DEMONSTRATION AND RESEARCH PEST CONTROL

A Training Program for the Certification
of Pesticide Applicators

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INTRODUCTION

This training manual is intended to provide information that you may need to comply with EPA's Standards for Certification. It will help you prepare for the Certification examination prepared and administered by the Virginia Department of Agriculture and Consumer Services.

The emphasis of these standards and this training is on the principles of applying pesticides safely for man and the environment. It is not intended to provide you with all the knowledge needed. Additional information in the form of publications, short courses, field days, and professional meetings can be obtained from the local Cooperative Extension Service Office in your area.

BASICS OF PEST MANAGEMENT

The dilemma of producing adequate food for a rapidly expanding population while maintaining a clean, stable environment has become a major problem in recent years, and will become a critical one within this decade. Problems of pest control will become more varied and intense as attempts are made to increase yield and quality of food and fiber. If these problems are to be met successfully, there must be a change in the concept and practice of pest control.

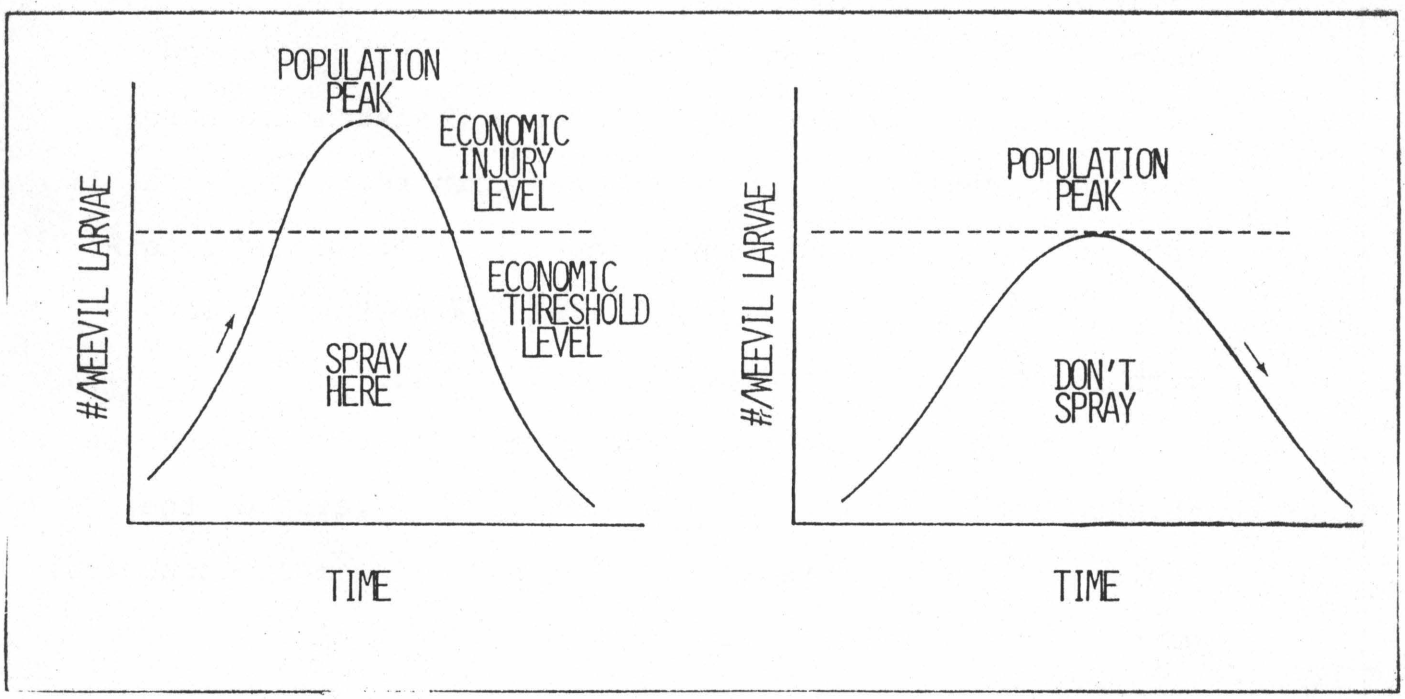
The concept, currently held by large segments of the public, that chemical weapons alone will suffice, is not acceptable. The application of pesticides to large acreages with little or no regard for deleterious side effects can no longer be ignored. If pest control is to contribute positively to a more productive environment, more attention must be focused on the <u>management</u> of pest populations, and with more concern for all the organisms in the environment.

Pest management involves the integration of various chemical and non-chemical actions with those of the ecosystem to lower and regulate pest populations. Success depends largely on the degree to which the integration of actions is guided by an understanding of the population dynamics of the pest and the general principles of ecology. The philosophy of pest management is to "manage" a pest population rather than to "eradiciate" it. The objective is to combine chemical and non-chemical methods to maintain a pest population below the economic threshhold established for that pest on a certain crop.

The concepts of "economic threshold" and "economic injury level" are the cornerstones of pest management. Establishing the economic threshold for a particular pest and crop is the decision of how large a pest population can be allowed to grow before a pesticide must be applied to control crop loss. The economic threshold is the density at which control measures should be applied to prevent a pest population from reaching the economic injury level.

The economic injury level is the lowest pest population that will cause economic damage to a crop. Subeconomic levels of a pest population not only do little harm, but in some cases may have a beneficial effect. For example, low populations of alfalfa weevil apparently stimulate the alfalfa plant physiologically to produce more growth. This appears to continue until the weevil population gets so large the plant can not tolerate it and loss occurs. The point between a sub-economic level that may benefit the host and a population that is causing economic loss is the <u>economic injury</u> level.

Pest populations can grow so rapidly that to wait for it to reach the economic injury level before applying control may be dangerous. Applying controls at the economic threshold is the best time.



Some of the non-chemical methods used in pest management are:

plant resistance
insect parasites, and predators
insect diseases
insect hormones and attractants
pest scouting programs

Plant resistance

One of the most important contributions to pest control during the pre-DDT era was the development of pest resistant varieties of crops. Research on insect-resistant crops is still going on. The success of this research is evident in corn varieties that are resistant to European Corn borer, corn, earworm, and corn rootworm; with alfalfas that are resistant to aphids, tolerant of alfalfa weevil; and with a new high yielding soybean variety with resistance to the Mexican bean beetle.

It usually takes ten or more years to develop acceptable resistant varieties. However, once developed, the resistant plant offers one of the safest and most economical ways of controlling insect pests.

Insect parasites and predators

For more than 80 years researchers in the U.S. have been searching for native of foreign parasites and predators of insects and plant pests. The U.S.D.A. has successfully introduced parasites for the control of several scale insects, the European corn borer, the gypsy moth, the alfalfa weevil, and others.

Recently, a tiny parasitic wasp was introduced into the U.S. from India to help control the Mexican bean beetle on soybeans. After careful study, thousands of these wasps were released in eastern U.S. The wasps attack the beetle larvae, and are a very effective control measure.

Virginia Tech, in cooperation with the USDA has been conducting extensive research on the use of foreign and native insects to control thistles. After several years of field work, this research is showing signs of success. The beetles that attack the thistle plants have been released in several areas of Virginia.

Insect diseases

There are about 1,000 viruses, bacteria, fungi, and prototype that attack insects. However, on a world basis, only one virus, two bacteria, and one fungus are produced commercially for insect control. There are many problems associated with the mass production and use of these agents. However, the potential is great, and their specificity is an important consideration in looking to their future use.

One bacterium causes the well-known milky disease of the Japanese beetle. Another bacterium Bacillus thuringiensis -- under the trade name of Dipel, Biotrol or Thuricide -- is used to control tobacco budworms and hornworms and is also effective against the cabbage looper and imported cabbage worm on cole crops.

Insect hormones and attractants

Insects respond to various chemical substances in plants in their search for food and to the chemical sex attractants produced by the insect for mating. Considerable research is directed to the development of natural and artificial attractants for insect detection and control. To date, insect attractants have been most useful for detection purposes. Examples include a number of chemicals for Japanese beetle adults, and disparlure for the gypsy moth.

During the last ten years several insect hormones have been synthesized. Natural and synthetic hormonal compounds are now being tested, some right here at Virginia Tech, for possible commercial production.

Pest Scouting

Pest scouting programs have been successful in several southeastern states, including Virginia. People are trained to survey or "scout" large acreages of crops to determine the insect infestation level. This information coupled with the data on the economic threshold of certain pests can help to reduce the amount of insecticide used while providing adequate control at a reasonable cost.

Virginia Tech has developed a pest scouting program for the soybean farmers in eastern Virginia. The program is successful and has been adopted by several large growers.

The concept of pest management employs a wide variety of options in devising solution to pest problems, with the realization that any one method or technique may not be sufficient to control pest species. For example, several of the previously mentioned methods have been combined in a Mexican bean beetle control program on soybeans. Resistant varieties have been developed, a larval parasite has been introduced, a pest-scouting program has been developed, and there are several effective insecticides registered for soybeans.

In pest management, the total complex of pest species of a crop is studied. Rather than trying to destroy a single species which may cause other pests to increase, a variety of methods are used to prevent explosive outbreaks of pest species. Pest management, therefore, takes into account the natural balance between pest and parasite manipulation of host plants, protection and encouragement of natural enemies of the pest species, cultural and environmental management practices that help reduce outbreaks of pests, and the use of chemicals to hold a pest in check without destroying its enemies.

GUIDELINES FOR MINIMIZING PESTICIDE POLLUTION

When Pesticides Become Pollutants

Pesticides, when properly used, are tools. When they move off target or are otherwise misused, they become pollutants. They would not be much of a problem if they stayed where applied, but the widespread distribution of DDT and similar compounds demonstrates that many pesticides do not remain where applied and do remain in the environment for relatively long periods of time.

Pesticides become particularly important as pollutants when they move into water and cause either immediate toxicity to organisms present or, more seriously, are of a persistent and accumulative nature and move into the food chain where they upset the normal life cycle of organisms in such ways as destroying their reproductive capacity, making them more vulnerable to predators by slowing their escape mechanism, or even by acutely poisoning the predator at the end of the food chain.

But areas other than water are also subject to pesticide contamination. When Sevin is sprayed on a field where bees are foraging on weed blossoms, the beekeeper considers it a pollutant. When 2,4-D drifts from the highway to injure or kill grapes, it is a pollutant. And the lindane illegally used to treat dairy cows becomes a pollutant when it shows up in the milk.

How Pesticides Move Off Target

Pesticides applied by spraying may drift in the air away from the target. Many factors contribute; some physical, some climatic. The smaller the spray droplet, the further it will drift. And, obviously, the stronger the wind, the greater the drift.

The choice of pesticide influences drift damage from toxicity, phytotoxicity, illegal residues, and volatilization. Choice of the proper formulation will reduce drift as will use of thickeners. And choosing the right machinery for a particular job is most important.

Pesticides adhere tightly to soil particles. Consequently, any type of erosion -- runoff or sheet erosion, or wind erosion -- transports the pesticides along with the soil particles. Conversely, cultural practices that prevent soil erosion also prevent pesticide movement and pollution.

Because of the tight adsorption to soil particles, leaching into ground water is not a particularly significant means of pesticide transport and contamination.

Pesticide residues on or in foods, both illegal and within tolerance limits, may be further distributed by humans and animals who consume the food and either excrete the pesticide or pass it along as a contaminant of their meat, eggs, or milk.

Poor choice of a pesticide for a given problem increases pollution. In most cases, a short-live, biologically degradable, non-accumulative compound may be substituted for a persistent, accumulative, environmentally dangerous compound. The use of DDT for a mosquito larvicide rather than a highly active modern biodegradable larvicide would be a bad choice even if it were not now illegal.

The careless operator hurts himself, his customers, and his environment through poor location of sprayer filling stations, slip-shod tank filling procedures, insufficient mechanical safeguards against contamination, accidental spills, and poor disposal of left-over mixed spray, surplus pesticides, and used containers. Poor operational procedures and misuses are probably the greatest contributors to pesticide pollution.

Being aware of these sources of pollution, one then should be able to come up with practical solutions based on existing methods and materials which will greatly minimize the contribution of agriculturalists, and other users, to pesticide pollution of our environment. The following are a few practical considerations to stimulate further preventative practices.

A Checklist for Practical Solutions to Pesticide Pollution

I. Is the treatment necessary? First make sure you have a control problem. Many urban or suburban applications are not necessary.

   A. For example, oak leaf skeletonizer occurs late in summer when leaves are soon coming off anyway, so little is gained by spraying.

   B. In agriculture, is the pest numerous enough to cause economic damage? Will the increased production pay for the cost of treatment? What are the alternate methods of control? Maybe the application should not be made.

   C. Will crop rotation or other cultural practices solve the problem?

II. If treatment is necessary

   A. Consider other problems beside control -- sensitive crops, streams, people, houses, bees.

   B. Consider public relations -- an informed public is more cooperative

III. Steps that reduce pesticide pollution

   A. Prevent drift

   The smaller the droplet and the greater the wind, the further the pesticide will drift.

1. Plan the farm or field layout.

   a. Consider prevailing winds to minimize drift.

   b. Lenthen fields, lower hedgerows, remove obstructions.

      -- Reduces turn arounds and overlapping of pesticides.

      -- Allows agricultural aircraft to remain low, minimizing drift.

   c. Consider crop pesticide requirements.

      -- Plant the crops which will require little or no pesticide use nearest sensitive areas -- houses and farm buildings, ponds and streams, bee yards, pastures, and forage crops. Leave buffer areas such as crops not requiring treatment or requiring only safer materials, or leave hedgerows between crops and sensitive areas. The border rows of a crop can be treated with safer materials.

      -- Where possible, avoid planting crops with high pesticide requirements

-- Position boom to give larger droplets as ground speed increases.

Tilted forward gives finer droplets.

Tilted backward gives larger droplets.

-- Be sure machinery is properly calibrated -- not overdosing.

Airblast equipment -- more chance of drift than with boom equipment.

-- Determine effective swath width and calibrate. Lay out field accordingly.

-- Operate in little or no wind. Not only will wind cause drift, but it will distort the swath pattern.

-- Choose time to operate when drift is away from sensitive areas.

-- Position nozzles to give larger droplets.

Facing into air blast gives finest droplets.

Directed with air blast gives coarsest droplets.

-- Lower pump pressures give larger droplets.

-- When spraying near sensitive areas to be sure airblast is directed away.

adjacent to or close upwind from crops that are sensitive either from phytotoxicity or residue standpoint. For example, if 2,4-D is to be used on corn, do not plant beans or tomatoes adjacent.

d. Do not place pastures next to crops requiring several pesticide applications; such as fresh market sweet corn or an orchard.

2. Choose equipment that will minimize drift.

a. Ground equipment -- slower, but less chance of drift than aerial equipment.

Boom equipment

-- Use lower pressures and spray discs with larger orifices to increase droplet size.

-- Choose best type of nozzle. Hollow cone nozzles produce more fine droplets than flat fan nozzles.

-- Keep booms mounted as low as possible to reduce wind effects. Use closer nozzle spacing and wider fan angles.

b. Aerial equipment will get the job done quickly and economically taking advantage of best weather conditions.

-- Use higher dosages per acre, larger droplets. Ultra low volume will increase chances of drift.

-- Mount nozzles away from wing tip so that spray is not sucked into vortices. Solid cone or fan nozzles form larger drops than hollow cones.

-- Position boom to give larger droplets.

    Tilted slightly forward gives finest droplets.

    Tilted backward 40 to 90^{o} gives coarsest droplets.

-- Use lower pump pressures for larger droplets.

-- Be sure your shut-off is positive -- no dribbling in turns. Use positive shut-off nozzles.

-- Consider new machinery such as controlled droplet size booms, controlled porosity spray heads, foam-forming nozzles.

-- Fly as low and slow as possible consistent with good spray technique.

-- Fly downwind from sensitive areas

-- if you must fly upwind from sensitive areas, fly with the wind or into it. Arrange swaths at right angles, not parallel to streams.

3. Choose the right pesticide and formulation to minimize drift problems.

   a. Use the safer chemicals according to the circumstances. Examples:

      -- If treating for alfalfa weevil:

         Parathion is generally less toxic to fish than malathion, but much more toxic to humans. Does the alfalfa field border a stream or is it near a house? Are fences tight? Will cattle break in? If there is a chance of this, don't use parathion. If the alfalfa is weedy and dandelions are in bloom and attracting bees, Sevin is a poor choice.

      -- If beans or tomatoes or other sensitive crops must be planted adjacent to corn use atrazine rather than 2,4-D. But remember, high doses of atrazine may injure sensitive crops planted the following year, i.e. oats, alfalfa, vegetables.

b. Choose the right formulation.

-- Sprays drift less than dusts.

-- Granules drift less than sprays.

-- Thickeners or additives may be needed and used under some conditions such as power line maintenance, roadside spraying etc.

4. Do the job at the proper time.

a. When weather conditions are right.

-- Low wind, away from sensitive areas.

-- Rain not expected.

b. Bees not foraging -- night or early morning.

c. Allow for sufficient harvest intervals to avoid residues.

d. Allow for sufficient interval between application and time workers have to be in the field.

B. Prevent Erosion

Pesticides ride along on eroding soil particles.

1. Cultivate with the contour, not across it.

2. Alternate cultivated crops such as corn with others such as oats, alfalfa. Leave sod buffer area, settling ponds, or dikes between cultivated crops and stream. Other things being equal, there is very little pesticide run-off from orchards with a sod floor.

3. Plan location of high pesticide requirement crops with topography in mind. Don't plant such crops where farm ponds, potable water supplies, etc. are further down the drainage system.

C. Prevent Transport of Pesticides as Illegal or Persistent Residues on Foods

1. Use all pesticides only as labeled paying attention to dosages, limitations, and making sure that the use intended is on the label.

D. Choose Safest Pesticide to be Used Under Circumstances

1. Points to consider:

a. Phytotoxicity -- will it hurt the target if overdosed? What is its compatibility with other pesticides used?

b. Legal residues -- will the pesticide drift from target crop to cause illegal residue on adjoining crop, or in meat or milk?

c. Persistence -- is the pesticide one which will persist in the environment, and either accumulate in wildlife or be damaging to following crops?

d. Bee toxicity -- if bees are working a field, choose a pesticide of low bee toxicity and time application when bees are not present.

e. Fish toxicity -- if drainage or erosion threatens nearby waters, choose pesticides having low toxicity to fish.

f. Human and domestic animal toxicity if located near houses or buildings or water supply.

g. Effects of drift or volatility -- will it drift from the target crop to harm sensitive crops? Foul smelling pesticides may draw attention and criticism.

h. Effect on wildlife from use of persistent, accumulative chemicals -- cost should not be the most important factor. Don't use accumulative pesticides as aquatic larvicides. When there is a choice use the least persistent chemicals.

E. Use Good Operational Procedures

1. Filling the tank -- poor procedure is a prime

source of pesticide pollution

a. Locate and construct filling station properly.

-- Away from pond or creek bank so that surface drainage is not back into water source.

Or with established stations:

-- Regrade to change slope and drainage away from water source.

-- Construct an apron and sump to catch overflow and drainage for safe disposal.

b. Use proper tank filling equipment.

-- Use separate pump for filling where possible.

-- Install check valves on intake hose to prevent backsiphoning from sprayer tank, particularly if the same pump is used for both spraying and filling.

-- Suspend filler hose from pump so that there is a space between end of hose and surface of spray mix in full tank to prevent backsiphoning.

c. Use good filling technique

-- Stay with sprayer while filling. Don't let it run over while your back is turned.

-- Protect yourself with proper gear as instructed by the label.

-- Use minimum amount of pesticide necessary. The label will give you the range. Follow recommendations -- more won't work better.

-- Before adding the pesticide, make a final check. Is the intended use specified on the label? Is the wind still down? Are other conditions still favorable?

-- Account for all empty pesticide containers and take them back to your storage. Don't leave them on the bank to fall in the water.

d. Use good application techniques.

-- Use required protective gear (see label). Investigate filtered air equipment -- helmets, tractor cabs, agricultural aircraft cockpits. Have water and commercial hand-cleaner on the sprayer in case of accidental contact with spray.

-- Check constantly for drift, overdosing, unauthorized persons in treated area, other poor conditions. Stop spraying if necessary.

-- Have alternate areas available to treat in case you have spray left over. Do not leave puddles of spray mix or dump indiscriminately.

* Adapted from the Cornell Fact Sheet #4-86, Dated June 7, 1971, by J.E. Dewey and R.F. Pendleton

AGRICULTURAL SPRAY ADJUVANTS

The discovery, a few short years ago, that spectacular improvement in the performance of many foliage-applied herbicides was possible when certain surfactants were included in the spray solution, firmly established at least one role of the agricultural spray adjuvant in improving the efficiency of pesticide chemicals.

Since then, we have been besieged by a whole gamut of surfactants and other additives, of varying effectiveness, from which the investigator, applicator, or grower must choose the proper product for his particular application.

It is from this mass of confusion over what surfactants are, what adjuvants are, and which one do you use when and where, that we must try to provide some order and understanding.

It is particularly timely now, with avid public interest and Federal scrutiny of chemical usage and its relationship to the environment, providing additional pressures, to improve our efficiency in the use of agricultural chemicals.

The remainder of this discussion will be presented to include definitions, functions of spray adjuvants, and a product list of adjuvants suitable for providing these functions.

DEFINITIONS:

Adjuvant

The dictionary defines "adjuvant" as a "substance added to a prescription to aid the operation of the main ingredient." A spray adjuvant performs this function in the application of an agricultural chemical. An effective spray adjuvant may be formulated to contain one or more surfactants, solvents, or co-solvents, solubilizers, buffering agents, film formers, and other components to provide the properties listed under "Functions."

Surfactant

A surfactant is a "surface active agent." Its primary function is that of a wetting agent or as a component of an emulsifier or a spray adjuvant. Some surfactants have been used successfully to enhance herbicidal activity.

Ions

Many water-soluble materials, when dissolved in water, split apart into electrically charged atoms or groups of atoms called ions. The ions with the negative charge are called anions and those with the positive charge are cations.

Anionic

Those surfactants, whose negatively charged ions provide the surface-active properties, are called anion-active or anionic. e.g. $Sodium^{+}$ $(lauryl\ sulfate)^{-}$

Cationic

Those surfactants whose positively charged ions provide the surface-active properties, are called cation-active or cationic. e.g. $(Coco\ amine)^{+}$ $acetate^{-}$

Nonionic

As the name implies, nonionic surfactants do not ionize in water and are, therefore, non-ion active or nonionic. e.g. ethylene glycol, alcohol, alkylarylpoly (ethylene oxy) ethanol.

Functions of Spray Adjuvants

A spray adjuvant may have one or more of the following functions to perform in order to provide a safe and effective application:

1. Wetting of foliage and/or pest.
2. Modifying rate of evaporation of spray.
3. Improving weatherability of spray deposit.
4. Enhancing penetration and translocation.
5. Adjusting pH of spray solution and deposit.
   a. prolong life of alkaline sensitive pesticides
   b. reduce re-entry time following application of hazardous chemicals.
6. Improving uniformity of deposit.
7. Improving compatibility of mixtures.
8. Providing safety to the treated crop.
9. Reducing the drift hazard.
10. Complying with FDA requirements.

The following brief discussion of each of the above ten points may be helpful in clarifying the many functions performed by the proper spray adjuvant.

1. Wetting of foliage and/or pest

   Adequate wetting is required to provide good retention and coverage of spray solution. A suitable surfactant, at the proper concentration, will normally suffice, although certain plants and pests may have special requirements.

2. <u>Modifying rate of evaporation of spray</u>

   The need for reducing the rate of evaporation of a spray solution applied at two to three gallons per acre in a hot dry area is obvious. The need, however, may be equally great in the application of a concentrate spray in an orchard. Once the spray has been applied it may be desirable to have the spray dry as rapidly as possible. Both functions can be performed by a proper adjuvant.

3. <u>Improving weatherability of spray deposit</u>

   Resistance to heavy dews, rainfall, and sprinkler irrigation can mean the difference between successful control and failure of a fungicide application, for example.

4. <u>Enhancing penetration and translocation</u>

   Many chemicals perform most effectively when they have been absorbed by the plant and transported to areas other than the point of entry.

"Systemic" pesticides have this ability. Their absorption can be enhanced and certain non-systemic chemicals can be made to penetrate plant cuticles through the use of a suitable adjuvant. Translocation is included as part of the systemic performance although I'm aware of no documented evidence to show that translocation is enhanced through the use of an adjuvant.

5. <u>Adjusting pH spray solution and deposit</u>

   a. Many currently used pesticides (primarily organic phosphates and some carbamates) degrade rapidly under even mildly alkaline conditions found in some natural waters and on certain leaf surfaces. Buffering adjuvants can prolong the effective life of alkaline-sensitive chemicals under these conditions.

   b. Experimental adjuvants are currently under test for reducing re-entry time following application of highly toxic pesticides.

6. <u>Improving uniformity of deposit</u>

   It is almost axiomatic that, with non-systemic pesticides, the quality of performance of a pesticide can be no better than the quality of the spray deposit. This is particularly true of most fungicides which require complete and uniform coverage.

7. <u>Compatibility of mixtures</u>

   With the savings in labor costs to be obtained from doing more than one job with a single application, the effort is made frequently to mix various combinations of pesticides, and pesticides with liquid fertilizers, in the same spray tank for simultaneous application. The attendant compatibility problems can frequently be corrected with the proper adjuvant.

8. <u>Safety to crop</u>

   Certainly we do not wish to harm the crop which we are trying to protect. This often happens, however, with chemicals that are potentially phytotoxic. The hazard can be increased through the use of the wrong adjuvant or substantially reduced through the choice of a proper one.

9. <u>Drift reduction</u>

   No method, currently in use for reducing drift of pesticide sprays, is entirely satisfactory. The most promising of the new approaches to drift reduction is the use of special foaming adjuvants applied through foam generating pumps or nozzles, often from conventional aerial or ground equipment. Special application problems may still favor spray thickeners or invert emulsions.

10. FDA approval

The Code of Federal Regulations, Title 21, Part 121.102, exempts from the requirement of a tolerance those adjuvants, identified and used in accordance with 120.1001 (c) and (d), which are added to pesticide use dilutions by a grower or applicator prior to application to raw agricultural commodities. All spray adjuvants must comply with these requirements.

The functions and properties of spray adjuvants listed above can contribute substantially to safe and effective pest control. Any one of the functions may be important in a given application. It is not likely that all would be of concern in a single application.

Although a single adjuvant may provide more than one of the above properties, no single product can provide them all. As a result, there are a variety of spray adjuvants available which have been formulated to encompass those functions which are important to a particular type of application.

The agricultural spray adjuvant is one more useful tool for improving the effectiveness of pest control and the safety of chemical application, and as with any chemical, only the proper spray adjuvant will do the proper job.

In part from Washington Pest Control Handbook, Washington State University, Washington State Department of Agriculture, November 1, 1971, pps 177-181.

VARIABLES AFFECTING THE EFFECTIVENESS OF PESTICIDES

The world food reserve is decreasing annually. For example, there were 95 days of world food reserve in 1961, but the reserve decreased to 24 days by 1974. The decrease in world food reserve is due, in part, to the vast increase in world population and, in part, to the greater demands for better nutrition throughout the world. For example, the world population was 250,000,000 at the time of the birth of Christ. This number doubled by 1600 A.D. and steadily increased to 3 billion by 1965. It has been postulated that this number will double by the year 2000. There is a net increase of 76,000,000 souls annually that requires 20,000,000 additional acres of land to feed the net increase in population.

There are three methods by which the world food reserve may be improved. One is by using high-yielding seed to better advantage. A second method is by using more and better fertilizer. Unfortunately, the countries that need more and better fertilizers do not have good financial backing in the major countries that produce and provide fertilizers. The third method of improving world food reserve is through better pest control. It has been estimated that 1/3 of the world's plant food is lost to pests. Presently, the majority of the work on plant pest control is with the use of pesticides.

Everything being equal, the results that one obtains from the use of pesticides on plants to control pests should be desirable when they are used as recommended. On the other hand, if pesticides are used other than for what they are recommended, and applied differently than the prescribed method, then the results obtained therefrom would be questionable. Many years of work and as much as 20 million dollars have gone into the selection and the development of a pesticide to control a specific pest problem. Therefore, the grower or the commercial pesticide applicator should always read and study the label, so that he is thoroughly familiar with the nature of the pesticide and what it is recommended for, before it is applied on the target plant.

There are several factors that affect the effectiveness of pesticides for plant pest control. For a matter of convenience for discussion, these factors may be called physical, mechanical, environmental, and biological.

First, I would like to discuss the <u>physical nature</u> of pesticides and how they may influence the effectiveness of the pesticides to control the target pest. Pesticides may be solids and mixed with inert ingredients and applied as a dust; or mixed with a wetting agent, suspended in water, and applied as a spray; or a few are liquids and are mixed with water and applied as sprays. The liquid pesticides frequently have an emulsifier and a solvent that they are dissolved in.

These solvents and/or emulsifiers frequently cause problems when they are mixed in the spray tank with other pesticides. This is particularly true with some oil-based solvents. For example, if a certain insecticide that has a strong oil-base solvent is mixed with a wettable powder fungicide that is not compatible with the particular oil solvent, than the latter may go through a process of buttering-out and become inactive or it may be changed to a compound that is phytotoxic. Thus, the mixture would be a liability rather than an asset if applied to the target plant. It is absolutely essential that intended mixtures be tested for compatibility before they are applied to large acreages.

Many plant surfaces are hard to wet, thus, for satisfactory results when applying certain pesticides, a wetting agent or surfactant should be used. Many weeds are extremely hard to wet; therefore, surfactants may be required for satisfactory weed control. One should be careful, however, when using wetting agents or surfactants. Some pesticides have the correct amount of wetting agents incorporated with the pesticide, and the addition of still more wetting agent would cause excess foaming in the tank and run-off of the active ingredient from the leaf surface. Therefore, always follow the instructions on the label and the recommendations from your Land Grant University.

There are several ways that the mechanical aspects of the spray equipment will affect the efficiency of pest control. No pesticide applicator equipment, regardless of the cost, is more effective than the operator of the equipment. The results obtained with a $20,000 piece of spray equipment with a sloppy operator will not be as effective for pest control as with a piece of equipment that costs 1/2 or even 1/4 as much that has a conscientious, common-sense operator. Thus, the operator becomes the key of success or failure. Low-volume spraying requires exactness in application. A mistake when spraying at 10X concentration becomes 2 1/2 times greater than when the same mistake was made at 4X concentration. Therefore, a conscientious, responsible operator is economical when one is applying low volume sprays.

There is no substitute for a properly calibrated sprayer. The machine is either calibrated or it is not. There is no in-between. A sprayer should be checked frequently to determine if it is actually spraying out the prescribed amount of active ingredient. It is equally important that the sprayer be delivering the correct amount of toxin from the designated nozzles. It is expensive and extremely disappointing to find that approximately 1 bushel of peaches from your trees has brown rot simply because you, as the owner, failed to check on calibration and 2/3 of the active ingredient was being discharged through the 4 lower nozzles rather than the proper 4 upper ones. Thus, careless mistakes cost extremely high and greatly reduce the net profits. All mechanical pesticide application equipment should be checked daily for general function.

The "environment" is a major factor that influences the effectiveness of pesticides that are applied to plants. If a rain occurs before the pesticide is dry, it will wash off and the application must be repeated. Similarly, a long prolonged rain will result in pesticide erosion and short residual life of the pesticide.

Extreme temperatures also influence the activity of certain pesticides. Oil, for example, should never be applied when the termperature is expected to be above 85^{o} or below 35^{o}F. Oil will frequently cause severe phytotoxicity when applied with prevailing incompatible temperatures. Liquid pesticides should never be permitted to freeze during winter weather unless it is specified on the label that activity is not altered by freezing. I have had experience with the use of liquid parathion that had been frozen. The results were extremely damaging; this parathion had more of the characteristics of an herbicide than that of an insecticide.

One should always be careful when applying herbicides to areas that are subject to overflows. Under these conditions the herbicide may be washed to an untreated area and kill non-target plants. These conditions would be expensive, and the kill of the target plants would be reduced.

Wind and strong air currents are nightmares to pesticide applicators. This statement is true whether working with aircraft or ground equipment. Coverage of the target is severely reduced when pesticides are applied during 10 to 20 mph wind currents. Thus, more material is required to cover the target and a greater liability exists as far as drift to non-target plants. The principle of not spraying during 10 to 20 mph wind storms must be thoroughly understood. The pesticide effectiveness is greatly reduced, drift hazards to non-target areas are extensive, and the possibility of a pesticide accident in quadrupled. Therefore, apply sprays when the wind velocity is below 10 mph, preferably much less.

The biological factor cannot be over-emphasized in a well developed pesticide program. In other words, the commercial pesticide applicator or the grower must be somewhat knowledgeable on the nature of plant pests. He must have a general concept of the life cycle of a specific insect or the disease cycle of a disease that he is trying to control. Every pesticide application made when there are no pests present increases the cost of production and reduces the profit margin. Growers should have a general knowledge that powdery mildew is most severe in dry weather; apple scab is most severe during cool, wet weather; and that a drought during the primary infection period will break the scab disease cycle. Similarly, that plant mites are more destructive during a hot, dry year than during a wet one.

It was determined in California that 11 applications of streptomycin was applied to pears for fire blight control before the fire blight bacteria were actually present. Thus, the cost of pest control was excessive. Careless use of pesticides such as excessive applications, frequently lead to tolerance or resistance by the target pest. Be familiar with the crop you are trying to produce, know what pests attack the crop and when they should be controlled.

Do not apply a pesticide haphazardly.

Generally speaking, pesticides have a good effective margin formulated into them to offset the physical, mechanical, environmental, and biological factors that reduce their efficiency in pest control. Therefore, if one uses good common sense when applying pesticides, a reasonable return may be expected on the dollars invested.

EFFECTIVENESS OF PESTICIDES APPLIED TO THE SOIL

Many factors influence the effectiveness of a pesticide. You have heard many of the factors associated with applications to the plant. Any chemical applied to the soil surface loses some of its potential pesticidal activity due to fixation on soil particles, leaching, volatilization from the surface, photodecomposition, and microbial decomposition. These losses are taken into account when the recommended rates of pesticides are established. They allow sufficient material to give maximum pest control and at the same time minimize soil and crop residues. Many of the pesticide losses can be associated with soil characteristics.

Soil results from the disintegration and decomposition of rocks and of organic materials. With Virginia's temperature and climatic conditions, its soils are largely an accumulation of finely divided, relatively insoluble mineral residues from the parent rock. The soil particles are of various sizes. The organic matter content of soils is relatively low throughout Virginia. The various size soil particles and organic content will impart certain characteristics to the soil. These characteristics have a definite bearing on how a pesticide will react when placed on the soil surface.

Growers often describe their soil as light, medium, or heavy. This is usually a comparison of soils on their farms or in the immediate vicinity. The farmer's description of a heavy soil in the coastal plain area is often quite different from the description of a heavy soil in the Piedmont or Mountain area. A more precise description could be made if the amount of sand, silt and clay are known.

Mechanical analysis procedures are available which will divide the various size soil particles into the various types: sand, silt, and clay. Soil particles more than 2 millimeters in diameter are usually classified as gravel or stone and are not usually included in an analysis of particle size. Particles under two millimeters are divided into three major types; sand, which has particles of 0.05 to 2 millimeters in diameter; silt, which has particles of 0.002 to 0.05 millimeters in diameter; and clay, which has particles less than 0.002 millimeters in diameter. The percentage of sand, silt, and clay determine the texture of the soil. Knowing the soil texture is very important to the determination of pesticide activity or loss.

The larger particles -- stone, gravel, and sand --

react as individuals. Soils high in these particles usually transmit air and water readily. Their retention of fertilizer, chemicals, and water is low. Most of the chemical and chemical-physical reactions in soil take place at the surface of particles. The surface area of stone, gravel, and sand particles is relatively small; therefore the activity on their surface is low.

Silt particles, intermediate in size between sand and clay, have a greater surface area to a unit volume of soil than sand, exhibits greater chemical activity than sand, but is insignificant when compared to the clay.

The clay particles (0.002 mm or less in diameter) of the soil contain most of the important properties of the soil. Their size would dictate that there would be a high surface-to-volume ratio. For example, if one acre was covered with particles 1.0 mm in diameter (sand), there would be a total internal surface area of 500 acres. One acre of 0.001 mm particles (clay) would result in a total internal area of 1,000,000 acres. As the clay content of soil increases, the greater the effect will be on the pesticide applied.

Most of the chemical and chemical-physical action in soil take place at the surface of the clay particles. Clays have a very large internal surface area. The chemical composition and arrangement of the elements on the particles imparts a negative charge to the clay particle. This negative charge will attract positive ions of certain elements and chemicals.

Ionization occurs when a substance goes into solution; that is, positive and negative charged ions are produced. Most pesticides are soluble to a certain extent in the soil solution. The charge and strength of the pesticide ion will determine whether they are held tightly to the clay particle and removed from the soil solution, is in equilibrium with the soil solution or not attracted at all. The efficacy of the pesticide can be altered by this reaction on the surface of the clay particle.

Positive ions of hydrogen, calcium, magnesium and potassium are held in a state of dynamic equilibrium with similiar ions in the soil solution. These ions can be replaced or exchanged in the soil solution in response to changes in concentrations in the soil solution. The charged clay surface together with associated exchangeable ions also react with water molecules. These impart the characteristics of plasticity, cohesion, and shrinkage to soil. These physical characteristics of the soil have a direct effect on the ease of and degree of incorporation necessary for pesticides.

The clays and intermediate products in decomposition of plant residues in the soil solution make up the colloidial system of the soil. Colloids refer to organic and inorganic matter having very small particles and a corresponding very large surface area for the unit of mass. Most colloids are too small to be seen with an ordinary compound microscope. Soil colloids do not go into solution as sugar or salt do. They may be dispersed to a relatively stable condition and thus be carried by moving water. The organic colloids work similiar to the clay particles. They also can have a definite affect on creating aggregates of clay, which in turn makes the soil more workable.

The sand, silt, clay, and organic particles occupy roughly one-half the total volume of soil. Space between these particles is called the spore space. This space is occupied by water and soil air. The pore size distribution is strongly affected by aggregation of the soil particles as well as by soil texture. Infiltration and movement of water or chemicals in solution through the soil therefore is greatly influenced by soil structure. Water and air occupy the soil's pores in reciprocally varying amounts. The amount of water in the soil's pores will determine how far and how fast applied pesticides will move in the soil.

Pesticide leaching is the downward movement of substances in solution through the soil. In most cases, when a pesticide is applied to the surface, the movement of the chemical to the pest area is dependent on leaching of the pesticide. The extent to which a pesticide leaches is dependent primarily upon: (1) solubility of the pesticide in water; (2) amount of water passing through the soil; and (3) absorptive relations between the pesticide and the soil.

In general, those pesticides which are completely water soluble are expected to be most easily leached. This is not always the case. Some of the water soluble herbicide may react with the clay and organic colloids and be taken out of the soil solution completely. The solubility of a pesticide in water is never a true indication of how it will move through the soil. The chemical concentration of the material when it is in the solution is in direct relation to the absorptive power of the soil. The strength of the absorption in relation to the particular pesticide is considered just as important as the water solubility in determining the leaching ability of a particular pesticide.

The amount of water passing down through the soil will affect almost all pesticides in the distance it will leach. If a pesticide is applied on a relatively dry soil, followed by rain or irrigation, the chemical will leach farther than if the soil were wet at the time of application. To restate the point, the strength of absorption bonds is considered just as important as water solubility in determining the leaching of a particular pesticide.

Pesticides have been known to move upward in the soil. If water evaporates from the soil surface, water may move slowly upward in the soil. The water may carry with it the soluble pesticides. As the water evaporates, the herbicides are deposited on the soil surface.

Whether pesticides are applied on the soil surface or move upward with the soil water, most of them are subject to volatilization or vaporization. Vaporization is when a liquid changes to a gas; whereas volatilization is when a specific substance changes from a solid to a gas. The vaporization or volatilization of a substance will be related to the soil temperature. The temperature of the soil on the surface is usually much higher than air temperature or soil temperature beneath the surface. Many chemicals will disappear because of vaporization or volatilization. If they were slightly below the surface this would not occur.

Another loss of pesticides is caused by photodecomposition. This is the break-down of a pesticide due to certain characteristics of sunlight. Some chemicals applied to the soil surface with no water to carry them into the soil can be lost completely by this. Some loss by this occurs with many of the pesticides.

The soil organic material is inhabitated by various micro-organisms, algae, fungi, actinomyces, and bacteria. They must have food for energy and growth. Organic compounds of the soil provide their major food supply. Most of the pesticides are organic compounds. Many of them can be used by the micro-organisms as food. This is a means of reducing the residue of pesticides in the soil. This break-down helps to deplete the pesticide residue in the soil, but seldom has an affect on the efficacy of the pesticide.

Rainfall and irrigation move surface-applied pesticides into the soil. Some pesticides are injected or surface-applied and mechanically incorporated. The depth of injection or incorporation is regulated to place the pesticide near the target pest. Some pesticides could be lost from the surface so rapidly that effectiveness would be decreased. Not all pesticides can be incorporated. Some could be absorbed by the clay and organic matter too quickly and too tightly; thus reducing efficacy. Others may need the depth of soil to protect the crop seed or plant roots. With the pesticides that can be incorporated, the practice eliminates the reliance on water to move them into the soil. Before a recommendation to incorporate a pesticide is made, the pesticide, the pest, and soil characteristics are all considered.

The above discussion on soil factors, especially clay and organic matter, has been simplified; but their importance cannot be stressed enough. They have a direct bearing on the efficacy and residual properties of all soil-applied pesticides. Many cases of pesticide failure could be sited where soil characteristics were not considered before applying the pesticide.

In developing a pesticide recommendation, the first step is to identify the pest and crop. After the pest is identified, the soil characteristics should be considered before selection of a soil-applied pesticide. The amount of the various soil particles and organic matter can be obtained by analysis. This information is needed for most effective and economical pesticide application When the proper pesticide has been selected, read the label and follow all directions for safe and effective pesticide use.

VARIABLES AFFECTING THE EFFICACY OF INSECTICIDES

There are many variables affecting the efficacy of insecticides when applied to animals. In order that we might look at these variables in a more organized fashion, I have divided these variables into four categories: biological, mechanical, environmental, and physical. Under the category biological we have three sub-categories: 1) the human applicator; 2) the animal; and 3) the ectoparasiste. The animal is a biological variable in that no two animals are alike. Animals will vary in many ways. For example: If you are trying to spray animals, the excitable animals will always be back in the corner of the pen, and you will not get to wet them as easily as you would the ones that are more docile. Consequently, when you look to see which animal you are spraying, you are spraying one that you have already sprayed. At the same time, you have some in the back that have not been sprayed properly.

We have the size of the animal which is a variable factor within itself. Many of the pesticides are recommended on the basis of milliliters or cc's per 100 lbs. of body weight. The size will vary and the person doing the treating must be able to look at the animal and accurately estimate the weight.

The length of the hair may also be a variable. It takes about twice as much insecticide to wet an animal with a coat of long winter hair as it does to wet an animal with short hair during the summer months.

There is another biological variable that we should think about - the differences in ectoparasites. For example, there are several insecticides that will do a good job on controlling adult cattle lice; yet that same insecticide may not control egg stage which is glued to the hair. This means that you apply an insecticide that kills all the adults, but immatures from eggs that hatch after treatment may reappear in ten days to two weeks. For this reason, one may need to repeat the treatment.

The horn fly is one of the easiest insects to kill because it spends its entire adult life on the cows except when the fertile females leave the cow to deposit eggs in the fresh droppings. This makes it an easy adult insect to kill. They are small and when they come in contact with insecticides they are easy to kill. Other flies that affect cattle are not so easy to kill. The stable fly takes a blood meal and goes and rests on the wall until it digests that blood meal, spending little time on the animal. This makes it more difficult to kill.

The horse fly is large and has a tough outer covering. It takes the blood meal and leaves the animal for a long period of time. Because of the tough outer covering and the fact that it takes the blood meal and leaves the animal, it more difficult to kill by far than any of the flies that we have to deal with on cattle.

The face fly is another pest that we have here in Virginia in great numbers. It spends a great deal of time off the cow as well as on the cow which makes it more difficult to kill. Most of those on any one herd may be controlled by a good treatment method. However, they are strong flyers and may migrate from neighboring herds and reinfest a clean herd.

Now, perhaps we should consider the cattle grub. This is one that has a life cycle of about nine or more months within the cow itself. The grubs emerge out of that hole on the animals backs and burrow into the ground to change into the winged form. Systemic insecticides are to be applied in late summer or early fall before the grubs start toward the animal's back. This means that timing may be a variable in that the applicator must think about the best time to treat.

Now we will go to the second category of variables which is the mechanical. Good spray pens are a must. If we are going to spray animals, good equipment is needed. For a few calves, a small compressed air sprayer would be all right, but it would not be adequate for a large herd. A large herd will require the use of a good motor-driven sprayer that will operate at least 200 pounds of pressure per square inch.

There are automated sprayers for treating dairy cattle as they leave the barn. The animal triggers a mist applicator by some means; usually a metal apparatus similar to the tip of a radio aerial on an automobile. Animals may stop while they are touching the trigger because they like to cool off on a hot day. The variable in this case is obvious. They will pump the spray machine dry and the animal becomes over-treated. This type of automatic sprayer is not as popular as it was in years past.

We will now consider dipping vats. Dipping vats are not as popular in Virginia as in other parts of the United

States. They could become important in an attempt to eradicate problems such as scabies which now occurs in some of the western states. Some of the variables pertaining to dipping vats are as follows: 1) sunlight may break down the chemical in the dipping vat solution; 2) animals will remove a certain amount of the chemical when they go through the dipping vat. This means that the dipping vat solution should be tested regularly to determine the concentration of the insecticide. More insecticide or more water must be added now and then to maintain the proper concentration.

The previous discussion pertains in part to dipping vats for cattle. Dipping vats for sheep should also be considered since there are a few portable dipping vats used for this purpose in Virginia. One of the variables here relates to how the sheep are handled to make sure that they are completely submerged in the dipping solution. They have a tendency to make a big lunge and avoid being dipped completely. The animals should be "tripped" to keep the sheep from lunging across the deep part of the portable vat.

We will now consider another type of mechanical applicator, the dust bag, which is used for the control of of external parasites on cattle. Some of the variables that affect the efficacy of dust bags are as follows: 1) moisture -- dust bags must have protection from rainfall; 2) animal contact with the dust bags -- forced use is a must; for example, animals must be forced to go under the bags to obtain water, feed, and/or mineral; and 3) height of bag -- bags must be suspended within 18-22 inches above the ground for proper distribution of the dust on the animals to aid control of face flies. Dust bags must also be suspended in such a manner that they swing freely to assure better dust distribution for more effective control of insects on the cattle. Mesh of the bag is also a variable. Coarse bags put out dust better than fine mesh bags. Another mechanical applicator is the backrubber. Most of the things mentioned above about dust bags would apply in part to the backrubber. However, one thing that should be mentioned as a potential variable with regard to the backrubber is they need to be resupplied with insecticide. The frequency of retreating is governed by how fast the backrubber is dried out by sunlight or animal usage.

We will now consider mechanical variables relating to the pour-on treatment method. Potential variables relating to this method of application area as follows: 1) Physical properties -- some pour-ons are called invert emulsions, and when mixed with water and stirred thoroughly as prescribed on the label, they reach a "milk shake-like" consistency. This mixture clings to the animal's hair and none of the mixture is lost by dripping. Other pour-ons do not perform in this manner and run off the animal if not applied slowly and carefully.

The "spot-on" method of application places only a spot of insecticide on an animal's back. One of the variables here relates to the person doing the applicating. This method is so convenient, some people tend to believe that the "spot-on" gun can be used in a manner as similar to a water pistol, thereby eliminating the need for a good holding chute. This is not true. A good holding chute is a must for applying either the pour-on or "spot-on" treatments in the proper manner.

With regard to holding facilities, the importance of a good pen for spraying cattle cannot be over emphasized. It is important that the spray pen not be too large or too small.

With regard to holding facilities, the importance of a good pen for spraying cattle cannot be over emphasized. It is important that the spray pen not be too large or too small.

Let us now consider some environmental variables. These are: 1) rainfall -- a variable in that the insecticide may be washed off the animals anytime after it is applied; thereby reducing the period of effective insect control; 2) cattle may also wash off a newly applied treatment by going from the spray pen into a pond, especially on a hot day; this may result in a fish kill; 3) temperature -- most insecticides are broken down by ultraviolet sun rays and high temperatures; 4) humidity -- heavy dews should be allowed to evaporate before animals are treated in the early part of the day; and 5) wind -- this is not as important a consideration with regard to animals as with plants because animals are usually treated under more confined conditions. However, it should be considered.

Now we will consider a fourth category - that of physical aspects with regard to variables. Let's think first about sprays. Under this category we have emulsifiable concentrates. This is a material that goes into suspension well. It usually turns milky white with water and it remains in a stable suspension. Emulsifiable concentrates are more ideal from this standpoint as opposed to wettable powders which require more agitation in the spray machine to keep them in suspension. In addition to that, wettable powders are more abhrasive and tend to wear out machines more. They may also cause more clogging of nozzles.

We also have the pour-ons that we mentioned previously and we talked about some of the variabilities there. But pour-ons can be, as we mentioned, the invert emulsion with a milk-shake-like consistency which clings to the hair well or it can be a material that is mixed with water and tends to run off the animal. This does not affect the efficacy of the material as much as one would think. But a farmer doesn't like to see the material running off on the ground. Ready-to-use light oils generally do a rather good job as pour-ons. It is very essential that the pour-ons be measured properly with regard to an estimate of the weight of the animal.

Dust are used in some cases to sprinkle on hogs and cattle for lice. This is usually in a confined situation and that is the reason we said wind velocity should not be as big a factor as it would on a crop.

One of the last things that we want to talk about is the mineral mixture plus an insecticide. The variable here is two-fold. One is that this mixture can be so palatable that cows consume it too rapidly. Fortunately, this has never shown any ill effects to the animal, but it can get to be quite expensive. The excess intake does not increase the effectiveness. The second reason is that some of the mineral mixtures are highly unpalatable and the animals eat them rather rapidly for a short period of time and then they don't eat them at all for a like period of time. Insect control decreases as consumption decreases.

We had a test several years ago in which everything was going fine with the mineral mixture plus an insecticide. Then the grass got short and the farmer opened up another pasture. The cattle were more hungry for grass than they were for the mineral mixture and they wouldn't come back to the mineral mixture as frequently as they should have. We should have moved the medicated mineral mixture to a more central location. The cattle didn't consume on a regular basis and the hornfly control fell from about 95 percent to 80 some percent; a decrease in fly control because animals were more hungry for grass from the new pasture than for the medicated mineral mixture. This caused the intake of the insecticide/mineral mixture to be erratic.

Last but not least, one that has been talked about for several years is feed mixtures. This is very much akin to the mineral mixtures. Mineral mixtures may be used all during the hornfly season but the feed mixtures are to be used only for 7 days or 14 days as a means of treating animals for the control of cattle grubs. The insecticide is mixed with the feed. The variables are largely about the same as with the insecticide mineral mixtures.

In summary, there are four categories of variables which can effect how well insecticides control insects on animals. These are, as we have discussed; biological, mechanical, environmental, and physical.

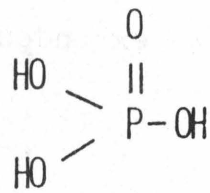
BASICS OF INSECTICIDES

Today I want to talk to you about insecticides, how they kill insects, and a little bit about their chemistry and properties. I need to make a few introductory remarks to lead into the subject I wish to discuss, and one of these remarks is that most of the insecticides which are currently used today are what we refer to as contact insecticides; that is, they must actually come in contact with the insect in order for them to exert their toxic action. The toxic action that we are concerned with is that which is referred to primarily as acute toxicity. In other words, that toxicity which occurs very rapidly after exposure to the material. We are also interested in the toxicity that is referred to as chronic toxicity or that which occurs at a longer period of time after exposure. In the latter instance, we are primarily interested in the effect on non-target organisms. For killing insects which are of economic importance, we want to kill them rapidly and therefore we're interested in the acute toxicity.

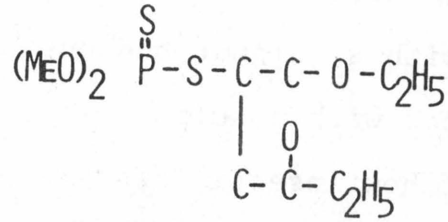
Another property which I must discuss with you is that most of the currently used insecticides are essentially insoluble in water. This means that in order to use them as insecticides, we must formulate them in some way that they can be more usable. To do this, they are prepared so that they can be extended in water, or used as an oil base spray.

Most of the insecticides we will discuss today can be grouped according to their chemistry or some other property. I find it easier in dealing with insecticides to approach them in this way, and that is what I propose to do for discussing the materials under consideration. The first of these groups is the organic phosphate insecticides. We will note that these materials can be thought of as being derivatives of the simple inorganic molecule phosphoric acid. What happens in this instance is that we can prepare an insecticide by substituting certain organic constituents for one or more of the atoms of this molecule. All of the hydrogens are usually replaced with an organic constituent. In addition, the double bonded oxygen can be replaced with a sulphur and one of the oxygens is sometimes replaced with a sulphur atom. Below we will see an example of how insecticides are actually prepared or derived from phosphoric acid. If you will focus your attention on the phosphorous atom, you will see that in methyl parathion, the oxygen has in fact been replaced by a sulphur.

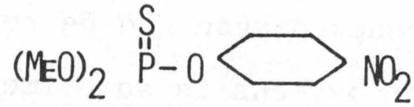
PHOSPHORIC ACID



Now if we can look at the next figures, we will see some other examples of organic phosphate insecticides. These materials have certain properties which we need to know something about. One of them is that the organic phosphate insecticides are rather short-lived which is probably the result of the fact that they can be easily hydrolized in a slightly alkaline solution. In nature, this means that they do not persist in the environment and from a practical point of view, they often have to be applied repeatedly to bring about insect control.

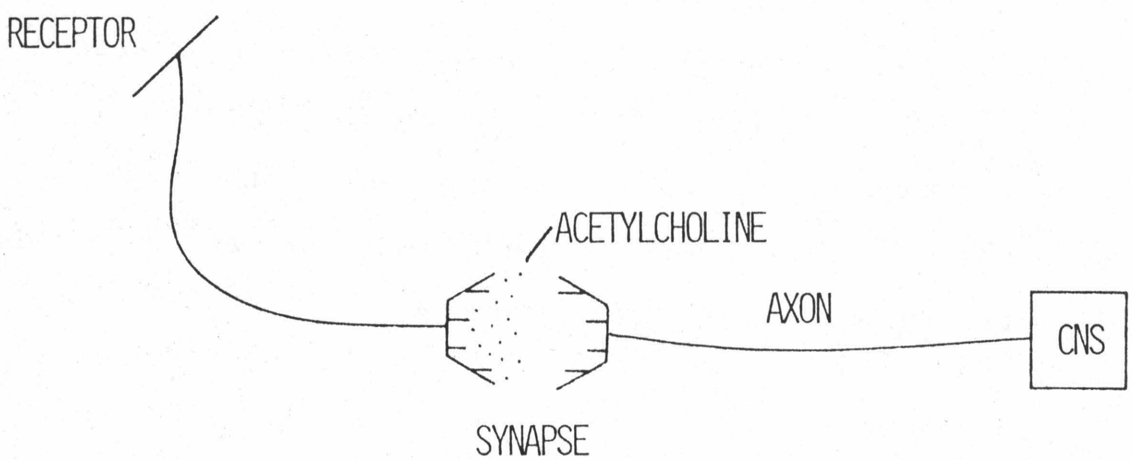


MALATHION



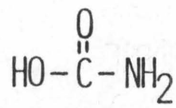
METHYL PARATHION

As far as the ways these materials kill insects, we need to examine a schematic diagram of the insect nervous system. In this nervous system we can look at the part referred to as the synapse. At this synapse, the way the nerve normally functions is that an impulse passes down the axon to the synapse. At that point, if the impulse is strong enough, it will cause the release of the neural transmitter substance acetylcholine.



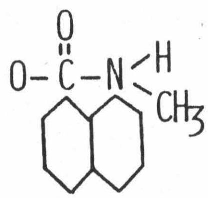
Acetylcholine is released, produces a stimulation on the post-synaptic side, and then is rapidly destroyed by the enzyme acetylcholinesterase. This enzyme is normally active for a very short period of time, destroying the acetylcholine. When an organic phosphate insecticide is introduced into this nervous system which is functioning in a normal manner, the effect is to bring about an irreversible inhibition of acetylcholinesterase. Under these conditions, acetylcholine accumulates at the synapse and itself, being rather toxic, produces a deteriorating effect upon the synapse. From this result, the insect nervous system rapidly degrades and is incapable of carrying out its normal function. As a result of this, the insect dies.

Turning to a second group of insecticides, the organic carbamate insecticides, we see the simple organic molecule, carbamic acid. Carbamic acid, as was the case with phosphoric acid can be transformed into an insecticide by substituting certain constituents.



CARBAMIC ACID

Specifically the H on the hydroxyl group of the molecule and one or two of the hydrogens on the amine group of the molecule are substituted. Below we see an example of this kind of a substitution.



NAPHTHYL-N-METHYL CARBAMATE
SEVIN

In this case, the insecticide is Sevin, or carbaryl, and we see that the hydroxyl hydrogen has been substituted with a naphthalene ring and one of the amine hydrogens has been substituted with a methyl group.

This group of insecticides is also easily hydrolized in nature and therefore tends to be non-persistant in the environment. It has another property in that the carbamates tend to be rather specific. They do not kill a wide spectrum of insects, but rather certain specific ones. This was in contrast to the situation with the organic phosphate insecticides which were rather broad spectrum insecticides killing most insects with which they come in contact.

The way carbamates go about producing their toxic action, this is essentially similar to the situation with the organic phosphate materials. In other words, they are acetyl cholinesterase inhibitors in the same sense that the organic phosphate materials are. There is one difference which needs to be mentioned, however, and that is that the inhibition produced by carbamate insecticides tends to be slowly reversible. This has a practical result in that sometimes when an insect appears to be under the toxic influence of a carbamate insecticide, it will subsequently recover. That recovery is probably related to the reversible nature of the inhibition of acetylcholinesterase produced by carbamate insecticides.

I want next to turn to another group of materials and talk briefly about them. This group is classified not according to chemical structure, but rather on the basis of origin. In this case, the origin is plants; in other words, these are the so-called botanical insecticides. There are several materials which belong to this group that are of importance as insecticides but the most important of these are the pyrethrins insecticides. I am not going to attempt to show you a chemical formula for this group of materials, because the product which is available commercially is a mixture of at least 4 very complex organic molecules. They vary in their presence from year to year depending upon the crop that happens to be produced. Therefore, we are not dealing with a constant chemical entity as was the case in the materials we have just reviewed.

The pyrethrin insecticides have one property which is very important as far as use is concerned. That is, they bring about an extremely rapid knockdown of the affected insects. This is an important property and is one that producers of insecticides wish to incorporate into their products as often as possible. When I speak of a rapid knockdown with the pyrethrin insecticides, I am talking here in terms of knockdown in a matter of minutes; whereas, in the case of the phosphate or the carbamate insecticides, it is usually in terms of knock-down of perhaps hours or even a day or more after exposure.

The mode of action of the pyrethrin insecticides is again on insect nervous systems. And, in this instance, we believe that the pyrethrin insecticides bring about their toxic action by simply blocking the transmission of a nerve impulse in the axon. The details of this action are not well understood, but this is perhaps the most accurate description that we can make at the present time.

I would like to turn next to a very brief discussion of two groups of insecticides which are no longer of much importance, but yet which are of considerable interest from a historical point of view. These are, of course, the insecticide groups DDT and the cyclodienes. These materials are no longer available for commerical use because of governmental regulations which have banned their availability and use. Nevertheless, the DDT insecticide is an example of a material which has been available and used for a long period of time. One of its outstanding properties is that it is a very stable chemical molecule. This has brought about some difficulties as well as some advantages from an insecticidal point of view. The advantages are, of course, that it can be applied once and remain effective for a long period of time. The disadvantage is that, from an environmental point of view, DDT persists and continue to exert its toxic action over that same long period of time.

Much the same can be said for the cyclodiene materials which are also quite stable chemical molecules and persist in the environment. Because of these properties of persistence in the environment, accumulation in food chains, and the possibility of carcinogenic properties attributed to them, these materials are no longer available.

From the point of view of mode of action, however, we will discuss both DDT and the cyclodienes. Both groups again act upon the nervous system of insects. Let's look at the schematic of the nervous system again. In this instance, what happens with regard to the presence of DDT is that it apparently unstabilizes the nerve membrane which we can see is a charged membrane. DDT prevents this membrane from fully regaining its charged state once a nerve impulse has passed down the axon. This results in a very rapid action of the nervous system. It responds to low level stimuli, and produces the so-called DDT tremors. As far as the mode of action of the cyclodienes is concerned, what I have to say in this instance is that in spite of many years of activity in searching for the mode of action, it remains largely unknown.

I would like to turn next to a discussion of certain newer groups of insecticides which are becoming available rather slowly at the present time, but which may be of importance to us in the future. This group of materials we can refer to as a class, but in this case we will simply say that they are biological insecticides. There are two such groups that are perhaps worth discussing at the present time. The first of these is the result of the action of certain microbial organisms. These organisms can be grown in culture and produce a toxin which is harvested commercially and transformed into an insecticide. When this is accomplished, the insecticide is formulated in an appropriate manner, and can be applied similarly to that which we would do with a typical chemical insecticide. In this instance, what we know about the results of the toxin is rather limited at present, but it seems to be a matter of the material having to be ingested or eaten by the insect. Once inside the insect body, the toxin produces a deteriorating condition in the gastrointestinal tract. Materials penetrate from the tract into the body cavity and produce an unstable physiological condition which is lethal. The nature of that toxic action is not well understood at the present time. The chemical nature of the toxin is not well known. This subject is being investigated and we should have additional information in the relatively near future.

The other group of biological materials is one we can refer to as hormone analogs. These materials are currently in the process of development and again, we can expect that a number of them will be available in the years ahead. Essentially what happens here is that the hormonal action of a given substance is studied and becomes reasonably well understood. The chemistry of the product or the naturally occurring material is also understood, and attempts are made to produce materials closely related chemically to this substance. In this instance, the snythetic materials can be formulated and applied in the usual manner. The idea behind the hormonal approach to insecticides is to mimic the action of the hormonal material and perhaps accentuate it to some extent. What we would be attempting to do is to produce an abnormal effect related to the normal developmental effect of the hormone itself. In this way it may be possible to interfere with the normal development of the insect so that it may result in the production of an extra immature stage or something of this nature. Alternatively, we could hope to interfere with the normal reproduction of the insect and, thereby, limit population growth.

I think that we can look forward into the future and say that materials such as I have just been discussing will assume greater importance in the future. We can expect to find some of these materials available commercially in the years ahead. I would also like to say in this connection there is extensive research going on at the present time attempting to develop materials which are related to the chemical groups of insecticides I discussed earlier. The ones that are perhaps of the most importance from this point of view are the pyrethrin insecticides. There is considerable activity going on at the present in which new pyrethrin-like materials are being synthesized in the laboratory. Some of these materials look quite promising and we can probably expect to hear more about them in the future. Likewise, there is research activity going on in the DDT group of insecticides. In this instance, the hope is that materials can be developed in the laboratory which will retain some of the desirable characteristics of DDT, but which will not produce the undesirable effects. In this way, we can perhaps avoid some of the environmental hazards which have arisen out of the use of DDT. So, with this information, I think we can say that we can look forward in the future to finding newer insecticides which will be of value to us.

BASICS OF HERBICIDES

There are many herbicides on the market today that will do a variety of jobs. This discussion is concerned with how herbicides work and how they kill plants. Before you can understand how herbicides kill plants, you must become familiar with basic plant growth. A review of some plants functions will help to understand how herbicides work.

Plants, like animals, are living organisms. They require food, water, and a favorable environment in order to grow. There are many types of plants, and they have different habitats or environments which are best suited to their growth. Plants are categorized as lower plants and higher plants. The lower plants are algae, bacteria, and fungi. Weeds and crop plants are flowering plants or higher. About 500 different weedy species occur routinely as pests in agricultural production.

The higher, or flowering, plants are divided into two main groups - the monocots which have parallel leaf veination and the dicots which have a net leaf veination. Corn is grass (monocot), and a bean is a broadleaf (dicot). Higher plants have roots, stems, and leaves and later produce flowers, fruits, and seeds.

Plants can also be grouped on the basis of their life cycles. Those which germinate, grow, flower, and produce seed within one year are called annuals. There are many common examples of annual weeds. The mustards and many of the things that we would grow in our garden are annuals.

Biennial plants, like the thistle, complete their life cycle in two years. The first year they grow vegetatively, and the second year they produce flowers and seeds. Perennial plants are those which grow for more than two years. Perennials are very difficult to control because they have underground storage systems. It is difficult to move chemicals down into those underground systems.

Photosynthesis is the process by which green plants are able to produce sugar. Light energy from the sun is trapped in the green leaves and then converted to sugar. This process is the basis of all life. Were it not for this photosynthetic process, there would be no food for humans or other animals. Leaves contain little structures call chloroplasts which house the chlorophyll molecules and give the leaf its green color. Carbon dioxide from the air and water form the roots are combined in the presence of chlorophyll to produce sugar and oxygen. The sugar is then converted into starches, proteins, and many other substances that are required for growth of the plant. Growth occurs by multiplication of the individual cells and then enlargement and differentiation of cells into various structures.

Interference with the photosynthetic process will inhibit growth or kill a green plant. It is a common practice in gardens or small landscape areas to use a black plastic mulch to shade out or kill weeds. The black plastic eliminates the photosynthetic process and the plants starve to death.

Water is an essential ingredient for both animal and plant life. When a plant is pulled from the ground it quickly withers and dies from lack of water. Water can be withheld from the plant chemically by use of salt. The salt draws water form the plant and restricts the movement of water into the plant causing the plant to dessicate and die. There is also the other extreme of too much water. This is used to our advantage in the production of rice where the roots of the rice will tolerate very wet conditions; but many weeds will not tolerate extremely wet conditions. The action by which excess water kills the plant is usually by prevention of adequate oxygen movement to the root system. Temperature is essential for the growth of plants. Extreme low or high temperatures will kill plants. Jack Frost is well known for his ability to control weeds. On the other extreme flame throwers have been used for many years to kill weeds. This has been refined somewhat with the flame cultivator where it is possible to obtain selectivity by directing the flame at the base of a woody cotton plant and killing annual weeds without destroying the cotton plant.

Contact herbicides kill by causing rapid destruction of cell membranes. Paraquat used in no-tillage corn production turns fields brown almost overnight. The paraquat destroys the lipid and protein membrane which surround the individual cells causing very rapid death. Contact herbicides do not move or translocate within the plant. Thus, good coverage is necessary for good control and higher spray volumes of water per acre and often wetting agents are used to disperse or spread the material over the leaf surface.

The photosynthetic inhibitors are herbicides which chemically interfere with the photosynthetic process. The triazine herbicides are a good exampel of photosynthetic inhibitors. Atrazine and simazine are triazine herbicides commonly used in corn production. Another group of photosynthetic inhibitors are the substituted ureas. Bromacil, (Hyvar) belongs to the substituted urea group which are also well recognized for their interference of the photosynthetic process. By interferring with photosynthesis, they prevent food formation and the plant starves. It is important to note that chemicals that interfere with plant metabolism are required in extremely small quantities. Metabolic reactions within the plants are controlled by substances called enzymes. Enzymes are catalysts - they are present in very minute quantities of metabolic inhibitors can prevent their normal action.

Respiration is the utilization or the breakdown of food resulting in energy. This is in essence just the reverse of photosynthesis. Indeed, they have many of the common intermediates. During respiration, starch or other food sources are converted back into carbon dioxide and water. The resulting energy is used to make other intermediates within the plant and growth.

Compounds which interfere with respiration can cause a plant to burn up or waste all of its energy and result in death. Proteins are essential within plants as structural proteins and enzymatic proteins. Structural proteins give structure to the plant cell membranes. Enzymatic proteins are catalysts which are useful in synthetizing chemical reactions. As we mentioned earlier, enzymatic proteins are required in only minute amounts for normal plant growth. Minute amounts of inhibitors that interfere with enzymatic proteins can kill plants. In order to visualize destruction of structural proteins, think of a hen egg. The white of an egg is protein. When you cook an egg, the egg coagulates forming a rigid structure as the egg protein is killed.

Cell division is a very complex process whereby one cell duplicates and becomes two. There are many processes involved with the cell division and these are not well understood. Many of the preemergent herbicides interfere with cell division. Two of these are CIPC and dacthal. They act at the growing points or meristems of the plant. The plant is unable to produce new cells in a normal manner and subsequent growth is prevented.

Growth regulator herbicides were discovered back in the 40's during biological war research. The first to be discovered was 2,4-D which was found to be a very potent inhibitor of plant growth. It's been studied for several years since then, and scientists still do not completely understand how it or other growth regulators are able to control plant growth. Their action apparently occurs at the cell nucleus. Nucleic acids within the nucleus of a cell contain the memory system or the brain of a cell. Working at the brain level, the regulators can cause wrong directions to be sent resulting in distorted or disorderly growth. Farmers use the expression that 2,4-D causes a plant to grow itself to death and, that seems as good an explanation as any.

The usefulness of a herbicide is often limited to the degree of selectivity that can be obtained in a given weed-crop situation. Corn has the capability of rapidly breaking down the triazine molecule while weeds lack this ability or have it only to a limited degree.

A similiar situation exists in the case of 2,4-DB which is used in legumes. Only in this case the 2,4-DB is an inactive material but is broken down within a plant to 2,4-D which is active. Many weeds are more efficient at converting 2,4-DB to 2,4-D than the alfalfa or other legumes. Selectivity can also be gained by placement of materials in the soil. Simazine is safe to use in ornamentals only because it remains at or near the soil surface above the root system of the plant. If it were picked up by the root system of the ornamental, it would cause injury or even death. Differential wetting of the plant foliage may contribute to selectivity. Wild garlic has a waxy leaf surface and some sprays bead up and roll off. Control can be obtained with an oil soluble formulation of 2,4-D which will dissolve its way through the waxy leaf surface. Entry of the 2,4-D into the garlic plant occurs with an ester formulation, but not with the water soluble amine formulation. Another type of selectivity relates to the location of the growing points of the plant. The monocots (grasses) tend to have enclosed growing points; whereas the broadleafs have growing points that are exposed. Contact herbicides are often more effective broadleaf weeds than grasses.

FUNGICIDES AND THEIR ACTION

Fungicides are important, if not essential, in plant culture. Although the manufacture and utilization of fungicides do not equal that of herbicides and insecticides, the total failure in the culture of many plants can be attributed specifically to the failure of the grower to apply the correct fungicide in the proper manner at the correct time. As plant protectionists, however, we need to consider seriously the integrated approach to disease and pest control in general; that is, we need to implement all known pest control measures -- cultural, control, biocontrol, host resistance, chemical control, etc. Then, in the chemical control of pests, we need to consider how fungicides might be used most effectively in an integrated program with insecticides, herbicides, nematicides and possibly other types of pesticides.

TERMINOLOGY - is an essential aspect of understanding any discipline, and the short glossary below provides brief definitions of basic terms.

fungicide - compound used specifically to kill fungus.

fungistat - compound used specifically to inhibit a fungus; often plant disease fungicides present in sub-lethal concentrations only inhibit rather than kill the target fungus.

efficacy - relative activity or effectiveness of a fungicide by which it can kill fungi or control plant diseases caused by fungal pathogens.

residue - that fungicide (or pesticide) which remains or is left on the plant surface after application. The marketability of a fungicide depends, in part, on how <u>residual</u> it is. If applied in proper concentrations at recommended times, the product must meet legal residue tolerances.

phytotoxicity - the capacity of a fungicide (or any pesticide or chemical) to poison or injure the plant upon which it has been placed. Bordeaux mixture, for example, is notoriously phytotoxic while the fixed copper fungicides are less phytotoxic.

active ingredient (a.i.) - the actual fungicide itself usually given in percent, in any of the commercial preparations - wettable powders, emulsifiable concentrates, dusts, gases, granules, etc.

inerts - the non-fungicides (non-active ingredient) constituents of a commercial fungicide preparation. Inerts are composed of fillers, spreaders (surfactants), stickers (flour, gums, resins, casein, etc.) and other substances.

LD_{50} - the lethal dose of a fungicide that kills 50% of the test population of the target organism (fungus). With regard to efficacy in killing fungi, the lower the LD_{50} value the better. This distinction is most important to note.

specificity - that attribute of a fungicide to be specific in its killing ability for certain fungi or certain classes of fungi. Some fungicides are broad spectrum, or have low specificity, and kill many different kinds of fungi; others are narrow spectrum in their activity, and kill only very few fungi. Specificity and spectrum of activity is a very important consideration in selecting fungicides.

prevention vs. cure of plant disease - prevention of plant disease is always the best approach and is achieved with fungicides by protecting the uninfected plant surface with an appropriate fungicide. These fungicides are known as contact fungicides, preventatives or protectants. The treatment (therapy) or successful cure of established disease is accomplished on a very limited basis in plant pathology. There has been success in treating Dutch elm disease in very early stages with surgery and/or systemic fungicide application.

conventional contact or topical fungicides are the major group of protectant compounds applied as dusts and sprays to plant surfaces, and do not move into or within the treated plant.

systemic fungicides are compounds which, after being applied to plant roots (or less frequently, shoots), are taken up and translocated within the plant. They may function preventively or curatively in disease control.

tolerance - is the "defense mechanism" developed by the target fungus by which it becomes insensitive to repeated contact with the same fungicides. This is believed to occur through selection and genetic processes. For example, Cercospora that causes peanut leafspot is becoming more tolerant to benomyl, and therefore benomyl can no longer provide the disease control that it did at first.

BASIC REQUIREMENTS OF FUNGICIDE USAGE - must be understood, and a few are:

Proper choice - one must hit the target organism; for example, one would not choose benomyl to control water molds.

Proper timing - one must apply the fungicide at the best time; for example, fungicides are not applied in late summer to control leafspots of landscape trees.

Proper placement - one must apply the fungicide on the correct site.

Proper solubility - most organic fungicides are poorly soluble in water, but a certain amount of solubility is essential so that the fungicide can move into and kill the fungus.

Proper formulations - must be chosen to get the best job done. Examples are wettable powders, emulsifiable concentrates, granules, gases, dusts, solutions, etc.

Proper coverage - is essential to provide maximum protection. To achieve this, spreaders (surfactants that lower surface tension) and stickers (flour, gums, resins, casein, etc. that enhance weathering properties) are added as inert ingredients.

In addition to these requirements, a fungicide should:

-not injure the plant on which it is placed;

-be reasonable in cost;

-be non-toxic to man and animals ;

-be compatible with other pesticides, especially insecticdes;

-be relatively stable but not too residual; and

-always have complete registration -- both state and federal.

FUNGICIDE USES are many. The major ones are:

Seed treatment - to afford protection against seed and soil borne fungi. Fungicides are dusted or sprayed onto seeds. Generally done by seed companies. Chloranil and thiram are effective seed treatment fungicides.

Soil treatment - help rid the soil of fungal pathogens is accomplished in some cases by application of fungicides to the furrow as the seed is planted.

Foliage treatment - is probably the most common use of fungicides, and wettable powder formulations the most popularly used. Air blast sprayers that apply high volumes and low fungicide concentrations or low volumes and high fungicide concentrations are very effective. Aircraft is also used.

Post-harvest treatment of fruit, for example, has been used with success. The major problem here, however, has been that of residues.

<u>CLASSES OF FUNGICIDES</u> should be considered to help us categorize major groups and examples of each. Fungicides can be classified in different ways. For example, one could indicate that there are inorganics and organics. However, the following categories appear to be the most commonly used and perhaps the easiest to remember.

Sulfur - is the oldest known fungicide. Effective against powdery mildew. Combined with lime, it is used as lime-sulfur, effective against peach leaf curl and other diseases.

Copper - is another old but effective fungicide. Used as copper sulfate with lime in Bordeaux mixture. It is highly effective, but as Bordeaux mixture is phytotoxic in many cases. Fixed coppers are much less phytotoxic. Copper controls many fungal and bacterial diseases.

Mercury - fungicides are among the effective of all. The organic mercuries especially have been used for control of anthracnose, seed-borne organisms and other problems. Due to their long residual and cumulative activity and toxicity to life systems, they have been banned from use.

Dithiocarbamates (including the ethylenebisdithio-carbamates) are the "workhorses"of the fungicides. The first organic fungicides were the dithiocarbamates, shown to be effective in controlling a very broad spectrum of causal organisms in the 1930's. Examples of this group would include <u>thiram</u>, <u>ferbam</u>, <u>ziram</u>, <u>nabam</u>, <u>zineb</u>, <u>maneb</u>, and others.

Heterocyclic nitrogen compounds constitute a very important group of fungicides. Important examples are captan and captafol (Difolatan), very broad spectrum toxicants, and glyodin used commonly in control of fruit diseases.

Aromatics have the benzene ring as a common feature of their chemistry. Examples are: 1) phenols such as pentachlorophenol - used as a wood preservative; 2) the quinones such as chloranil - used in seed treatment; 3) the nitrated benzenes such as PCNB (pentachloronitrobenzene) - used as a seed treatment and soil fungicide; and 4) botran - used to control Rhizopus rot of fruits; and 5) the aromatic dyes such as Dexon - used to control the water molds.

Antibiotics - are compounds produced by assorted microorganisms that have activity against plant disease as well as human and animal pathogens. A good example is streptomycin, used in both plant and human diseases, that is effective against fireblight of apple and pear. Another is cycloheximide, an antifungal antibiotic usted to control turf and other diseases. The tetracyclines have good activity against the mycloplasma-like organisms that incite "yellows" diseases in several important plant groups.

Systemics are the newest members of the fungicide group of pesticides. These compounds are so named because they have the unusual property of being able to gain entrance and move within the plant after application. These compounds are also used as conventional contact spray fungicides. Important groups are the benzimidazoles such as benomyl and thiabendazole - used to control a wide variety of plant diseases, the oxathiins such as Plantvax and Vitavax - used to control smuts and rusts and thiophanates which also have broad spectrum activity like the benzimidazoles. Many other groups of systemics have been and are being synthesized and tested.

Not included in this listing of fungicides are the very important group of soil sterilants which have the capacity to kill many if not all forms of life in the soil.

In summary, there are many different classes of fungicides, designed for specific uses. These compounds have various plant disease fungi. The best compound should be applied at the right time in the recommended manner to achieve optimum results. One should always consult the VPI&SU Extension Division for these recommendations.

RODENTICIDES AND AVICIDES - MODES OF ACTION

All the numerous rodenticides and avicides have one shortcoming or another. Such factors as toxicity, dosage levels, and relative effectiveness are obviously important. Less often considered, but of equal importance, are degrees of acceptance and reacceptance and the development of tolerances. Odor and taste must be considered in some instances. Safety precautions are an essential part of any procedure. An understanding of the mode of action will enable you to use rodenticides and avicides more effectively and safely.

Rodenticides are chemicals used to control rodents such as rats, mice, and squirrels. They are normally employed in solid baits, in liquid forms, as dusts, or are volatile chemicals used as fumigants. The most effective rodenticides are those with high toxicities, palatibility, and one or more safety features.

Rodenticides used in solid baits or liquid forms can be divided into two groups based on the mode of action: the acute rodenticides and the chronic rodenticides. The acute rodenticides are those which contain a lethal quantity of poison that is ingested in a single dose, in the food or drink of a rodent. Some common acute rodenticides are Red Squill, Strychnine, and Zinc phosphide. They cause death by heart paralysis, gastro-intestinal and liver damage, or by attacking the central nervous system. The target animal must consume a lethal dose before the onset of poisoning symptoms. A sub-lethal dose may produce side effects which will make the rodent "bait shy." Pre-baiting is recommended before applying acute rodenticides so the animal will be conditioned to the bait. The unpoisoned bait is first presented to the rodents until they freely feed regularly and then it is replaced by bait containing the poison.

Chronic rodenticides bring about death of an animal only after the poisoned bait or liquid has been consumed on a number of occasions. Some common chronic rodenticides are Warfarin, Pival, Fumarin, and Diphacinone. Because the poison is consumed over a period of time, a number of repeated low dosages are lethal. For example, a Norway rat can survive a single 50 l.c. dose, but succumbs to 5 consecutive doses of 1 l.c. taken on successive days. The symptoms of poison are so delayed that the animal never learns to associate discomfort with bait consumption and continues to feed until a lethal dose has been ingested. The main components possessing chronic poisoning action are the anti-coagulants, which interrupt the synthesis of blood-clotting factors so the poisoned animals die from internal bleeding. Chronic rodenticides are relatively nontoxic to domestic animals and man; however, there is no such thing as a "safe" rodenticide.

However toxic a chemical poison might be, it will not be lethal unless a rodent of its own volition consumes a lethal dose. Additives are sometimes included in the bait to improve performance. Attractants such as flavoring or oils are sometimes added to bait to make it more appealing by enhancing the taste or masking disagreeable odors. Anti-coagulants may be made more lethal by adding potentiating agents that accentuate the action of the anti-coagulants. Preservatives and binders are used in baits to keep them from deteriorating over time. To guard against accidental consumption of the poisoned bait by nontarget animals, safety additives may be incorporated. Since rodents are unable to vomit, it is often the practice to incorporate an emetic agent in the bait. The emetic agent will induce vomiting and provide a safety factor for nontarget animals.

Secondary poisoning to animals which feed on dead or dying rodents should be anticipated. This danger may be reduced by removing rodent carcasses whenever possible.

Acute or chronic poisons may be used in dust formulations. A poisoned dust is placed in the holes and burrows of rodents where it adheres to their feet and fur and is transferred to their mouths during normal cleaning and grooming activities. This method requires a high concentration of poison since the animal can only be expected to consume small amounts. The advantage of contact dusts is that rodents do not suspect the source of illness.

In situations where rodents do not respond to poisoned baits or dusts, a fumigation technique can be used. Rodents breathe the volatile substances and gases which cause death. The most frequently encountered fumigants are hydrogen cyanide and methyl bromide.

Avicides and pesticides used to control birds in pest situations. Some common avicides include strychnine, compound DRC 1339, and Avitrol. Most avicides are acute poisons which act on the central nervous system. The reaction time required to kill a bird varies with the type of poison. Strychnine used as an avicide will kill birds shortly after the bait is consumed; the avicide containing the compound DRC 1339 does not kill the birds for several hours, generally after they go to roost. This difference in mode of action is important in reducing the effects of secondary poisoning to animals that consume dead birds. Birds dying at the roost sites can be easily picked up and disposed of.

No avicide has been found that is specific for a given bird, thus there is always a danger that non-target birds will be affected. A poison such as strychnine is lethal to all animals while DRC 1339 is more lethal to starlings and birds with dark plumage but will also kill smaller birds. Avitrol is an avicide which is used to control flock-conscious birds. Birds ingesting Avitrol react with distress symptoms and calls which frighten away the remainder of its flock from the feeding area with a minimum of mortality. The advantage of Avitrol is that only few birds need to ingest the bait, thus a relatively small amount of bait needs to be put out.

Not all animals react alike to rodenticides. Some individual animals, even within the same species, are considerably more resistant to toxic effects than others. Some effects vary with the seasons, diet, and even with the sexes of the animals. Dosage levels are usually calculated to include the bulk of the above-average-resistant animals. Nothing is gained by increasing these levels. A thorough knowledge of rodenticides and avicides will assist you in selecting the best control measure for a particular situation.

AGRONOMIC USE OF NEMATICIDES

Nematicides are agricultural pesticides used for control of plant-parasitic nematodes. Nematodes are small, slender roundworms which may feed on various plants. Usually they do most of their damage to the plant's root system although some may feed on stems, leaves, and seeds of plants. The damage from their feeding activities is usually seen as stunted growth which may be accompanied by symptoms of nutrient deficiencies. These above-ground symptoms are usually accompanied by below-ground symptoms of galls, tiny lesions, stubby roots, or complete loss of feeder roots.

The kind and numbers of nematodes present in the soil are determined by the processing of soil samples by the Cooperative Extension Service at Virginia Tech. Analysis of soil samples can indicate when application of nematicides for control of plant-parasitic nematodes is necessary. The increase in crop value as a result of nematicide application is usually due to increase yield, but this may also be accompanied by an increase in quality of the produce.

The primary use of nematicides is for control of nematode populations in soil before planting annual crops.

This use is called pre-plant treatment and is the treatment of choice for field crops. Post-plant treatments are used for control of nematodes in established plantings of perennials such as orchards or vineyards although pre-plant treatments are often used before the establishment of orchards. The toxicity of some nematicides to plants dictates a waiting period of 3 weeks between application of the nematicide and the planting of the crop. The phytotoxic nematicides cannot be applied as post-plant treatments. The phytotoxicity of each nematicide will be listed on the label of the nematicide. Read it carefully.

The three types of nematicides are:

1. Soil fumigants - chemicals which are usually injected into the soil as a liquid which produces fumes that move through the soil and kill nematodes. The fumigants may be injected into the soil as a broadcast treatment in which the injection chisels are set on 12-inch or 8-inch spacing (depending on the nematicide used), or may be injected under a plastic cover as either a broadcast or a strip treatment. The advantages of fumigants are a highly effective initial activity against nematodes and the activity of some against soil borne diseases caused by fungi. The disadvantages are the waiting period

between application and planting dictated by the phytotoxicity of most of the fumigants and the requirement that soil temperature be between 50° and 80°F at the time of treatment.

Table 1. Some Examples of Fumigant Nematicides

Common Name	Trade Name	Activity
1,3-D	Telone, D-D	Nematicide
EDB	Soil Brom	Nematicide
DBCP	Nemagon	Nematicide
Methyl Bromide	Dowfume MC-2	Biocide
MIC	Vorlex	Biocide
VPM	Vapam	Biocide
Chloropicrin	Telone C-17	Biocide
(Comb.)	Terro-O-Cide 72-27	
	Brozone	

2. Non-fumigant systemic poisons - chemicals which may be taken up by the plant through the roots after application to the soil or through the foliage after spray application. Nematodes are killed after attempting to feed on the plants. These nematicides may be incorporated into the soil as granules or liquids to the soil as a broadcast or a band application. Some may be applied as either a spray to the foliage or as a drench in transplant water. The advantages are ease of application and incorporation,

low phytotoxicity, and control activity against some insect pests. The disadvantage is that most are not as effective against nematodes as most fumigants.

3. Non-fumigant contact poisons - chemicals which may be applied and incorporated into the soil as granules or sprays. They are water soluble and inactivate or kill nematodes as they move in the soil moisture. Some of the chemicals which kill by contact may also have systemic activity. The advantages of this type of nematicide are their ease of application and incorporation, their low phytotoxicity, and their control activity against some insect pests. The disadvantage is that they are not usually as effective against nematodes as most fumigants.

Table 2. Some Examples of Non-fumigant Nematicides

Common Name	Trade Name	Activity
Organic Phosphates		
Ethoprop	Mocap	Nematicide-Insecticide
Fensulfothion	Dasanit	Nematicide-Insecticide
Phenamiphos	Nemacur	Nematicide
Carbamates		
Aldicarb	Temik	Nematicide-Insecticide
Aldoxycarb	Standak	Nematicide-Insecticide
Carbofuran	Furadan	Nematicide-Insecticide
Oxamyl	Vydate	Nematicide-Insecticide

Finally, the following four points may be emphasized.

1. Apply a nematicide which is registered for the crop and which is effective against the nematode species to be controlled.

2. Apply a nematicide at recommended rates.

3. Apply a nematicide when temperature, moisture, and soil conditions are right.

4. Rotate nematicides so that the same nematicide is not used in the same field for several years in succession.