certain green surface treatments.

A 30-year-old Seaside bentgrass green was selected on this same course during the spring of 1963, to test vertecutting, machine aeration, and a wetting agent on the appearance of dry spots. Lack of adequate soil moisture in the dry spots was believed to be related to thatch buildup and alternate green soil surface layering. The spots were irregular circles, 3 to 30 inches in diameter, depending upon the severity of water deficit.

Treatments. Strips 40 inches wide were verticut north and south across the green on April 19, May 17, June 14, July 19 and August 23. Alternate or east-west strips, 48 inches wide, were aerified on May 3, May 26, June 21, July 26, and August 30. Twenty-five replications were selected at random. Each replicate block contained a control and seven treatment areas (or treatment combinations) randomized differently in each block. A wetting agent was applied to certain replicates on August 9, followed immediately by hand-watering. The wetting agent concentration used was greater than thae normally used, but less than that believed to cause turf injury.

During the summer of 1963, irrigation of Green No. 7 was manipulated to encourage the development of dry spots. Irrigation water applications were determined by turf appearance and from tensiometer readings taken twice daily. The turf condition was observed shortly after noon each day.

Dry spots were located by turf color and by use of probes made from 1/16-inch-diameter wires, or an ice pick. The resistance of the soil to penetration by the wire or ice pick was confirmed occasionally through the use of an Oakfield-type soil tube constructed from the handle and shaft of a golf club. The location of each dry spot was recorded by measurements from two of four permanent sprinkler heads.

Each day's data were plotted on a different 1:100 scale map. Dry spots less than 18 inches in diameter were plotted as a single small circle on the map; larger spots were outlined, using four peripheral measurements.

Dry spot areas were hand-watered daily where necessary to avoid excessive turf injury. The entire green received sufficient irrigation water to wet the soil to the depth of the root system the morning following the formation and measurement of dry spots.

Near the conclusion of this experiment, 20 golfers, agronomists, and greenskeepers were asked to score each of the 200 tagged plots. This evaluation was made to determine if the treatments imposed had contributed to the improvement or deterioration of turf appearance. Each rectangle was scored from 1 to 10. These data and that from the previously located dry spots were related to the treatments and statistically analyzed.

RESULTS OF DRY SPOT CONTROL EXPERIMENTS 1963

Monthly aerification during the summer, with holes left open, prevented the formation of dry spots on the green under test to a degree that this procedure may be considered a successful control measure. Excessive water buildup on the green surface was not eliminated completely by the monthly machine-aerification treatment.

The judges' visual rating of the aerified, verticut, and wetting agent treatments indicated the following: The monthly machine-aerified treatments were rated higher than all other plots, but the difference between the check and aerified treatments was not statistically significant.

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(Their ratings, however, did not indicate that machine aerificacion resulted in deterioration of turf appearance.) Verticutting did not reduce the number of dry spots until late in the experiment (late summer) and it was then only slightly beneficial. The judges' scores for the verticut-treated plots were lower than those for the nonverticut areas -- this difference was highly significant.

The wetting agent used during the last portion of the experiment significantly reduced the number of dry spots that formed, but, at the concentration used, the wetting agent plot scores were rated low by the judges due to some turf injury.

During one portion of the 1963 work on Green No. 7, low output sprinklers were tested. Water sometimes had to be applied at night, due to the long period required to provide adequate water penetration. These sprinklers had a precipitation rate of .16 inch per hour, compared to .35 inch per hour from the regular high-output sprinklers, as determined from can tests made on the green from 30-minute runs.

When low-output sprinklers were used, tensiometer readings indicated it was possible to dry out the soil more before dry spots appeared, probably because the green was wetted more uniformly. It was also easier to re-wet dry spots with low-output sprinklers.

DRY SPOT CONTROL CONCLUSIONS

It is possible to carry on highly replicated experimental tests on golf course greens if management and players understand the importance of solving the problem, and if the experimenters arrange their work schedule to cause a minimum of inconvenience to the greenskeeper and the golfers.

Monthly aeration in a warm interior valley on a 30-year old Seaside bentgrass green materially aided in the control of dry spots without turf injury.

Verticutting during the summer months reduced turf vigor and appearance under the conditions of this test, but appeared to be of benefit in the control of dry spots after moderate to heavy thatch had accumulated.

At the concentration used, the wetting agent aided in the control of dry spots but caused some injury to the turf grass.

Judges not trained in the scoring of turf grass appearance were able to accurately appraise the visual effects of different management practices. Experienced golfers, greenskeepers, and graduate agronomists rated turf appearance in approximately the same manner. Differences of levels of scores were evident among the three groups, but the relative turf appearance ratings were in close agreement from all three groups.

Summer Aeration Helps Turf Growth

by Wayne C. Morgan
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The value of mechanical aeration of a turfgrass soil has been known to turfgrass superintendents for a long time. Surprisingly, many superintendents still have not taken full advantage of this practice to help them grow a healthier and more attractive turf.

Some golf and bowling greens may receive only two aerations a year, one in spring and another in fall. One-half-inch spoons are then used, followed with a top-dressing to backfill the holes.

Unfortunately, many people believe that aeration in warm weather is detrimental to turfgrass. Some also feel that the newer "sand" greens can't become compacted and therefore have no need for aeration. Both of these assumptions are incorrect.

An ideal soil for growing plants is one where one half of the volume is solids and one half pore space. One half of the pore space is filled with wafer and the remainder with air. Soil compaction, prolonged over irrigation, and lack of drainage increase the amount of water filling the pore space at the expense of a decreased supply of air.

Maintenance of good grass growth on golf or bowling greens, as on athletic fields and other heavily used turf-grass areas, is often difficult because of severe soil compaction. Compaction is harmful to grass growth because closely packed soil particles restrict root growth, reduce water intake rates and decrease the rate of oxygen supply to the roots.

The term "aeration" implies that this practice is done to supply air to the soil. This is partially correct, but perhaps the greatest benefit comes from allowing water to enter the soil where it can be useful to the plant.

An understanding of the role respiration plays in plant growth is helpful in further emphasizing the importance of having a plentiful supply of oxygen in the soil. It is from respiration that a plant derives energy for its growth and metabolic activities. In order for a plant to take up water and plant nutrients, work is required of the plant. Energy for this work is derived from respiration,. In this process oxygen (O_2) is consumed and carbon dioxide (CO_2) is released. Carbon-containing compounds of the plant's sugars (CH_2O) are the source of fuel.

$$(CH_2O) + O_2 \xrightarrow[\text{living organisms}]{\text{Respiration of}} CO_2 + \text{Energy}$$

This process is the reverse of photosynthesis, the food-making process of the plant.

$$CO_2 + H_2O + \text{Light energy} \xrightarrow{\text{Green plant}} \underset{\text{(sugars)}}{(CH_2O)} + 0_2$$

Thus, the inverse relationship between photosynthesis and respiration is as follows:

$$\text{Energy} + CO_2 + H_20 \underset{}{\overset{\text{Photosynthesis}}{\rightleftarrows}} \text{Carbon-containing compounds of plants (sugars)} + CO_2$$

A recent study by Stolzy and Letey of the University of California at Riverside, revealed that low soil oxygen conditions were found most detrimental to plant growth when air or soil temperatures were high. Test results also emphasized the importance of promoting rapid water in-take rates to eliminate prolonged flooding of the soil to get water into root zones.

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It can be seen that in warm weather a compacted soil can create an ever increasing problem for growing healthy turf; with less water infiltrating into the soil, roots become shallow and water must be applied more often to meet the needs of the turf. The available pore space is filled with water and the amount of air decreased, hence less respiration and energy for root growth and activity.

Aeration programs on golf and bowling greens, including several new "sand" greens, during the summer of 1963 provided added evidence that this practice is beneficial and practical. In this work, one-quarter-inch spoons were used and the holes were allowed to remain open. Some greens were aerated as often as every four to six weeks from June through October. No interference with playability of the greens was reported.

It was found that with a summer aeration program there were fewer hard, dry areas; less hand watering was required; deeper rooting had developed; and the greens were healthier.

When the turf was watered following aeration, no problems of drying out were noticed. It was found on a couple of greens that sod web-worms became active around the open holes but an insecticide soon controlled these pests.

From the results of this work, summer aeration can be recommended. The frequency can be determined by the speed with which the turf recovers and holes fill in. Use one-quarter-inch spoons in the summer and one-half-inch spoons followed by top dressing in the spring and fall.

Aeration during the winter may be of benefit under conditions of heavy turf use and compaction but should not be done so frequently that the turf cannot recover.

TURF IRRIGATION BASED ON INSTRUMENTS

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The irrigation of turf is being carried out over extensive areas under many different climatic situations and on widely varying soils. For most situations, however, turf hardiness and adaptability tend to minimize irrigation problems. Awareness of irrigation problems is more acute when a drought sensitive turf species is grown under adverse climatic conditions and/or continuous use.

The "textbook" approach to irrigation often is phrased in terms of delaying the application of water as long as possible and then applying ample water to fill the entire root zone. In contrast, many irrigators have observed adverse effects of too little water, and hence, apply lavish amounts frequently, to avoid the "evil" of drought conditions.

It appears that some compromise in the theory of turf irrigation is yet to be reached, and, still more important, any compromise or theory must be workable. A written statement about turf irrigation usually contains explanations relating to soil properties and concludes with estimates of quantities of water which an average turf uses under average climatic conditions. While such information is meant to be helpful, neither measured soil properties nor measured water use rates are commonly available for guiding routine irrigation.

Much of the scientific progress of the world is based on man's ingenuity for constructing instruments for measuring specific quantities and thereby being able to keep records in terms of numerical values. The list of "gadgetry" associated with irrigation techniques is too long to be reviewed, but the fact that so many devices (not all of them workable) have been conceived is an indication of the need for reliable instruments.

Instruments called tensiometers have been in use for over 30 years. By following readings on tensiometers, a continuing record of soil moisture conditions may be obtained without calibration or reference to soil characteristics. Because such instruments respond to a well-established "wetness" scale of values, they are well suited for use in guiding irrigation practices which are carried out to control soil moisture.

Irrigation management based on applying water when tensiometer readings reach prescribed values has been practiced extensively for various tree and vegetable crops. For this reason, the commercial tensiometer models have been designed largely for use with such crops.

When a widespread interest in the use of such instruments for turf is indicated, it is likely that modified models to meet the unique requirements of turf will be forthcoming. The uniqueness in the use of instruments for turf is related to: (a) the location of the porous cup sensing element at shallow depths in the soil, and (b) the placing of the vacuum indicating gauge below ground level or in a border area so as not to interfere with the use of turf areas.

In one major development, the commercial use of tensiometers for turf is further advanced than for any other crop. There are now available commercial irrigation systems using tensiometers as hydrostats. Such completely automatic systems involve a timing device as well as a hydrostat. When the soil near the hydrostat is dried to the point where irrigation is indicated, the hydrostat calls for water, but the time clock then takes over and determines the time of day and the duration of the irrigation. The tensiometer-hydrostat irrigation program automatically adapts the applied irrigations to changes in water use resulting from climate or from changes in plant requirements.

At best, the hydrostat can assure good irrigation management in the area where the hydrostat is located. This makes the need for a well-engineered sprinkler system more acute. Uniform distribution of water, with rates of water application adapted to the intake of the soil, is clearly needed before automatic systems can function properly.

Since hydrostat controlled irrigation for turf is now a reality, it is reasonable to assume that indicating type tensiometers can be constructed to function properly under turf. Every greens manager who wishes to evaluate his irrigation management now has the means for doing so. He may not wish to install exposed tensiometers in the middle of the 18th green to serve as an additional golfing hazard, but there are always nursery areas or practice greens where installations can be made to gain experience in the use of instruments for improving irrigation management.