1968

Summer 1968

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TURF BULLETIN

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BETTER TURF THROUGH RESEARCH AND EDUCATION

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The Massachusetts Turf and Lawn Grass Council Incorporated is chartered under the laws of the Commonwealth of Massachusetts as a non-profit corporation. The turf council seeks to foster "Better turf through research and education".

More detailed information on the subjects discussed here can be found in bulletins and circulars or may be had through correspondence with the editor.

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Management Of Penncross

by

GEOFFREY S. CORNISH and WILLIAM G. ROBINSON

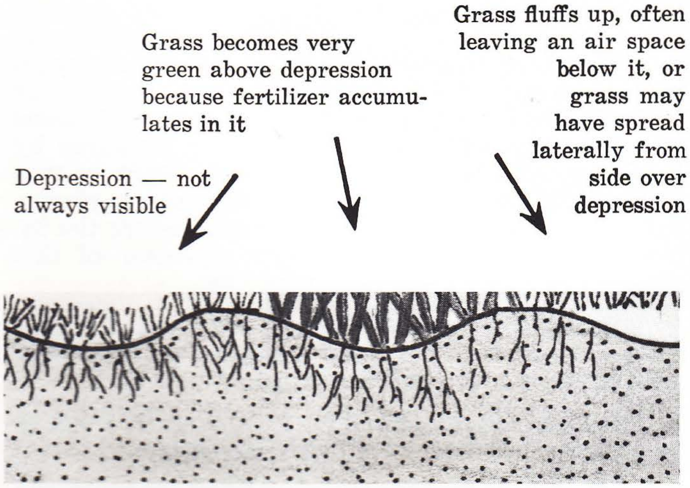
Golf Course Architects

Innumerable superb putting surfaces that can be rated among the very best are composed of Penncross. On the other hand some inferior greens have been developed from this same grass.

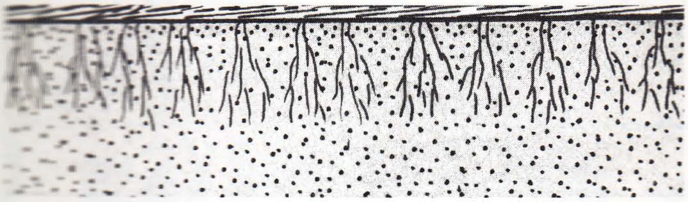
Many factors are involved. Among these are construction, local conditions, and type and amount of traffic. Penncross is often used on greens rebuilt in problem areas where the specific problem, be it shade, lack of air drainage or a similar factor, is not completely removed before replanting.

Penncross, even when grown under ideal conditions, requires special care because of its tremendously vigorous growth habit. Because greens of this grass may soon predominate in numbers in the cool humid region it is vitally important that turfgrass agronomists, superintendents and golf architects record their observations regarding this excellent and practical seed grown creeper.

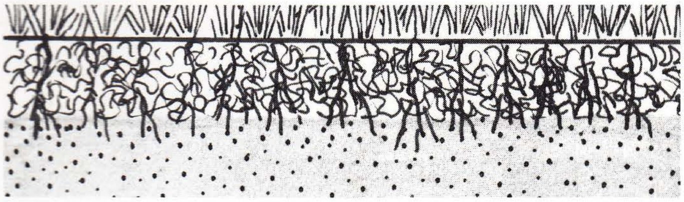
Listed below are several observations made in cooperation with many North Eastern superintendents and those in the neighboring provinces of Canada. Because there is a difference in nomenclature in different regions for defining conditions of nap, thatch, etc., several sketches are included to illustrate the conditions to which we refer.



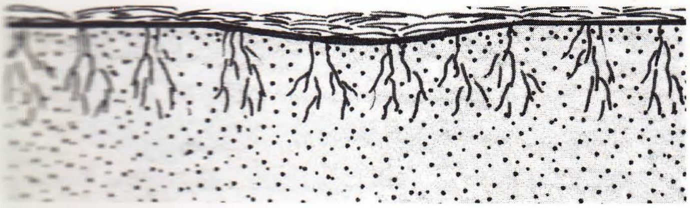
THREE STAGES OF FLUFFING OR PLUFFING: Patches of grass above small depressions rise above putting surface. A fluffed green scalps when mowed and is not a true putting surface. Actually fluffing is a severe and localized form of matting.



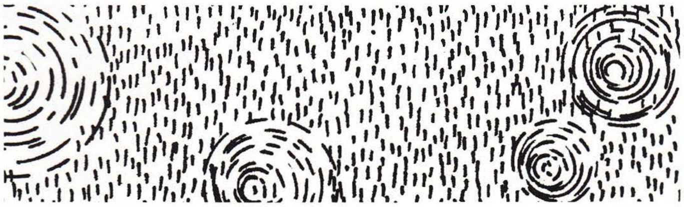
NAP OR GRAIN: Grass blades lie in one direction making downhill putts lightning fast and uncontrollable with uphill putts comparable to putting on a fairway.



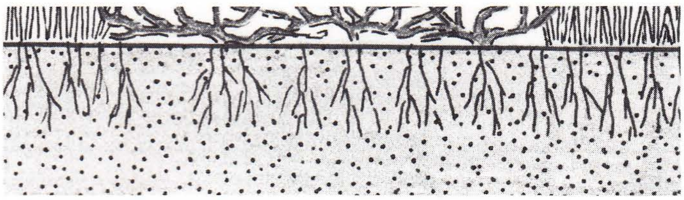
THATCH: A layer of partially decomposed organic matter sometimes many inches thick. There may be few if any roots below the thatch making the grass vulnerable to unfavorable conditions.



MAT: Grass blades are not upright. They lie in any or all directions forming a distinct mat of living spongy grass on uneven areas that may die in hot weather or over winter. Matting often occurs on Pencross collars not cut with greens mowers.



SWIRL: Grass produces distinct swirls on the putting surface, reducing eye appeal and putting qualities. More often than not this occurs the first year after seeding rather than on mature turf.



STEMMY CONDITION: Grass coarsens in patches on the entire green. In extreme cases the putting surface loses all its trueness. Most often this is caused by a heavy nitrogen application followed by overwatering and hot humid weather.

We hasten to add, however, that these are by no means peculiar to Penncross. Indeed, they occur with all other bentgrasses. In fact these definitions are largely based upon a classification prepared by Ed Casey, superintendent at Baltusrol, when he was a student in Professor Lawrence Dickinson's classes before World War II. This was years before the introduction by Professor H. Burton Musser of this superb new grass.

These observations concern established Penncross greens two or more seasons old. Obviously modifications are required for brand new turf.

1. **Mowing:** A minimum of 4 cuttings a week is mandatory, but five or six times are better.

2. **Brushing or Combing:** Brushes or combs should be placed on mowers by late May and kept on through September. But in hot humid and other unfavorable growing periods the brushing and combing **must not** be vigorous.

3. **Vertical mowing and slicing:** These are required at least twice yearly, perhaps in early May and again in September. Frequent mowing, brushing or combing together with vertical mowing and slicing are required to prevent this vigorous grass from matting and thatching.

4. **Topdressing:** At least three topdressings are required per season. Penncross will nap, fluff or swirl if the surface beneath the turf is uneven.

5. **Thatch:** Although too thick a thatch must be prevented, one-quarter to one-half inch is acceptable to provide the green with adequate holding qualities for approach shots. In permitting this thin thatch it is important to keep roots growing downward rather than horizontally as often occurs. Vertical rooting will be helped by deep aerifications and/or slicing.

6. **Fertilizing:** Frequent light applications of ½ pound of nitrogen or less per thousand square feet are best if the fertility level of the green is high. Indeed, ¼ pound of nitrogen per thousand per week is often ideal. Phosphorous and potash must not be overlooked and the latter is particularly valuable in autumn. ALWAYS BEWARE OF HEAVY NITROGEN APPLICATIONS. An application of one pound of nitrogen per thousand or more followed by overwatering, together with a hot humid period of several days with temperatures in the high eighties or nineties, often causes Penncross to become stemmy and the putting surface to lose all resemblance of trueness.

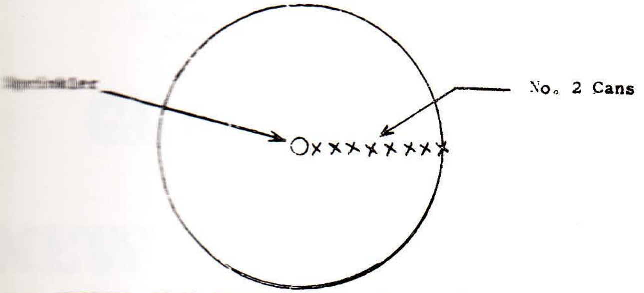
7. **Watering:** Penncross grown on well prepared soils is remarkably drought tolerant because of its deep root system. Many a superintendent has noted that a Penncross putting surface can actually be improved by letting it reach close to the wilting point before resorting to irrigation. As noted above, overwatering in humid weather contributes to the stemmy condition.

8. **Fungicides:** As with all putting grasses, preventative treatment is best. The idea still persists that Penncross is highly disease resistant and less frequent fungicide applications are required. This has not been our observation, nor that, I believe, of many New England superintendents, although the grass is relatively resistant to several fungi.

It is emphasized that this paper is based on observations in the field of superintendents and ourselves and not on documented scientific data. It is therefore probable that turfgrass scientists who have worked with this superb grass have many other recommendations for its management. Indeed, with so many honest differences of opinion concerning Penncross it is highly likely that many a superintendent with the highest quality Penncross greens manages these quite differently from the procedure outlined above.

We can, however, conclude that Penncross more often than not produces superior quality greens turf of the type the golfer wants. Nevertheless, under some management procedures that do not compensate for its extreme vigor, it can be a disappointing grass. We should also observe that concern has been expressed about the quality of Pencross seeds. Dr. Eugene Nutter, who recently consulted with Dr. Joe Duich on this subject, has informed us this matter is now well in hand and Penncross will be maintained true at both growers and marketing levels.

Irrigation Facts



C.E. STEWART, CIVIL ENGINEER, HOMEWOOD, ILLINOIS.

It has often been the desire of the golf course superintendent to obtain a cheap, easy, and accurate method for determining the exact precipitation of water in inches per hour from a sprinkler. The following suggested method fulfills this desire.

MATERIALS REQUIRED

a — A number of No. 2 cans, or any similar type of container which has a diameter of 3¼". No. 2 cans are commonly used at grocery stores to contain peas, beans, tomatoes, etc.

b — One glass or plastic cubic centimeter tube, this graduated cc tube costs about $1.00 and may be purchased at most drug stores or surgical supply stores.

METHOD TO EMPLOY

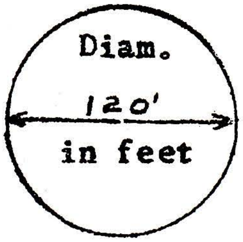
1. Place the sprinkler in its desired position.
2. Use as many of the No. 2 cans as are required to extend from the sprinkler in a straight line to the outer edge of the sprinkler coverage and at 2 to 5 feet intervals apart.
3. Set the sprinkler in operation and **RUN IT FOR EXACTLY 44 MINUTES.**
4. Shut off the sprinkler and pour the contents of any No. 2 can into the cc tube, a reading in centimeters will be obtained but each cubic centimeter will equal exactly 0.01 inches, or (1/100th inch) of sprinkler precipitation **PER HOUR.**

EXAMPLE

If a reading of 37 cubic centimeters is obtained from a can after the sprinkler has been running exactly **44 minutes** the sprinkler will, or the area where the can was located, precipitate 0.37 inches **per hour.**

By plotting the precipitation from each can on graph paper a true sprinkler precipitation curve may be obtained.

The above test should be conducted where there is water distortion by wind velocity as well as a test with NO WIND.



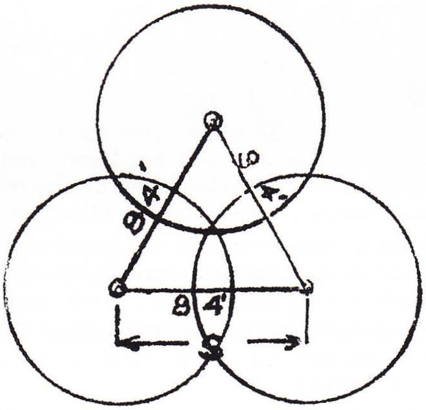
Formula for finding the precipitation in inches per hour from any sprinkler when discharge in gallons per minute and coverage in feet is known.

$$\text{Precipitation in inches per hour} = \frac{122 \times \text{g.p.m.}}{\text{Diam. squared}}$$

EXAMPLE: If a sprinkler discharges 25 g.p.m. and covers a circular area of 120 ft. in diameter the precipitation is

$$\frac{122 \times 25}{120 \times 120} = 0.21 \text{ inches per hour}$$

—Reprinted from
The Bull Sheet, Vol. 18, No. 11

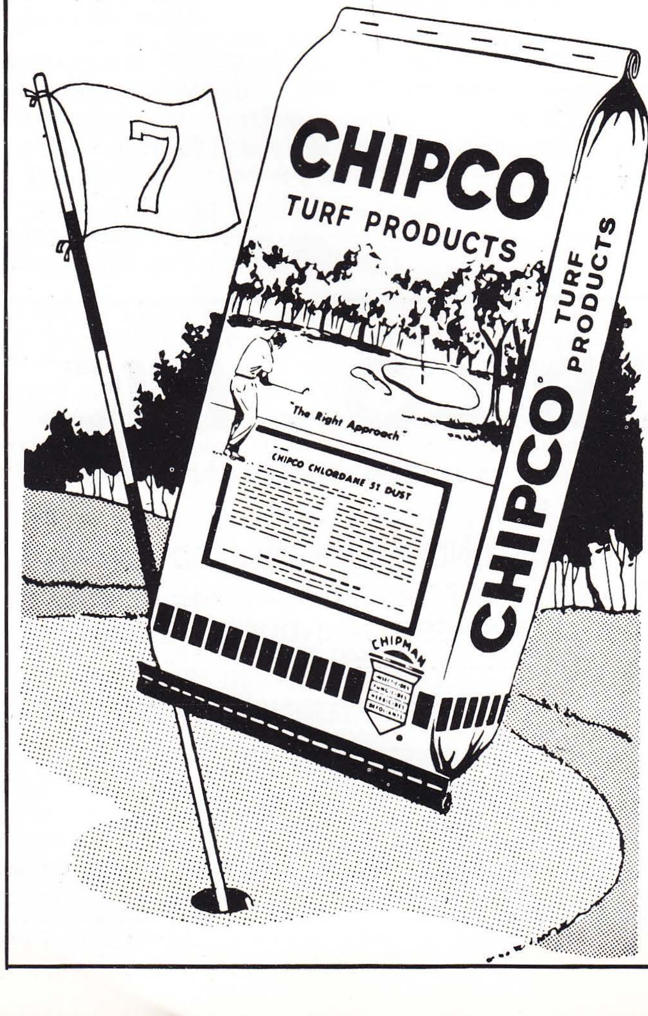


Formula for finding the precipitation in inches per hour from identical sprinklers located in an equalateral spacing when the discharge from any one sprinkler and distance between sprinklers in feet is known.

The precipitation in inches per hour within the triangle is: $\frac{111 \times \text{g.p.m.}}{S \text{ in feet squared}}$

EXAMPLE: If each of the above sprinklers discharges 25 g.p.m. and they are spaced 96 feet apart in an equalateral position the precipitation in inches per hour **within the triangle is:**

$$\frac{111 \times 25}{96 \times 96} = 0.30 \text{ inches per hour}$$



EUROPEAN CHAFER CONTINUES ITS FIGHT WITH NEW YORK LAWNS

By E. L. GAMBRELL, *Department of Entomology, Geneva*

During the fall of 1939 and the spring of 1940 serious damage was observed in lawns at Newark, New York, in Wayne County. Further investigations revealed that there was injury to nearby pastures and meadows. At first, the damage was presumed to be caused by one of our native white grubs (commonly called May beetles in adult stage) since several species were known to occur in western New York. However, further study revealed that the insect was of European origin. In 1942 it was definitely identified as the European chafer, *Amphimallon majalis* Razoumowsky.

At that time approximately 24 square miles were known to be infested. Every effort was made by state and federal authorities to limit its spread and to develop information on control. In spite of this, other infestations have been detected in different parts of the state as well as in other eastern states. These include Connecticut, Massachusetts, New Jersey, Pennsylvania, Ohio and Canada.

Based on information provided by the N. Y. Bureau of Plant Industry and the Plant Pest Control Division, U. S. Department of Agriculture, approximately 2,000,000 acres are under regulation in New York. This is represented by several fairly large areas in the north-central and western parts of the state as shown in the accompanying map. In addition, small isolated, incipient infestations of undetermined area have been observed in Broome, Bronx, Clinton, Genesee, Herkimer, Jefferson, Kings, Montgomery, Oneida, Orleans, Richmond and Schenectady Counties. These include new records in 1966 for Bronx, Jefferson, Montgomery, Orleans and Schenectady Counties. The scattered distribution of the species in New York and other states suggests several possibilities: (1) local extensions could have occurred either from direct adult flights or in the movement of the immature stages in soil about the roots of infested plants or gravel; (2) adults could have "hitchhiked" on clothing or in trucks, cars, trains or aircraft. Recent studies suggest that various common carriers may have been a more important factor to some of the wide dissemination of the species than had been realized previously. These means of commercial and personal travel doubtless will receive further investigation in the future.

Current state and federal quarantine regulations require that all sand, gravel, topsoil and plants moved from infested areas be treated with a suitable insecticide to prevent dissemination of the species.

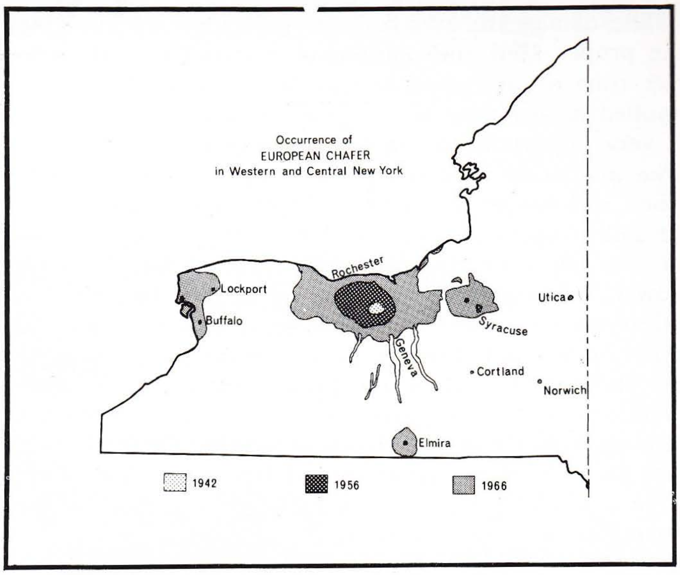


Fig. 1.—Map of the portion of New York State where major infestations of the European chafer occur. Smaller infestations in other areas of the state are indicated in the text.

The European chafer has a 1-year life cycle. Practically 11 months of the year is spent in the soil as grub or one of the other two immature stages. Beginning from early to mid-June the adult or beetle stage starts to emerge from the soil, starting about sunset and continuing until dusk each day. The emergence period may continue for up to 2 months or longer but the heaviest concentrations of beetles are observed usually from mid-June to mid-July. The beetles tend to congregate around trees, shrubs and other objects. As they fly around they make a "buzzing noise" and are often mistaken for bees. Even though they are oftentimes a nuisance to people sitting or working on the lawn they do not bite or sting and they do not feed on foliage after settling down in the trees and shrubs. This is in marked contrast to a number of our native species of May beetles and the Japanese beetle, all of which are voracious feeders.

The beetles deposit their eggs singly in a small cell in the soil. A female may lay from 20 to 50 eggs. These eggs hatch in from 2 to 3 weeks, depending upon the soil temperature. The larvae feed upon the roots of various grasses, legumes and weeds. Most of the feeding by the grubs and damage to grass, or other plant roots, occurs during late summer, early fall and early spring. The grubs remain active in the fall until late October or early November, depending primarily upon the soil temperature. As the soil temperature approaches the freezing point the grubs tend to go deeper into the soil and they usually remain just below the frost line until the spring thaw occurs. After this, they move upward to the roots near the surface of the soil and complete their feeding period by early or mid-May. At maturity, the grubs are approximately 1 inch long, creamy white in color with a yellowish head, and are in the shape of a tight C. Following the feeding period the larvae transform to a pre-pupal, pupal and finally to the adult or beetle stage, thus completing the life cycle in 1 year.

—Reprinted from Farm Research, Vol. 33, No. 2 & 3

Control of the Grubs

The damage to grass can be prevented by applying the proper kind and amount of insecticide at the correct time of the year. Actually the insecticidė can be applied at any time of the year. However, temperature is very important to the performance of the material. The insecticide is most effective and kill is most rapid when soil temperatures are near or in excess of 70°F. At soil temperatures of 50–60°F., such as are common in late fall or early spring, the rate of kill is much slower. Consequently, early spring or late summer applications are preferred. If possible, treatment should be made immediately before a rain, or it should be "washed in" thoroughly with water from a garden hose. This practice serves a dual purpose in that it removes excessive residues from the grass and aids in washing the insecticide into the soil. Repeated rains and freezing and thawing serve a useful purpose in helping to incorporate the insecticide into the soil where the grubs will be exposed to it. The small, young grubs which are present during July and August are more readily killed than the larger, older grubs in late fall and early spring.

Repeated experiments have shown that such pesticides as aldrin, chlordane, dieldrin and heptachlor are quite effective in controlling the grubs in the soil and that these materials will provide protection to grass for several years following application. The effective period is determined largely by the particular pesticide, the amount applied and the type of soil. However, a single application of one of these materials at the rate suggested in the table should grub-proof a lawn for several years under average conditions. If treatments are applied in late summer or early spring it is not uncommon to observe some larvae coming to the surface of the soil before they are killed. Such occurrences should not be interpreted as indicating that the treatment is not effective—rather it is definite proof that the grubs have been affected by the chemical.

Since there are a number of chemicals, formulations and different rates of application involved it is not possible to suggest any one method or rate of application that would meet all conditions. In general, dry formulations such as dusts or granular mixtures can be applied with regular lawn seeding or top-dressing equipment calibrated to apply the proper amount for a given area, i.e., per 1,000 square feet. Emulsifiable concentrates and wettable powders can be applied in water with hand sprayers of various types. Some garden supply stores provide directions and suitable equipment on a rental or loan basis for applying their particular products. Insecticide-fertilizer mixtures are also available for use.

Control of European chafer grubs in lawns is based upon the use of aldrin, dieldrin or heptachlor at the rate of 3 pounds or of chlordane at the rate of 10 pounds of the active chemical per acre. The actual amount used, for example, on 1,000 square feet will depend upon the insecticide and the per cent of active ingredient in the formulation. For details, consult Table 1.

***Table 1.* Recommendations for control of the European chafer in lawns.**

Material (use one only)	Amount per 1,000 sq. ft. of lawn (10 × 100 ft. in area)
Dusts:	
5% aldrin, dieldrin or heptachlor	1½ lbs.
5% chlordane	5 lbs.
Wettable Powders:	
25% aldrin or heptachlor	4½ ozs. in 15 gals. of water
40% chlordane	10 ozs. in 15 gals. of water
50% dieldrin	2¼ ozs. in 15 gals. of water
Liquid Emulsifiable Concentrates:	
24.5% aldrin (contains 2 # /gal.)	4½ fl. ozs. in 15 gals. of water
75% chlordane (contains 8 # /gal.)	3¾ fl. ozs. in 15 gals. of water
18.6% dieldrin (contains 1.5 # /gal.)	6 fl. ozs. in 15 gals. of water
2 E heptachlor (contains 2.0 # /gal.)	4½ fl. ozs. in 15 gals. of water
Fertilizer mixtures, including aldrin, chlordane, dieldrin or heptachlor	Concentrations vary in active ingredients. Use as recommended on label.

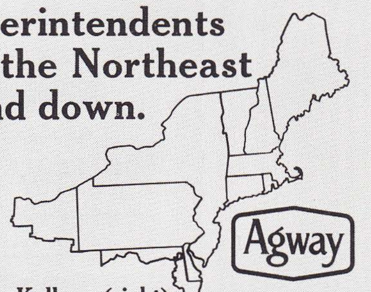
Suggestions in Grub-proofing Your Lawn

1. Read directions on package carefully and follow directions.
2. Remove all lawn furniture, toys, dog bones, receptacles for pets or other objects before applying insecticide.
3. Dilute insecticide and apply evenly and uniformly as directed on container.
4. Water insecticide into soil after treating lawn. This serves the dual purpose of removing insecticide from the foliage and washes it into the soil around grass roots.
5. Keep children and pets off treated areas insofar as possible for several days.
6. Avoid inhaling materials or direct contact with them.
7. Annual treatment is not necessary if applied according to recommendations. Most treatments should last for 3 years.
8. Milky spore disease has not proved satisfactory for control of the European chafer.

***Editor's Note:* Shortly after completing this article on the incidence of European chafer in New York State, Dr. Foster L. Gambrell died suddenly while attending a meeting in New York City. He had been with the Geneva Station since 1925. During his 42-year career with the Station, Dr. Gambrell became world famous for his research on insects affecting nursery, turf, shade tree, and ornamental plants. Much of his research effort was directed toward eliminating and controlling the insect about which he wrote in this article—the European chafer. He was the first scientist to discover its presence in North America. More than 40 of his 100 scientific papers and numerous popular articles dealt with this pest that attacks New York lawns. Because of his diligence and accurate recommendations, home owners are able to prevent infestation by the European chafer, thereby preventing total destruction of established lawns.**

How Agway helps bring golf to you in living color

Agway serves golf course superintendents everywhere in the Northeast from the ground down.



Agway

Lynn Kellogg (right), superintendent, Oak Hill C. C., Rochester, N.Y., and Agway's Bob Carson discuss condition of the greens in preparation for the 1968 U.S. Open. Carson is an Agway specialist in professional turf maintenance.

Compaction And Wear Of Turfgrasses

WILLIAM E. CORDUKES
Plant Research Institute,
Ottawa, Ontario

Considering the varied sites and uses of turf grasses by society with increased time for recreation, it can be appreciated that compaction and wear of turf areas could cause considerable concern for turf managers. Sports stadia, playing fields, parks and paths of public and institutional gardens are particularly subject to heavy and concentrated traffic by man. In addition, the use of heavy equipment for turf maintenance practices can add to the problem.

The pounding and abuse that turf areas take from human traffic is difficult to realize but perhaps can be appreciated from statistics concerning play on a golf course. If 200 people play a course every week-day (not unusual on many courses), the golf greens would receive some 36,000 lbs. of foot pounding, while double this number on Saturday and Sunday would provide the equivalent of 36 tons weight on each green. The same number of players, each swinging 75 times and making 30 putts, result in approximately 2/3 of an acre of turf per week flying through the air in the form of divots on the course!

Compaction of turf grass areas presents quite a different problem from compaction of soil for agricultural production in that turfgrass is a permanent cover. To destroy the turf, lessen compaction and improve physical characteristics, and then renew the sward is a costly and time-consuming procedure. Also such operations must be accomplished at the very time when the area is needed for recreation. Research has approached the problem from two directions. On the one hand, there are studies of the physical properties of soil in relation to plant growth and the possibility of improving the soil with additives before grass has been established. The other approach has been to study artificially compacted turf grass areas or to work on already compacted sites by means of surface tillage treatments and equipment to relieve the effects of compaction.

Studies to assess compaction effects on typical lawn swards of Eastern Canada were begun in 1965 and continued in 1966 and 1967. Five lawn mixtures in 4 replications were seeded to plots 20 ft. x 8 ft. in the fall of 1962 on a sandy loam soil. A 'West Point Jr.' aerifier was equipped with 16 metal shoes to simulate foot traffic (1). The shoes were designed to deliver the equivalent packing effect (pressure per square inch) to that of a walking adult. The self-powered aerifier was operated across the lawn mixtures covering a strip approximately 3 ft. in width. The compaction treatments simulated varying seasonal compaction. The details of the five lawn mixtures and the compaction treatments are given in Tables 1 and 2. Four renovation treatments to enhance turf recovery were later applied singly, one to each replicate of lawn mixtures. These treatments consisted of combinations of irrigation, fertilizer aeration and verti-cutting or vertical slicing. Fol-

TABLE 1
LAWN MIXTURES UNDER COMPACTION TREATMENTS AT OTTAWA

Mixture	Percentage weight by species at time of seeding
1	Merion Kentucky bluegrass — 75, Norlea perennial ryegrass — 25
2	Common Kentucky bluegrass — 75, Norlea perennial ryegrass — 25
3	Merion Kentucky bluegrass — 75, Pennlawn creeping red fescue — 25
4	Merion Kentucky bluegrass — 50, Pennlawn creeping red fescue — 50
5	Merion Kentucky bluegrass — 25, Pennlawn creeping red fescue — 75

TABLE 2
Compaction Treatments Imposed on Lawn Mixtures at Ottawa

Tr. No.	Compaction treatment and time applied (applied across all lawn mixtures)
1	Spring compaction — 50 passes / day, May 15 - June 15, 1966
2	Summer compaction — 50 passes / day, July 1 - July 15, 1965
3	Summer compaction — 10 passes / day, June 1 - October 1, 1965
4	Fall compaction — 50 passes / day, Sept. 1 to Sept. 30, 1965

TABLE 3
SOIL PROPERTIES BEFORE AND AFTER COMPACTION TREATMENTS AT OTTAWA
(Means of 8 samples)

Compaction treatment	Soil Bulk Density gm./cc.	Soil Pore Space		
		Non-capillary %	Capillary %	Total %
Check	1.33	39.7	17.1	56.8
*50 passes/day May 15-June 15	1.50	35.4	9.2	44.6
50 passes/day July 1-July 15	1.45	36.3	14.1	50.4
50 passes/day Sept. 1-30	1.45	39.6	10.3	49.9
10 passes/day June 1-Oct. 1	1.42	42.0	8.6	50.6
Check (1966)	1.33	34.7	17.1	51.9

* Treatment applied in 1966, other treatments applied in 1965.

lowing renovation, the compacted plots were maintained as regular lawn area and received normal fertilization and irrigation practices. In May 1967, they were re-sampled for soil bulk density and pore space analyses.

All of the strips compacted by the aerifier showed marked visible wear and compaction — the grass became brown, the surface grade was depressed and later there was some invasion by such weeds as Dandelion and Common Plantain. The heavier seasonal compaction (50 passes/day treatments) was more drastic than the light continuous compaction. This was indicated by the appearance of the turf and also by the results of analyses for soil bulk density and percentage pore space (Table 3). In general, these treatments increased the soil density by approximately 6 percent and reduced the total percentage pore space by 6-12 percent. Severe packing for a period in either spring or fall lowered the capillary fraction (the important fraction for good moisture and nutrient relations) of total soil pore space by more than 7 percent. The compaction treatments also severely restricted water percolation rates (Table 4) and consistently lowered the total dry matter of roots in the 2-inch to 6-inch soil zone (Table 5).

By mid-summer of 1966, the turf on the strips compacted in 1965 had fully recovered. Similarly, the area compacted in 1966 was healthy and dense by the summer of 1967. Weed populations at these times were less than those observed in the late fall in the year of treatment. Soil analyses of samples taken in May 1967 showed no significant differences due to treatment when compared with analyses of samples obtained from the same plots at the beginning of the experiment. Renovation by aeration and/or vertical slicing tended to enhance recovery immediately following the compaction treatments. The plots of Merion Kentucky Bluegrass recovered more quickly than did the plots containing largely common Kentucky Bluegrass or creeping Red Fescue. Merion Bluegrass was particularly striking in its ability to recover from the severe wear and tear of the compaction machine.

These experiments have shown that compaction of the surface soils of loams or sandy loams could be quite serious. Immediately following such compaction, the leaf blades of all species are severely bruised, and turn brown in color, but given time and good nutrition and watering practices, they will recover. Unfortunately, many turf areas are subject to continuous summer traffic and it may not be possible to provide respite from such pounding, to allow the turf to recover. A comparison of soil analyses of samples taken at the beginning of the experiment, following compaction and renovation in 1965 (fall), in the fall of 1966 and summer of 1967, indicate that frost penetration of this soil has helped relieve soil compaction effects. It can also be surmised that soil compaction of turf on clay soils would be considerably more serious than that illustrated in these experiments.

TABLE 4
RATE OF WATER PERCOLATION BEFORE AND AFTER COMPACTION OF LAWN MIXTURES AT OTTAWA
(Means of 2 samples)

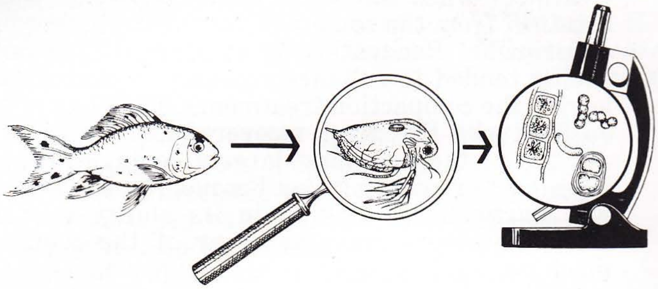
Lawn mixture (percentage seeded by weight)	Percolation time — minutes for 6 gal. water to penetrate sod in a 24 dia. ring			
	Oct. 5, 1965		Oct. 13, 1965	
	check	10 passes/day July to Oct.	check	50 passes/day Sept. 1 - 30
Merion 75 — Norlea 25	13	67	40	138
Common 75 — Norlea 25	15	260	37	101
Merion 75 — Pennlawn 25	14	257	54	280
Merion 50 — Pennlawn 50	20	192	59	174
Merion 25 — Pennlawn 75	14	283	40	95
Mean	15	212	48	156

TABLE 5
EFFECT OF COMPACTION TREATMENTS ON PRODUCTION OF GRASS ROOTS
(Means of 8 samples)

Lawn mixture (percentage seeded by weight)	*Dry weight of roots	
	Check gms. d. m.	10 passes/day July to Oct. gms. d. m.
Merion 75 — Norlea 25	.033	0.25
Common 75 — Norlea 25	.025	0.24
Merion 75 — Pennlawn 25	.035	0.27
Merion 50 — Pennlawn 50	.032	0.17
Merion 25 — Pennlawn 75	.038	0.21

* Rootweights are total dry matter from a 4″ core from the 2″ to 6″ soil layer (means of duplicate samples).

(Continued on Page 14)



The author develops specific criteria for determining safe pesticide use, especially in relation to non-target organisms and the environment. Four unidentified pesticide chemicals are used to illustrate a wide spectrum of biological behavior. An understanding of the inter-relationships of a pesticide with soil, water, air, and living organisms is required for proper evaluation of its utility.—Editor

Guidelines for Evaluating the Properties of Pesticides for Safe Use in the Wildlife Environment

By EUGENE E. KENAGA*
The Dow Chemical Company

INTRODUCTION

The object of this paper is to present an outline of investigations designed to evaluate the likely effects of pesticides on wildlife with special reference to applying the information to estimating hazards to non-target organisms and their environment. This problem involves an understanding of:

A. How pesticides can contaminate the environment.
B. How pesticide contamination can be decreased after application.
C. How to estimate maximum residues in the environment from given pesticidal usage and dosages.
D. How to make use of the physical, chemical and biochemical properties of pesticides in order to predict their fate in various segments of the environment.
E. How to make use of representative toxicological tests in order to predict effects on fish and wildlife organisms if their environment is to be involved in target or non-target uses.
F. How to correlate intended target pesticide uses and dosages with available biochemical, toxicological, chemical and physical properties of different chemical classes of pesticides, to assess their respective hazards to non-target organisms.

The following are some of the factors to be considered in answer to the questions in the sequence given above.

A. HOW PESTICIDES CAN CONTAMINATE THE ENVIRONMENT.

1. *Air Contamination*
   a. Vapor or particles directly from pesticide application.
   b. Volatility from treated surfaces (plants, soil, animals, water, paint, wood, masonry).
   c. Secondary volatility from coated surfaces not originally treated.
   d. Volatility from water or mixtures.
   e. Air movement and mixings of vapor or particulate matter (contamination of untreated areas mostly by wind and air inversions due to temperature change).
   f. Bio-transfer from flying organisms.
2. *Water Contamination*
   a. Direct application to water.
   b. Run-off from treatment.
   c. Sorption from vapor.
   d. Leached from or through soil.
   e. Wind transfer of contaminated particles (soil, plants).
   f. Water movement and mixing from one area to another.
   g. Cosolvents (especially in polluted waters).
   h. Bio-transfer through organisms feeding, metabolism, reproduction and other energy exchange media.
   i. Rain, snow, etc. filtering through the atmosphere.
   j. Erosion of contaminated soil from rain, melting snow.
   k. Water turnover of buried contaminants in ponds, rivers.

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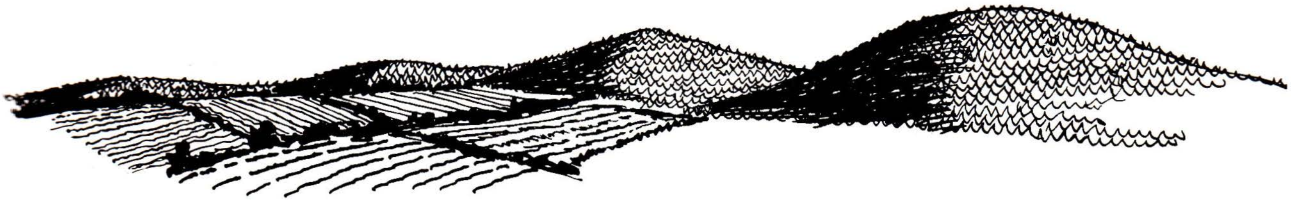

3. *Soil and Rock Contamination*
    a. Direct application of chemical.
    b. Run-off from treatment.
    c. Wind transport of contaminated particles.
    d. Water erosion of contaminated soil particles.
    e. Water solubility transfer (leachings, run-off, flooding).
    f. Soil mixing (farming, road building, equipment and mechanical machinery).
    g. Bio-transfer through feeding or contaminated organic material, reproduction, metabolism, elimination and other energy exchange media (animal defecation and urine onto soil).
    h. Sorption from vapor, water, organic or mineral sources (living plant root emissions into soil).
4. *Living Organisms Contamination*
    a. Direct application of pesticide.
    b. Ingestion of chain-of-life food (causing possible biological magnification of pesticides).
    c. Contact with contaminated non-food environment (including water, air and soil) causing biological magnification.

B. HOW PESTICIDE CONTAMINATION CAN BE DECREASED AFTER APPLICATION.

1. *Dilution into*
    a. Air
    b. Soil and rock
    c. Water
    d. Plants and animals (dead or alive).

Using the same mechanisms causing contamination in reverse such as solubility, erosion, volatility, preferential sorption, weather.

2. *Chemical Breakdown (molecular transformation)*
    a. Metabolism in plants, animals (enzymatic, pH dependent reactions).
    b. Weathering (ultraviolet and visible light, heat, rain, ice, snow, wind).

Weathering and metabolism cause such reactions as hydrolysis, oxidation, reduction, polymerization, condensation or addition reaction with a non-contaminant, dehalogenation, dehydrohalogenation and dealkylation.

C. HOW TO ESTIMATE MAXIMUM RESIDUES IN THE ENVIRONMENT FROM GIVEN PESTICIDAL USES AND DOSAGES.

It is important in the development of a pesticide to be able to approximate the maximum residues that might result from the use of target dosages on various non-target segments of the environment. Once these dosages are determined, formulas can be employed to calculate the maximum residues in various environmental media. This assumes no loss due to environmental factors and application techniques. The hazard and amount of pesticidal residues is greatly reduced if the chemical is readily decomposed by environmental factors or is metabolized by plant or animal tissues to less biologically active compounds. Methods of calculating maximum residues are shown below.

Soil Conversion Factors—Assuming one cubic foot of soil equals one hundred twenty-five pounds, a 1 pound dosage of a pesticide will equal 0.73 ppm if evenly distributed in an acre of soil three inches deep. Of course, soils do differ in specific gravity so this is an approximation.

Food Conversion Factors—The amount of chemical applied to an acre of surface is easily calculated. However, an animal eats various weights, shapes and sizes of foods, which makes the amount of pesticide occurring in its diet highly variable due to variations in spray deposit on different surfaces. In the absence of actual chemical analyses, the estimate can be regarded only as theoretical. For purposes of estimation, the weight of wheat grains, closely packed in a one kernel thick layer was determined on an acre surface basis. This weight (15,000 lbs) in relation to one pound of pesticide applied per acre is equivalent to 67 ppm by weight of pesticide. This is used as the food conversion factor in this paper.

Water Conversion Factors—Using water weighing 62.4 lbs per cu ft, a 1 lb per acre pesticide dosage thoroughly mixed in a 3 inch depth of water would result in a concentration of 1.5 ppm of the pesticide in water. Compounds of very low water solubility may not reach the concentration predicted from the dosage applied.

Air Conversion Factors—To determine the saturation dosage of a compound in air in terms of pounds per 1000 cu ft the following formula is used:

$$\frac{\text{Vapor pressures at ``y''°C} \times \text{Molecular wt} \times 1000}{\text{Air pressure in mm} \times \text{factor } .082 \times (273 + \text{``y''°C}) \times 16} = \text{lbs/1000 cu ft at ``y''°C.}$$

This saturation dosage in air is possible only under conditions where air is confined and static.

The above conversion factors have been used to obtain maximum expected residues of four specifically chosen pesticide chemicals (A, B, C, and D) as shown in Table I.

These four pesticides are chosen to represent four classes of chemical compounds. The chemical names are omitted here so that attention can be focused on the diagnostic properties of the pesticides. The calculated amounts of residues of these four pesticides in soil, food, water and air is based on the highest dosage of the pesticide as prescribed by the target use as shown in Table I.

(Continued on Page 16)

WEAR OF TURFGRASSES

(Continued from Page 11)

TABLE 6
RESIDUAL EFFECTS OF COMPACTION TREATMENTS ON SOIL PROPERTIES
(Means of 8 samples)

Compaction treatment	Soil bulk Density before tr. gm./cc.	1967 gm./cc.	Total pore space Before tr. %	1967 %
Check	1.33	1.35	56.8	58.9
*50 passes/day May 15-June 15	1.33	1.38	51.9	49.9
10 passes/day July 1-Oct. 1	1.33	1.31	56.8	54.3
50 passes/day Sept. 1-30	1.33	1.34	56.8	52.9

* Treatment applied in 1966; others, 1965.

REFERENCE

(1) Goss, R.L. and Roberts, J. 1964. A compaction machine for turf grass areas. Agron. J. 56, 522-523.

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GUIDELINES FOR PESTICIDES

(Continued from Page 13)

TABLE I

Estimation of residues from use of four pesticides applied to soil, food, water and air

	Compounds			
	A	B	C	D
Crop, soil or water use (max. dosage recommended, lbs/A)	3.0	0.05	0.025	3.0
Max. calculated initial ppm in soil*	2.19	0.037	0.018	2.19
Calculated initial ppm in food**	200	3.4	1.7	200
Max. calculated initial ppm in water*	4.5	0.075	0.037	4.5
Max. calculated concentration in air (as vapor) as lbs/1000 cu ft at sea level	0.0000029 (20° C)		0.00035 (25° C)	0.0000078 (35° C)

*3 inches deep.
**Wide variations in residues may be expected because of obvious variability of types, shapes and weights of food on the treated area.

The above residues are those occurring immediately after application. Actual residues are usually less than shown above because of environmental factors. In addition, wildlife usually is not restricted to the treated area and thus may have only a part of the diet contacted by the pesticide.

D. HOW TO MAKE USE OF PHYSICAL AND BIOCHEMICAL PROPERTIES OF PESTICIDES IN ORDER TO PREDICT THEIR FATE IN VARIOUS SEGMENTS OF THE ENVIRONMENT.

The solubility, volatility and stability of pesticides in soil, plants, animals, water and air are properties needed to predict the environmental fate of these materials. The environment contains many organic and mineral solvents. Each pesticide has a certain solubility in a group of solvents, and each may vary greatly, one from another. Some chemicals have low solubility in all solvents and some have high solubility in numerous solvents. The low solubility type is least likely to be systemic in plants or to be leached through soil. Compounds which are water soluble and resist degradation tend to spread in the environment by leaching or general dilution but do not tend to concentrate in animal or plant tissues.

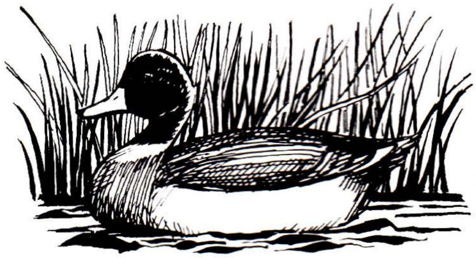
Animals in particular tend to eliminate water soluble pesticides or their water soluble metabolites by excretion. Concentration of such compounds may occur by evaporation of the water solutions in soils or water. Pesticides which are fat or organic soluble (solvents like xylene) tend to accumulate in fatty tissues of animals and plants and are held in storage until the fats are used for metabolic purposes or the pesticide is metabolized into water soluble derivatives. The use of these pesticides may result in high residues such as those that occur in chain-of-life organisms.

Compounds which are volatile may cause non-target effects, however, in the molecular state they are most susceptible to degradation by actinic light and such effects are likely to be transient. The amount of transfer of a pesticide by the atmosphere away from a given area is a function of its vapor pressure and the environmental factors surrounding it.

Pesticides often are sorbed tightly onto organic or mineral soils and volatility or solubility altered by physical and chemical factors such as hydrogen bonding, Van der Waal's forces, capillary action, and molecular sieving. Such sorption can be determined by simple soil leaching tests.

Purely chemical and physical factors such as heat, pH and cosolvency factors affect hydrolysis, oxidation, and dehalogenation, thus tending to reduce the pesticide to water soluble metabolites or to more elementary compounds, which may even be reincorporated as useful or even essential molecules in living organisms. Many organisms contain enzymes which are able to adapt to the presence of a pesticide and its metabolites and change them to more water soluble compounds for disposal.

Some important chemical, physical and biochemical properties of these four pesticides (A, B, C, D) are given in Table II.

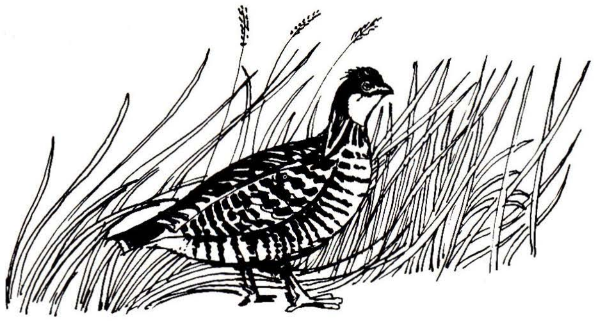


E. THE USE OF REPRESENTATIVE TOXICOLOGICAL TESTS TO PREDICT EFFECTS ON FISH AND WILDLIFE ORGANISMS.

Pesticides which are shipped in interstate commerce in the United States are registered by the United States Department of Agriculture (USDA) after a review of available data shows that they are effective pesticides and may be used in a manner that will avoid injury to man, useful vegetation and useful or beneficial animals. The Fish and Wildlife Service of the U.S. Department of Interior and the Food and Drug Administration and the Public Health Service of the Department of Health, Education and Welfare (DHEW) are given the opportunity to review proposed registration and to offer comments and suggestions.

The Fish and Wildlife Service in cooperation with the National Agricultural Chemicals Association, recognized the need for a testing protocol and in 1964 set up a guideline for testing compounds which might cause toxicity to fish and wildlife[1]. The difficulty in selecting laboratory fish and animals which represent wild fish and animals was recognized. Such tests measure the relative toxicity to genera, families, orders or phylla of organisms and serve as a guide to estimate toxicity to specific organisms.

On this basis the following tests were selected as desirable minimal requirements: (a) acute and sub-acute toxicity data on mammals as recommended by the USDA and DHEW (typical of such data are acute oral studies on three mammals, one a non-rodent, acute dermal tests on one species and a sub-acute 90 day dietary feeding test on one species); (b) eight-day dietary acute toxicity studies on 2 species of birds, one waterfowl and one upland game bird; (c) acute toxicity data on three species of fish, one cold water and two warm water species; (d) acute toxicity data on a marine mollusk. Representative species for these tests are mentioned. Additional toxicity data may be required, depending on the chemical and physical properties of the compounds. Data on stability, volatility, persistence, metabolites and solubility are required.



Other tests are needed for USDA registration by the Food and Drug Administration if a pesticide leaves a residue directly or indirectly in or on food which is eaten by animals or humans[2]. Such situations, depending on the amount of residue present, may require chronic dietary tests (90 days to 2 years) and a report of the effects the pesticide may be capable of causing on such things as body and organ weights, blood composition, enzyme systems, central nervous system and cell reproduction in mammals and birds. Safety is judged in view of the amount, nature and proposed conditions of use of the pesticide chemical.

In addition to these representative laboratory tests, actual field tests are conducted in the habitat of the target organism. Although field tests are necessary and invalu-

TABLE II

Chemical, physical and biochemical properties of four pesticides

	A	B	C	D
Related to solubility				
Water (25-30° C) ppm	0.0002	100	0.4	430
Acetone (g/100 cc)	58	162	650	2
Alcohol (g/100 cc)	2	116	63	1
Xylene (g/100 cc)	53	51	Approx. 790	.02
Significant residue found in animal fat	yes	no	yes (temporary)	no
Compound excreted via urine or faeces	little	little*	little*	much
Compound leaches through soil	no	yes (?)	no	yes
Compound absorbed on organic material	yes	yes	yes	yes
Related to volatility				
Vapor pressure (mm Hg)	1.5×10^{-7} (at 20° C)	—	1.87×10^{-5} (at 25° C)	6.16×10^{-7} (at 35° C) 1.07×10^{-6} (at 45° C)
Vapor easily measured by bioassay	no	no	yes	no
Related to stability				
Effect of pH	little or none	decomposition rate increased above pH 8 and below pH 5	decomposition rate increased above pH 7 and below pH 4	little or none
Hydrolysis	no	yes	yes	no
Decomposition temperature	195° C	100° C	115° C	215° C
Residue remaining in soil	years	days	months	months to years
UV decomposition				
(a) as a crystalline solid	very little	little	little	little
(b) in shallow water	very slow	rapid	medium	medium
Oxidation	no	no	yes	no
Enzymatic metabolism	very slow	rapid	slow	very slow
Dealkylation	no	yes	yes	no
Dehydrochlorination	yes	no	no	yes (?)
Dechlorination	yes	no	yes	yes
Decomposition by bacteria	very slow	rapid	slow	very slow
Other				
Cholinesterase inhibition	no	yes	yes	no
Molecular weight	355	222	351	242

*Rapid excretion via water soluble metabolites.

able, subtle effects of pesticides are difficult to perceive or measure under usual wildlife conditions. It is often prudent to seek the advice of a competent wildlife toxicologist for specific tests to estimate hazards. State fish and game conservation agencies and the U.S. Fish and Wildlife Service are usually interested in cooperative field tests to determine effects on wildlife. These tests are varied according to the specific pesticide use and in reference to the expected non-target environmental hazards.

In recent years the practicing toxicologists have developed much expertise in evaluating toxicity tests with laboratory animals to assess hazards of the handling and use of pesticide chemicals. The acute oral toxicity test, for example, in several animal species is useful in calculating the amount of pesticide that wildlife may be expected to ingest safely in large single doses, or in multiple doses in a short period of time. Results of skin absorption studies in rabbits are likewise useful for estimating hazard from excessive amounts of the pesticide which may come into contact with the skin of wildlife species.

Many problems of wildlife exposure to a pesticide are those resulting from exposure to diluted formulations and low concentrations of the pesticides over a period of time. Thus, long term evaluations of toxicity to small amounts of pesticide are most important in wildlife and environmental studies, particularly with persistent chemicals. The long-term feeding studies in laboratory animals include such tests as the 2 year feeding studies on rats and dogs, as well as the 2-3 generation reproduction studies.

Various tests in the laboratory and natural environment help assess such factors as the individual species populations survival, adaptation to the pesticide, or ability to metabolize and excrete the chemical agent. Metabolic distribution and excretion investigations give valuable information as to the eventual decomposition and disposal of the original pesticide in the organism.

It is important that suitable tests be done with the chain-of-life organisms as well, since the total environment is dependent on the well-being of its separate parts. Results of some standard toxicology tests with mammals, birds, fish and other aquatic organisms are shown for the four example pesticides, in Tables III, IV, V and VI.

TABLE III

Toxicity of four different pesticides to mammals

Type of study	Species	A	B	C	D
		Acute studies—LD$_{50}$—mg/kg			
Acute oral	rat	87-420	15-63	97-276	8200
	mouse	150-400	39		2000-4000
	rabbit	250-400	37	1000-2000	Approx. 2000
	dog		15-30		
Acute dermal	rat	1931-3263	—	—	—
	rabbit	2820	>500	2000	>4000
		Dietary studies (ppm) no effect level			
2 year feeding	rat	1-5	ca 100*	<10*, **	3000
	dog	400		>0.6-<6.0*, **	5000
				>60-<200*	
3 generation reproduction	rat	—	—	—	3000

*90 day feeding study.
**No effect level on cholinesterase.

TABLE IV

Toxicity of four different pesticides to birds

Type of Study	Species	A	B	C	D
		Acute studies—LC_{50}—mg/kg			
Acute oral		100-1000 (4 species)	1-16 (8 species)	8-357 (5 species)	4000-8000 (1 species)
		Dietary studies (ppm)			
7-8 day feeding-LC_{50}	Jap.quail	—	500	>100, <500	>1000
	bobwhite	449	250 (97 days)	721	>1000
	mallard	500-746	<1000	361	>1000
Reproductive (No effect level)	Jap.quail or pheasant	<10	>10, <300	30-50	>1000

TABLE V

Toxicity of four different pesticides to fish

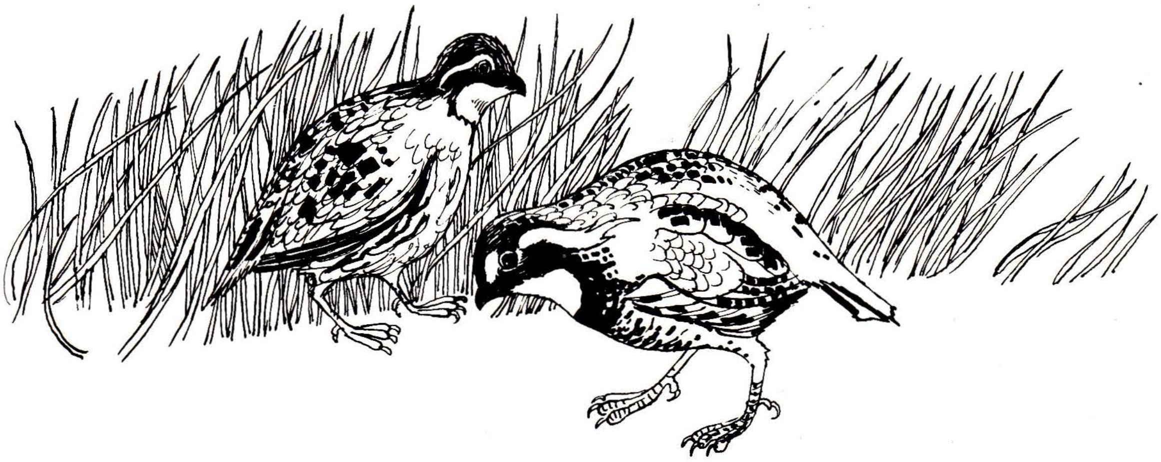
Fish Species	Temp.	**LC_{50}—ppm—96 hour exposure** A	B	C	D
Rainbow trout	60°F	0.0115	16.0	0.0030	13.0
Bluegill	80°F	0.0042	5.8	0.0033	24.0
Channel catfish	80°F	0.0128	12.0	0.0134	14.0
Goldfish	70°F	0.3	>1.0	0.5-1.0	>40.0

TABLE VI

Toxicity of four different pesticides to aquatic organisms (other than fish)

Species	Temp. °F	Hrs. exposure	A	B	C	D
			LC_{50}—ppm			
Oyster	82	24	0.007* (63°F)	—	0.27*	0.06*
	37	96	0.009* (86°F)	>1.0*	0.034* (24 hrs)	
Brown shrimp	81	48	0.0010	0.0052	0.0002	>0.22
Daphnia magna	70-80	24	0.2	1.0	0.0015	>2

*EC_{50}=50% decrease in shell growth



(Continued on Page 21)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GUIDELINES FOR PESTICIDES

(Continued from Page 19)

F. HOW TO CORRELATE INTENDED TARGET PESTICIDE USES AND DOSAGES WITH CHEMICAL, PHYSICAL, BIOCHEMICAL AND TOXICOLOGICAL PROPERTIES OF DIFFERENT CHEMICAL CLASSES OF PESTICIDES TO ASSESS HAZARDS TO NON-TARGET ORGANISMS.

Having accumulated the essential data on the compounds A, B, C and D as presented in Tables I-VI, plus all other supplementary data, one is prepared to match up the target use, dosage and application techniques with non-target effects of the particular compound in question. An important fact which soon becomes apparent is that these four pesticide chemicals present significant differences in uses, toxicological effects and physical and chemical properties.

Pesticide A

This is a broad spectrum insecticide intended for application in many types of habitat, at dosages as high as 3 lbs per acre. The theoretical concentration of vapor (Table I) in air is insignificant, since it is essentially non-volatile in a practical sense. Small amounts, in the form of very fine particles, would be expected to be decomposed by sunlight. In soil, theoretical maximum concentration amounts to about 3 ppm, and it is expected to be stable. Transfer of such soil by wind or water constitutes a potential source of environmental contamination. In water, it is very insoluble but stable in ppb quantities.

This pesticide is tightly bound to soils and organic matter and not easily leached, a factor in part related to its low water solubility. It can remain in plant and animal tissue for a long time and as such is only slowly metabolized. Its fat solubility permits storage in fat depots. Altogether its residual life results in long term effects nearly everywhere in the environment.

Pesticide A is not very toxic in single doses to mammals either orally or dermally. Chronic feeding tests, however, show an accumulative effect at dosages below that estimated as a maximum theoretical amount in the environmental food when applied at target dosage rates. Residue studies in animals show it to be stored per se. A similar story is shown with birds where the acute oral toxicity is moderate but some chronic studies result in greatly reduced reproduction at dosages in or near the range expected in soil and greatly below that in the diet.

The same factors apply to organisms in the aquatic environment except that fish, insects, shrimp and many other organisms are killed by acute applications at extremely low dosages. In addition, these organisms accumulate the compound in fat tissues and magnify the residues in their body tissues to amounts greatly in excess of the surrounding environment. This accumulation may occur in fish even without feeding on aquatic organisms by sorption through the gills. A is a pesticide which can affect a great variety of organisms in the environment on a long term basis (meaning one to many generations of the organism). Thus, its use should be directed to selected targets in order to leave non-target organisms free from persistent effects.

Pesticide B

This is employed as a fairly broad spectrum insecticide in the forest habitat at extremely low dosage rates (.05 lbs/A). It is not very stable in sunlight (in air or on foliage) or in soil, thus the residual life is short. It is not very toxic to aquatic organisms, except possibly to shrimp, in acute tests. Pesticide B can be hydrolyzed and dealkylated by organisms and is decomposed readily by bacteria. It is acutely toxic to birds and animals but at environmental use concentrations, it is metabolized by these organisms quickly and without accumulative storage or significant effect on the organisms. It does not appear to affect the reproductive capacity of Japanese quail at feeding dosages far above those used for the target effect. Since it is not accumulative in chain-of-life organisms and is relatively unstable under many conditions in the environment, B is one of the safer pesticides for use at the dosages applied for target organism control, even in such varied habitats as occur in forest lands and streams and in spite of the fact that initial toxicity tests show that it is very toxic acutely to birds and mammals.

Pesticide C

This insecticide is used in aquatic habitats at the very low rates of 0.025-0.05 lbs per acre. C possesses an entirely different combination of properties than A or B. It is not very residual on foliage due to volatility and decomposition by ultraviolet light, but is very stable in soil and water. It can be hydrolyzed, oxidized and dechlorinated at varying rates depending on pH, presence of moisture, heat and enzymes. It possesses enough vapor pressure and toxicity to kill insects by treating surfaces in enclosed areas. It has low water but high fat solubility.

As expected from these facts, it accumulates in fatty tissues. Unlike A it is readily metabolized in organisms such as fish, birds and possibly mammals, which can handle small amounts and avoid accumulation in fat tissues at the above dosage rates. Any accumulation is fairly rapidly eliminated via water soluble metabolites. It is not easily leached through soil and is heavily sorbed on organic material even when in water, thus forming a solubility reservoir for water which may last for several months.

This insecticide has moderate acute toxicity to birds and mammals and in chronic studies shows cholinesterase effects at about 1 ppm in the diet. Physiological effects are not shown until a level of over 30 ppm in the diet is reached, even in bird reproductive tests. This greatly exceeds the expected residue in wildlife food.

It is very toxic to many forms of arthropod aquatic organisms and fish. The amount applied to control the target organism does not always provide a sufficient margin of safety for non-target organisms such as shrimp, bluegills, and *Daphnia.* This means that where such organisms occur, C should not be used unless such non-target consequences are evaluated and accepted in advance. Even where such mortality occurs with the target use, the effect is not usually eradication of the susceptible non-target organisms since certain life stages are often resistant (eggs, pupae, dormant stages). Smaller members of the affected species are the most vulnerable. Population decline, followed by recovery in a few days, weeks or months depending on the length of the life cycle of the aquatic organism, and adjacent sources of repopulation is typical of moderately toxic dosages of C.

Pesticide D

This is an herbicide normally used at rates below 3 lbs per acre, mostly on non-crop land for the control of brush and broad leaved weeds. It is quite water soluble and leachable in soil. However, leachability is somewhat modified in organic soil by its sorptive affinity for organic material. It is quite stable in soil, water and on plants except for surface deposition or solutions where ultraviolet light will cause decomposition. It can be dechlorinated and is slowly decomposed by soil microorganisms.

This compound has low solubility in fat and does not accumulate in the tissues of organisms. Aquatic organisms (fish, *Daphnia*) reproduce normally and without accumulating any more D in their tissues than exists in the surrounding water. It is low in toxicity to all animal organisms tested and exhibits a wide margin of safety at the target dosage over any dosage known to cause acute or chronic toxicological effects. Pesticide D is low in toxicity to lower forms of plants such as fungi and algae. However, many higher plants are susceptible to its herbicidal effects. Applications are to be avoided which are likely to leach into water or are applied directly to water or to desirable, susceptible, non-target plant species.

CONCLUSION

As seen from the "character" descriptions of four very different pesticides, each must be considered in context with the usage and the environment affected. Each one is different in its uses, properties, advantages and restrictions.

Careful planning and testing are necessary with each pesticide to evaluate possible effects on non-target organisms and their environment. An impartial analysis of the data must follow such work in order to make sure that target uses result in the minimum of hazard to non-target organisms.

SUMMARY

Four pesticides of different chemical classes are used to illustrate the problem of identifying the inter-relationship of the expected commercial usage and dosage with the effect on non-target organisms and the environment. Predictions of such effects are judged on the basis of correlating toxicological, chemical, physical and biochemical properties of each pesticide with representative phylla and orders of organisms treated. An understanding of the inter-relationship of pesticides with soil, water, air and living organisms, from both short and long term viewpoints, is important and necessary. Further, these relationships must be evaluated on an individual compound basis. Guidelines for such evaluations are presented in this paper.

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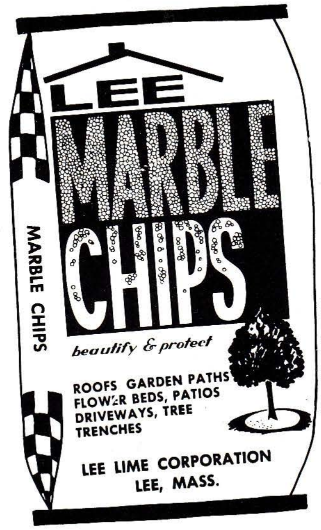
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Fish Farming

by G. L. RUMSEY
Specialties Division

Fish farming in both salt and fresh water ponds is one of the oldest forms of agriculture. Rotation of fish pond bottoms with dry land crops has been known and practiced for many centuries in Europe and Asia.

In the United States, very little warm water fish farming was done until the end of World War II, but in recent years fish farming has attained commercial stature as a result of the explosive increase in channel catfish farming. Catfish production now exceeds 26 million pounds as compared to only a few thousand pounds as recently as 1963. It now looks as if the volume of farm raised fish will double during the next year or two.

One of the world's big problems, as scarcely anyone needs reminding, is malnutrition due to lack of animal protein. Even if the world's great production of vegetable protein and its much smaller production of animal protein could be distributed better, the problem would not be solved. Fish protein, however, is especially suitable and does offer a partial solution.

Fish cultivation has been exploited much more in other countries than in the United States. For instance, fish are produced on a large scale in China, Japan, the USSR, and in several European countries. In Europe, shellfish, carp, and its relatives are the popular types although cultivation of trout has been developed in several countries. Denmark and Italy each produced over 12,000 tons of trout last year, while the combined federal, state, and commercial production in the United States was less than 10,000 tons. Pond production in the USSR is said to have at least tripled in the last few years.

In three to four months, a vegetable farmer can produce about eight tons of fresh spinach containing 350 pounds of protein. The same acre sown to pasture will feed milking cows producing 530 gallons of milk, or only 220 pounds of protein of somewhat better quality. But this acre of land, when flooded and put into fish production, can yield up to 4,000 pounds of fish containing 800 pounds of protein. Feed efficiencies of 50% or better are common.

Country Best's interest in fish culture started with trout . . . and its *Strike Trout Food* became one of the first commercially successful trout foods. Today, *Strike* is one of the largest selling trout foods east of the Mississippi and is rapidly attracting customers in the West.

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