1964

Knowing Agricultural Chemicals

Air Applicator Institute

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KNOWING

AGRICULTURAL CHEMICALS

Air Applicator

INFORMATION SERIES

Vol. 1
The purpose of this book is to present brief descriptions of various chemicals used in agriculture. Insects and weed pests will be discussed only incidentally, as they are the subjects of other volumes of this information series. The reader who wishes to make a more detailed study of agricultural chemicals should consult the Bibliography in Volume Six for additional reference material.

This volume quotes freely from many of the published materials of the United States Department of Agriculture and the state agricultural colleges and experiment stations. Reference numbers at the end of the paragraphs refer to the source of the information quoted or cited. These sources are listed in the Bibliography.

The Agricultural Aviation Academy is most grateful to the many authors and researchers for their excellent first hand, authentic information made available to the public through published reports, articles and speeches. The entomologists, plant pathologists and chemical experts are the ones to whom we must continuously look for guidance in the highly technical industry of air-application. Bringing together this large body of widely scattered information is the main contribution of this series of books.

The Agricultural Aviation Academy wishes to give grateful recognition to the following persons for their outstanding work in the field of agricultural aviation:

E. O. Essig, Alden S. Crofts, W. A. Harvey, W. S. Stewart, E. R. Parker, University of California, College of Agriculture; C. D. Sherbakoff, W. W. Stanley, University of Tennessee; Rodger C. Smith, Kansas State College; E. J. Kreizinger, R. L. Webster, H. S. Telford, Washington State College; George H. Berggren, J. M. Fry, James O. Dutt, Donald E. F. Frear, Pennsylvania State College; H. H. Crowell, H. E. Morrison, B. G. Thompson, Don C. Mote, Leroy Childs, R. H. Robinson, Oregon State College; J. A. McClintock, University of Indiana, School of Agriculture; Jack P. Corkins, Robert L. Warden, James L. Krall, V. C. Hubbard, J. Pepper, Montana State College; N. E. Shafer, D. L. Klinger, J. D. Furrer, Glen Viehmyer, University of Nebraska, College of Agriculture; Wayne B. Fisher, Author; R. S. Dunham, R. F. Crim, H. G. Heggeness, University of Minnesota, College of Agriculture; Dwight Powell, S. C. Chandler, Victor W. Kelley, University of Illinois, College of Agriculture; W. J. Henderson, Colorado State College; C. E. Smith, K. L. Krockerham, O. T. Deen, Louisiana State University,
THE APPLICATION AND USE OF CHEMICALS TO COMBAT WEEDS AND INSECTS IS NOT NEW, AND THE AIR-APPLICATION OF THESE MATERIALS IS NO LONGER IN THE PIONEERING STAGE. MORE THAN 2500 DIFFERENT POISONOUS CHEMICAL PREPARATIONS ARE NOW REGISTERED IN SOME OF THE STATES. EVEN THE TRAINED ENTOMOLOGISTS AND PLANT PATHOLOGISTS ARE OFTEN STUMPED TO RECOMMEND THE BEST COMPETITIVE INSECT AND WEED MATERIAL FOR A GIVEN JOB. IT IS NOT SURPRISING THEN THAT GROWERS AND OPERATORS ARE PUZZLED BY THE WIDE VARIETY OF MATERIALS FROM WHICH THEY MAY CHOOSE.

Since the discovery of DDT and 2,4-D there has been a constant flow of new insecticides and herbicides produced. Each basic chemical is best for a particular job. Careful study of the characteristics and uses of the new popular chemicals will prove a good investment of time and effort by all air-applicators and users. This volume is designed to help its readers become familiar with the most common chemicals. Most important characteristics and uses are treated sufficiently for general handling by air-applicators, however, you must obtain specific guidance from your local state agriculture experiment station people and county agents for dosage recommendations.

There are many new and more powerful agricultural chemicals coming on the market each season. Consult your state entomologist, plant pathologist or county agent before using these materials. See volume Number Six for a list of reference materials for further study.

THERE IS NO SUBSTITUTE FOR KNOWLEDGE

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Before proceeding with the description of the various chemicals let us review briefly and clarify the meaning of a few simple chemical terms. These terms will be used both in this volume and on the container labels of the commercial chemicals you use.

- **ELEMENT** is a substance which cannot be decomposed into simpler substances by any known means. Example: copper, sulfur, oxygen, carbon, iron, silver, mercury.

- **COMPOUND** is a substance consisting of two or more elements chemically united, for example, water (hydrogen and oxygen). They are combined in such a manner that each element loses its characteristic individual properties by which it is distinguished from other elements. A compound can be separated, if desired, into its original elements, for example, the compound water can be separated into hydrogen and oxygen.

- **MIXTURE** is a substance consisting of two or more elements. In a mixture these elements are not chemically united. For example, in air, soil, flour, and petroleum the elements have not lost their identity.

- **CHEMICAL CHANGE** is any action which alters the composition of a substance and results in the formation of one or more new substances, for example, souring of milk, rusting of iron, digesting of food, burning of coal, explosion of gunpowder.

- **DERIVATIVE** is the product of a reaction between the parent substance and some other material. For example, 2,4-D acid and lye may be treated together to form sodium salt derivative.

- **ACIDS** are hydrochloric, sulfuric, nitric. Soda water contains carbonic acid. Sour milk contains lactic acid.

  Acids are sour to taste. Litmus, an extract from the lichen plant, changes from blue to red in the presence of acid. Methyl orange changes from yellow to orange in the presence of an acid.

- **BASE** is the opposite of an acid. Sodium chloride is a base, also ammonium hydroxide. Calcium hydroxide when mixed with water is the well known suspension milk of magnesia. Bases turn red litmus

† FIG. 1. Courtesy Bell Aircraft Corporation.

Here a bell Aircraft helicopter distributes a DDT-laden aerosol fog over a section of woodland near Old Forge, N. Y., in an attack aimed at ridding the popular vacationland of blackfly, an annual pest. The helicopter-borne fog registered a nearly 100 per cent kill.
blue—just the opposite from an acid. Bases usually have a bitter taste and their solutions have a soapy, slippery feel. Bases neutralize acids, forming salts and water.

- SALT is a compound consisting of a metal or metallic radical combined with a non-metal or an acid radical. Salts are usually white, crystalline solids with a salty taste. They are usually soluble in water and neutral to litmus — (some exceptions).

Most of the inorganic compounds are salts—sodium chloride, and calcium carbonate are examples. Luestone is mostly sodium carbonate—clay is impure aluminate.

- ESTER is an organic salt formed when alcohol reacts with an acid. Just as the reaction between a base and an acid, called neutralization, produces water and a salt, so in like manner, the reaction between an alcohol and an acid, called esterification, produces water and an ester or ethereal salt.

- ALCOHOL is an organic compound containing one or more hydroxyl groups. Alcohols may be regarded as substitution products derived from hydrocarbons by replacing hydrogen atoms with hydroxyl groups.

- SOAP is a metallic salt of a fatty acid. Ordinary soap is prepared by boiling a fat with sodium hydroxide. The process is called saponification.

- FORMULATION is the process of combining for suitable use. We read and talk much about formulation. Few, if any chemicals can be used in their original state for insect or weed control. They must be compounded and mixed with suitable carriers. Many factors, such as solubility in various mediums, compatibility with hard water, type of emulsifier needed, stability in storage, temperature ranges and corrosive properties, are taken into consideration in preparing the material for the consumer’s use.

Although the primary chemical itself is the active ingredient which does the killing, the other elements have specific functions to perform and are important supplements in the total formulation. The purpose of commercial formulation is to make available to the user a material which is effective, uniform and convenient to handle and store.

It is possible for a grower or applicator to do his own formulating, however, it is seldom feasible. First, it would require a vast amount of technical knowledge in many cases and second, it can usually be done more economically by commercial formulators, as often hundreds of experiments must be conducted before finding the best formula.
CHEMICAL TERMS

ORGANIC AND INORGANIC

Chemicals are divided into two categories; organic and inorganic. Organic chemistry refers to living matter or the carbon compounds.

ORGANIC chemicals are manufactured synthetically, obtained from plant sources or obtained from petroleum oil. Some examples are: from synthetics — DDT, DDD, 666, Chlordane, Tepp, Parathion; from natural plant sources — Nicotine, pyrethrum, rotenone, sabidilla; petroleum — highly refined mineral oils.

INORGANIC chemicals are the flourine compounds, arsenicals or chemical substances other than those derived from some form of carbon.


INORGANIC CHEMICALS are: Arsenate of lead, Calcium arsenate, Aluminum arsenate, Magnesium arsenate, London purple, Arsenite of zinc, Paris Green, Arsenate of zinc, Basic copper arsenate, Sodium fluoride, Barium fluosilicate, Sodium fluosilicate, Sodium fluoalumin-ate, Nicotine bentonite, Boron compounds, Mercury compounds, Sel- enium compounds, Thallium compounds, and Cuprous cyanide.

CHEMICAL CONTROL

Years ago, before nature's relationships had been disturbed to any great degree, there were comparatively few insects whose damage seriously affected man from an economic standpoint. However, as the balance of nature gradually was upset in many ways, normal insect control factors also were changed so that today one of the most serious problems facing us is the control of countless varieties of insects.

The problem has been accelerated by the introduction into this country of many plants which carry insects and diseases of minor importance in the country of origin but which under our conditions often become serious if not fatal enemies to our vegetation. In order to combat the attacks of insects several new methods of control including chemical treating have been developed.

The oldest use of an insecticide on record is by Homer, about 1000 B. C., of "pest-averting sulfur". In 200 B. C., Cato recommended boiling sulfur and bitumen (asphalt) where the fumes would drift
into trees to kill the vine fritter. As early as the first century of the Christian era the skin healing value of sulfur ointments was known.

The toxic properties of arsenic were known as early as A. D. 40; later, about A. D. 900, the Chinese set apart a day in June to kill garden pests with a mixture of arsenic sulfides and wine. In the United States, one of the first records of the use of arsenic was in 1848, when a teaspoonful of powdered arsenic was mixed with a tablespoonful of mashed potatoes as a bait for cockroaches.

The discovery, about 85 years ago, that Paris Green would kill the Colorado potato beetle marks the beginning of insect control by the use of chemicals as insecticides. Lead arsenate was discovered and found to be an effective insecticide in 1893. Its development may be considered a distinct achievement. It still is the most effective material known for certain pests. Later, such arsenicals as calcium arsenate, and basic copper arsenate were developed and used. Cryolite and other fluorine compounds as field insecticides were introduced and investigated by the Tennessee Agricultural Experiment Station in the 1920's and reached their zenith during the Second World War.

The severity of the codling moth infestation, and the beginning of the British blockade on American apples because of the arsenical-residue fallacy, stimulated research for a more suitable insecticide. Many manufacturers of chemicals realized the importance of finding new insecticides, and thousands of compounds were tested (screened).

In 1942, DDT was reported as being toxic to insects, and its development and use during the war was tremendously important. This discovery showed that "chlorinated" compounds are of insecticidal value, and as a consequence benzene hexachloride, chlordane, toxaphene, and many other compounds have been found toxic to insects. After the war, German research workers revealed the fact that certain phosphate compounds, such as TEPP, and parathion also were toxic to insects.

The term control is always used by entomologists rather than eradication. This is because few methods of treatment are efficient enough to give a 100% kill. 90% or better, however, is often possible and therefore insects and weeds can be kept in control and economic loss is at a minimum.

**Control vs. Eradication**

The term control is always used by entomologists rather than eradication. This is because few methods of treatment are efficient enough to give a 100% kill. 90% or better, however, is often possible and therefore insects and weeds can be kept in control and economic loss is at a minimum.

**HOW CHEMICALS KILL**

Insecticides in general are divided into two classes because of the manner in which they kill.
CHEMICAL TERMS

Stomach Poisons

STOMACH POISONS are those that kill by their action in the intestines after being eaten by the insect with its food. These insecticides, such as lead arsenate and rotenone, cryolite, sodium fluosilicate, and paris green are effective on such chewing insects as beetles, fruit-tree leafrollers, cut worms, grasshoppers, caterpillars, katydids, orange tortrix, holcocera, and other insects that chew foliage.

Contact Poisons

CONTACT POISONS are those that kill by touching the feet, legs or body of the insect. The poison enters the nervous system or vital organs of the insect through the breathing or sensory pores or directly through the body walls. Contact insecticides are of most value in combating insects that do not chew foliage but rather pierce the leaves or stems and suck the juices from the plant, such as aphids (plant lice), mites, scale, thrips, potato leaf hopper, false chinch bug. (Parathion, TEPP, DDT, BHC, lindane, chlordane and toxaphene are some of the contact insecticides.)

CONTACT poisons are sometimes effective as stomach poisons too. Stomach poisons, however are limited to insects which chew. Pyrethrum and rotenone are effective as either stomach or contact insecticides.

FUMIGANTS kill insects through gas vapor breathed by the insect and are used in air tight enclosures, such as graneries, greenhouses and barns. Hydrocyanic acid (HCN), carbon bisulfide, methyl bromide and napthalene are examples of fumigants.

In the case of chewing insects that actually bite out portions of the plant, it is possible to apply control measures before the insects actually appear. In the case of sucking insects (such as plant lice, aphids) the insect must be hit directly by the insecticide. In other words, the insecticide must contact the insect itself. The questions of whether the insect gets his food through chewing and swallowing, by sucking juices and whether the insect is ambulatory show the need for a careful selection of insecticides.
PART TWO

INSECTICIDES FOR CROP USE

Insect control is profitable in the production of most crops and essential in many. Research workers, both federal and state, are directing their efforts toward the development of new or better means of insect control. New insecticides, and equipment to apply them, are continually being developed and appearing on the market. There is no question that these new developments are of value, but to avoid injury, serious illness, or even fatal results, users must be fully informed as to the proper use and limitations of these new pesticides.

A federal act, administered by the U.S. Department of Agriculture, requires the registration of all pesticides offered for sale in commerce. Before a product can be offered for sale certain requirements concerning label information must be met, including, instructions on use, hazards, antidote. Laws such as these are for the protection of the public in the use of pesticides. Labels on packages should be read and instructions followed with regard to the proper use of insecticides.

Entomology is a broad and complicated study. It has been estimated there are some two million species of insects. At any rate, approximately 850,000 named species are known.

FUNDAMENTAL PRINCIPLES OF INSECT CONTROL

It should be kept in mind that effective insect control by means of chemical demands adherence to certain fundamental principles:

1. Knowledge of the insect to be controlled, its life history, identification, and recognition of its injury.

2. Proper timing for control, or when to apply the insecticide. Often this is a local consideration. Certain varieties of fruits and vegetables are frequently susceptible to injury. Experience is the teacher; it is unwise to apply insecticides unless their effect on the plant in that locality is known.
3. **Insecticides must be applied properly and thoroughly.**

It is not our purpose here to discuss these principles other than to briefly mention them. Anyone engaged in commercial insect control should have access to entomology textbooks and college bulletins. County extension agents send out spray notices with regard to the control of some of our more important insect pests.

**Classification of Insecticides**

Dr. Donald E. H. Frear, in his 1961 *Pesticide Handbook*, gives the following classification of insecticides:

"Stomach Poisons or Protective Insecticides - Insects which eat plants and some other types of edible material can usually be controlled by covering the surfaces on which they feed or travel with a poisonous substance. These poisons are absorbed through the alimentary tract, and hence are called stomach poisons. Since they are usually applied before the insect feeds on a plant surface, they are also sometimes called protective insecticides.

Most of the stomach poisons are inorganic chemicals and some familiar examples of this type are lead arsenate, Paris green, cryolite, sodium fluoride and sodium fluorosilicate. Less commonly, poisons such as arsenic trioxide, sodium arsenite and other compounds are used in poisoned baits to control ants, grasshoppers and others.

Contact Poisons or Eradicant Insecticides - Insects which cannot be controlled by poisoning their food supply often may be killed by direct application of suitable toxic sprays or dusts. In order to kill insects in this manner the toxic material must actually come in contact with some part of the insect's body. This may be accomplished in three ways: (1) applying the materials directly to the body of the insect; (2) applying the materials to a surface on which the insect may walk or crawl (residual treatment) or (3) introducing the toxic material into the air which the insect breathes (fumigation).

"(1) Direct application of contact insecticides is usually accomplished by sprays, dusts, or aerosol treatments. A wide variety of compounds is available for this purpose."
Examples of these are nicotine, petroleum oils, pyrethrum and parathion. These may be applied as sprays, dusts, or, in some cases, as self-propelled aerosols.

"(2) Surface or residual applications of certain toxicants are effective in killing insects which come in contact with them for considerable periods of time. DDT, chlordane, methoxychlor and aldrin are examples of insecticides used for this purpose.

"(3) Fumigants are used in closed spaces, such as warehouses, mills, ships, etc., in which a toxic gas can be released in sufficient concentration to kill the insects present. Hydrocyanic acid gas, methyl bromide, paradichlorobenzene and carbon disulfide are common fumigants."

Systemic Insecticides — A more recent development in insecticides is the systemic insecticides. Under this classification are those insecticides that are absorbed by the plant and translocated in the sap stream in amounts sufficient to be toxic to insects which feed on the plant. The advantage of this type of insecticide is that only the insects which feed on the plant are affected. Also, it cannot be washed off by rain once the plant has absorbed the chemical. The hazards are that in general the systemic compounds are quite toxic and should be handled with care. Materials such as Phosphamidon, Demeton and OMPA are some of the systemics presently on the market. Label instructions should be followed to insure that residual tolerance will be met and that proper waiting time has lapsed prior to harvest in case of food crops.

Problems associated with use of insecticides

The increased use of insecticides has created many new problems, not only for the entomologist but also for the plant physiologist, the insecticide chemist, the soil biologist, the food technologist and the toxicologist. Some of the problems which must be considered are as follows:

1. Determination of the effectiveness of the chemical in combating injurious crop insects. Does the chemical also kill the natural enemies of the injurious insect, i.e., its parasites and predators?
2. Determination of the phytotoxicity of the chemical. It should not injure or cause blemishes on the crop.

3. Residues remaining on the harvested product should not be injurious to the health of man or animal when the food is consumed.

4. Determination of the effect of the chemical on the spray operator.

5. Determination of what becomes of the chemical in the soil. It must break down rapidly enough so that no residue injurious to crops builds up in the soil.

6. The use of the chemical should not result in undesirable flavor change.

7. To what extent are the materials compatible with other insecticides or fungicides which might be used in combinations?

**GENERAL PROPERTIES OF INSECTICIDES**

1. **The Chlorinated Hydrocarbons.** This group of insecticides includes some of the materials which have been useful to the commercial applicator. The characteristic which these compounds have in common is that they are the products obtained by treating hydrocarbons with chlorine. Since the various members of the group contain the same elements, carbon, hydrogen, chlorine, and occasionally oxygen and nitrogen in similar structural arrangements, their chemical properties are similar. Commercially available members include the following:

<table>
<thead>
<tr>
<th>DDT</th>
<th>Lindane</th>
<th>Aldrin</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDE (DDD)</td>
<td>Heptachlor</td>
<td>Dieldrin</td>
</tr>
<tr>
<td>Methoxychlor</td>
<td>Chlordane</td>
<td>Toxaphene</td>
</tr>
</tbody>
</table>

The chlorinated hydrocarbons are characterized by their low vapor pressures and water solubility. They are relatively inert to such physical and chemical agents as heat, air, moisture and sunlight. These properties contribute to their stability in the soil and on the plant and explain their longer residual lives.
THESE MATERIALS ARE SOLUBLE IN COMMON ORGANIC SOLVENTS SUCH AS CHLOROFORM, BENZENE, ACETONE AND ETHER. THEY ARE ONLY PARTIALLY SOLUBLE IN PETROLEUM SOLVENTS SUCH AS KEROSENE AND ARE ALSO OF LIMITED SOLUBILITY IN ALCOHOLS. THEY ARE FAT SOLUBLE WHICH ENABLES THEM TO PENETRATE THE INSECT CUTICLE BUT SOMETIMES GIVES THEM THE DISADVANTAGE OF BEING ACCUMULATIVE IN ANIMAL BODY FAT. RESIDUE PROBLEMS ASSOCIATED WITH THIS CLASS OF INSECTICIDES LIMIT THEIR USEFULNESS IN MANY AREAS OF PEST CONTROL.

2. THE ORGANIC PHOSPHATES. THIS IS ANOTHER VERY IMPORTANT GROUP OF INSECTICIDES WITH MANY PROPERTIES IN COMMON. COMMERCIALY AVAILABLE MEMBERS OF THIS GROUP ARE:

<table>
<thead>
<tr>
<th>Parathion</th>
<th>Malathion</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPN</td>
<td>Systox</td>
</tr>
<tr>
<td>TEPP</td>
<td>Diazinon</td>
</tr>
</tbody>
</table>

THESE COMPOUNDS ARE CHARACTERIZED BY HIGHER VAPOR PRESSURES THAN THE CHLORINATED HYDROCARBONS AND THE INORGANIC COMPOUNDS. THEY ARE ALSO MORE SOLUBLE IN WATER AND LESS STABLE TO MOISTURE, HEAT AND OXYGEN. THESE CHARACTERISTICS EXPLAIN THEIR SHORTER RESIDUAL LIVES AND THEIR MORE RAPID DEGRADATION IN PLANTS AND SOIL.

THE ORGANIC PHOSPHATES ARE UNSTABLE IN THE PRESENCE OF ALKALINE MATERIALS - A FEW EVEN IN WATER OF SLIGHTLY ALKALINE pH. THIS MAKES THEM INCOMPATIBLE WITH ALKALINE PESTICIDES SUCH AS LIME, BORDEAUX MISTURE, OR LIME-SULFER.

THESE MATERIALS ARE SOLUBLE IN THE COMMON ORGANIC SOLVENTS AND A FEW, TEPP, OMPA, AND DYLON, ARE EASILY SOLUBLE IN WATER. THE OTHER MEMBERS OF THE GROUP ARE CONSIDERABLY MORE WATER SOLUBLE THAN THE CHLORINATED HYDROCARBONS. THIS HELPS EXPLAIN THEIR GREATER TENDENCY TO TRANSLOCATE IN THE PLANT. INDEED, SOME SUCH AS OMPA, DIMETHOATE (CYGON) AND DEMETON (SYSTOX), ARE HIGHLY SYSTEMIC.

ALL OF THE ORGANIC PHOSPHATES ARE POTENTIAL CHOLINESTERASE INHIBITORS. THEIR TOXICITY TO HUMANS VARIES CONSIDERABLY AND MANY OF THEM ARE CONSIDERED VERY DANGEROUS.

3. BOTANICALS. INSECTICIDES WHICH ARE DERIVED FROM PLANTS ARE CALLED BOTANICALS. THE LIST INCLUDES NICOTINE,
rottenone, pyrethrum and ryania. The use of these materials is probably on the decline although they are still useful in certain cases. One member of this group, allethrin, is actually a synthetic compound but since the chemist used pyrethrin as his model, allethrin is included in this group. Thus allethrin is the first botanical to be synthesized by man.

Aside from their origin, the main characteristic of this group is their short residual life. This plus their relatively low acute toxicity enables them to be used in situations where spray residues are undesirable.

4. MISCELLANEOUS INSECTICIDES. Several valuable insecticides which cannot be organized according to origin or similarity of properties are the following:

ARAMITE – an organic compound containing chlorine and sulfur. It is a liquid at ordinary temperatures and is hydrolyzed by alkalies.

LEAD ARSENATE – an inorganic, long residual life.

LIME-SULFUR – an inorganic, incompatible with most other pesticides because it is highly alkaline.

SEVIN – a carbamate insecticide derived from the salt or ester of carbamic acid.
Insect Killers

New chemicals are coming on the market every day. The formulations are different. Chemicals are being mixed. Some chemicals are very dangerous to man. Others are very dangerous to plants. Again, there is no substitute for knowledge. Consult someone who knows before handling a new product. Be sure that the material is right for the particular crop situation and that you have the local recommendations of your state and county agricultural authorities.

In the following paragraphs are described most of both the common and the newer type insecticides, herbicides and fungicides. The descriptions of these insecticidal chemicals have been grouped in alphabetical order according to common names.

Insecticides

ARSENIC TRIOXIDE (Arsenious Oxide) is a by-product of the roasting of mineral ores. The chemical element known as arsenic is of use in insect control only in certain of its compounds. One of these is arsenic trioxide, it is a grayish white to white crystalline powder. This

![Image of Dr. S. W. Frost conducting an insect survey](http://example.com/image3.png)

FIG. 3. Courtesy Pennsylvania State College, School of Agriculture. Dr. S. W. Frost of the Pennsylvania Station is conducting an insect survey of the State. In conjunction with his work he has been able to advise in the control of insects not usually given consideration by economic entomologists. He is seen here examining the roots of a cattail plant pulled from a waterhole for mosquito larvae.
form of arsenic may exist in three crystalline forms, the cubic or fibrus form, monoclinic and the amorphous form. It has a relatively low solubility in water, but is soluble in alkalies and acid.

Since arsenic has two different combining powers, its compounds fall into two classes which have decidedly different properties. The starting point for the manufacture of the first class, called “trivalent” or “arsenite” compounds, is arsenic trioxide, which is the white arsenic of commerce. (The second class, lead arsenate is described later.) The poisonous properties of arsenic oxide were well known to the ancients who fed white arsenic as a favorite method of murder.

As early as 1861 it was used as an ant poison. This substance is only sparingly soluble in water, though sufficiently so to prevent its use on plants. Its uses as an insecticide are therefore limited to poison baits for control of such insects as grasshoppers, armyworms, also sow-bugs, and to certain other cases where the insecticide is not to be applied to growing plants. 60 (See elsewhere calcium magnesium, lead arsenates and Paris Green.)

ALDRIN is the official name given compound 118 by the U. S. Department of Agriculture. It was developed by and is manufactured exclusively by Julius Hyman and Company. Compound 118 is the laboratory name under which this product is sold to insecticide formulators. It is used to control bollweevil, alfalfa weevil, olive fly, thrips, tarnished plant bug, cotton flea hopper, cutworms and grasshoppers. As a larvicide it can be used against flies and mosquitoes. As of March 1950, Aldrin was approved only for the control of cotton insects. During the summer of 1950 it was used very effectively against grasshoppers in the Montana area. Two to four ounces per acre is sufficient for locusts, grasshoppers and crickets. It is said to offer a faster and surer kill with extremely low dosages than has heretofore been possible. 190

Aldrin is a white crystalline solid highly soluble in most organic solvents but insoluble in water. It is readily formulated as a wettable powder, an emulsifiable concentrate, an oil solution or as a low percentage dust. 191

ALLETHRIN (Compound 264) is a synthetic pyrethrum and is said to be almost identical with the natural pyrethrum. Its manufacturing process is extremely complicated. A large amount of raw material is required to produce a relatively small amount of finished pesticide. As much as a million pounds of raw materials, including water must be handled in order to produce 5000 pounds of finished chemical.

This material eventually will compete with the natural pyrethrums which now must be imported. It remains to be seen whether its synthetic source will bring down the cost. At present, allethrin is thought to
be no more toxic than the natural pyrethrum. Its effectiveness as a pesticide gives promise of being satisfactory, however, it will require more time to prove its real value. In extensive tests with fleas and roaches its knock down and kill appear to equal that of the natural pyrethrum.

Allethrin is manufactured exclusively by the Union Carbide and Carbon Corporation of New York. Sales are made through S. B. Penick and Company and John Powell and Company of New York and McLaughlin Gormley Kink Company of Minneapolis.

AMMONIUM POLYSULFIDE: Instead of reacting with lime, sulfur may be reacted with ammonia to form a yellow solution of ammonium polysulfide. The commercial preparations contain about 41 per cent ammonium polysulfide and are offered for use instead of lime-sulfur solution. Ammonia readily escapes with simultaneous deposit of sulfur, and hence solutions must be kept in tightly closed containers. Ammonium polysulfide is reported to be useful as a greenhouse spray against red spider and as a spray against gooseberry mildew.

ARAMITE (15-W) is a product of Naugatuck Chemicals Division of the U. S. Rubber Company. This material was tested extensively in 1949. The manufacturer recommends one pound of the 15% wettable powder to 100 gallons of water. The manufacturer claims that aramite is effective against the active stages of mites and that the following mites have been controlled: brown, clover, citrus bug, Pacific Spruce, European, poultry, 2 spotted, red and red spider. Aromite is said to be compatible with the organic chlorinated hydrocarbons, oils and many of the dithiocarbamate fungicides.

BARIUM FLUOSILICATE: The fluosilicates were developed in an effort to get away from the residue problem of the arsenicals. Barium fluosilicate is said to be more toxic to insects than the natural cryolite, however, its cost is also greater. It was first used in 1926 against the Japanese beetle. Barium fluosilicate is not compatible with lime sulfur, soap solutions, calcium arsenate, Bordeaux mixture, or nicotine. (See Cryolite)

BASIC-COPPER ARSENATE is a light grey green crystalline compound. This material is useful in the control of the cotton boll worm, cotton leaf worm and the flea hopper, horn worms, flea beetles, and the Colorado potato beetle. It is the only copper fungicide that is compatible with calcium caseinate, blood albumin, wettable sulfur and dusting sulfur.

BHC (666) (Benzene Hexachloride) is of English origin and is well known abroad under the name "666". It is available in the form of a dust or diluted wettable powder, the insecticidal strength of
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which is dependent upon the percentage of the gamma isomer present. A striking feature of this insecticide is its objectionable, penetrating, persistent, disagreeable odor which has been described as resembling the odor of a musty mattress. Lately, a refined form called lindane which is virtually odorless has become commercially available. It consists primarily of the gamma isomer portion but is more expensive than the crude form. It is likely to give an off flavor to vegetables. Some commercial names for BHC formulations are gamtox, gamex, gammexane, and lexone.

BHC is compatible with most insecticides and fungicides but its effectiveness is greatly reduced when used in Bordeaux mixture, calcium arsenate or lime diluents. BHC acts as a stomach poison, contact poison, and slow acting fumigant. The crude BHC is a pale brown to white powder. The odorless form of BHC, which is the pure gamma isomer, is a white, practically odorless, crystalline material. Because of its objectionable odor BHC is of limited usefulness on food crops; however, it has received wide acceptance for use on crops such as cotton.

BHC is somewhat more toxic to man and domestic animals than DDT. 182 (See Lindane for further discussion.) Any time that high gamma benzene hexachloride in oil is sprayed on orange trees after the fruit is set an off-flavor will result, according to the experiments done at the Citrus Experiment Station, Lake Alfred, Florida. There is no off flavor, however, when used as a wettable powder. 250

CALCIUM CYANAMIDE is white in color and freely soluble in water. This material, in the form of granules or dust, is an increasingly important insecticide and herbicide. It differs from other cyanide compounds in that an acid does not need to be added in order to liberate hydrogen cyanide. Moisture from the air is sufficient unless the humidity is low. The dust may be used straight or diluted with 50 to 75 per cent of hydrated lime, sulfur, or other carrier. Calcium cyanamide is used chiefly to control aphids, leafhoppers, and similar insects. Its use must be avoided with plants when they are moist because of danger of burning. 60

When used alone or in combination with sodium fluosilicate, calcium cyanamide is used as a defoliant spray to remove the leaves from

FIG. 4. Courtesy Pennsylvania State College, School of Agriculture.

Field experiments conducted by the Pennsylvania Station indicate that sprays of BHC are effective against plum curculio for six or seven days. Egg is deposited under the skin — larva feed on the plum.
cotton. (See defoliants elsewhere in this volume.) Calcium cyanamide contains both nitrogen and calcium and therefore has double value as a fertilizer when used as a defoliant or herbicide. 226

● CALCIUM ARSENATE is a stomach poison. It should be used similar to lead arsenate, but is not interchangeable when the recommendations call for one or the other. It is a little safer to use on some plants than lead arsenate in that both the lead and arsenic are poisons. Calcium arsenate is also colored pink as a safety measure.

Calcium arsenate is used extensively against insect pests of cotton and of many truck crops, especially potatoes and tomatoes. On many other plants it is not so safe as lead arsenate. The pure material gives rise to far too much soluble arsenic, and possible damage to foliage. Accordingly all commercial products contain varying amounts of hydrated lime, usually from 20 to 30 per cent. 60

● CHLORDANE (CHLORDAN) is the official name of a chlorinated hydrocarbon which in concentrated form is a viscous, nearly odorless, amber colored liquid. The manufacturing process produces a mixture containing sixty to seventy-five per cent of the pure compound, and the remainder consists of related active compounds. Chlordane is completely soluble in common organic solvents, including deodorized kerosene. It is not soluble in water. Chlordane reacts with many alkaline reagents and therefore should not be mixed with chemicals having an alkaline reaction.

Because it exhibits a multiple effect in killing insects, chlordane is capable of acting as a stomach poison when eaten, as a contact insecticide when touched or walked upon, and as a fumigant when insects are exposed to its vapors. As a stomach poison, it is effective by application to foliage against many leaf-eating insects such as grasshoppers. As a contact insecticide, it will control such pests as roaches, flies, animal lice, plant (lygus) bugs and carpet beetles. There is evidence that chlordane residues usually disappear in fourteen to twenty-one days. 182

Chlordane is reportedly effective against many garden pests, particularly promising against root maggots. 167 It is used extensively on curculio and is recommended for spittle bug control on strawberries. 179 It is also useful against ants and is becoming popular in grasshopper control where it is desirable to spray entire young crop fields being attacked by grasshoppers. Chlordane may be used in preparing either wet or dry grasshopper baits.

● CRYOLITE (Sodium Fluosilicate): Fluorine is a constituent of hydrofluoric acid, which is used to etch glass. Several derivatives of this compound have been advocated as insecticides. The simplest,
sodium fluoride, is too soluble for use on plants but may be used in poison baits. Another material which is a complex fluoride containing both sodium and aluminum, called cryolite is sodium fluoaluminate. This compound is but slightly soluble and can be used against many chewing insects. In damp climates it is apt to cause burning. Both the naturally occurring mineral and a synthetic preparation are on the market.

The fluosilicates all lack adhesiveness, therefore, require a sticker-spreader. (See elsewhere in this series for discussion of spreaders and stickers.) The cryolites when used in place of the arsenicals are said to be effective against chewing types of insects such as the: apple maggot, horn worm, bean leaf beetle, leaf roller, blister beetle, melon worm, tobacco budworm, Mexican bean beetle, cabbage worms, pea weevil, corn earworm, pickle worm, codling moth, potato beetles, berry fruit worm, rose chafer, cranberry weevil, sod webworm, cucumber beetles, soybean caterpillar, squash vine borer, curculio, tomato fruit worm, flea weevil, flea beetle, tobacco flea beetle, and tobacco worms.

Barium fluosilicate, sodium fluosilicate, and sodium fluoaluminate make up the cryolite family. These materials have been advocated as horticultural dusts and sprays to replace the arsenicals. Cryolite is relatively non-injurious to plant foliage, and in some sections of the country has been used satisfactorily for codling moth control. The tolerance for fluorine residue on apples and pears is 7 parts per million or approximately 0.05 grains per pound. This limits the use of cryolite on edible fruits in late application.

Cryolite is also effective against certain species of beetles. Certain fluosilicates are used extensively in powdered form as cockroach and ant poisons. Soluble fluosilicates are used in moth proofing woolen goods to protect them against feeding of clothes moth larvae. Cryolite is compatible with more material than are most other fluorine containing insecticides. It may be used successfully with mineral or fish oils, soaps and flotation sulfur.

DDD, TDE — (Rothane D-3): DDD is similar to DDT but lacks one fluorine atom and resembles it in most respects. It is manufactured by Rohn and Haas under the trade name Rothane. DDD is only 1/10 as toxic as DDT to warm blooded animals. It is also somewhat less toxic to insects, however, it is useful particularly for late applications to small fruits. DDD takes the place of cryolite which cannot be used on late applications because of residue.

According to Lloyd Stitt, Western Washington Experiment Station, DDD was just as effective as DDT used on potatoes against the flea beetle. Seven applications of DDD were made with 5% concentra-
tion. A fixed copper was used for disease control, and 1% petroleum oil was added to hold down drift. DDD cannot be used with oil as a sticker on raspberries as they will develop chlorosis.

DDD is being used in the northwest against the orange tortrix and in California for tomato insects. It is recommended particularly for the control of the red banded leaf roller. 169 The proposed tolerance for DDD is 5 ppm. A spray applied to red raspberries one month before harvest is said to have had a residue of only 2 ppm upon harvest.

**DINITROS**: The original German name for the dinitros was antinonnin. During recent years a number of commercial products containing nitro derivatives of phenol or cresol have come on the market. These are soluble to only a very slight extent in water and to the extent of several per cent in spray oils. The pure compound of 4,6-dinitro-o-cresol is a yellow solid. If it is treated with alkali to form the sodium or ammonium derivatives, the solubility ratio in water and oil is reversed, for these derivatives are freely soluble in water and only slightly soluble in oil. By keeping the spray water acidic, it is possible to keep the dinitro compounds in the oil, and they are of value as oil-soluble toxicants for red spider and similar pests.

The ordinary dinitrophenol and dinitrocresol are highly injurious to foliage and hence are chiefly of value in plant protection during the dormant season or as weed killers. For such use the water-soluble sodium derivatives, such as sodium dinitro-o-cresolate, are prepared either as dry powders or as solutions of fixed concentration in water. In the latter case a special wetting agent usually is included in the solution.

A compound somewhat similar, which is much safer on foliage, is dintro-o-cyclohexylphenol, sometimes called "DNOCHP" for short. This substance is slightly soluble in water, but dissolves to several per cent in spray oils. It may be made water soluble by addition of alkali, such as sodium hydroxide, but at the same time the solubility in oil is greatly decreased. Solutions in oil are also used, for example, a 4 per cent solution of DNOCHP in winter oil. In the presence of lime, the calcium salt is formed and the effectiveness is greatly decreased. Similarly, lime-sulfur is not compatible.

Dust containing dinitro-o-cyclohexylphenol or derivatives formed from it are often called "DN dusts" or "dinitro dusts". A derivative of particular value for use on citrus is dicyclohexylamine dinitro-o-cyclohexylphenate. The best diluents are acidic, principally walnut-shell flour or redwood-bark flour. 60 "Dinitro compounds, derivatives of cresol and phenol, have found a place in dormant apple sprays, chiefly to kill aphid eggs.

**DILAN** is a combination of the two experimental nitroparaffin materials CS 645A and CS 647A manufactured by Commercial Solvents
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Company. These materials were given wide experimentation during the summer of 1949 and give promising results on the peach and other fruit and bean insects. It has been especially successful against the Mexican bean beetle, the southern army worm, range grasshopper, leaf hopper, and cabbage worm. Dilan is said to be about half as toxic as DDT to warm blooded animals. 251

DIELDRIN (Compound 497) is one of the newer materials giving considerable promise of usefulness as a control for grasshoppers. As yet no recommendations are available. Dieldrin differs from aldrin in that it possesses a higher vapor pressure with a much longer residual action. The manufacturer, Julius Hyman Company, does not recommend its use in situations where its residue might be hazardous to edible or forage crops. It is said to be useful against all of the pests affected by aldrin. Dieldrin is of particular interest in the control of insects attacking forest trees and wood products. Its toxicity has not as yet been determined. 251

DDT became available for commercial agricultural use in 1947. It was first produced by a German scientist about 75 years ago, but not until 1939 was it patented as an insecticide by Geigy Incorporated, a Swiss company. The economic importance of DDT is indicated by the fact that over 50 million pounds of it were manufactured in 1950. There are three main reasons for the rapid acceptance of DDT. First, DDT possesses a high toxicity toward many insects. Second, it is harmless to man and animals, and third, its discovery came at a time when our national supplies of rotenone and pyrethrum were low. DDT is one of the most effective insecticides ever discovered for the control of some insects, but it is not effective against a number of others.

As an acute poison to higher animals, DDT is not considered dangerous, but it accumulates in the body and may constitute a health hazard through its chronic toxicity. The use of DDT may cause an increase of certain pests, for example, DDT may kill the natural enemies of the black bean aphid and red spider-mites, thus allowing these pests to increase to damaging numbers. 167

Between 4 and 5 million pounds of DDT were used in the potato, pea, apple and pear crops of the State of Washington in 1947. DDT has largely replaced cryolite and rotenone for combating many crop pests.

A report of the U. S. Department of Agriculture in March 1945 lists 30 insects as those against which DDT is especially toxic (definitely more effective than the insecticides previously used). It listed 19 other insects in which DDT was only equal in effectiveness as currently used chemicals and 14 in which DDT had little or no effect such as mites and ticks.
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DDT poses a very impressive list of crops and pests on which it is effective. It can be used against the codling moth in orchards, pea aphids in peas, fireworm and fruitworm in cranberries, lygus bugs in alfalfa, tussock moth in fir trees, the cornborer, the cucumber beetle, the flea beetle, the leaf hopper, the oriental fruit moth, cutworms, and tarnish bug.

DDT is tasteless and resembles flour in its dust formulations. Generally speaking warm blooded animals can survive 100 times the dose that cold blooded animals can take. For insects, DDT is both a contact and stomach poison. An insect walking across a DDT impregnated surface may appear at first not to be affected but soon it begins to tremble, has convulsions and dies.

Investigations have shown that DDT, while it may be injected in small amounts daily by animals with no immediate effects, does accumulate in the fatty tissue and cause later harm. For this reason, care must be taken not to use DDT on any forage crop to be fed to dairy or livestock. It must not be used on cattle or in dairy barns. Methoxychlor is recommended to take the place of DDT in controlling flies in dairy barns.

DDT is soluble in oil and does not deteriorate to any appreciable extent when exposed to the sun and weather. It is insoluble in water and its use is therefore limited to a suspension when used in spray form. The addition of a small amount of wetting agent facilitates the suspension of the wettable powders.

Bees light and take off from the white blossom petals. The DDT program requires no calyx spray for codling moth control. Therefore, poisoning of bees which have been brought into the orchard for pollinating should no longer occur. If you should apply insecticides for aphids or climbing cutworms, during the blossoming period, however, be sure to notify bee keepers to remove the bees from such orchards. 58

Investigations were made during 1947 of the effect of insecticides on wildlife, these included field and laboratory tests, and evaluations of actual operations. In one area consisting of more than 400,000 acres of forest land in northern Idaho, DDT in oil was applied by airplane at the rate of one pound to an acre for control of the Douglas fir tussock moth. Studies near the center of a large, continuously treated block indicated about the same wildlife effects as had previously been found in smaller units. Birds and mammals were unaffected. Fish were affected but slightly in the area as a whole, however, rather heavy losses of some species were noted in limited regions. Uneven spray distribution or unintentional retreatment may have been the cause for the heavy fish kill in some parts of the area. A complete
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authentic summary on this subject may be found in Circular 15 "Effects of DDT and Other Insecticides on Fish and Wildlife Service".

DDT is insoluble in water. Washing by the ordinary methods is therefore difficult and unsatisfactory. Exact extent to which residues are present in harmful quantities on unpeeled fruits and vegetables has not yet been determined. Until this information is available the best advice is to not use DDT at those stages where it can accumulate on the actual fruit but rather to use other insecticides in the post-blossom stage.

Warning... DDT MUST NOT BE USED ON CATTLE, AROUND BARNs or on any FORAGE CROPS.

The Food and Drug Administration in 1945 established a tolerance on DDT of .05 grain per pound. This is the equivalent of 7 parts per million. Where DDT is used against the codling moth first brood the residue at harvest is so low that washing of the fruit is unnecessary. However, late applications of DDT applied only a week or so before harvest results in fruit residue accumulations which are impossible to clean within the tolerance, according to Kenneth C. Walker of the Tree Fruit Experiment Station at Wenatchee, Washington. 1 If the residue at harvest exceeds ten parts per million, it is usually impossible to remove DDT to a point below federal tolerance.

○ DMC (DIMITE) is a trade name for one of the chlorinated hydrocarbons. This material is formulated by the Sherwin-Williams Company. It has shown considerable promise for control of orchard mites on the West Coast. Dimite is a close relative of DDT.

According to the manufacturer, "Data concerning toxicity to human beings indicate that DMC is less toxic to humans than DDT". 105 Dimite is said to be very effective against the Willamette mite, the European red mite and the two spotted mite.

○ DORMANT SPRAYS for apples and pears (northwest) are of two types: one is an oil emulsion consisting of 3.2 actual oil (usually 4 gallons of oil in 100 gallons of spray). Oils should be of 100 to 120 viscosity and a sulfonation test of 50 to 70. This spray is effective in controlling scale, pear psylla, European red mite, and clover mite. The second type of dormant spray consists of liquid lime sulfur (32° Baumé) 11 gallons to 100. Four pounds of dry lime sulfur is equivalent to 1 gallon of liquid lime sulfur. When using 3 gallons liquid lime sulfur to 100, use 1% actual oil. This spray is effective against scale, rust mite, and blister mite. 58 (See Petroleums for further discussion.)
ELGETOL is marketed under many brands as wettable powders and solutions. It is a 23 per cent solution of sodium dinitro-o-cresylate. The same chemical is also sold as krenite.

Wettable powders are used mostly with dormant oil sprays. They are very effective against oystershell and scurvy scale and aphids. Do not use dinitro-o-cresol compounds except in strictly dormant period. Do not use on peaches at any time.

EPN is a new organic phosphorus miticide. According to its developers, it is effective against most species of mites and protects from reinestation for several weeks.

FLOURINE COMPOUNDS (See Cryolite).

HELLEBORE, now outdated, is another natural organic material. It is obtained from a plant known as Indian poke or itch weed. This material, like rotenone and pyrethrum, is poisonous to insects but harmless to humans. Hellebore is both a stomach and contact poison.

HETP (Hexeythltetrophosphate) (See TEPP).

KRINITE (Sodium- dinitro-o-creslate) (See Elgetol).

LEAD ARSENATES (Pentavalent): The second class of arsenical compounds, is the pentavalent or arsenate type which includes some of the most important of all insecticides. Two compounds containing lead are extensively used in controlling all kinds of chewing insects. Each has been called by various names: (1) Standard lead arsenate, also called acid lead arsenate, lead hydrogen arsenate, di-lead arsenate; and (2) basic lead arsenate, also called triplobic lead arsenate, neutral lead arsenate. These two substances differ in the ratio of arsenic to lead. The standard lead arsenate averages approximately 20 per cent arsenic and 60 per cent lead by weight, whereas the basic averages approximately 14 per cent arsenic and 63 per cent lead.

The standard type of lead arsenate contains more arsenic per pound than the basic type, is a stronger poison, and acts more quickly. It is also more susceptible to the action of other chemicals, particularly those of an alkaline nature (such as soaps and lime sulphur solutions). Although safe to use on most plants, in cases where there is possibility of damage to foliage an equal quantity of hydrated lime may be added as a safener.

The disadvantage of lead arsenate is residue, which may be dangerous to food. A federal law prohibits the interstate sale of foods having more arsenate than a ratio of 1 pound to 40 tons of food. Lead arsenate is naturally white but is usually colored pink to identi-
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fy it better and avoid its being mistaken for flour or powdered sugar. Lead arsenate may be combined safely with nicotine sulfate, bordeaux mixture, or oils; but it should rarely be used with soap because of the possible burning action of the arsenic freed by this combination. (See elsewhere, arsenic trioxide, magnesium, and calcium arsenates.)

LETHANE was substituted for the shortage of rotenone during World War II. Organic thiocyanates are highly toxic as a contact insecticide to many species of insects. The one most widely used is sold under the trade name Lethane. It may be used as a toxicant in oil sprays, as in fly sprays, or absorbed upon a carrier and applied as a dust. Lethane is available in three commercial concentrates, 384, 384 Special, and 60. The latter is used largely to boost the killing power of rotenone.

LINDANE is the pure gamma isomer of benzene hexachloride. This highly refined product is recommended by the agricultural department entomologists as the preferred material for use in fly control in dairy barns. It is also potent stomach, contact and fumigant insecticide. Gives quick kill to flies immune to DDT, however, it has only \( \frac{1}{4} \) the chronic toxicity of DDT. The technical grade benzene hexachloride is being used successfully against cotton pests and other insects.

There is some reason for confusion between the terms benzene hexachloride and lindane. Benzene hexachloride is actually a mixture of five closely related materials which are called isomers. Only one of these five materials, the gamma isomer, has been found to be generally effective as an insecticide. This insecticidal effective material (gamma isomer) has been separated in a very nearly pure state from the other four materials in the mixture, and is called lindane. Lindane, like other agricultural chemicals, is not used in its pure form, but is blended or formulated into ready-to-use insecticides such as a 25% lindane wettable powder. A 25% lindane wettable powder would contain 25% of the gamma isomer of benzene hexachloride.

Keep in mind that benzene hexachloride is the mixture of all five isomers. Lindane has almost no odor as compared with the crude, or technical benzene hexachloride. According to Oregon entomologist, it too has been found to impart off flavors to certain food products when used in excessive amounts.

LIME-SULFUR: This compound is obtainable in liquid commercial concentrated form, dry powdered form, as well as by home manufacture. It is used in concentrated form usually at 2 gallons to 100 gallons of water and is useful principally in orchard spraying in place of bordeaux. Lime-sulfur is unpleasant to use since it has an offensive odor, is corrosive to the skin, and causes discoloration of painted surfaces.
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Lime-sulfur is now obtainable in dry powder form which is useful because of convenience. It is efficient as a summer spray at the rate of 6 pounds per 100 gallons. 71 (See lime-sulfur discussion under fungicides). Lime-sulfur is used as a dust insecticide carrier as well as a fungicide. Also it is very useful as an insecticide itself against red spider mites, however, it is limited in this function because of its lack of ovicidal value. 1 Lime-sulfur solution has many uses in controlling insect pests and fungus diseases in fruit trees. The strength of the concentrate varies, and should be ascertained from the manufacturer or by means of the Baumé or specific gravity scale on a lime-sulfur hydrometer.

- LONDON PURPLE: Like Paris Green this is another of the arsenical family. London purple was discovered by the Hemingway Company of London as a waste product in the manufacture of dye. London purple is not used extensively now that calcium arsenate has largely replaced it. London purple cannot be used on tender foliage or on fruit tree foliage.

- MAGNESIUM ARSENATE has several special purpose uses. Magnesium arsenate has been the principal arsenical recommended for control of the Mexican bean beetle because both calcium and lead are inadequate to control the beetle and because lead arsenate and calcium arsenate are likely to cause injury to bean foliage. Magnesium arsenate gives good control without severe plant injury. It is more expensive than lead arsenate. Magnesium arsenate has now been largely supplanted by rotenone products and cryolite. 100

- MERCURY COMPOUNDS: Metallic mercury has been found to function as a fumigant when confined to an enclosed space. All soluble compounds of mercury are extremely poisonous and are widely used as germicides. Mercuric chloride (corrosive sublimate) is used to some extent in treatment of plant diseases. Its insecticidal use is largely confined to action as a larvicide and repellent for root maggots and similar insects. One ounce of mercury chloride and 8 gals. of water gives a 1:1,000 solution. Distilled or rain water should be used, and the solution must not be kept in a metal container. Contact with any kind of organic matter or absorbent material, for example, clay, results in removal of the mercuric chloride from solution. The solution may be prepared more readily with warm water. It must be stressed that this substance is extremely poisonous even in very dilute solution.

The slightly soluble compound, mercurous chloride, called calomel, is useful against certain root-infesting insects, for example, the cabbage maggot. Mercurous chloride is used as a dilute dust, at 1 part to 25 parts of talc. 60

- METHOXYCHLOR (Methoxy DDT) is an analogue of DDT prepared by the DuPont Company and offered to the trade under the
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name "Marlate" or "Orthotox" manufactured by the California Spray Chemical Company. Its chief advantage is that it is safer to apply on vegetables and animals and is far less toxic to man than DDT. Methoxychlor is available both as a wettable powder and as a dust. It is compatible with fungicides, including a low-lime bord-eaux mixture, and is used wherever DDT presents residue or other hazards.

Methoxychlor gave results equal to DDT in horn fly control in Kansas. Because of its safety, it is a desirable substitution for DDT for fly control on livestock, especially dairy cattle. There is less danger to vegetables, especially on cucurbits and beans, than when DDT or BHC is used for control. Methoxychlor is said to be only 1/24th as toxic to warm blooded animals as DDT. For this reason it will probably be used extensively for after blossom sprays where other materials might result in excessive residues. It is unsoluble in water but soluble in many common solvents used in industry.

METACIDE is a mixture of the dimethyl analog of parathion and parathion. It was developed by Dr. Gerhard Schrader who also discovered Parathion. This product was formerly available under the name of Gearphos. It is reported to be marketed in the future by a joint company formed by Pittsburg Coke and Chemical Company and Geary Chemical Corporation.

This material is said to have been offered in Europe for the past 2 years during which time it has shown much promise as a control for aphids, mites and some promise for the larvae of the Mexican bean beetle.

NEOTRAN, a Dow Chemical Company product, formerly known under the code number K 1875, is another acaricide closely related to DDT and used to a limited extent in the Pacific Northwest. Formulated as a wettable powder, neotran contains 40 per cent of the active ingredient. It is reported to be only 1/10th as toxic to warm blooded animals as DDT, and like DDT, is not readily absorbed through the skin.

NICOTINE is a stomach poison, contact insecticide and fumigant. It is obtained from scrap tobacco and is useful in killing a wide range of both chewing and sucking insects. It is highly poisonous to both man and animal but is safe to apply to plants. It is quite expensive but can be diluted considerably.

Tobacco dusts and infusions were used many years ago both as fumigants and as contact poisons. Substantial progress, however, was not made until the toxic constituent, nicotine, was isolated in commercial quantities. Dusts are in the form of nicotine sulfate. Sprays are based on nicotine sulfate solution and soap. A pint of concentrate to 100 gallons of water along with 5 pounds of soap makes a good solu-
tion. Nicotine sulfate may be combined safely with arsenate of lead as a combination spray. The addition of soap or miscible oil as a wetting agent will increase the effectiveness of nicotine sulfate from 1½ to 2 times. Nicotine decomposes very rapidly when exposed to air and light.

Certain facts must be kept in mind in order to use nicotine preparations to the best advantage. By itself, nicotine is a fairly volatile and very toxic liquid. It reacts with a great variety of substances to form nonvolatile compounds, which are relatively nontoxic as long as they remain undecomposed. Free nicotine is liberated from any of its compounds by the addition of an alkaline substance such as lye, soap, washing soda, lime, bordeaux mixture, lime-sulfur, and to a less extent even by limestone. For insecticidal use it is marketed chiefly as a 40 per cent solution of nicotine in the form of nicotine sulfate.

NICOTINE BENTONITE: When used with bentonite nicotine is a stomach poison as well as a contact poison. It is available under the trade name Blackleaf 155. It gives excellent control of many sucking insects such as aphids and apple leaf hoppers. A disadvantage of nicotine bentonite is that it is about twice as expensive to use as lead arsenate.

PARIS GREEN: Another compound of the trivalent arsenic group is paris green which was formerly used in very large amounts in the control of many kinds of chewing insects and is still used on particularly hardy plants. The decreasing use of paris green is an example of the previously mentioned tendency to use materials of known and strictly controlled properties. When paris green is used as a spray usually a safener consisting of 2 pounds of lime to each pound of paris green is used.

Disadvantages of paris green are:

1. It is toxic to the foliage of many plants, burning most plants except potatoes and sugar beets and the most resistant ones.

2. It is toxic to man and animal and is relatively expensive.

As a dust, paris green should be diluted at the rate of one part of paris green to 6 to 9 parts of diluent. As a spray use a ratio of 1 ounce of paris green to 6 gallons of water with 2 ounces of hydrated lime added. Paris green should not be used on the foliage of fruit bearing trees.

PARATHION: Here is an insecticide being viewed with terror by some people because of its high toxicity to man. When used properly there is no more danger than there is in handling many other poisons. You must understand its characteristics, however, namely that it has
INSECT KILLERS

no odor and therefore can be breathed without detection. It can be absorbed through the skin very readily.

This material was tested in 1947 by over 150 entomologists in state and federal agricultural experiment stations. Results have shown thiophos to be an excellent insecticide for the control of a wide range of insects on a wide range of crops. One reason for parathion’s popularity is that it is effective for almost every pest in which DDT is not effective.

Parathion is the official name for one of the organic phosphate insecticides. It is of German origin and was originally distributed by the American Cyanamid Company under the name thiophos 3422. It is now offered for sale by various companies under the trade names of thiphos, P.A.R., vapophos, penphos, aphamite, paradust, phos kil, lethalaire G-54 (aerosol), parathion and perhaps others. It kills as a contact spray, stomach poison and a fumigant. Parathion is available in the dust, wettable powder and aerosol forms, the latter for use in greenhouses. The dusts contain 0.5, 1.0 and 2.0 per cent of the toxicant; the wettable powders contain fifteen per cent and twenty-five per cent of the toxicant and are used at the rate of one-half to one pound to 100 gallons of water.

Parathion is recommended by the American Cyanamid Company, the leading sponsor of it, as a control for “aphids, mites, thrips, beetles, red-banded leaf-roller, cottony-cushion scale, oriental fruit moth, woolly apple aphid, plum curculio, pear psylla, mealy bugs, and bud moth”. It also has been reported as effective for the control of bean beetles, cucumber beetles, cabbage worms, leaf hoppers, grasshoppers, and many others. It has been used in Kansas against the juniper lecanium with satisfactory results. It appears to be particularly useful in greenhouses since it kills all insect pests and red spiders without injury or discoloration of plants or flowers. The wettable powder spray, applied while the operator is protected by a respirator, raincoat, gloves, and hat or cap, has given highly satisfactory results in greenhouses. Parathion has residual killing power for seven to fifteen days during which time it gradually disappears.

Parathion should not be used on plants either as dusts or sprays within thirty days of harvest. It is not stored in the tissues of plants or animals to an appreciable extent. In fact, parathion appears to be rapidly destroyed by body tissues. Parathion is said to be 70 times as toxic to warm blooded animals as DDT. It must never be handled without using a respirator mask. (See illustration in volume 4)

Although its high rate of toxicity makes it a dangerous insecticide to handle, there are two features which should also be taken into consideration: First, the low concentrations at which parathion is effective in controlling aphids and mites; Second, the rapidity with which parathion breaks down following its use as a spray. Parathion residues on plants are lost very rapidly after application.
PART II

American Cyanamid Company developed a very sensitive method of chemical analysis for determination of residues on plants. It was developed before marketing the product commercially and has been used successfully in tens of thousands of determinations on practically every crop, in practically every area in the United States. Even when the intake of parathion considerably exceeded the amount that would be fed to animals under practical conditions, parathion did not affect milk quality, rate of milk flow, or food consumption. 160

Parathion was available for experimental use first in 1947, has been found very effective in controlling orchard mites and aphids on tree fruits in the Pacific Northwest. Some 600,000 pounds of parathion were used on tree fruits in Washington in 1949. It is only slightly soluble in water (20 p.p.m.). It is completely miscible in such organic solvents as the alcohols, ketones, ethers, aromatic hydrocarbons, animal and vegetable oils. It is practically insoluble in petroleum ether, kerosene, and refined petroleum oils used as sprays. 105

According to the American Cyanamid Company 250 "It has been definitely established that when used according to directions, insecticides containing parathion give outstanding protection against most insects and mites attacking such fruits as apples, grapes, peaches, pears, prunes and plums, strawberries and walnuts. And on vegetables it kills most insects common to beans, cabbage, celery, cucumbers, corn, squash, peas, peppers, tomatoes, potatoes and most root vegetables".

The Cyanamid Company urges as do all insecticide manufacturers that you consult local agricultural authorities on your insect problems. Weather, timing, method of application are important factors in the successful use of parathion. Send to American Cyanamid Company; 32-D Rockefeller Plaza, New York 20, New York for your copy of "Growers Manual" giving latest recommendations for using parathion.

PETROLEUM OILS: Petroleum oils are assuming a large and important place in the insect and weed controlling picture. Petroleum oil products serve in two ways. Oil contains many insect and weed killing properties in itself, and second, it provides an excellent carrier for insecticide and herbicide sprays. In addition to its toxic effect it possesses good spreading and penetrating qualities which add to its usefulness as a carrier. Also it does not volatize as readily as a water carrier.

Kerosene was probably the first form of oil used as an insecticide. It was mentioned in insecticide literature as early as 1763. Commercial orchardists used a combination of kerosene, soap and water as early as 1871. Most any kind of salvage oils such as crank case drainings can be used to kill insects and vegetation non-selectively.

The nature of petroleum oils is complex. Petroleum is a mixture of substances consisting mainly of carbon and hydrogen but with a
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varying amount of sulfur and nitrogen-containing compounds also present. By distillation, usually under a vacuum, it is divided into a number of fractions. That fraction which at normal pressure distills between approximately 500° and 750° F is the source of spray oils. It may also be considered as light lubricating oil, the fraction coming over at the next higher temperature range gives the commercial lubricating oils.

Since material distilling over such a wide range would vary greatly in its properties, it is customary to take the spray-oil fraction in two or more cuts, each covering a narrower temperature interval. These cuts are still composed of a great variety of compounds, some of which are very toxic to plants. It is therefore necessary to purify or refine them. This is done by mixing either with cold liquid sulfur dioxide or with hot sulfuric acid. Both processes are often used to obtain very highly refined oils.

In order to determine how far the process of refinement has been carried, a test has been devised called the "unsulfonated residue test". This depends upon the fact that when a petroleum oil is treated with strong hot sulfuric acid under certain specified conditions, a reaction goes on until only very nonreactive constituents of the oil are left. For any particular sample of oil, the portion not acted upon will be a certain percentage of the volume taken for the test. This percentage, the "unsulfonated residue", represents the portion which is too inert chemically to react with sulfuric acid under the conditions of the test. It has been found that toxicity to plants is less, the greater the unsulfonated residue, but effectiveness as an insecticide is only slightly decreased.

A number of other tests are used to further identify their properties. The most important is the distillation range. The oil is heated in a long-necked flask under certain definite conditions, and the percentage distilling over a 5 to 25-degree interval of temperature is determined. The California State Department of Agriculture 60 has established a classification of oils used on foliage according to the percentage by volume distilling at 636° F under atmospheric pressure. Five classes are recognized, as follows:

Percent by Volume Distilling at 636° F

<table>
<thead>
<tr>
<th>Class</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>64 to 79</td>
</tr>
<tr>
<td>Light medium</td>
<td>52 to 61</td>
</tr>
<tr>
<td>Medium</td>
<td>40 to 49</td>
</tr>
<tr>
<td>Heavy medium</td>
<td>28 to 37</td>
</tr>
<tr>
<td>Heavy</td>
<td>10 to 25</td>
</tr>
</tbody>
</table>

Another property used in describing spray oils is the viscosity, which is a measure of the ease of flowing. It is stated in terms of the number of seconds needed for 60 cubic centimeters of an oil to flow through the orifice of a Universal Saybolt Viscosimeter when the
latter is kept at 100° F. The more viscous the oil the longer the time required to flow out of the viscosimeter, and vice versa. The viscosities of spray oils vary from about 40 seconds to considerably over 100.

Selection of Oils

Selection of oils is very important. A consideration in the use of oils is the fact that plants and trees are much more easily injured when they are growing and in foliage than when they are in dormant condition. This has given rise to the grouping of spray oils into two classes: (1) dormant or winter oils, whose unsulfonated residue is approximately 65 to 80 per cent; and (2) foliage or summer oils, whose unsulfonated residue is approximately 80 to 100 per cent.

The viscosities vary widely, with the dormant oils more viscous on the average than the summer oils. In general, the distillation ranges and viscosities vary similarly. Since both the insecticidal value of oils and their harmful action to plants are also proportional to the length of time they remain after spraying, the distillation range affords a useful basis for classifying both summer and winter oils.

An important distinction between the requirements for spraying deciduous trees and those for spraying citrus trees is that the latter have no true dormant season and accordingly can be treated with summer oils. The two groups of oils overlap somewhat, for oils of intermediate properties are often necessary for use on deciduous trees at the time of budding.

A further classification of spray oil intended for dormant uses is necessary. (This classification also is taken from California State Department of Agricultural Standards.) Any mineral oil or petroleum oil sold to be applied to dormant trees or plants for use in pest control, whether or not mixed with other materials, shall be labeled with the minimum guaranteed percentage of unsulfonated residue as determined by the California State Method. Statement of the Class is not required, but if the Class is given, it shall be determined by the percentage distilling at 636°F Fahrenheit as follows:

**Dormant Light:** 64 to 79 per cent of the oil distilling at 636 degrees Fahrenheit.

**Dormant Light Medium:** 52 to 61 per cent of the oil distilling at 636 degrees Fahrenheit.

**Dormant Medium:** 40 to 49 per cent of the oil distilling at 636 degrees Fahrenheit.

**Dormant Heavy Medium:** 28 to 37 per cent of the oil distilling at 636 degrees Fahrenheit.

**Dormant Heavy:** 10 to 25 per cent of the oil distilling at 636 degrees Fahrenheit.
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Foliage Oils

The following classification is taken from the California State Standards. This classification serves as a general guide to classification terms, however, the same standards do not necessarily exist in other states. Any mineral oil or petroleum oil sold to be applied on foliage for use in pest control, whether or not mixed with other materials, shall be labeled both with the minimum guaranteed percentage of unsulphonated residue as determined by the California State Method, and with the Grade or Class in which it belongs as follows:

Light: 64 to 79 per cent of the oil distilling at 636 degrees Fahrenheit. Minimum unsulphonated residue 90 per cent.

Light Medium: 52 to 61 per cent of the oil distilling at 636 degrees Fahrenheit. Minimum unsulphonated residue 92 per cent.

Medium: 40 to 49 per cent of the oil distilling at 636 degrees Fahrenheit. Minimum unsulphonated residue 92 per cent.

Heavy Medium: 28 to 37 per cent of the oil distilling at 636 degrees Fahrenheit. Minimum unsulphonated residue 92 per cent.

Heavy: 10 to 25 per cent of the oil distilling at 636 degrees Fahrenheit. Minimum unsulphonated residue 94 per cent.

Unclassified: (Any mineral oil or petroleum oil that does not conform to the specifications of one of the preceding Classes shall be labeled "unclassified" and with the minimum unsulphonated residue — per cent.)

Oil Forms

Miscible oils, oil emulsions and emulsifiable oils are the forms in which oil is used in the different methods of application. Miscible oils, oil emulsions and emulsifiable oils differ mainly in the character of the concentrates. Oil emulsions are prepared by breaking the oil up into fine globules and adding water up to 50%. Emulsions vary in consistency and color. Their appearance can vary from a thin cream to a thick brown paste. Miscible oils contain an emulsifier dissolved in the oil. The concentrate is prepared by mixing the miscible oil with a small amount of water (4 to 6 per cent). This material has the appearance of clear lubricating oil when added to the spray tank. With the agitator running a creamy-white mixture is obtained. An emulsifiable oil looks like a miscible oil, however, when it is added to the spray tank (agitator running) it does not change color in the tank. It emulsifies and assumes the whitish color only under pressure as it leaves the spray gun nozzle.
Stable oil emulsions containing approximately 85 per cent oil are made by a large number of manufacturers. A wide variety of oils are used but, in general, these preparations fall into the two classes of winter and summer oils previously mentioned. The convenience of using emulsions, particularly for the small user, has made them very popular, and supervision by the State Department of Agriculture has standardized the oils used.

Data on the oils used are published by the State Department of Agriculture, but the emulsifying agents are secret. Since the type and amount of emulsifying agent largely control the amount of oil that is deposited in spraying, it is not possible to obtain the same results when various oil emulsions are used at the same concentration, even though the oils in them are similar. Each manufacturer gives directions for using his preparations.

One decided advantage that commercial oil emulsions have is that they require comparatively little agitation, since an excess of emulsifying agent is used. The corresponding disadvantage is that some deposit less oil than tank-mix sprays of equal oil content, and somewhat higher concentrations may be advisable for securing equal control of the same insects. The emulsions are made in two forms known as the paste and flowable types. The latter has become more popular because it is easier to remove from the container and to disperse in the spray tank.

Tank-mix oils preceded the use of commercial oil emulsions. Before the introduction of emulsive oils, the Agricultural Experiment Station of the University of California and others pioneered in the development of the tank-mix method of preparing oil sprays. By this method the oil and emulsifying agent are added separately to the spray water and the emulsion is prepared in the spray tank immediately before use. Accordingly, the amount of emulsifier can be varied to suit local conditions, and the best possible use of the spray oil may thus be made.

Since the cost of oil and emulsifier is considerably less than that of either commercial emulsions or emulsive oils, a large saving is possible. On the other hand, each step of the process must be thoroughly understood and carried out correctly or the results will be unsatisfactory either because of poor control or because of plant injury.

The most commonly used emulsifier is powdered-blood-albumin spreader, which consists of 1 part commercial blood albumin plus 3 parts fuller’s earth. It is used ordinarily at the rate of 4 ounces to 100 gallons of spray. The order of adding materials to the spray tank is not important, but is preferable to add the oil and the emulsifier while the spray tank is being filled so that the emulsion is first formed in only a part of the spray water.

Agitation must be continued constantly until the tank is emptied. Most spray outfits in the citrus districts are adequately powered to
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run large agitator blades of the propeller type at about 200 r.p.m. Tank-mix oil sprays are used extensively on deciduous fruits. For use during the foliage season, light or light-medium oils of 90 per cent or higher unsulfonated residue are satisfactory. On Yellow Newton or Smith Cider apples, only light oil should be used. During the dormant season, tank-mix sprays are very useful for destruction of various scale insects, brown-mite eggs, and leaf-roller eggs. Oils of 70 per cent or slightly higher unsulfonated residue and 100 to 120 seconds Saybolt viscosity at 100° F. are most widely used. Particular attention should be paid to securing adequate agitation with such comparatively unrefined oils. The same blood-albumin spreader that is used for citrus spraying is entirely satisfactory for dormant sprays.

Dormant oil specifications are less exacting. One grade of oil only is necessary for all dormant spray emulsions. It should have a viscosity between 100 and 120 seconds, Saybolt, and a relatively low "sulfonation" test that may vary between 50 and 70. This grade of oil has been found effective and safe.

PYRETHRINS: For many years the powdered flowers of the pyrethrum plant have been sold for use against such pests as fleas and bedbugs, and mixed with water have been used against such insects as cankerworms. Within the last few years extracts of the flowers have appeared under various trade names.

At first these were not standardized except that a certain weight of dried flowers was used to make a gallon of prepared spray. Since different methods of extraction varied in efficiency, the products were far from uniform. It was then discovered that the principal insecticidal constituents are two complex organic compounds which have been called "pyrethrins". The pyrethrins are all viscous liquids soluble in a variety of solvents but not in water. The present practice is to produce pyrethrum concentrates having a guaranteed pyrethrin content. This material is frequently used with oil. A typical formula for use against grape leafhopper is: Pyrethrum extract (for example, 2 per cent pyrethrins) . . 1 to 2 pints Summer-grade commercial oil emulsion or emulsive oil or tank-mix oil with 4 ounces of blood albumin spreader . . 2 gallons water to make 100 gallons. It is non-poisonous to animals and man and useful where such considerations are important. Although primarily a contact poison it is also toxic as a stomach poison. Its efficiency is increased by using soap or other setting agent in the spray mixture. It may be applied as a dust or spray. It is used against aphids (plant lice) and many other sucking insects.

Pyrethrum decomposes rapidly when exposed to sunlight. This plant product from the chrysanthemum family has very low toxicity for higher animals and gives a very rapid knock-down of a wide variety of insect pests. The effects of pyrethrum alone, however, are often temporary, the insects recovering later to continue their feeding.
Chemicals almost identical with the natural insecticidal principles in pyrethrum flowers have been synthesized in the laboratory. This achievement is the culmination of about 15 years’ investigations on the chemistry of pyrethrum by chemists of the United States Department of Agriculture. The compounds responsible for the insecticidal properties of pyrethrum are esters known as pyrethrins. The newly synthesized compounds are closely related to one of the esters. They have the same knock-down, or paralyzing, effect on insects, and indications are that they will not lose their insect-killing value so quickly as the natural material. One of these compounds, or pyrethroids, has been found in laboratory tests to be several times as toxic to house flies as the combined active principles of pyrethrum flowers. The toxicity of the synthetic products to higher animals is being investigated.

PYRENONE: Piperonyl cyclonene and piperonyl butoxide are now referred to as pyronones. They are manufactured by the United States Industrial Chemicals, Inc. The chief advantage in the use of the pyronones is that they are not poisonous to man and warm-blooded animals. The pyronones are toxic to insects but are used most commonly as synergists (boosters) for pyrethrum and rotenone.

Manufacturers report that pyronones, with or without pyrethrum or rotenone, are effective against the Colorado potato beetle, squash bugs, cucumber beetles, red spider, flea beetles, cabbage loopers, and possibly other vegetable pests. Pyrenone is available as a wettable powder T-194, as an emulsion, T-195, and as a dusting powder.

ROTENONE: Nature herself holds the key to insect control. Wild plants which are unable to protect themselves are provided with spines, needles, hairs, thorns to protect them from insects and animals. They even manufacture repellants such as bitter tastes, odors and even poisons. Many lichens produce insect poisons such as vulpinic acid from wolf moss. Not only have we learned how nature protects but we have learned to use some of the natural plant insect poisons as well as to produce synthetic mixtures for use as insecticides.

The roots of several species of tropical plants have long been used by natives as fish poisons. Investigation of these has shown that many of these plants contain compounds of high insecticidal potency. The most toxic of the compounds is rotenone, and analysis is usually expressed in terms of rotenone and total extratives, which include the other valuable compounds. The plants concerned are varied in appearance and habit of growth, and their popular names differ in various regions. In the Orient several species of derris are the principal source, and in South and Central America numerous species of lonchocarpus are most important. These are popularly called cube, timbo or barbasco.

The three forms of rotenone-containing materials are: ground roots intended for use as dusts or sprays, extracts of the toxic contstitr-
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Insecticides either ready for use or intended for suitable dilution in sprays, and dusts consisting of impregnated inert carriers such as talc to which extracts have been added. Since various commercial products contain differing concentrations of active ingredients, the manufacturer's specifications and recommendations should be followed. Alkaline diluents should be avoided because rotenone is less stable in the presence of any alkaline material.

Different species of insects and cold-blooded animals, such as fish, differ greatly in their susceptibility to rotenone. Warm-blooded animals and humans are in general but little affected when the material is swallowed or applied to the skin, and this safety is a very valuable property. Certain individuals, however, are hypersensitive and develop severe skin irritation. One of the interesting differences between the natural insecticides and the synthetic ones is that the naturals are much less stable.

Rotenone is a contact poison primarily but is effective with both chewing and sucking insects. It is used against aphids, caterpillars, many beetles and various other insects including red spiders. Rotenone

Fig. 5. — DUST-MASTER DUSTERCourtesy Mississippi Valley Aircraft Service
This photo shows Stearman with Dust-Master installation laying swath. Note width and general evenness of pattern.
is non-toxic to warm blooded animals and is therefore satisfactory for use on small fruits since there is no poisonous residue. Rotenone is rapidly destroyed by light and oxidation. It must be effective at once or not at all. Its effectiveness lasts only four or five days. For the same reason it results in little residue and is therefore adaptable as an after-blossom treatment for small fruits.

• RYANIA is one of the newer insecticides and claimed to be very efficient as a treatment for control of the corn borer. It leaves no residue, however, it is more expensive than either DDT or parathion for this purpose.

Ryania is a genus of plants of which the most important one insecticidally is R. speciosa from northern parts of South America. The active principles are present primarily in the roots and stems. Of these, ryanodine has been isolated and found effective both as a contact and a stomach insecticide. Ground stems of ryania are generally recommended for control of the European corn borer, applied as a dust or water suspension. The product is generally compatible with fungicides, wetting agents, and inert diluents. Activity is reduced some in combination with hydrocarbon oils. Because the toxic principles are relatively stable, ryania products possess significant residual effect and undergo little loss of activity in storage.

• SABADILLA is a newer insecticide which is made from the poisonous plant, cevadilla, grown in Mexico and Central America. This insecticide is made from the ground bulbs of a lily-like plant. It is available as 10 and 20 per cent dust formulations. It has very low toxicity to higher animals, will not injure sensitive plants, and is effective against plant bugs such as squash and lygus bugs. The dust may cause sneezing when breathed. 167 Sabadilla is available in dust form containing 10 or 20 per cent sabadilla seed with lime or pyrophyllite as a diluent. Exposed to air on plants, sabadilla loses toxicity rapidly.

• SELENIUM: Chemically selenium is a solution in potassium and ammonium sulfides. This insecticide was tried out in 1939 by the Tree Fruit Experiment Station at Wenatchee, Washington, and was very effective in the control of Pacific mites.

Because of their high toxicity to warm blooded animals, selenium compounds are not advised for use on food crops. The Food and Drug Administration allows no tolerance and fruit sprayed with selocide is subject to seizure if an excessive quantity of selenium is found. Determining what is an excessive amount of selenium is difficult for it occurs naturally in some soils and even can be detected in the fruit. Selocide is the name of a selenium compound manufactured by the McLaughlin Gormley King Company. Under suitable conditions it has been found possible to introduce selenium compounds into plants.
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through their root systems. This affords protection from insects within
the plant itself protecting these plants from red spiders and aphids. Because selenium is toxic to the higher animals it cannot be used against
insects on edible plants.

- SODIUM FLUOSILICATE (See cryolite).
- SODIUM FLUOALUMINATE (See cryolite).
- SULFUR: Generally speaking, sulfur has little value in controlling
most insects. However, it is useful in controlling mites. Its main use
is in the treatment of fungus diseases of plants. A full discussion of
sulfur is therefore included in the “Fungicides” section of this volume.
- TEPP: Cut off from their normal supply of nicotine as an insecticide
during the last war, German scientists worked on several of the
organic phosphates as substitutes. Captured enemy reports indicated
that one of these phosphates, known as bladan, was particularly
efficient for the control of aphids and mites, even more so than nicot­
tine alkaloid itself.

Research chemists in the United States later found that the active
ingredient in bladan was not hexaethyl tetraphosphate, as claimed by
the Germans, but another phosphate ester best described as tetra­
ethyl pyrophosphate. Consequently, the real value of commercial prep­
arations depends on the tetraethyl pyrophosphate content. Tetraethyl
pyrophosphate is a colorless, mobile liquid, miscible with water, ace­
tone, alcohol, benzene, carbon tetrachloride, and other solvents. It is
not miscible with kerosene, petroleum ether, or other paraffinic oils. 105

For the most part TEPP is formulated with a solvent and emulsifiers
so that the commercial product has a content of 20 per cent tetra­
ethyl pyrophosphate. This material is available from a number of
manufacturers of which the following is a partial list: Vapotone -
California Spray Company; Teratone - Lucas - Kiltone Company;
Nifos - Monsanto Chemical Company; Bladex - Shell Oil Company;
Tetrone - Easton Chemicals Incorporated; Hexamite - Niagra Chemi­
cal Company.

The concentrated forms of HETP and TEPP are highly poisonous
to warm blooded animals, including man. For this reason, precautions
should be taken to avoid spilling the concentrate on the skin or cloth­
ing, since it is absorbed through the skin. Persons applying the sprays
to vegetation should protect themselves from the spray because many
persons are highly susceptible even to the dilute spray. 182

Tetraethyl pyrophosphate has been used successfully to control some
species of mites and aphids. It has little residual action. 58 Promising
results have been noted on the two spotted spider mite, green chrys­
anthemum aphid, pea aphid, green peach aphid, plum curculio, sweet clover weevil and the rose sawfly. TEPP residues are reported to disappear rapidly. According to some authorities grains may be pastured three days after application. This, however, does not apply to BHC and parathion. The latter may require 3 or more weeks to disappear. Consult your local county agent freely on such questions.

There is no evidence at the present time that TEPP is fatal to game birds. It appears that where dead birds have been found in treated orchards that the cause is due to chronic DDT poisoning, rather than any other new insecticides. According to Dr. Arnold J. Lehman, U. S. Food and Drug Administration, tetraethyl pyrophosphate is 125 times as toxic as DDT. Considerable care must be used in handling this material. Manufacturers recommend that persons susceptible to the product be removed from the job whenever there is tightness of chest, painful vision or nausea.

● TDE (See DDD).

● TOXAPHENE is now the official name for an insecticide manufactured by the Hercules Powder Company and formerly frequently designated by the name chlorinated camphene. As an insecticide it is most closely related to chlordane. It can be used successfully against most of the pests controlled by DDT, benzene hexachloride and chlordane, with certain advantages. It has prolonged killing power, is of low volatility, and possesses a faint pleasant odor. This insecticide now appears to be slightly more toxic to warm blooded animals than chlordane. Toxaphene has been recommended extensively for the control of boll weevil.

Technical toxaphene product is an amber, waxy solid with a mild odor suggestive of both chlorine and camphor. It is readily soluble in such commercial solvents as acetone, benzene, fuel oil and kerosene. Toxaphene is available as liquid spray concentrates that contain 45 per cent and 60 per cent of the technical material. The first named contains 4 pounds of technical chlorinated camphene per gallon; the second, 6 pounds per gallon. Dust formulations are also available, containing 5 per cent, 10 per cent and 20 per cent chlorinated camphene — a 40 per cent spray powder is also available for use as a spray or as a base for making dusts.

● PHENACIDE is the term utilized by the Thompson-Hayward Chemical Company. Geigy Company, Inc. put out a 40 per cent chlorinated camphene under the trade name GY-Phene 40, while the Stauffer Chemical Company uses the names Emtox 45 and Toxadust. Pennsylvania Salt Company formulates a chlorinated camphene in concentrations of 20 per cent and 40 per cent under the trade name Penn-Phene. Toxaphene has been found to be phytotoxic to cucurbits.
USES OF INSECTICIDES

Since each insect pest may require a specific insecticide and with the constant development of new insecticides, no attempt will be made to recommend rates or use in this manual. Information regarding the rate of application, residue tolerance, specific insect control and hazards can be obtained from the following sources and should be consulted prior to application:

1. The manufacturer's label or chemical company representative.

2. State and county agricultural authorities.
PART THREE

WEED CONTROL IN THE U. S.

Weeds are now the number one cause of large grower losses on the average farm. Recently the United States Chamber of Commerce published the results of a survey which reveals that weeds cause the farmers and gardeners of the United States an annual loss of $3,000,000,000. This loss from weeds is probably as great, if not greater, than the loss to farmers from all livestock diseases, insect pests and plant diseases combined.

GROWERS LOSE MORE THAN $3,000,000,000 ANNUALLY BECAUSE OF WEEDS

Herbicides like insecticides are of both organic and inorganic types. Among the organic herbicides are: 2,4-D; 2,4-T; MCP; IPC; trichloracetic acid; phenolic compounds; carbon bisulphide; chloropicrin. Among the inorganic herbicides are: arsenical compounds; Boron compounds; chlorates; cyanate; cyanamid; ammonium sulfamate; thiocyanates; sodium chlorates. The following paragraphs describe briefly the most common of these weed killers. These chemicals are treated in alphabetical order according to their most commonly used names.

This nation did not know the real losses which weeds impose upon agriculture until about the year 1930. By that time millions of acres had been seriously infected with harmful noxious weeds. Eradication of weeds permits better water penetration. Getting rid of the weeds eliminates much competition for food and moisture. Without weeds to contend with, crops are more easily harvested. Finally, weed elimination produces clean and more salable seed crops.

Because of the hidden way by which weeds spread, they frequently go unnoticed until they seriously reduce crop yields. The control or eradication of weeds is probably one of the oldest problems confronting the agricultural industry. Nature seems to have endowed many of the widely distributed weeds with special characteristics which enable them to compete favorably with crop plants. Most crop plants do not possess these special characteristics. Consequently, if crop plants are to survive, they must be cared for by man and protected against the aggressiveness of weeds.
SELECTIVE WEED CONTROL

Weed control has now become a science. Early methods involved cultivation and competitive cropping. More recently chemicals such as sodium chlorate, carbon bisulfide and borax have been used effectively and today there is a wide choice of selective and non-selective weed sprays on the market most of which are highly effective when properly used.

The interest in chemical methods of weed control has had its impetus largely from the discovery of using growth regulators, such as 2,4-D as a means for killing weeds. Since the beginning of the use of 2,4-D, there have been many other new chemicals placed on the market. Such terms as prochloros, dichloropropenes, and dinitros, are widely advertised. Some of the chemicals can be used as selective materials, others only as contact herbicides, and still others can be used for both types by varying the rate of application or the concentration of the spray.

Chemical weed control is never a "cut and dried" program. Variables, such as the difference in weed susceptibility and density, crop and growth conditions and climatic factors, require the applicator to call on his experience, knowledge and judgment.

What Information is Needed?

Herbicides like insecticides work according to several different principles. Keith C. Barrons, speaking before the 6th Annual North Central Weed Control Conference, listed these types of information needed on all new herbicides:

1. How it enters the plant. (This affects application technique).
2. The extent and nature of translocation.
3. Nature of selectivity. To what extent is it due to differential wetting, differential absorption, or physiological differences in reaction.
4. Importance of the physiologic condition of the plant as affected by growth stage and growing conditions before and after treatment.
5. Effects of external factors such as temperature and humidity.
6. If the herbicide acts through underground parts we must understand the effects of various soil properties and the soil environment including rainfall on absorption, on leaching, and on chemical and biological decomposition.
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CONTACT HERBICIDES are compounds which "burn" off all above-ground growth simply by destroying the plant cells with which they come in contact. Except for hardy perennials, the damage to the plant caused by the contact herbicide is so great that the root dies as well. Sanophen 20 (pentachlorophenol, technical) and santobrite (sodium pentachlorophenate, technical) are examples of contact weed killers.

TRANSLOCATED TYPE weed killers are compounds which are absorbed by the foliage or roots and are spread throughout the growth. Translocated type herbicides cause the entire plant, including roots, to die. 2,4-D and 2,4,5-T are examples of the translocated type of weed killers.

FOUR GENERAL METHODS

Selective, non-selective, pre-emergent and post-emergent are the four methods of treating weeds. The selection of method depends upon the type of crop and conditions. No single method can be applied universally and often a combination of methods is most effective.

SELECTIVE weed killing is the most commonly practiced of the four methods of weed killing and therefore will be given more comprehensive treatment in this volume.

SELECTIVE HERBICIDES are chemicals that kill weeds but do not injure crop plants. It is by utilizing some characteristic which is not shared in common by both weed and plant that selective spraying can be effective.

GENERAL CONTACT weed killers destroy all kinds of vegetation, both weeds and crops. Any chemical, if applied in sufficient quantity, will kill all vegetation.

Selective Method

Some weeds can be treated chemically during the growing period of the crop without serious damage to the crop. This is called selective weed killing. Selective weed killing is possible because of the varying structure of plants. The principle of selective weed killing should be carefully understood by those who plan to operate a custom weed control service.

Selective weed control depends basically on the resistance of certain crop plants and the susceptibility of the undesirable weeds. There are numerous factors which affect the performance of certain chemicals and method of treatment. These factors will be discussed individually later in this book.
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Fig. 6. Courtesy Pennsylvania State College, School of Agriculture

This exhibit was used at the Pennsylvania Station at a weed-control conference to show those weeds which are easily killed, hard to kill, and are not killed by common commercial chemicals.

In all work with selective sprays it should be remembered that selectivity is relative. For example, 2,4-D at 250 ppm may be used to kill ribes species in the forest; no harm is done to conifers and many other brushy species. At 500-750 ppm, 2,4-D will kill mustards out of flax; and at 1000-2000 ppm it will control fiddleneck in barley and lilies in rice. At excessive concentrations, 2,4-D will injure any plant, and in every situation there are definite limits of concentration between which it is safe to work. This rule applies to other selective herbicides as well and in all situations where selective sprays are used the operator must know and keep within these limits if he is to have success with the chemicals. Two or more types are simultaneously effective in many cases.

It is important that the spray operator know the range of selectivity of his material on both the crops and weeds to be sprayed. Too little chemical will not kill the weeds. Too much chemical, or wrong application methods, may not only kill the weeds, but also injure the crop.

When the seedlings of certain weeds, such as knotweed attain true leaves, they are as difficult to wet as are crop plants. It has been found
impossible to kill such weeds in peas, flax, young alfalfa, and other broad-leaved crops where selectivity depends upon differential wetting alone. In such cases, the weeds can be controlled only by spraying while they are in the cotyledon (two-leaf) stage. All plants are more susceptible to herbicides when in the small seedling stage than when growth is farther advanced. They are also more susceptible during warm, moist weather than they are when it is cold and dry.

HOW WEEDS ARE AFFECTED

Broadleafed plants as a rule have a soft porous surface. Such a surface readily absorbs the chemical liquid droplets which come to rest on the plant. In contrast to the spongy porous surface of the broad leafed plants is the hard waxey surfaces of many of the grassy type plants such as the small grains. Many of the small grains also have a structure of ridges which run the length of the grain. This type of structure also tends to cause droplets to bounce off the plant.

Some plants, such as cereals, have waxy leaf surfaces that are corrugated or formed of very small ridges. See Fig. 7 (A). Water solutions can stick to only a small portion of these surfaces. When water sprays hit cereal leaves, they bounce off in droplets or wet the surface only in small spots.

Broad-leaved plants have smooth leaf surfaces which are more easily wet by water sprays. See Fig. 7 (B). When broad-leaf weeds, such as wild mustard, radish, or fiddleneck, are sprayed with water solutions, the spray tends either to spread as a thin film or to remain as many small droplets that wet a fairly large portion of the leaf surface.

Leaves of cereals are narrow, and stand upright, so that droplets of spray roll off them. Fig. 7 (C). Leaves of weeds are wider, and grow out horizontally from the plant stem, so spray spreads over them and sticks — another example of differential wetting. See Fig. 7 (D).
The growing points of cereals are located in the crown of the plant, below the soil level, and are protected by surrounding leaves. Fig. 8 (E). Because of this, any spray which sticks to cereals may injure the upper leaves, but not reach the growing points and kill the plants. The broad-leaved weeds, however, have their growing points exposed at the tips of the shoots and in the leaf axils. Fig. 8 (F). These plants are easily killed by toxic sprays.

Some plant cells tolerate the toxic action of certain chemicals better than do others. For example, 2,4-D applied in non-toxic oil or as dust will kill weeds such as mustards, radish, or fiddleneck, in cereals, and leave the cereals unharmed. See Fig. 9 (A). This biochemical selectivity. Weed sprays having this type of selectivity may be used with success in fields where the weeds are susceptible to the toxic action of the spray while the crop plants are not damaged.

Biochemical selectivity operates in the root systems as well as the foliage of plants. Fig. 9 (B). This makes it possible to kill young seedlings of crabgrass and watergrass in corn and milo by spraying 2,4-D on the soil just after the crop has been planted. The weeds will die, but the crop roots will tolerate the chemical.

Some perennial crops, such as alfalfa, have a dormant period in winter. At that time, it is safe to use a general-contact spray for control of annual weeds. Such a spray used when the alfalfa is in its

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**Fig. 8.** Courtesy of California Agricultural Extension Service.
WEED KILLERS

growing period, however, would injure the crop. It may be used effectively just after a crop has been cut and removed from the field. This is particularly true where alfalfa is to be dehydrated, and is removed immediately after being cut.

When annual weeds grow in deep-rooted crops, they may be killed by general-contact sprays. The crops, with perennial root systems, recover. Normally, contact sprays kill grasses. However, some grass pastures or seed crops are perennials, and will withstand contact sprays used to kill annual weedy grasses. See Fig. 10.

Optimum Development for Kill

The best time for spraying is when there is plenty of moisture for weed growth. Annuals are most susceptible when young, while perennials are usually most susceptible just before bloom. Weather conditions may influence the date and extent of these susceptible stages of growth. Thus adequate moisture and high temperatures will induce a lush growth that is susceptible to 2,4-D, while under dry, cool conditions plants may develop considerable resistance. The successful operator must vary the dose to correspond with the condition of the plant at the time it is possible for him to spray. During rapid growth minimum amounts of 2, 4-D will be adequate. During almost dormant periods, even the maximum amounts may be insufficient. Formulations also differ in effectiveness under adverse conditions. Sodium salt, amine salt, and ester may all provide a kill under favorable conditions, but ester is more effective when plants are resistant.

Fig. 10. Courtesy California Agricultural Extension Service.
Selecting Proper Chemical

Weeds have many characteristics in common, however, they vary considerably in life span (perennial or annual), crop association, seasonal development and response to various chemicals. Selecting the chemical to be used is determined by:

(a) Whether the weed is annual or perennial.
(b) Whether it is grasslike or broad-leafed.
(c) Ease of wetting as determined by surface texture.
(d) Physiological tolerance or resistance.
(e) The crop in which it is growing.
(f) Growth stage of weed and crop.
(g) Nature and moisture condition of soil.

There are two general classes of foliage sprays that act upon contact. These are.

1. Water solutions (for broad-leaved annuals) (a) Amonium dinitro-o-sec, (b) Butylphenate, (c) Sodium dinitro-o-cresol, (d) Sodium pentochlorophenate, (e) Potassium cyanate, (f) Sulfuric acid, (g) Copper salts, (h) Salt.

2. Petroleum Oils (For annual grasses and broad-leafed weeds). Those that act systemically (translocation) (for annual and broad-leaves) (a) 2,4-D, (b) 2,4,5-T, (c) MPCA.

Morphological Selectivity

Plants of mustard, radish, fiddleneck, and other weeds have their growing or meristematic tissues at the tips or in their leaf axils. These can be hit by spray. In contrast, grass plants grow from meristems located at or below the soil surface and protected by the bases of all the lower leaves. To kill grasses you need a spray of low surface tension such as an oil that will creep and penetrate down into the crown and kill the meristematic tissues.

NON-SELECTIVE METHOD

The non-selective method of weed control provides for killing all vegetation both the crop and weeds. This method obviously is very simple and is used only in cases of severe weed infestation where the objective is to gain maximum control regardless of the extent of dam-
Selective weed killers are those used in crops to control the weeds with as little as possible damage to the crops. Many herbicides can be used both selectively or non-selectively. Such chemicals will be described under both headings.

- **CALCIUM CYANIMID**, a common nitrogen fertilizer, has contact weed killing properties. Granular and powdered grades are available. The granular form, applied to the soil before seeding, has been used for several years in tobacco seedbeds. Both forms are used extensively by asparagus grower for weed killing purposes and as a source of nitrogen for the crop. Granular cyanamid is applied to the soil when weed seeds are germinating and is effective for a period of 3 to 5 days, then is broken down into harmless compounds.

  The chemical is a contact herbicide which is effective only when weeds are small and covered with a film of moisture. Heavy dew and still air, followed by a warm, bright day, are needed for satisfactory results with this form of cyanamid. Vine killing and defoliation are other uses for cyanamid. Both forms of cyanamid are heavy, black substances and somewhat disagreeable to handle.

- **DINITROS** are complicated organic compounds originally used as yellow dyes. In weak solution, dinitros are good selective weed killers and may be used to destroy mustards and other weeds in grain, flax, and peas, and several kinds of weeds in lawns. In strong concentration or when used to "fortify" petroleum oils, the dinitros are non-selective and are employed as general weed killers. As selective weed killers they compete with 2,4-D. As non-selective weed killers they compete with arsenicals, sodium chlorate, borax, and toxic oils.

  The dinitros are poisonous and inflammable under some conditions but with reasonable care can be used without danger. They impart an indelible yellow stain to clothing and skin. Unlike 2,4-D which is
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highly damaging to such broadleafed plants as alfalfa, peas, vetch and other legumes, dinitros can be used with these crops. Sodium dinitro-ortho-cresylates is a water mixture (slurry) commercialy formulated by Dow Chemical Company and sold as Sinox. Ammonium salt of dinitro-ortho-secondary-butyl-phenol is sold as Dow Selective and Sinox W.

The dinitro herbicides are being used to a considerable degree on peas and flax. The dinitros will do a good job of selective weed control where conditions are right. However, they are said to require better conditions than does 2,4-D, and are somewhat more expensive and require a larger volume of water per acre. These herbicides kill only on contact and as a result, the treated plants must be completely wet in order for the dinitros to do the best job. 157

Another new chemical, dinitro-o-secondary butyl phenol used in water solution can be a selective spray. This material is very new and manufacturers directions should be followed carefully. Conditions should be dry at time of application and for a 12 hour period after spraying. This same material if dissolved in diesel oil becomes a contact herbicide. 179 (See Sinox described in later paragraphs.)

IPC: Developed shortly after 2,4-D, this growth regulator has a similar but opposite action — it kills certain grasses but does not kill broad-leaved plants. To kill perennial grasses, IPC must be mixed with the soil, an inconvenient practice. The killing action occurs from the material being absorbed through the roots. In this respect also IPC appears to work just opposite to 2,4-D which is absorbed through the leaves. The chief use of IPC is to kill annual grasses growing in crops such as clover not sensitive to the substance. Thus far IPC is reported not a commercial success for perennial grasses.

Quoting from the proceedings (Oregon State Report) of the 1949 Western Weed Control Conference, 225 "A development in 1948 that has aroused considerable interest was the demonstration of the practical usage of IPC on Ladino clover and certain other crops has made a substantial economic rate to the farmers employing it. It has enabled them to maintain their yields and stands for a longer period of time. It is expected that even more IPC is going to be used in 1949, at its current high price."

PCP is the sodium salt derivative of sodium pentachlorophenol. It is soluble in water and is used for selective spraying of annual weeds in onions or for pre-emergence treatments in vegetable or other crops that are sensitive to 2,4-D.

VERIFY ALL DOSAGE RECOMMENDATIONS WITH LOCAL AUTHORITIES BEFORE USING

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Petroleum Oils Used Selectively

Certain refined oils, such as Shell Weedkiller No. 10 and Pentox No. 1, were developed for use as selective sprays on carrots and related crops because stove-oil sprays left an unpleasant flavor and reduced the market value of the crops. These new sprays also have a greater selectivity and higher toxicity than stove oil, so that the dosage may be somewhat reduced. (See also discussion of oils in part 1.)

Another recent development in the use of selective oils has been the field trials of Shell Weedkiller No. 11 for controlling wild oats in flax. The preliminary tests indicated that the method is effective, and large-scale trials followed, in the spring of 1948. These trials showed that sprayed flax averaged 34.1 bushels per acre, whereas unsprayed areas averaged 20.3 bushels. Sprayed flax had an average dockage of 8.1 per cent; unsprayed, of 15.8 per cent.

Oils serve two purposes in chemical weed control. They act as toxicants (killers) and as carriers. In selective weed oils, the toxicants (medium-weight unsaturated compounds) should be present at concentrations that kill weeds without killing crops. For carrots, this concentration may be fairly high (around 25 per cent). To spray safely in flax, it should be considerably lower, and for onions, still lower. The oil should be so light that all toxicity is of the acute type. This means that it should have a gravity above 38° A.P.I. (Shell Weedkiller No. 10, for example, has a gravity of about 43° A.P.I.) This guarantees that the toxicity is acute. At the same time, such oils evaporate fast, so that the oil flavor soon leaves the crops.

The nontoxic part of the selective oil acts as a carrier for the toxic parts. It cannot be replaced by water because the selective toxicants are oils and will not act in emulsion. Also, the wetting properties of straight oil are required to kill grasses in the crop. Oil is a better carrier than water because it has a low surface tension and high wetting ability. This means that instead of running off the plants as water does, the oil creeps over them. In doing this, it soaks into the growing parts and kills the tissues. This wetting ability is especially important where the oil is to be used on weed growth containing rank, vigorous grasses.

New methods in the processing of petroleum gasolines has produced even greater toxicity in some of the by products used extensively in the production of petroleum weed killers. For example, the material extracted from distillate to improve kerosene was found to be quite toxic to plants.

Some petroleum weed killers now rank with 2,4-D and the dinitro compounds. There are 50 or more registered petroleum oil herbicides. Most of them are non-selective types. Sovsol, Stoddard and Stanasol
WEED KILLERS

are the names of a few of these oils used as herbicides. The lighter grades of fuel oils are useful to control grass and annual weeds in uncultivated areas but have the disadvantage of setting up a condition which is a fire hazard. Oil-sprayed vegetation ignites readily and such fires are difficult to extinguish.

Naphthas of the Stoddard solvent series, with an aromatic content of 5 to 15 per cent, are excellent herbicides. Members of the parsley family (carrots, parsnips) are tolerant of these materials, but most other crop plants and annual weeds are killed by contact with Stoddard solvent. Ragwood and beggar’s tick, however, are exceptions in the annual weed group. Perennial weeds are killed only to the ground line.

Stoddard solvent is an excellent pre-emergence material for use on small seeded, or rapidly germinating crops because it has no residual effect. It may be applied the day before the crop plants emerge, without reducing the stand of desirable plants. The rate of application for Stoddard solvent depends upon the weed and crop situation where it is used. When complete coverage of the field is desired, 75 to 100 gallons per acre is generally needed. In some cases, however, the oil is sprayed in a 4 to 8-inch band directly over the row, and satisfactory kill can be obtained with 30 to 50 gallons.

Other naphthas and similar compounds have the ability to kill submerged water weeds. Chlorobenzene and xylene, when sprayed as an emulsion in lakes and irrigation ditches, have given a quick kill of many types of water weeds. They are, however, toxic to fish and other small animal life. Livestock will not drink enough oil-treated water to be harmed and the emulsions soon break down, permitting the oil to settle to the bottom or evaporate.

The toxicity of an oil depends upon (a) the amount of unsaturated compounds it contains and (b) how volatile it is. Oils, therefore, vary greatly in their effectiveness. Some kill only weeds and some kill all plants. Highly refined oils are practically non-toxic and are used only as carriers for selective insect or weed killers.

- **ACUTE TOXICITY** is the term applied when rapid burning of the leaves occurs when the oil contains light unsaturated compounds. Very light unsaturated compounds such as those from gasoline stock, cause burning of the leaves. Injury is not complete, however, if the spray incompletely saturates the plant, because these oils may evaporate before all tissues of the plant are killed.

- **CHRONIC TOXICITY** is the term used when injury comes about more slowly due to the use of heavy unsaturated compounds. These elements cause chlorosis — a yellowing of the leaves. Heavy unsaturated compounds, such as those in Diesel and other heavy fuels kill
plants slowly by chronic toxicity. Crop plants as well as weeds are killed by such oils. (See petroleum oils under insecticides and non-selective weed killers for further information on oil properties.)

PMA: Several formulations of PMA, an organic mercury, have been reported as having selective herbicidal properties for certain annual grasses. The fact that all mercury compounds are poisonous to man and livestock, and the slight difference in toxicity levels for crab grass and desirable grasses, as well as the relatively high cost of the chemical, limit the usefulness of PMA for grass control purposes. Climatic and soil factors seem to affect the results obtained. Because of the limited information available, the use of organic mercury compounds must be considered as still in the experimental stages and no suggestions for usage can be offered. Should trials be made, careful attention to the manufacturer’s directions is essential.

POTASSIUM CYANATE: This new selective herbicide is sold under the trade name Aero Cyanate, and has been introduced for the control of weeds in onions. Originally developed in the east, where the dinitro compounds were not sufficiently selective for use on onions, potassium cyanate is replacing sulfuric acid, which has been the principal spray for onion crops. It is somewhat more selective than sulfuric acid, and much less corrosive. The manufacturers recommend using Aero Cyanate at two different concentrations, depending upon the size of the onions. For small weeds in seedling onions, the recommendation is 5 pounds of chemical per acre. For onions 6 inches tall or over, 10 pounds per acre.

In the Imperial Valley, all weeds except chessweed and watergrass were killed, in young onions and garlic, by potassium cyanate used at the rate of 12 pounds per acre. Best results followed application at midday, on young weeds in onions 2 to 3 inches tall. Pressure below 100 pounds was better than high pressure. A wetting agent lowered the selectivity of the spray. Garlic was somewhat more tolerant than were onions. (See volume No. 4 for precautions).

SINOX: The three formulations of dinitro compounds which are now known to be on the market are sinox, Dow Selective, and Dow General. Dow General is non-selective and described later under that heading. Sinox and Dow Selective are two materials which have been used for the control of annual weeds in crops which are sensitive to 2,4-D. They are satisfactory for canning peas, field peas, and in small grain and flax where there are new seedlings of alfalfa or clover. They are also used in controlling annual weeds of the broad-leafed type in flax and small grain.

Activated Sinox, according to Crofts, 28 controls such weeds as mustards, wilt turnip, hedge mustard, fiddle neck, fanweed, penny
cress, Russian thistle, prickley lettuce, corn cockle, shephard's purse, small nettle, nightshade, wild buckwheat, lambsquarter, and hunger weed in crops of wheat, oats, rye, flax, peas, corn, onions, garlic, rye grass, fescue. 28

When using dinitro compounds, it is imperative to follow the directions on the container regarding dilution and dosages. The materials are used at high rates of water application — 80 to 100 gallons per acre (ground rig application). This has been one of the drawbacks for use on extremely large areas. Sinox has essentially the same chemical constituents as Dow Selective. 166

**SULFURIC ACID (Sulfamic Acid)** (See also Ammonium Sulfamate): A technical grade of this chemical has been used for weed control purposes for many years. Dilute solutions, 2 to 19 per cent by volume, have selective action on small grains, onions, and certain coniferous seedlings. Selectivity seems to be based on the waxy nature of the foliage of these plants which prevents actual contact with the spray solution. Grasses and a few species of broad-leaved weeds, such as lamb’s quarters, are not killed by this treatment.

The rate of application depends upon the crop being treated. Dilutions are made from commercial, concentrated sulfuric acid, 66° Bé specific gravity 1.84, one gallon of which weighs 15.3 pounds. The ammonium salt is preferred as a herbicide. It is reported to function as a contact toxicant when applied directly to plants. According to Fromm, a molar solution will destroy Bermuda grass completely. Sulfamic acid is also useful against poison ivy. 226

**2,4-D:** One of the most important and spectacular scientific discoveries in the last decade has been the discovery of the selective herbicidal action of certain derivatives of acetic acid. Discovery of 2,4-D has brought about almost a completely new revolutionary concept of weed control. In the short period since 1945 it has become the most widely used chemical weed killer in the United States. Commercial sales in 1948 are estimated at more than 8 million pounds. But 2,4-D can kill crops as well as weeds. An understanding of this new substance is essential to effective and safe use.

A group of chemicals was discovered about 1935 that could be used to modify in some ways the growth of plants. At first they were thought of as plant growth stimulants, and attention was directed toward using them for such purposes as to stimulate the rooting of cuttings, to inhibit shoot and leaf growth of nursery plants, and to prevent the cropping of fruits. It was soon found that some plants were injured and others killed when large quantities were used.

2,4-D is the abbreviation for the closely related chemical compounds now commonly used for killing weeds. Originally 2,4-D meant one
substance known to chemists as 2,4-dichlorophenoxy-acetic acid. The abbreviation now used designates a number of compounds that are derived from this acid. As weed killers they are seldom sold in pure form. They are usually mixed with other chemicals to increase their solubility, or with a carrier such as oil, and are sold as a powder or liquid ready to mix with water.

2,4-D was first used as a plant growth regulator in 1942. It was extremely potent. Initial tests conducted by scientists of the Department of Agriculture with weeds revealed that 2,4-D could be used to kill plants selectively — it killed some but had very little effect on others. Intenified research in the Department and elsewhere was directed toward its early development as a weed killer. Commercial distribution began in 1945. Today 2,4-D is used extensively to control weeds on farms and ranches and around homes. Research is being continued by the Department, by State agricultural experiment stations, and by other organizations.

2,4-D IS HIGHLY EFFECTIVE: Most broad-leaved annual weeds can be killed when actively growing by the use of ¼ to ½ pound of any formulation of 2,4-D. One minute drop of pure 2,4-D, smaller than a flyspeck, is enough to affect the growth of sensitive plant seedlings. In most instances less than 1 pound of the chemical will control the weeds on an acre of cropland.

HOW 2,4-D WORKS: 2,4-D as a plant stimulant — it speeds up respiration, digestion of plant foods, and use of reserve food materials. When is is applied in relatively large quantities, some of the growth processes may be stimulated to excess and the plant eventually dies. Death is due at least in part to the loss of reserve foods and to the activity of organisms that prey upon the weakened plant. Most plants absorb 2,4-D rapidly. It will penetrate any part of a succulent plant — roots, stem, leaves, flower, or bud. Once inside, the chemical moves rapidly. It apparently accumulates most readily in such fast-growing parts as buds and new roots.

Small quantities of 2,4-D stimulate the growth of new cells in some parts of the plant, deforming it. The veins of young leaves may become enlarged and flattened, and the leaves develop as long narrow strips with curled edges. Even a little 2,4-D may cause stems of succulent plants to grow more rapidly on one side than on the other, giving the plant a bent or wilted appearance and weakening it. Larger quantities stimulate to a marked degree some of the growth functions, such as respiration and digestion. It causes the plant to use up reserve starch. Under warm moist conditions, weakened plants become susceptible to attacks of soil-borne organisms and these cause the roots and lower stems to rot away. 2,4-D has no beneficial effect upon crops except weed elimination, which results in the availability of greater amounts of soil moisture and fertility for the growing crop.
WEED KILLERS

- **2,4-D ACTS SLOWLY**: 2,4-D usually acts much slower than other weed killers. It causes twisting, coiling and bending of the stems and yellowing of the leaves. This evidence is not to be taken as a measure of the kill. Sometimes there is a good kill without much of this evidence.

The count should be made about six weeks after the treatment. On annual weeds only those that actually die should be counted. For perennial plants only the amount of regrowth which occurs the following year is a fair measure of the result of the treatment. The general statement that 2,4-D is more effective on the broad-leaf plants does not mean that it will kill all broad-leaf plants nor that it will not kill any of the grasses.

Plants with the widest leaves are not always the most sensitive to 2,4-D. All plants carry some resistance but the amount of resistance varies with the plant and the conditions under which it grows. How 2,4-D kills weeds we do not yet know. The whole plant does not need to be covered in order to get effective results. 2,4-D acts on the plant system moving through all or part of the plant. Contrary to earlier beliefs plants do not grow themselves to death as a result of this treatment. Any treatment strong enough to kill the weeds will do some injury to the crop, but, when a treatment destroys the weeds the crop may benefit enough to give increases in grain yields.

- **FORMS IN WHICH 2,4-D IS AVAILABLE**: There are various forms of 2,4-D and each has different characteristics. Several, including the esters and the sodium, morpholine, amine, and ammonium salts, are commonly used for killing weeds. These salts are soluble in water and can be sold as a powder, with directions for making a spray mixture. Salt-type 2,4-D can be applied most readily as liquid spray. The ester types most commonly used are the butyl and isopropyl esters. They are liquids, mix readily with oil, and are generally sold as oil emulsions to be diluted with water for spraying.

Although available in three different chemical forms, all three of the forms have approximately the same weed killing power when based on the actual 2,4-D acid content.

- **2,4-D FREE ACID FORM**: The free acid form, 2,4-dichlorophenoxyacetic acid (2,4-D) is a light-colored powder, insoluble in water. For this reason, this form rarely is used under practical conditions. However, the other forms of 2,4-D usually are expressed in terms of free acid for purposes of comparison. For example, a label will state “this formulation contains the equivalent of 3 pounds of free 2,4-D acid per gallon”, and the careful buyer will compare these equivalent figures in order to determine the most economical formulation to buy. Always read carefully the label on any proprietary weed killer.

- **THE SODIUM SALT — FORM OF 2,4-D**: This is one of the cheapest forms of 2,4-D and is satisfactory for species of weeds that are
PART III

easy to kill. It resembles common salt in appearance but is less easily soluble, especially in hard water. It usually is not so effective as other forms on plants with waxy leaves or on most shrubs. Its killing action is said to be improved by adding wetting agents, alkalis, or other substances. The salt washes from leaves readily and may not give good results if rain falls within 6 hours. It may be used either as a dust or a spray but the spray is preferred because of the impossibility of controlling drifting dusts. This salt is less soluble than other forms of 2,4-D and is not as well adapted to “low-gallonage” applications.

AMINE FORM OF 2,4-D: Amine forms of 2,4-D are made by treating the pure acid with amines. Several amine salts of 2,4-D are available on the market. They include diethanol and triethanol amine salts, monoethylamine and triethylamine salts, the triethylammonium salt, and morpholine salt and certain mixtures designated by the general name, alkanolamine salts. They are soluble in water and it is possible to make concentrated spray from them. This is a decided advantage where low-volume sprayers are used. Being liquids, they are not likely to clog fine spray nozzles, and are popular for these reasons. Like the sodium salt, the amine salts are not volatile. 161

USE OF SALTS OF 2,4-D IN HARD WATER: According to Wm. W. Allen of the American Chemical Paint Company, speaking before the 6th Annual North Central Weed Conference, “In the hard water areas both the Na salt and amine salts will be thrown out as low soluble salts of 2,4-D such as the calcium salt unless a sequestering material is added to keep these salts from forming or keeping them finely dispersed by a non-ionic surface active agent. In either case the amine solution will not then clog screens or plug nozzles. Amine solutions are not as effective on the hard-to-kill perennials and woody plants as the ester formulations, apparently because the amine-water solution does not penetrate the plant as well as esters of 2,4-D. They also appear to be less injurious on crops than the esters.” 207

ESTER FORM OF 2,4-D: Ester forms of 2,4-D are made by treating the pure acid with alcohols. The ester forms of 2,4-D are volatile (new non-volatile forms of 2,4-D are now becoming available), and their vapors can affect plants at a distance, even though no spray has come in contact with them. For this reason, great care always should be observed in applying any esters of 2,4-D. The esters are liquids, insoluble in water, but soluble in oils and other organic solvents. Commercial formulations are prepared with emulsifying agents so that they are miscible with water in all proportions. Thus they are adaptable to low-volume spraying and apparently work well in most types of application machinery.

The esters available commercially include the methyl, ethyl, propyl, isopropyl, butyl, and amyl. These have similar properties and as far as is known at present, there is little to choose between them. Con-
WEED KILLERS

Concentrations of the ester may vary from 14 to 99 per cent (approximately equivalent to 18 to 80 per cent free acid) in commercial preparations. 161

The advantages of 2,4-D are several. It is the least expensive selective herbicide which has been developed because very small amounts are required to kill weeds. 2,4-D is non-poisonous to animals and is non-inflammable. Normal applications of 2,4-D only temporarily affect the soil and does not build up from year to year. Very high rates of 15 pounds or more of parent acid have temporarily delayed the development of nitrate producing bacteria. 2,4-D applied to the soil will remain effective for various lengths of time, but in most cases, not more than 90 days. Soil moisture, soil temperature, soil type and amount of organic matter seem to be the factors determining the period in which 2,4-D will remain dangerous. 157

- 2,4-D SODIUM SALT: Sodium salt may be dissolved directly in water.
- 2,4-D AMINE: The amines are useable as water solutions. They have extremely low vapor pressures and therefore can be used more safely adjacent to susceptible crops. They can be used for low volume application or diluted to high volume sprays.
- 2,4-D ESTER: The esters can be applied as oil-in-water emulsions or as straight oil concentrates. The formulation is at times more effective on the tough, hardy vegetation and woody bush. The esters can be used in low volume concentrates. The ester formulation can be made into highly concentrated sprays requiring fewer landings for refills. A disadvantage of the ester form of 2,4-D is that small grains have less resistance to it than either the salts or amines and it therefore must be sprayed at a lower rate than either the salt or amines.

- PRE-EMERGENT TREATMENT WITH 2,4-D: Pre-emergent treatments are treatments applied after a crop is planted but before it begins to grow. 2,4-D has been publicized for this purpose, particularly on corn. 2,4-D cannot be used for a pre-emergent spray on any susceptible crop. Even on crops tolerant of 2,4-D, such as corn, the dosage must not be excessive. A rate of one pound per acre of 2,4-D is enough. Pre-planting treatments are often made in lieu of pre-emergent treatments. If susceptible crops are to be planted, the treatment must be made at least six weeks ahead of planting. Pre-emergent treating is a new practice. There is still much to be learned about it. Trials are under way at Oregon State College to get more information on this subject. 181

CROPS WHICH ARE SUSCEPTIBLE TO 2,4-D:

<table>
<thead>
<tr>
<th>Vetch</th>
<th>Onions</th>
<th>Sweet clover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beets</td>
<td>Peas</td>
<td>Spinich</td>
</tr>
</tbody>
</table>
Weeds Effectively Controlled

The following is a list of weeds which have been effectively controlled by 2,4-D. (This list is published by Montana and applies to Montana conditions. Results may vary in other areas.)

Arrowhead lily  Agriculture Field cress  Beggar ticks
Black medic  Blue lettuce  Bullthistle
Burdock  Bur-weed  Buttercup
Canada fleabane  Canada thistle  Cattail
Chessweed  Chickweed  Chicory
Cocklebur  Creek nettle  Curly dock
Dandelion  Dog fennel  Fan weed
Hoary cress  Indian strawberry  Kelp
Klamath weed  Knotweed  Lambsquarters
(St. John’s wort)  Mouse-ear chickweed  Mustards
Milk thistle  Pennywort  Perennial dogbane
Nettle  Plantain  Poison hemlock
Perennial ragweed  Prostrate pigweed  Prickly lettuce
Poison oak  Purslane  Red clover
Puncture Vine  Russian thistle  Sedge
Rough pigweed  (young)  Sow thistle
Sheep sorrel  Shepherd’s purse  (annual)
Sow thistle  Spiny clotbur  Spotted spudge
(perennial)  Sweet clover  Teasel
Star thistle  Tumbling pigweed  Water hemlock
(rosette)  Water plantain  Water primrose
Tules

Clovers  Squash  Alfalfa
Cucumbers  Fibre flax  Pumpkin
Strawberries  Tomatoes  Cane berries
Cabbage  Orchard trees  Cauliflower
Ornamental shrubs  Flowers  Mint 181
WEED KILLERS

| Water hyacinth | Wild buckwheat | White horse nettle |
| Wester ragweed | Wild morning-glory | Wild lettuce |
| Wild carrot | Willows 225 | Wild sunflower |
| Wild radish | Yellow star thistle 225 |

Weeds Difficult to Control

This list covers weeds which were found to be difficult to control. (Montana conditions. Results may vary in other areas.)

| Alkali mallow | Annual bluegrass | Baby tears |
| Bermuda grass | Blackberry | Bluegrass |
| Bracken fern | Buttonwillow | Crabgrass |
| Foxtail | Goldenrod | Goosegrass |
| Horsetail | Italian ryegrass | Johnson grass |
| Mayweed | Milkweed | Mullein |
| Nutgrass | Okalis | Quackgrass |
| Ripgut grass | Russian knapweed | Sand bur |
| Soft chess | Tansy ragwort | Water grass |
| Wild barley | Wild oats | Yarrow 225 |

WHAT DO YOU PAY FOR WHEN YOU BUY 2,4-D? Regardless of the formulation used the active ingredient is 2,4-D. This is usually expressed in terms of acid equivalent and the amount of this is usually indicated on the container label in pounds per gallon or percentage. (See volume V of this series for information on computing dosages.)

- 2,4,5-T: In general, 2,4,5-T is formulated in the same manner as 2,4-D except that the sodium salt is not used. It is a translocated type of herbicide. The action of 2,4,5-T is similar to 2,4-D but 2,4,5-T affects certain species resistant to 2,4-D and appears more effective particularly on many woody plants, including poison ivy, species of gooseberry, brambles, mesquite, osage orange, blackberry, poison oak, maple and alder. 102

2,4,5-T is usually available in acid and in isopropyl ester forms. The acid is used in forming soluble amine salts, the isopropyl ester is used in preparing oil emulsion concentrates. Both compounds have approximately the same weed killing power when compared pound for pound on the acid basis. The herbicidal power of 2,4,5-T varies
with climate, season and type of susceptible vegetation. It is usually sold as a brush killer and contains one-third 2,4,5-T and two-thirds 2,4-D.

**TCA:** The sodium salt of this acid is approximately neutral, but the ammonium salt is acid and corrosive. Read and follow the directions on the label carefully. Both the sodium and the ammonium salts are being used to control perennial grasses. These materials are effective either as sprays or as soil treatments. Experiments indicate that a spray treatment which is followed by rains that wash the chemical into the soil may be the most effective. There is some indication that after spraying, the chemical is translocated into the underground rhizomes of Johnson grass.

On perennials, trichloroacetates are effective at rates of from 20 to 100 pounds per acre, depending upon the species of grass and the vigor of its underground root systems. Spray applications at rates around 5 pounds per acre seem promising for controlling watergrass in cotton and sugar beets, but tests have not been extensive enough to warrant a general recommendation at present. The acid itself is used in oil sprays, often in combination with other oil-soluble herbicides. The sodium salt is simply dissolved in water for use. TCA isopropyl ester is non-corrosive and is miscible with oils. It is used in oil alone or emulsified with water.

Residual toxicity from TCA sometimes disappears in a few weeks but may persist for one year or longer. Crop susceptibility varies and extensive studies are needed before overall spray can be suggested. However, spot treatment is possible where localized crop damage can be tolerated in order to eliminate perennial grasses.

**NON-SELECTIVE WEED KILLERS**

Non-selective weed killers destroy all kinds of vegetation — both weeds and crop plants. There is a wide number of chemicals which may be used as non-selective weed killers. Some common ones are: sodium chloride, sodium chlorate, sodium arsenate, sodium hydroxide, sodium borate, and sulfuric acid. Many of these, however, are not recommended because they are extremely dangerous to both humans and animals. Some are injurious to soil. Many of these chemicals have been used to control plant growth along highways, railroad rights of way and fence lines.

There are three types of general-contact herbicides. Do not confuse the use of the term contact or general contact as applied to weed sprays with the use of the same term relating to the insect sprays. A contact or general contact weed spray is one which kills all vegetation above the ground with which it comes in contact. In other words, it is non-selective.
WEED KILLERS

The three types of general-contact herbicides are:

(a) Water-soluble materials, including common salts and corrosive chemicals, sodium chlorate, and salts of the phenol compounds.

(b) Emulsions, made by combining water and oil. Additional toxic chemicals may be incorporated in either the oil or water base or both.

(c) Oils, including Diesel fuel, smudge-pot oil, stove oil, kerosene distillates, low-grade oils, proprietary weed-killer oils, and oils fortified by addition of phenol compounds or sulfur.

New Chemicals of High Toxicity

Several new chemicals, the phenol compounds, have been recently introduced. They are extremely toxic to plants, and are now being used in place of the dangerous, more common chemicals, for general-contact sprays. Among them are pentachlorophenol, dinitrocresol, dinitro secondary butyl phenol, dinitro secondary amyl phenol, and their salts. Most of these compounds are sold under trade names. Their content in such commercial products is shown on the labels. Examples of these products are: Contax, Sinox General, and Dow General weed killers.

Sodium pentachlorophenate or sodium dinitro cresylate may be used as general contact sprays in many situations if their toxicity is increased by activating them with an acid salt, such as ammonium sulfate, aluminum sulfate, or sodium bisulfate. These salts, at concentrations of 1 to 2 percent (or even less when no grasses are present) will kill weeds that have been protected from full effects of sun and wind and, consequently, do not have thick leaf surfaces. Such protected areas are found, for example, in deep drainage ditches, shady orchards, and lathouses. Higher concentrations up to 5 per cent may be used on hardier weeds. If grasses are present, a wetting agent should be included in the spray solution.

The ammonium salt of dinitro secondary phenol is so toxic that it will kill even grasses in their seedling stages. When used at concentrations of 0.5 per cent and over, with a good wetting agent, this herbicide has proved effective in killing mixed weeds on roadsides, ditchbanks, etc. On state highways in central California, fire strips sprayed with this material in April could be burned sufficiently within two or three weeks to provide adequate fire protection for adjoining crops and pastures.
ADVANTAGES:

1. The salts of the phenol compounds are soluble in water.
2. They are highly toxic; so little chemical is required that hauling is reduced to a minimum.
3. If used in large quantities, they can be bought at prices that compare favorably with those of fuel oils.
4. They have no serious poison hazard.
5. They form true solutions and require no agitation once they are dissolved.
6. They kill certain oil-resistant weeds, such as sweet fennel, yellow star thistle, mayweed, and pineapple weed.

DISADVANTAGES: They are not economical for use on coarse, vigorous grasses, such as wild oats, foxtail, ripgut, and the like. On these weeds, an oil spray is necessary, because it will creep down the grasses and penetrate the crowns, where a water spray, unless applied in very large amounts, will run off. 66

All water-soluble herbicides require thorough application. Formulas for mixing them will be found on the labels.

○ AMMONIUM THIOCYANATE: Ammonium thiocyanate is extremely toxic to plant life. It is odorless, colorless and readily soluble in water. Solutions of ammonium thiocyanate are corrosive to iron and other metals but not harmful to the skin. Used at 10 pounds per square rod ammonium thiocyanate is said to cause soil sterility for at least 4 months. Thiocyanate is believed not to be toxic to warm blooded animals. 226

○ AMMONIUM SULFAMATE: This substance, under the trade name "Ammate", has been sold for several years as a destroyer of poison ivy and poison oak. It originally was used to flame proof fabrics and wood. When used against poison ivy it is applied in concentrations of 0.75 pounds per gallon of water and higher concentrations for more resistant weeds. For that purpose it is unexcelled. The residue ammonium sulfamate is reported not to be harmful to humans or animals when sprayed on foliage. More recently, use has been made of it to destroy sprouts that arise from cut stumps. A freshly cut stump treated with ammonium sulfamate decays more quickly than untreated stumps and produces fewer sprouts. Ammonium sulfamate disintegrates in the soil and eventually becomes a nitrogenous fertilizer. Brass implements used to apply ammonium sulfamate corrode badly unless cleaned immediately.
WEED KILLERS

- AMMATE, manufactured by the Du Pont Co., is a coarse, granular, yellow substance. It is soluble in water and applied as a spray. Ammate is a contact, translocated herbicide, non-selective in action, and is especially effective on many types of woody plants. The chemical is absorbed through the leaves of plants but does not penetrate the bark of trees. This fact makes it useful in the control of poison ivy, in and under fruit trees or other valuable plants. Ammate is not poisonous to livestock or other animal life, but is corrosive to metals. Ammonium sulfate should not be used on foliage crops.

- AROMATIC SOLVENT (Solvent naphtha): In a search for a cheap, effective means of killing aquatic weeds in irrigation canals, the Bureau of Reclamation and the Department of Agriculture found that aromatic solvent naphtha, a compound widely used as a paint thinner, could be emulsified and sprayed under water at the head of an irrigation ditch with results fatal to many kinds of aquatic plants that clog waterways. Aromatic solvent is made from both coal tar and petroleum oil, but the latter is usually cheaper. Details as to the use of this process are contained in a publication "Controlling Submerged Water Weeds on Irrigation Systems with Aromatic Solvents", issued by the Research and Geology Division, Bureau of Reclamation, Denver, Colorado.

- ARSENICALS (Sodium Arsenite): Arsenic is as poisonous to plants as it is to animals, and the soluble forms are powerful weed killers. Sodium arsenite and arsenic acid are the forms most commonly used. Sodium arsenite has long been the principal ingredient of commercial "weed killers" used to treat driveways, tennis courts, brick walks, gutters, railroad tracks, and similar places. Solutions of arsenic acid are sold for killing crabgrass in lawns and weak solutions of sodium arsenite are used for killing chickweed. Ordinarily, however, the arsenicals are not considered to be selective. Sodium arsenite is, normally, one of the cheapest herbicides. It may be obtained in various grades on the open market through any dealer in commercial chemicals.

This chemical is particularly good in the areas adjacent to buildings as it is not inflammable and is ever a fire deterrent. Arsenic is toxic to many cultivated plants and repeated sprayings may sterilize the soil for some crops, particularly legumes. Many Washington orchardists who have used arsenical sprays can no longer use legumes for cover crops in their orchards. Because arsenic is poisonous both to animals and man it is not generally recommended in farm weed control.

- ATA (Ammonium Trichloracetate): This material, known chemically as ammonium trichloracetate, was introduced as a weed killer in 1947. It has proved effective in killing quack grass as well as other perennial weedy grasses. The material is still under trial, and spraying should be on an experimental basis.
Quoting from the 1949 Western Weed Conference (Washington State Report) 225: "The herbicide ATA (ammonium trichloracetate) and STA (sodium trichloroacetate) have been used very successfully in controlling and eradicating quack grass. These herbicides are new products placed on the market in 1948. Rates used were 1 pound to 1 1/2 pounds per square rod with retreatments applied directly to the ground.

**BENOCLOL USED AGAINST AQUATIC PLANTS:** Benoclor (14) is considered by some as the greatest single development in control of aquatic plants by chemical means. Benoclor is a heavy liquid that readily disperses in water to form a milky suspension. When sprayed through nozzles below the water surface into a flowing stream it will make the total mass of liquid into a stable milky emulsion. When it comes into contact with aquatic weed growth, it is absorbed by the plants and they are injured or killed. By means of a simple powered pump and nozzle system, irrigation ditches may be treated as the water flows past a station. Static water in a ditch may be treated by moving the pump. The pump can be mounted in a boat to treat aquatic plants in lakes. Water fauna are killed in treated ditches.

By carefully treating narrow strips of vegetation in lakes, injury to fish can be minimized. This chemical is not considered injurious to wildlife or stock. Applications are made after the growth in spring and early summer begins to cut the flow of water. The action of the chemical is rapid and normal carrying capacity of a ditch can be restored within 24 hours. Exposure to a concentration of 500 ppm (by weight) for 1 hour kills weeds. Benoclor is being used in eastern states for controlling aquatic weeds in ponds and along lake shores.

Fig. 11. Courtesy Bell Aircraft Corporation.
The Bell-47B1 helicopter applies a 2,4-D spray to kill water hyacinth.
BENZOIC ACID HERBICIDES

Benzoic acid herbicides are a relatively new and expanding group of herbicides of considerable value. Among the members of this group are 2,3,6-TBA or trichlorobenzoic acid, polychlorobenzoic acid, dicamba and several experimental chemicals that probably will be developed in the near future. The benzoic acid herbicides control a spectrum of plants not controlled by some of the presently available herbicides. TBA for example has given good control of many deep perennial weeds such as morning glory when applied at heavy rates of application.

The benzoic acids in the parent state are a group of crystalline, sharp melting acids. Their solubility ranges from a few hundred parts per million up to nearly 8 thousand parts per million in the case of TBA. Most of them have relatively low mammalian toxicity. The persistence of these chemicals in soil range from intermediate to being a fairly persistent as compared to products such as 2,4-D.

Amiben. Amiben or 2,5-dichlorobenzoic acid is a herbicide that enjoys some selective use on a number of vegetable crops and soybeans.

Dicamba. Dicamba and its relative the trichloromethoxybenzoic acid are known commercially as Banvel D and Banvel T. Dicamba has proven highly effective for the control of certain 2,4-D resistant plants such as sheep sorrel, cow cockle, corn cockle and certain others. It is sufficiently selective that it may be used on grasses including wheat at low rates of application.

2,3,6-TBA, and the related polychlorobenzoic acid have proven useful for the control of hard-to-kill perennial weeds. These chemicals applied at 10 to 30 pounds per acre give control of deep rooted perennial weeds such as morning glory, other broad leafed weeds and certain other grasses. TBA is quite persistent in soil, one of its principal routes of loss being by leaching. On occasion, particularly in areas of low rainfall the chemical may carry over into the second crop year.
DICHLOBENIL

Dichlobenil is the common designation for 2,6-dichlorobenzonitrile which is known commercially as Casoron. This product is chemically related to benzoic acids and probably does give rise to 2,6-dichlorobenzoic acid upon hydrolysis. This is a cream solid melting at about 140°C with a water solubility of about 5 parts per million. But when incorporated into the soil the product is fairly persistent lasting for several weeks to a few months after the incorporation. The chemical does have some volatility and when applied to the surface of a moist soil it may be lost in appreciable quantities. This product is quite active against a number of plants and is being developed as a selective herbicide for certain crops.

DCPA (Dacthal)

Dacthal is a white crystalline product melting at about 160°C. It has a very limited solubility in water being soluble to the extent of about 5 parts per million. Dacthal is a dimethyl ester of tetrachlorol terphthalic acid and as such has many of the properties of esters. For example, although this compound has a high melting point it does show some volatility, particularly with steam or water vapor.

Dacthal is readily bound by soils and this coupled with its low solubility makes for very limited leaching under normal rainfall conditions. Dacthal or DCPA is more active on light sandy soils and heavy soils high in organic matter.

This chemical is presently used on a wide variety of crops as a pre-emergence herbicide. It is used on many vegetable crops including those of the cabbage family and shows some promise of control of dodder in alfalfa.

DIQUAT

Diquat is a highly water soluble organic compound that is finding use as a contact seedling weed killer for crop desiccation. This compound is a representative of the class of chemicals known as quaternary ammonium compounds. Diquat is highly active as a foliar application
BUT IS PROMPTLY INACTIVATED BY SOIL. THIS COMPOUND IS
THOUGHT TO ACT BY INTERFERRING WITH KEY OXIDATION REDUCTION
REACTIONS THAT GO ON IN THE PLANT.

IN ADDITION TO BEING USED AS A CONTACT WEED KILLER,
DIQUAT APPEARS VERY PROMISING FOR CONTROL OF MANY AQUATIC
PLANTS.

• DINITRO: Although used extensively as selective weed killer
in strong concentrations, dinitros may be used as a general weed killer
for example, "Dow General" is used for quick temporary elimination
of grassy and broad-leaved weed growth along highways, railroads
and fence rows. A "Chemical mowing" effect is produced, but the
roots of perennial grasses are not killed, even though the tops are
killed down to the ground line. Sinox "W" is in the same category.

The dinitro herbicides labeled as "generals" are contact herbicides
which, when mixed with a fuel oil will kill all vegetation. There is
considerable use for this type of a herbicide where it is desired to
control all top growth. Directions for use are on the labels and should
be followed with care. When contact herbicides are used it should be
remembered that the effect on perennial roots is essentially the same
as that accomplished by one mowing or tillage operation.

• PCP is a popular wood preservative. It is used as a fortifying agent
to increase the toxicity of oil sprays when used for non-selective weed-
ing. It is soluble in certain oils. It is not soluble in water, therefore,
must be used as an oil spray or emulsion. Pentachlorophenol is used
primarily as a contact type weed killer.
BORON COMPOUNDS

There are a number of different compounds of boron used as herbicides. These materials are salts of boron such as calcium borate, sodium tetraborate, or sodium metaphosphate. The borate salts, commonly used as herbicides, vary all the way from being extremely insoluble to fairly soluble in water. All of these materials have fire retardant properties.

When applied to the soil boron compounds are lost slowly through leaching. They act slowly in killing the plants, but the method by which they kill is not known.

Boron compounds have only a slight toxicity toward animals but they should not be used carelessly.

Compounds containing boron are widely used as soil sterilants. The most widespread use at the present time is in combination with sodium chlorate for use around industrial sites, along roadways, and other places where the elimination of all vegetation for a year or more is desirable. The use of boron is widespread as a means of reducing the fire hazard that is inherent in sodium chlorate. There are several mixtures of boron and sodium chlorate on the market in which the percentage of the two compounds varies in relation to each other. Recently boron combined with 2,4-D and other organic herbicides has been placed on the market for spot treatment to control deep-rooted perennial plants.

CARBAMATE HERBICIDES.

The carbamate herbicides are a class of herbicides showing varying properties. They may range from waxy solids to liquids depending on the nature of the chemical and its purity. The carbamate herbicides are usually slightly soluble in water, seldom above 200 parts per million. These chemicals are esters and as such have the usual ester characteristic being somewhat oily or waxy in nature and possess a reasonable volatility. Also by virtue of their chemical makeup, these compounds seldom have a long residual life in soil.

Among the better known members of this class of herbi-
ICIDES ARE IPC AND CIPC. IN RECENT YEARS HOWEVER, A NUMBER OF OTHER CARBAMATES HAVE BEEN INTRODUCED AND ARE FINDING USE AS WEED KILLERS. AMONG THEM ARE THE CARBAMATES KNOWN AS BARBAN WHICH IS ONE OF THE FEW CARBAMATES THAT HAS FOLIAR ACTIVITY, BIPC AND ONE OR TWO OTHER SOIL ACTIVE CARBAMATES.

IPC, CIPC AND OTHER CARBAMATES DEPEND FOR THEIR EFFECTIVENESS UPON THEIR RESIDUAL LIFE IN THE SOIL. BREAKDOWN OF THESE CHEMICALS BY MICROORGANISMS IN THE SOIL, LEACHING BY WATER, AND VAPORIZATION ALL CONTRIBUTE TO THE LOSS OF THE CHEMICAL FROM THE SOIL. CIPC HAS THE LONGEST RESIDUAL EFFECT, BUT IT ALSO APPEARS TO BE ONE OF THE LESS SELECTIVE CARBAMATES.

THE CARBAMATES KILL PLANTS BY INTERFERING WITH CERTAIN KEY PROCESSES ESSENTIAL TO THE LIFE OF THE PLANT AND BY INHIBITING THE GROWTH AND DEVELOPMENT OF THE PLANT. THESE CHEMICALS ARE NOT VERY READILY ABSORBED OR TRANSLOCATED BY MOST PLANTS SO THAT CERTAIN TYPES OF APPLICATION AND FORMULATION ARE NECESSARY TO ACHIEVE GREATEST EFFECTIVENESS WITH THE MATERIALS.

THE CARBAMATES MAY BE FORMULATED AS PELLETS, WETTABLE POWDERS, OR EMULSIFIABLE CONCENTRATES. THE WETTABLE POWDER FORMULATION WAS ONE OF THE EARLY ONES THAT WAS USED. SINCE IT IS MORE CONVENIENT TO USE EMULSIFIABLE CONCENTRATES, CONSIDERABLE ATTENTION HAS BEEN DEVOTED TO DEVELOPMENT OF SUITABLE EMULSIFIABLE CONCENTRATES OF IPC AND CIPC. THE EMULSIFIABLE CONCENTRATES OF CIPC, FOR THE MOST PART GIVE NO TROUBLE IN USE. THE EMULSIFIABLE CONCENTRATES OF IPC, HOWEVER, FREQUENTLY GIVE TROUBLE, PARTICULARLY IN WATER-OIL MIXES. THE DIFFICULTY HERE IS THAT THE IPC FORMS VERY FINE CRYSTALS WHICH TEND TO PLUG THE SPRAY RIG. FREQUENTLY, THIS DIFFICULTY ARISES FROM ATTEMPTING TO GET TOO MUCH IPC IN THE ORIGINAL CONCENTRATE. THESE CONCENTRATES ARE BEING IMPROVED ALL THE TIME SO THAT IT NOW IS POSSIBLE TO GET CONCENTRATES WHICH CAUSE NO DIFFICULTY IN SPRAYING.

THE CARBAMATES ARE NOT CONSIDERED HIGHLY TOXIC BUT SHOULD BE HANDLED WITH CARE.

IPC IS USED TO KILL WEEDY ANNUAL GRASSES IN CERTAIN PERENNIAL CROPS SUCH AS CHEWINGS FESCUE AND CREEPING RED
FESCUE. It can be used for this purpose on many of the grass seed crops. It is normally applied in the fall, usually during October, for this purpose. It is also used to control weedy grasses in certain legume crops such as alfalfa, clover and lotus.

It is used in the areas producing peas to control wild oats. In the dry areas such as the Columbia Basin it is normally applied and tilled into the soil prior to the planting of peas. IPC is used to control chickweed and annual grasses as dormant applications in strawberries and caneberrries. Pre-emergence treatments of IPC in combination with the dinitro compounds control many weeds in the bulb crops such as croft lily.

CIPC has been used for many of the same purposes as IPC but it lasts longer in the soil and is generally effective on a wider range of grass and broad-leaved species. It is effective against most germinating grasses and many broad leaves. Its most widespread use has been on grass seed crops. It is applied in the early fall. It may also be used on some of the perennial legume crops, such as red clover, alfalfa and lotus, much the same way as IPC. It is not used on strawberries or peas due to injury to these crops. Caneberrries and bulb crops, however, seem to be tolerant to CIPC.

Barban is unusual among the carbamates because of its activity in foliar application. This chemical has proven to be particularly effective against wild oats. Fortunately certain of the cereals are tolerant of the chemical if applied at the right time. Barban is used then at low rates of application for selective control of wild oats in cereals.

Thiolcarbamates

The thiolcarbamates are carbamates that have had sulfur introduced in place of one of the oxygen atoms of the carbamate series. The thiolcarbamates that are perhaps most familiar to the readers are EPTC (Eptam) and DATC (Avadex) which are alkyl-substituted thiolcarbamates. These compounds differ from such carbamates as IPC and CIPC not only in having sulfur in the molecule but where IPC has a benzene ring, EPTC has straight chain
ALKYL. Other members of the thiolcarbamate series include Tillam and Avedex BW which contains one more chlorine atom then DATC.

The thiolcarbamates for the most part are very low melting solids or liquids at room temperature. They have a low solubility in water and tend to be quite volatile. For this reason best results are obtained with these materials by incorporating them into the soil.

EPTC and related compounds find wide use for pre-planting weed control for wide variety of crops. In addition, EPTC has been found effective for the control of certain perennial weeds such as nutgrass when used at sufficiently high rates.

DATC (Avedex) or Avedex BW are effective for the control of wild oats. Proper use permits them to be employed as a selective treatment on several crops including certain of the cereals.

UREA HERBICIDES

MONURON, (3(3 chlorophenyl) 1:1 dimethyl urea) and (3(3, 4 dichlorophenyl) 1:1 dimethyl urea). This material is a white crystalline powder with an extremely low solubility in water. The product is so insoluble in most solvents that it is most easily formulated as pellets or wettable powders. Attempts have been made to prepare suspensions and pastes of this material, but these have had no more success than the wettable powders.

Monuron is slowly destroyed by micro-organisms and is lost from the soil only slowly by leaching and by volatilization. There appears to be some indication that at high temperatures monuron will steam-distill or volatilize from the surface of the soil. This product is quite long lasting in the soil but the length of time a treatment will last depends upon the type of soil, the amount of rainfall and the temperature. Monuron has a longer residual life in heavier soil but is less effective initially than in a light sandy soil. High rainfall tends to shorten the residual life, as does high temperature.
Monuron and other urea herbicides are absorbed or "tied up" by the soil. It is clay (colloid) fraction and organic matter of the soil that does this. This "tying up" of the monuron appears to reduce its effectiveness depending on how tightly it is bound. As a soil gets heavier (higher in clay) and particularly as the organic matter increases, the effectiveness of the urea herbicides decreases. The presence of large quantities of charcoal, partially decomposed sawdust or crop residues may render a treatment nearly ineffective.

Monuron is translocated in the plant either from the roots to the top or from the leaves into the plant. The action of the chemical is slow with no visible symptoms appearing for a number of days after application. In contrast to 2,4-D, monuron is only slowly broken down by the plant. The exact plant processes that are disturbed by monuron are not definitely known. It is safe to say, however, that this chemical exerts a systemic action on the plant as contrasted to quick acting contact killers such as oils.

Monuron has a low animal toxicity, being even less toxic than 2,4-D.

This material has been most widely used as a soil sterilant, particularly for the control of grasses. It is used to give a year or more control of most perennial and annual grasses. It is effective against most annual broadleaf species and will control many perennial broadleaf species. It does not give complete control of deep rooted perennial broadleaf species so it is used in combination with 2,4-D. Low rates of monuron have been used successfully for annual weed control in asparagus and some bulb crops.

Diuron. Diuron is very closely related to monuron. This material is even less soluble in water than monuron, and has a longer residual life in the soil.

Like monuron this material is broken down by microorganisms in the soil and may be lost by leaching. The low water solubility and slow leaching contribute in part to the greater selectivity of diuron when used at low dosages.
The urea herbicides are finding considerable use as selective and pre-emergent herbicides for certain crops at low dosages. Since the materials are relatively long lasting as sterilants, it is natural that some concern might be felt about building up a toxic residue in the soil upon prolonged use of the material. At the present time it appears that the micro-organisms of the soil are capable of destroying sufficient amounts of the material that this should not be too much of a problem.

Because this material is less soluble, it has been used as a soil sterilant in areas where there is high rainfall. It gives the same type of sterilant action as monuron. It will last longer under high rainfall conditions, particularly on light soil types. It also is normally used with 2,4-D.

Low rates of Karmex DW are being used to control weedy annual grasses and broad-leaved weeds in perennial grass seed crops such as alta fescue, red fescue, Merion bluegrass, and bentgrass. It is also used on bentgrass and similar grass seed crops to control velvet grass (mesquite). It shows promise for selective use on a number of perennial crops such as caneberries and asparagus, pre-emergence and post-emergence applications to some bulbs also appear promising.

Fenuron. Fenuron is one of the most soluble of the ureas and is therefore highly active on a wide range of soil types. Fenuron has proven particularly useful in certain instances for control of brushy plants. Fenuron does not have the soil persistence of either monuron or diuron.

Linuron. Linuron has shown some very promising uses for pre-emergence weed control in crops and as an agent for weed control in corn. At higher rates it has also proven useful for control of certain grassy weeds.

Other Ureas. A number of other urea herbicides are being developed for a wide variety of crop use and specific control of specific weeds. Neburon, for example has found use for weed control in ornamental plantings and certain of the other ureas (e.g. cycluron, tenuron) have shown indication of considerable usefulness for con-
TROL OF WEEDS IN CERTAIN CROPS.

ENDOTHAL (Disodium 3,6 endoxy hexahydrophtHALATE)

Endothal is a water-soluble contact spray. In the pure state, Endothal is a white crystalline powder, but in the manufacturing process it is difficult to separate this material from water. The formulated product is put out as a liquid formulation or a spray-dry powder containing 40% active ingredient plus wetting agent and activator. Endothal breaks down very rapidly in the soil and its effectiveness may be severely limited by rainfall.

Endothal should be handled carefully to avoid exposure to the chemical.

Endothal is used as a pre-harvest contact spray on alfalfa and crimson clover. It has not gained widespread use.

MALEIC HYDRAZIDE (MH)

Maleic hydrazide is a white crystalline material with somewhat acidic properties. The product readily forms salts with diethanolamine or forms a sodium salt with sodium hydroxide or lye. The diethanolamine salt of maleic hydrazide is usually offered as a liquid formulation, whereas the sodium salt is available as a white water-soluble powder.

Maleic hydrazide, while somewhat phytotoxic, appears most effective as a growth inhibitor and anti-auxin. It is absorbed by the plant leaf and translocated. It severely stunts or inhibits growing tips and shoots and consequently has been used frequently as a sprout inhibitor on potatoes. Maleic hydrazide is not compatible with copper, calcium, magnesium, and other metals.

Maleic hydrazide appears to have a reasonable margin of safety so far as its toxicity is concerned, but until more is known about it, it should be handled with some caution.

This material has been used to a limited extent for suppressing vegetation along roadways in certain sections.
OF THE COUNTRY. IT HAS ALSO BEEN USED FOR THE CONTROL OF QUACKGRASS WHEN APPLIED AT HEAVY RATES AND TURNED UNDER SHORTLY AFTER TREATMENT.

IT HAS BEEN USED FOR SPROUT INHIBITION IN ONIONS AND POTATOES AT VERY LOW RATES.
TRIAZINE HERBICIDES

The triazine herbicides are a rather large group of herbicides of slightly differing structures. There are three major groups of the triazines namely, the chlorotriazines as represented by simazine and atrazine, the methoxytriazines such as prometone and the methylmercapto triazines such as prometryne. The different groups of triazines, although having certain properties in common, differ slightly in their physical and chemical properties and in the weeds that they will control or the crops toward which they are selective.

The triazines by and large are relatively low in water solubility and are therefore somewhat resistant to leaching. Water is usually required to carry enough of the triazine into the soil where it can become active against germinating seed or young seedling weeds; however, the triazines for the most part are absorbed by soil and in general the lower the solubility of the triazine the more tightly it appears to be bound.

Thus the triazines in general are more active on light sandy soils than they are on heavy clays and organic soils. There is sufficient difference in water solubility and soil behavior between the triazines that a wide range of activity on different soil types may be obtained by selecting different members of this class of herbicide.

Selectivity on the part of the triazines appears to be due at least in part to the ability of tolerant plants to metabolize the chemical, thus rendering it non-toxic. A classical example of this is the tolerance of corn to the triazines whereas most other grasses have varying susceptibility to them. The tolerance has been shown to be due in large measure to the ability of the corn plant to metabolize the triazine. However, corn is varyingly tolerant to the different classes of triazines, having the highest tolerance to the chlorotriazines and much less tolerance to the methoxy and methylmercapto triazines.

SIMAZINE, ATRAZINE AND PROPAZINE

These three compounds are three widely used members of
THE CHLOROTRIAZINE GROUP, THEY ENJOY USE AS SOIL STERILANTS (PARTICULARLY SIMAZINE AND ATRAZINE) AT RATES OF 10 TO 40 POUNDS PER ACRE AS PRE-EMERGENCE HERBICIDES ON CROPS SUCH AS CORN AND SORGHUM AND FOR SELECTIVE WEED CONTROL IN PERENNIAL CROPS SUCH AS STRAWBERRIES, CANEBERRIES AND ORCHARDS. SIMAZINE, THE MEMBER OF THE GROUP HAVING THE LOWEST SOLUBILITY, IS MOST ACTIVE ON SANDY SOILS AND ON HIGH RAINFALL CONDITIONS. ATRAZINE AND PROPAZINE MAY BE USED ON SLIGHTLY HEAVIER SOILS AND UNDER LIGHTER RAINFALL CONDITIONS.

PROMETONE

PROMETONE IS A REPRESENTATIVE OF THE METHOXY GROUP OF TRIAZINES. BECAUSE OF ITS PROPERTIES IT HAS CONSIDERABLY MORE FOLIAR ACTIVITY OR CONTACT ACTIVITY THAN THE CHLOROTRIAZINES AND A DIFFERENT SPECTRUM OF WEEDS THAT IT WILL CONTROL AND CROPS THAT SHOW AT LEAST SLIGHT TOLERANCE TOWARD IT. PROMETONE IS CONSIDERABLY MORE VOLATILE FROM SURFACES THAN THE CHLOROTRIAZINES BUT STILL IS BOUND QUITE STRONGLY BY SOIL.

PROMETRYNE

PROMETRYNE IS A REPRESENTATIVE OF THE METHYLMERCAPTO TRIAZINES AND SHOWS EVEN DIFFERENT SELECTIVE PROPERTIES THAN THE CHLOROTRIAZINES AND THE METHOXYTRIAZINES. CARROTS, FOR EXAMPLE, ARE QUITE TOLERANT TO THIS MATERIAL.

TRIFLURALIN

TRIFLURALIN IS A LOW MELTING SOLID WHICH HAS BEEN RECENTLY INTRODUCED FOR WEED CONTROL. IT HAS A SOLUBILITY OF 24 PARTS PER MILLION IN WATER AND APPRECIABLE VOLATILITY. TRIFLURALIN IS A SOIL ACTIVE COMPOUND THAT REQUIRES EITHER WATER TO LEACH IT INTO THE SOIL OR MECHANICAL INCORPORATION TO OBTAIN MAXIMUM ACTIVITY. TRIFLURALIN IS COMPARATIVELY SLOWLY LEACHED AND HAS A FAIR PERSISTENCE IN SOIL.

TRIFLURALIN IS USED FOR THE CONTROL OF WEEDY ANNUAL GRASSES SUCH AS CRABGRASS IN TURF AND HAS PROVEN EFFECTIVE AS A PRE-EMERGENCE WEED CONTROL TREATMENT FOR A NUMBER OF VEGETABLE AND ROW CROPS.
TCA AND RELATED COMPOUNDS (sodium TCA, sodium MCA)

These materials are very soluble in water which is sometimes a disadvantage under conditions of high rainfall. The common form of TCA used for weed control is the sodium salt. This is a solid material that "draws" moisture rapidly. Sodium TCA breaks down in solution and should not be permitted to stand in solution for any length of time before application.

TCA is toxic to man and animals and should be handled carefully. Once applied to plant foliage, the chemical is usually sufficiently well diluted that not too much poisoning hazard is present. In the concentrated spray solution, however, the material can be dangerous and may cause blisters of the skin upon long exposure.

TCA has been most widely used for the non-selective control of quackgrass and similar deep-rooted perennial grasses through the use of heavy rates. It has also been used at low dosage to control grass type weeds in sugar beets and flax.

DALAPON

Dalapon is the sodium salt of dichloropropionic acid. The parent acid is a liquid of strongly acid properties and is freely soluble in water. Dalapon is also very soluble in water. The solution may be slightly acid to neutral.

A water solution of Dalapon will break down on standing, particularly when warm or exposed to light. The material once mixed should be used within one or two days.

Dalapon appears to be absorbed and translocated by grasses. Its killing action seems to be systemic in contrast to the contact action of TCA.

It is not highly toxic but continued skin exposure can result in some irritation.

Dalapon is largely an experimental material that is finding use for the control of quackgrass and other perennial grasses. It is also used for the control of annual
GRASS TYPE WEEDS IN CROPS SUCH AS SUGAR BEETS. IT MAY HAVE WIDESPREAD USE FOR CONTROL FOR ANNUAL AND PERENNIAL GRASSES ALONG DITCH BANKS, ROADWAYS, AND OTHER AREAS IN WHICH THEIR ELIMINATION IS DESIRABLE. IT ALSO MAY BE USED WIDELY FOR CONTROL OF PERENNIAL GRASSES ON AGRICULTURAL LAND. IT MAY HAVE SELECTIVE USES IN CERTAIN CROPS.

AMINO TRIAZOLE (3 AMINO, 1, 2, 4-TRIAZOLE; AMITROLE)

Amino triazole is a white to gray crystalline material soluble in water. A solution of this material has a slightly acidic reaction. It is strongly absorbed by soil.

Amino triazole may be offered as a herbicide either as a technical grade material (80 per cent or as a 50 percent product). Either one dissolves in water with mixing.

This material has a unique action on plants in that it turns them white. It is absorbed and translocated by the plant. Amino triazole has a systemic, that is, a general slow action on plants. It appears to be a highly effective herbicide for many plants.

In connection with the use of this material, it should be remembered that it is effective in quite small amounts. Accordingly in the application one should avoid drift of the material on susceptible plants.

Amino triazole forms salts with acidic materials. Some of these, such as with Dalapon, are reported to be more effective on certain plants than amino triazole alone.

This material has been used as an additive to cotton defoliants. Uses are for non-selective control of certain deep-rooted perennial weeds such as Canada thistle and horsetail rush. It may also be used as a non-selective spray along ditch banks and roadways to eliminate vegetation. It affects both grass and broadleaf type weeds. It has shown considerable promise for the control of quackgrass and similar perennial grasses.

URACIL WEED KILLERS

The uracil weed killers are a new class of chemicals
that have been introduced. These compounds show very high activity on a wide range of plants. To date, the uracils appear to have the most promise as soil sterilants, although a few instances of selective use appear possible. The uracils represented by the compounds given the trade name Hyvar and Hyvar X (bromocil and isocil) are crystalline substances having water solubilities in the order of 0.2 percent in water. They may also be formulated in a manner to bring about complete solubility of the uracils which makes them more mobile in leaching than either the triazines or the ureas also used for soil sterilization.

The uracils are generally less seriously affected by soil type, that is heavy clay and organic soil, than are the urea herbicides or the triazine herbicides. The uracils have approximately the same persistence as the ureas and triazines when used at soil sterilization rates.

Aminotrichloropicolinic Acid (Tordon)

Tordon is the trade name of a new compound, aminotrichloropicolinic acid, that is showing considerable promise for controlling many hard to kill broad-leaved plants. Rates of as little as $\frac{1}{4}$ to 2 pounds per acre have given good initial control of deep rooted perennial weeds such as Canada thistle and many hard to kill brushy plants.

The parent compound is a solid material melting above $200^\circ$ C and having very low solubility in water. It is readily formulated as a salt however to give a water soluble preparation that is highly active either in foliar application or through the soil. This chemical has an appreciable residual life in soil which is a factor to be considered because of the high activity of the chemical. Moreover because of the high foliar activity of this chemical, drift too, toward nearby susceptible plants must be avoided.
NEMATOCIDES

Considerable progress has been made toward the control of plant diseases produced by nematodes (eelworms, thread – or roundworms) with the use of nematocides. An important method of control is the application of certain chemicals to the soil.

A continuous search for chemical compounds with nematocidal properties has resulted in only a few standard treatments. The similar behavior of present day nematocides are usually marketed and applied to the soil in a liquid form. The toxic action is dependent upon the volatilization and dispersion of the material within the soil.

Growers who intend to use nematocides are cautioned to read the manufacturer's recommendations very carefully. Volatilization of these materials produces vapors which are generally harmful to man. A prolonged exposure may produce severe symptoms, occasionally death. Some nematocides are absorbed directly through the skin. The danger from continuous breathing or absorption through the skin is considerably less in the field where there is free movement of air. Serious burns have resulted from material carelessly splashed upon the shoes or clothing and allowed to remain throughout the day. Nematocides are able to penetrate through leather and ordinary clothing. Injury is more likely to occur on areas of the body where there is little or no air circulation.

Other precautions for the general use of nematocides are: the observation of proper time interval between treatment and planting due to the phyto-toxic nature of these materials; and a proper cleaning procedure to avoid excessive corrosion to application machinery.

In spite of many hazards, nematocides are safely applied to thousands of acres each year. Some materials are also used in greenhouse soils, flower beds and home gardens. Nematocides are used most effectively in good seedbeds relatively free from unrotted organic material. The time of treatment, dosage, and depth of application are important factors to consider in relation to the soil type, temperature, and moisture content of the soil.

The following common materials or mixtures contain—
ING THEM ARE SUPPLIED BY VARIOUS COMPANIES UNDER NUMEROUS TRADE NAMES:

DICHLOROPROPANE—DICHLOROPROPENE
DIBROMOCHLOROPROPANE
ETHYLENE DIBROMIDE
METHYL BROMIDE
TRICHLORONITROMETHANE (CHLOROPICRIN)

RODENTICIDES

Rodenticides are chemical materials that are used to kill rodents and other small mammal pests. Most of these materials are poisons and must be handled carefully to avoid endangering livestock, poultry and human lives. Several new and highly effective materials have been developed during the past few years, particularly for the control of rats and house mice. Others are being tested in both field and laboratory and may soon be available for use.

To date, no single chemical poison has been found that will meet all requirements at all times and under all conditions. Several are quite effective but most have one shortcoming or another. A rodent control operator should be familiar with the characteristics of all of the poisoned bait materials he uses as well as the habits and characteristics of the animals he is attempting to control.

Not all animals react alike. Even within the same species some individuals are considerably more resistant to poisoned baits than others. Toxic effects of the various poisoned bait materials vary with seasons, diet, age and even sex of the animals involved. Dosage levels are calculated to include most of these resistant animals in the kill. Thus the theory that if one pound is good two pounds should be better is not only false but expensive. Such a practice not only increases costs but also greatly increases the hazard to other animals and often results in poor bait acceptance and thus poor control of the rodent.

The most widely used rodenticides today, particularly for controlling rats and mice, are those known as the anti-
Coagulant rodenticides. Baits which include anticoagulants differ radically from the conventional "single dose" poisoned baits in that they are cumulative in effect. Relatively low dosages taken repeatedly at daily or two-day intervals during a period of 5 to 15 days are fatal to rodents, although a single dose in the same total amount may produce no signs of toxicity. While there are specific chemical differences in the anticoagulant rodenticides now most commonly used, all are similar in results attained and are generally fatal to Norway rats, roof rats, and house mice after several feedings on baits containing 0.025% of the chemical. Anticoagulant baits are not as yet generally used for controlling field rodents, rabbits, or moles. Single dose poisoned baits are still generally preferred for these rodents.

**Warfarin** 3-(a-acetonylbenzyl)-4-hydroxycoumarin

One of the first, and probably best known, of the anticoagulant rodenticides, was introduced by the Wisconsin Alumni Research Foundation and given the coined name "warfarin". It is a stable, odorless, tasteless chemical and has been in general use since 1950. It has received wide acceptance by the general public as well as professionals in rodent control. As with other anticoagulants, warfarin is cumulative in effect and rats and mice must feed on warfarin baits several times during a 5 to 15-day period to acquire a lethal dose. Death results from general internal hemorrhage within this period. Rodents apparently do not associate the effects of internal bleeding with the bait materials containing warfarin and thus continue to feed on properly prepared baits even after the symptoms of poisoning are evident.

Thus the problem of bait shyness or poor bait acceptance is overcome and at the same time the hazard to other animals is greatly reduced. Properly placed baits containing warfarin are not considered dangerous to children, household pets or farm animals, because a single accidental feeding would not be fatal.

Recommended bait mixtures for rats and mice include one part commercial grade warfarin (0.5%) mixed with 19 parts bait by weight. This mixture results in a ready
TO-USE BAIT TESTING 0.025 % WARFARIN ON A DRY SUBSTANCE BASIS. RECOMMENDED BAIT MATERIALS INCLUDE YELLOW CORN MEAL, ROLLED OATS, ROLLED BARLEY, CHICKEN MASH AND OTHER SIMILAR DRY CEREAL-TYPE FEEDS. SINCE REPEATED FEEDINGS ARE REQUIRED, PERMANENT COVERED BAIT STATIONS ARE THE MOST SATISFACTORY FOR EXPOSING BAITS.

THE ANTIDOTE FOR WARFARIN POISONING INCLUDES WHOLE BLOOD TRANSFUSIONS COMBINED WITH INTRAVENOUS INJECTIONS AND ORAL DOSES OF VITAMIN K AS IN THE CASE OF HEMORRHAGE CAUSED BY OVERDOSES OF DICUMAROL.

WARFACIDE IS A CONCENTRATE OF SODIUM SALT OF WARFARIN AND IS WATER-SOLUBLE. IT IS GENERALLY PACKAGED IN SMALL PLASTIC CONTAINERS CONTAINING THE PROPER AMOUNT OF THE CHEMICAL TO MIX WITH ONE QUART OF WATER. CHICK WATERING FOUNTS WHICH FIT ONE QUART JARS ARE FREQUENTLY USED AS DISPENSERS FOR THIS WATER-SOLUBLE FORM OF WARFARIN.

PROLIN (WARFARIN PLUS SULFAQUINOXALINE)

PROBABLY THE NEWEST IN THE ANTICOAGULANT GROUP HAS JUST BEEN INTRODUCED BY THE WISCONSIN ALUMNI FOUNDATION AND GIVEN THE TRADE MARK "PROLIN". THIS NEW RODENTICIDE IS WARFARIN WITH THE ANTIBACTERIAL AGENT N1-2QUINOXALYSULFANILAMIDE (SULFAQUINOXALINE) ADDED AND IS REPORTED TO BE SOMEWHAT MORE EFFECTIVE THAN WARFARIN FOR CONTROLLING RATS AND MICE. VITAMIN K, THE ANTIDOTE FOR ANTICOAGULANT POISONING, IS SOMETIMES INGESTED BY RODENTS IN THEIR NORMAL FEEDING ACTIVITIES. ALSO, SUBSTANTIAL AMOUNTS OF THIS VITAMIN ARE REPORTED TO BE PRODUCED BY CERTAIN BACTERIA IN THE DIGESTIVE TRACT OF RATS AND MICE. PROLIN CONTAINS THE ANTIBACTERIAL AGENT, SULFAQUINOXALINE, WHICH REDUCES THE EFFICIENCY OF THE VITAMIN K-PRODUCING BACTERIA IN THE INTESTINAL TRACT OF THE RODENT. THIS MAKES THE ANTICOAGULANT EFFECT OF THE WARFARIN MORE EFFICIENT, THUS ASSURING BETTER CONTROL.

TESTS HAVE SHOWN THAT SINGLE DOSES OF PROLIN BAIT ARE NO MORE HAZARDOUS TO PETS OR OTHER ANIMALS THAN ARE SINGLE DOSES OF WARFARIN ALONE.

PIVAL 2 PIVALYL-1, 3-INDANDIONE

THIS CHEMICAL, A PRODUCT OF MOTOMCO, INC., IS AN
INDANDIONE DERIVATIVE AND IS NOT RELATED CHEMICALLY TO THE 4-HYDROXOCUMARIN GROUP WHICH INCLUDES WARFARIN AND COUMACHLOR. FIRST PREPARED AND TESTED AS AN INSECTICIDE, IT WAS LATER FOUND TO POSSESS ANTICOAGULANT PROPERTIES WHICH SUGGESTED ITS USE AS A RODENTICIDE. PIVAL IS QUITE SIMILAR TO WARFARIN IN ITS OVERALL EFFECT ON RODENTS. IT IS MIXED WITH SIMILAR CEREAL-TYPE BAITS AND SHOULD BE EXPOSED IN BAIT BOXES WHICH PERMIT REPEATED FEEDINGS. IT REQUIRES APPROXIMATELY THE SAME LENGTH OF TIME TO KILL THE RODENT. "PIVAL" BAITS HAVE SHOWN SOME RESISTANCE TO FUNGUS AND INSECT INFESTATION WHICH WARFARIN AND COUMACHLOR HAVE NOT SHOWN.

PIVALYN IS THE WATER SOLUBLE CONCENTRATE OF PIVAL ALSO AVAILABLE FROM MOTOMCO, INC. IN GRAIN ELEVATORS, WAREHOUSES AND OTHER SITUATIONS WHERE FOOD IS VARIED AND ABUNDANT IT HAS OFTEN BEEN FOUND ADVANTAGEOUS AND MORE EFFECTIVE TO USE WATER BAITS. NEITHER WARFARIN NOR PIVAL ARE WATER SOLUBLE BUT THE SODIUM SALTS OF EACH RETAIN THE RODENTICIDAL CHARACTERISTICS AND ARE WATER SOLUBLE. WATER BAITS GIVE BEST RESULTS UNDER CONDITIONS WHERE OTHER SOURCES OF WATER ARE LIMITED SUCH AS DURING THE DRY SUMMER MONTHS OR IN GRAIN AND FEED STORAGE AREAS,

DIPACINONE 2-DIPHENYL-ACETYL-1, 3-INDANDIONE

THIS ANTICOAGULANT, SOLD UNDER THE TRADE NAME DIPHACIN-110, IS SIMILAR TO THE OTHERS IN MOST RESPECTS. LIKE THE OTHER ANTICOAGULANTS, IT IS MIXED 1 TO 19 WITH A SUITABLE BAIT MATERIAL. THE FINISHED BAIT WILL THEN HAVE A CONCENTRATION OF .005% DIPACINONE. THERE IS SOME INDICATION THAT DIPACINONE MAY BE MORE TOXIC ON A SINGLE DOSE BASIS THAN OTHER ANTICOAGULANT RODENTICIDES CURRENTLY IN USE. CHEMISTS FROM THE UPJOHN COMPANY, KALAMAZOO, MICHIGAN REPORT THAT THE ACUTE ORAL LD$_{50}$ FOR DIPACINONE WAS FOUND TO BE 3 MG/KG FOR RATS AND 340 MG/KG FOR MICE. TOXICITY STUDIES INDICATE THE HAZARDS INVOLVED FROM USING DIPACINONE AS A RODENTICIDE ARE LIMITED. THE ANTIDOTE IS THE SAME AS FOR OTHER ANTICOAGULANTS,

COUMACHLOR

COUMACHLOR, A DERIVATIVE OF WARFARIN, WAS DEVELOPED IN SWITZERLAND AND HAS BEEN DISTRIBUTED THERE AND IN OTHER EUROPEAN COUNTRIES AS A "TRACKING POISON" UNDER THE TRADE-
NAME "TOMORIN". THIS MATERIAL HAS BEEN TESTED IN THE UNITED STATES BY THE U. S. FISH AND WILDLIFE SERVICE BUT TO DATE HAS NOT BEEN MARKETED IN THE UNITED STATES.

FUMARIN

FUMARIN IS STILL ANOTHER COMPOUND OF THE 4-HYDROXY-COUMARIN GROUP. IT WAS FIRST MADE IN GERMANY, BUT HAS BEEN TESTED IN THE UNITED STATES AND FOUND TO BE PROMISING AS A RODENTICIDE. FUMARIN HAS BEEN APPROVED BY THE DEPARTMENT OF AGRICULTURE. IT IS DISTRIBUTED AS A 0.5 PERCENT FORMULATION UNDER THE TRADE-NAME "RATAFIN-22".

PMP

PMP AND PNP-P ARE WATER SOLUBLE SODIUM SALTS OF 2-SUBSTITUTED -1, 3-INDANDIONE AND HAVE BEEN TESTED EXPERIMENTALLY AS RAT AND MOUSE CONTROL AGENTS. THESE ARE ANTICOAGULANTS SIMILAR TO PIVAL BUT ARE NOT GENERALLY IN USE TODAY.

OTHER POISONS

WHILE THE ANTICOAGULANTS HAVE BEEN IN GENERAL USAGE ONLY SINCE 1950, THEY HAVE ALMOST REPLACED THE CONVENTIONAL SINGLE DOSE POISONS FOR CONTROLLING NORWAY RATS, BLACK AND ROOF RATS, AND HOUSE MICE. IN ADDITION TO THOSE MENTIONED ABOVE STILL OTHERS ARE BEING DEVELOPED, IMPROVED AND TESTED AND MAY EVENTUALLY FIND A USEFUL PLACE IN THE RODENT CONTROL PICTURE. HOWEVER, FOR CONTROLLING FIELD RODENTS SUCH AS POCKET GOPHERS, MOLES, GROUND SQUIRRELS, AND SIMILAR PESTS, WE CONTINUE TO RELY ON SUCH WELL KNOWN MATERIALS AS STRYCHNINE, THALLIUM, AND ZINC PHOSPHIDE. OTHER POISONS INCLUDING RED SQUILL, ANTU, COMPOUND 1080, AND SOME OF THE ARSENIC COMPOUNDS ARE ALSO USED, PARTICULARLY IN RAT AND MOUSE CONTROL, AND THEREFORE SHOULD BE GIVEN SOME CONSIDERATION.

WARFARIN, PIVAL, RED SQUILL, STRYCHNINE, ZINC PHOSPHIDE, AND THALLIUM SULPHATE ARE THE RODENTICIDES MOST FREQUENTLY RECOMMENDED FOR USE BY THE GENERAL PUBLIC. BAITS CONTAINING THESE RODENTICIDES ARE USUALLY AVAILABLE COMMERCIALY IN THE FORM OF READY-TO-USE BAITS.

RED SQUILL

RED SQUILL IS STILL CONSIDERED TO BE ONE OF THE SAFEST
RODENTICIDES TO USE PARTICULARLY WHERE THERE IS SOME DANGER THAT LIVESTOCK, PETS, POULTRY OR OTHER FORMS MIGHT HAVE ACCESS TO THE BAIT MATERIAL. DUE TO ITS EMETIC ACTION IT IS NOT CONSIDERED HARMFUL TO ANY ANIMAL CAPABLE OF VOMITING. SINCE IT IS GENERALLY MIXED AT THE RATIO OF ONE PART SQUILL TO NINE PARTS BAIT, BY WEIGHT, THE BITTER TASTE IS OBJECTIONABLE TO MAN AND MANY DOMESTIC ANIMALS AS PROVIDING AN ADDITIONAL SAFETY FACTOR. IT IS GENERALLY RECOMMENDED ONLY FOR THE CONTROL OF BROWN OR NORWAY RATS. NEITHER ROOF RATS NOR HOUSE MICE ARE CONTROLLED EFFECTIVELY WITH IT DUE TO POOR ACCEPTANCE OF SQUILL BAITS. THE MOST EFFECTIVE USE OF RED SQUILL IS FOR A QUICK REDUCTION OF A HEAVY POPULATION OF RATS BY INTENSIVE BAITING WITH AN ATTRACTIVE BAIT SUCH AS MEAT OR FISH. BAIT SHYNESS DEVELOPS QUICKLY IN RATS EXPERIENCING A SUB-LETHAL DOSE.

STRYCHNINE

STRYCHNINE, PARTICULARLY THE ALKALOID FORM, IS A QUICK ACTING POISON STILL USED EXTENSIVELY FOR CONTROLLING POCKET GOPHERS, GROUND SQUIRRELS, PORCUPINES, MARMOTS, RABBITS, AND A HOST OF OTHER SMALL MAMMAL PESTS. SINCE IT IS NOT SOLUBLE IN WATER, IT IS GENERALLY COATED ON GRAIN BAITS BY USING A THIN STARCH PASTE OR DUSTED ON LEAF AND VEGETABLE BAITS. SINCE IT HAS AN EXTREMELY BITTER TASTE, IT IS EASILY DETECTED AND AVOIDED IN BAITS PREPARED FOR RATS. IT IS THEREFORE NOT RECOMMENDED FOR EITHER BROWN OR ROOF RATS.

ZINC PHOSPHIDE

ZINC PHOSPHIDE IS NOT WIDELY USED OR RECOMMENDED EXCEPT IN THE FORM OF COMMERCIALLY PREPARED BAIT FOR FIELD MOUSE CONTROL. IN ANY OTHER FORM IT IS NOT READILY AVAILABLE TO THE GENERAL PUBLIC. IT HAS A SOMEWHAT PUNGENT ODOR AND AN UNATTRACTIVE BLACK COLOR WHICH TENDS TO CAUSE MOST BIRDS AND ANIMALS TO AVOID IT. RATS AND MICE AND SEVERAL OTHER RODENTS, INCLUDING WILD NUTRIA, SEEM TO TAKE ZINC PHOSPHIDE BAITS READILY.

THALLIUM SULPHATE

THALLIUM SULPHATE IS NOT WIDELY USED OR RECOMMENDED EXCEPT IN THE FORM OF COMMERCIALLY PREPARED BAITS FOR MOLE CONTROL. IN ANY OTHER FORM IT IS NOT READILY AVAIL-
ABLE TO THE GENERAL PUBLIC, PREPARED BAITS CONTAINING 1% THALLIUM SULPHATE HAVE BEEN QUITE SUCCESSFUL FOR CONTROLLING MOLES. AT SUCH LOW LEVELS THESE BAITS ARE CONSIDERED SAFE FOR THE GENERAL PUBLIC TO USE SUBJECT TO THE USUAL PRECAUTIONS AND FOLLOWING THE MANUFACTURER'S DIRECTIONS FOR APPLICATION. PARTICULAR CARE SHOULD BE TAKEN WHEN USING THALLIUM-COATED PEANUTS SINCE THIS FORM OF BAIT IS MORE ATTRACTIVE TO CHILDREN THAN PELLETED OR OTHER FORMS OF BAIT CURRENTLY AVAILABLE.

U.S. Fish and Wildlife Service agents have also used thallium sulphate successfully in the control of starlings. Cull French-fried potatoes and "tater-tots" were dusted with thallium at the rate of 1:400. Birds were found dead at their roosting sites six to eight hours later. No effect of secondary poisoning was evidenced in domestic cats that were fed these poisoned birds.

SODIUM FLUOROACETATE (COMPOUND 1080)

SODIUM FLUOROACETATE, COMMONLY CALLED 1080, IS COLORLESS, ODORLESS, TASTELESS AND EXTREMELY TOXIC TO MAN AND OTHER WARM BLOODED VERTEBRATES. IT IS NOT AVAILABLE TO THE GENERAL PUBLIC AND ITS SALE IS RESTRICTED BY THE MANUFACTURER TO TRAINED PERSONNEL OF GOVERNMENTAL AGENCIES AND EXPERIENCED PEST CONTROL OPERATORS.

ITS TOXIC ACTION IS RAPID AND THERE IS NO KNOWN EFFECTIVE ANTIDOTE. IT HAS AN ESTIMATED ORAL LD 100 FOR CHILDREN OF 2 MG/KG BUT IS CONSIDERED DANGEROUS FOR MAN AT 0.5-2.0 MG/KG. IT AFFECTS THE MYOCARDIUM AND CENTRAL NERVOUS SYSTEM. THERE IS A HIGH HAZARD OF SECONDARY POISONING TO ANY ANIMALS FEEDING ON THE 1080-POISONED ANIMALS.

Ten-eighty is used by trained personnel under carefully supervised situations for controlling rats and certain field rodents though the excellent anticoagulant rodenticides available today make such use generally unnecessary. Fish and Wildlife Service agents use it successfully under carefully supervised conditions for coyote control.

ANTU

ANTU (ALPHA NAPHTYLTHIOUREA) CAN BE MIXED WITH BAIT
MATERIALS OR USED AS A TRACKING POISON FOR BROWN OR NORWAY RATS. IT IS INEFFECTIVE AGAINST ROOF RATS OR HOUSE MICE. IT IS HIGHLY TOXIC TO DOGS, CATS, AND PIGS BUT IS MUCH LESS TOXIC TO OTHER DOMESTIC ANIMALS. SINCE THE DEVELOPMENT OF THE ANTICOAGULANTS WITH THEIR MUCH HIGHER SAFETY FACTOR IT IS SELDOM USED.

INSECTICIDES USED IN RODENT CONTROL

Arsenic trioxide in the micronized form and 50% DDT dust are sometimes used as tracking poisons, particularly for the control of house mice. Care must be taken in their use to insure that no contamination of human or animal foods occurs.

In Washington state endrin sprays have been used for controlling field mice in some orchard areas where heavy cover crops are grown. October and November spraying (after the fruit has been picked) is recommended using 1 quart of endrin emulsion per 100 gallons of water. Spray the cover crop until thoroughly wet. This amounts to 1.2 to 1.4 pounds actual endrin per acre. The heavier the cover crop the more spray needed for coverage. This method is considerably more expensive than controlling with the conventional rodent baits and the hazards are considerably greater. Sprayed cover crops should NEVER be fed to livestock.

Dieldrin, toxaphene, chloradane and certain other insecticides have also been shown to have some beneficial effects in controlling rodents under certain conditions. However, to be effective most of these require that the vegetation be saturated. This in turn presents a distinct hazard to any form of animal life grazing or ranging through the sprayed area. Therefore, until more experimental work is done, these highly toxic insecticides are generally not recommended for rodent control.

REFERENCE

DISEASE PROTECTANTS

One of the common and effective methods for control of certain fungus and bacterial diseases is the proper use of the recommended spray and dust materials on the plants. Spraying a crop affected by root rots; Fusarium yellows of beans, cabbage and celery; Fusarium wilt, blackleg, Rhizoctonia, scab, and leak of potatoes, and many other diseases; or applying sprays and dust at the wrong time, or an insufficient number of timely applications, or poor coverage of the plants is a waste of time and materials, and it is costly.

Fungicide materials are used to protect the plants from infection or further spread of the disease rather than to cure the plant of the disease. Therefore, spraying or dusting should begin at the proper time, employing the recommended materials, and obtaining complete coverage of the plants for the required number of applications for effective control.

Chemical fungicides used to protect fruit crops have always caused some damage to the fruit and foliage. The goal as in weed and insect spraying is to get maximum or satisfactory control with minimum injury. In general, spraying and dusting with fungicidal materials are used for control of blights, mildew, and rusts of crop plants.

**Classes of Fungicides**

Fungicides may be divided into two classes. Protectant fungicides are most generally used in plant disease control practices. These fungicides are applied before the disease is expected to appear and must persist or be maintained by repeat applications throughout the danger period. By their presence invasion of the plant tissue is prevented. These fungicides may be used as sprays or dusts to protect plant foliage or fruits; as seed protectants for grain and vegetables, (seed disinfectants); as a wood or fabric preservative, or in chemotherapy to treat plants to aid in their resistance to disease.

Eradicant fungicides kill by direct action on the fungus at the time of application, causing the death of the fungus or preventing sporulation. Formaldehyde and volatile organic mercury products when applied to seeds, kill the fungi causing smut, blight or scab of cereals and certain diseases of potatoes. Sulfur is used to "burn out" apple scab and powdery mildew infections; sodium dinitro orthocresolate kills the scab fungus in over wintered apple leaves; pentachlorophenol, copper napthenate or creosote oil kills fungi in wood products; copper napthenate (G-4) phenyl mercuric acetate and other chemicals kills...
PART IV

the fungus growing in cloth, canvas, paper, rope, nets, etc.; benzol or paradichlorobenzene will check the growth of the tobacco blue mold fungus.

A given material may be used both as a protectant or an eradicant fungicide, as noted with lime-sulfur solution or phenyl mercuric triethanol ammonium lactate solution in the control of apple scab.

For the sake of economy, it is important for the user to know when it is advisable to apply both insecticides and fungicides in the same spray or dust mixture. This involves not only a knowledge of the proper uses of insecticidal aid fungicidal materials, but of their compatibility. Obviously it would be a mistake to mix materials that would react to form a product injurious to the plants, or that would possess reduced killing power.

Common Spray and Dust Fungicidal

Copper, sulfur and dithiocarbamate are the chemicals commonly used for spray and dust materials for control of certain plant diseases. These materials may be compounded with many other fungicides such as zinc and mercury, or non-fungicidal materials such as iron and hydrated lime, and often with insecticidal materials such as DDT, arsenicals, and nicotine sulfate, and other compatible materials. Furthermore, many manufacturers and growers incorporate spreader and sticker materials in the sprays, and sticker materials in the dusts, to increase the efficiency of the fungicidal materials.

The two oldest and most common materials used in fungicides are copper and sulfur. The coppers are used either as a Bordeaux mixture (includes copper, lime and water) or fixed copper preparations in the form of wettable powders. There are a number of newer materials which are proving their value for particular uses with individual crops and fungus problems. Some of these materials described later are ferbam, nabam, phygon, Tag 331, zineb and ziram.

BORDEAUX MIXTURE: The action of Bordeaux mixture is protective. It should be applied as most fungicides before the period of infection. In other words, its use is to prevent rather than cure. Bordeaux mixture, which is one of the oldest and still one of the most widely used fungicides, is a chemical combination of copper sulfate, lime and water. Freshly prepared Bordeaux mixture contains a gelatinous precipitate that dries on the leaf as a continuous adhesive film.

How the Bordeaux mixture protects the plant against invasion of the fungus is not definitely agreed upon. There is much evidence to show that an acid secretion from the germ tube of a germinating fungus spore brings minute quantities of copper in the protective film into solution, causing death of the protoplasm within the germ tube.
FUNGICIDES

The standard Bordeaux mixture is prepared as a 4-4-50 formula. This means that 4 pounds of copper sulphate (bluestone or blue vitrol) and 4 pounds of lime (freshly slacked quick lime or fresh finely divided hydrated lime) are added simultaneously to 50 gallons of water. Various modifications of this formula, chiefly in terms of reduced copper and increased lime, or a reduction of both ingredients, are recommended for the control of certain fungus diseases, or the reduction of spray injury.

For special purposes a so-called, "Zinc Bordeaux" is used, in which zinc sulphate is substituted for the copper sulphate. This name, however, is generally not acceptable to the Federal Insecticide Division and many state Economic Poison officials, since the word "Bordeaux" refers only to the product derived from the chemical reaction of copper, lime, and water. This fungicide is the more fungitoxic of the copper fungicides and is also very phytotoxic to the tissue of many plants. 187

A satisfactory Bordeaux mixture may be made as follows: Slake the lime and dissolve the bluestone in separate barrels. Fill the spray tank half full of water, add the dissolved bluestone, strain in the slaked lime while the agitator is running, add remainder of water, and mix thoroughly. In order to hasten solution of the bluestone, it should be ground as fine as possible and placed in a sack kept near the top of the water in the barrel. 60

The purpose of the lime in Bordeaux mixture is to prevent plant injury from the copper. Actually, many vegetable plants are sensitive also to the lime. A number of newer fungicides, therefore, are now replacing Bordeaux mixture. Bordeaux mixture is most efficient of the fungicides but it is fully effective only if fresh. If Bordeaux mixture is to be used with oil, add the oil just before the tank is completely filled. Always add the oil last. 168

**FIXED COPPERS:** Much work has been done with the many copper compounds developed for use in place of the old standard Bordeaux mixture, which though hard to excel for effectiveness and persistent protection, leaves a conspicuous deposit and on many crops may injure foliage or fruit, increase moisture loss, accentuate frost damage, delay maturity and lessen yields or fruit size. The need for a copper fungicide without the objections of Bordeaux mixture and the desire of growers for a material which could be applied as a dust has resulted in the development of the fixed or insoluble copper fungicides.

These are the so-called fixed coppers, also known as neutral coppers and insoluble coppers. The fixed, neutral, and insoluble copper compounds include copper oxychlorides, copper oxides, copper hydroxides, basic copper sulphates, basic copper chlorides, and various other
preparations. These are generally commercial compounds that are sold under trade names. They are likely to be somewhat more expensive than Bordeaux mixture but are more easily prepared. No lime is used, and they are less likely to cause excessive loss of water from the plant than is Bordeaux mixture. Fixed copper dusts are composed of insoluble copper compounds plus an inert diluent. Fixed copper dusts usually contain about 7% copper.

**BLUESTONE** is the common name for copper sulphate 23 D 25% copper content. Bluestone is one of the major ingredients of Bordeaux mixture and it available in crystal form or as a soluble powder. 50

**COPPER - LIME DUST** is composed of 20% monohydrated copper-sulphate and 80% hydrated lime. The actual copper content is about 7%. 50

**FERRIC DIMETHYL DITHIOCARBAMATES** is marketed under several trade names such as "Fermate", "Niagara Carbamate", "Kar-bam Black", etc. May be used in apple schedule for scab, blotch, and cedar rust. May be substituted for or used with sulfur. May be substituted for Bordeaux mixture or hydrated lime but must *not* be used in combination with either. Do not use before or after a Bordeaux spray — may injure fruit and foliage. 168 Ferbam is also said to be useful on apple, grape, cherry, raspberry, and strawberry diseases. 179 It is an organic sulfur in the form of a black powder which does not require copper or mercury to manufacture.

**NABAM**: This substance plus zinc-sulphate-lime was tested on potatoes, tomatoes and some other truck crops. The cited report states that potatoes treated with nabam, and also those treated with ziram, in the 12 experiments, were high in yield rank in the absence of late blight, whereas in the presence of late blight the copper containing sprays ranked high in yield aid in late-blight control. Bordeaux 8-8-100 was the only fungicide that provided adequate control of the severe late blight which prevailed in three tests, one in New York state and two in Ohio. 201

**ZINEB** in 1947 gave excellent control of snapdragon rust. Potatoes sprayed with it, or with ziram, ranked high in yield, in the absence of late blight. 201

**ZIRAM** in its effect on yield of carrots, in 1947, was second only to bordeaux 6-6-100. It performed very well on cantaloupe in all three locations, as to yield, even though its control of downy mildew was not as good as that of bordeaux 6-3-100. Cucumbers sprayed with it had the most vigorous vines. Ziram, together with zineb, favorably affected the yields of potatoes in the absence of late blight. On tomatoes, either alone or in combination with tribasic copper sulphate, it appeared to be about as efficient as tribasic alone in controlling early blight. 201
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According to the Federal Food and Drug Administration little work has as yet been done with such fungicides as nabam, zineb and ziram. Some work has been done with ferbam in the Food and Drug laboratories. Information, however, is inconclusive. It is possible that continuous injection of small amounts may constitute a human health hazard. Ziram is probably more toxic than ferbam. 250

• THIODOW: A new liquid organic fungicide, thiodow, has been added to the Dow agricultural chemical line. This product is a liquid containing disodium ethylene bisdithiocarbamate. The spray will control many plant diseases on vegetables, particularly early and late blight on potatoes and tomatoes. Thiodow is compatible and may be used with such common insecticides as DDT, nicotine sprays, arsenicals, rotenone, pyrethrum and methoxychlor. The product has shown good results on certain diseases of celery, cucurbits, peppers, azaleas and camellias as well as potatoes and tomatoes. 223

• PURITIZED on apples, in 1947, was reported to remove leaves bearing scab lesions and may be found injurious to some varieties, particularly if poor drying conditions prevail at the time the spray is applied. It delayed maturity of apples as much as two weeks. 201

• “PURITIZED APPLE SPRAY” is an organic mercury which contains no sulfur. It has given excellent control of apple scab and is said to be more dependable than the “Puratized Agricultural Spray”. “Tag 331” is another formulation of the same chemical. It also has proven to be excellent scab fungicide. These formulations contain mercury, so should be used only in the early sprays. Do not use with hydrated lime, sulfur, or oil sprays. Both formulations cause serious damage to peaches. Spray operators should avoid contact with the concentrated material. 681 Puratized is compatible with lead arsenate, lime rotenone, nicotine, calcium arsenate, and DDT.

• PHYGON: According to the United States Department of Agriculture, tests in 1947 phygon (2,3-dichloro-1, 4-napthoquinone) was found to be comparatively ineffective against apple blotch, Brooks fruit spot and black rot. It was somewhat injurious to fruit and foliage and often toxic to operators. In its 1947 form it was not recommended. 201

• SULFUR is an element of great importance in industry. About 1½ million tons of it are consumed each year in the United States alone. A considerable portion of this veritable mountain of sulfur goes into the manufacture of sulfuric acid, a chemical which plays a prominent part in the preparation of a host of other materials. Sulfur dioxide, another important compound of sulfur, is used for disinfecting, bleaching, and refrigeration. In addition, sulfur is employed in the process of vulcanizing rubber, and as an ingredient of chemical sprays for trees and shrubs. It is also used for making carbon disulfide, matches, dyes, fireworks and explosives. 74
Sulfur is used in four agricultural forms: (1) as a dust, (2) as a suspension, (3) as a solution of lime-sulfur or ammonium polysulfide, and (4) as dry lime-sulfur. The dust and the suspension have comparatively little value against most insects but are of great value against fungi and against mites. Sulfur can be bought as liquid or dry lime sulfur, 70-per cent sulfur pastes, microfine wettable sulfurs, ground wettable sulfur, and fused and ground sulfur and bentonite.

Dry lime sulfur is more expensive than liquid but more convenient. Both forms are very efficient but more likely to cause injury than other sulfur fungicides. Next to lime sulfur, sulfur pastes are the most efficient sulfur fungicides. Have particle size of 1/25000 to 1/25-00 inch. Not convenient to handle but their mildness and efficiency off-set their bulkiness. Microfine wettable sulfurs are highly efficient. Have average particle size of 1/2500 inch. (Microfine commonly means dry sulfurs that have been especially treated to break them into small particles and make them wettable in water.) Select brands with care — fineness of particle is very important.

Lime-sulfur solution is a reactive solution containing several compounds of lime and sulfur. Those of chief insecticidal value are the polysulfides, which consist of one atom of calcium combined with three to five atoms of sulfur. Such compounds readily take up oxygen, decompose, and deposit extremely finely divided sulfur. Lime-sulfur solution is alkaline and decidedly caustic to most foliage. Its principal use is as a dormant spray for the control of certain fungus diseases, scale insects, red spider, and a variety of other resistant pests of deciduous trees.

Commercial lime-sulfur solution is usually 32° or 33° Baumé. The Baumé scale is a method of expressing the density of liquids. It is being replaced by the use of specific gravity. A 33° Baumé preparation has a specific gravity of 1.295, which means that 1 cubic centimeter weighs 1.295 grams, or 1 gallon weighs 10.8 pounds. Such material needs only to be diluted for use.

Commercial lime-sulfur solution has the important advantage that it is standardized at 29 to 30 per cent by weight of calcium polysulfide, which is the valuable ingredient. Hence it can be diluted with assurance. Homemade preparations are nearly always weaker than the commercial product; and while their value is indicated by the specific gravity, the polysulfide content should be determined by chemical analysis if the finished spray must have a precise concentration of active ingredients.

Dusting sulfur is mostly produced either by precipitation by cooling sulfur vapor, or by grinding. Precipitated sulfur usually has less tendency to cake. Caking can be prevented with any type of sulfur.
by adding a small percentage of dehydrated lime, kaolin, or other inert powder. The essential feature of any good dusting sulfur is extreme fineness. Recognition of this by the manufacturers has led to the use of the names "superfine", "cloud", "microscopic", "smoke", "colloidal", "fog", and similar terms. Practically all brands are now fine enough so that only a very small percentage fails to pass through a 300-mesh screen. Such materials usually adhere well and find extensive use against red spiders and mites. Combination treatments including sulfur for control of mildew are also widely used.

Sulfur paste or wettable sulfur form suspensions of finely divided sulfur in water. Either precipitated or ground sulfur will serve. An emulsifying agent is needed to make the suspension stable enough for use. Soap, calcium, caseinate, glue, flour, or any of a wide variety of commercial preparations may be used. If the emulsifying agent is intimately mixed with the sulfur, the resulting powder is readily wet by water, from which fact the term "wettable sulfur" was derived. When a small percentage only of water is added, a thick paste is produced, which may be diluted further as needed. Home made wettable sulfur may be prepared by the following formula:

**Home-made Wettable Sulfur**

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium caseinate</td>
<td>½ pound</td>
</tr>
<tr>
<td>Water</td>
<td>½ gallon</td>
</tr>
<tr>
<td>Sulfur (dusting grade)</td>
<td>5 pounds</td>
</tr>
<tr>
<td>Water to make</td>
<td>100 gallons</td>
</tr>
</tbody>
</table>

Make a smooth paste of the calcium caseinate and ½ gallon of water. Mix with the sulfur and add enough water to make 100 gallons. The same formula may be used with ¾ ounce of glue dissolved in 1½ gallons of hot water instead of the calcium caseinate paste.

**LIME-SULFUR** is a contact insecticide. The prepared mixture is a brownish syrup liquid in concentrated form. It is used mostly for killing over wintering stages of various insects on trees and shrubbery. Lime sulfur is also an excellent fungicide. The concentration of lime-sulfur is expressed in degrees Baumé, commercial material usually being of from 32° to 34° Baumé. However, even commercial lime-sulfur often varies considerably in concentration; and home-made material is always very variable. Hence, each lot of lime-sulfur should be tested with a Baumé hydrometer, an instrument in appearance resembling the floating thermometer. With the hydrometer floating in the lime-sulfur, the reading is readily obtained. For convenience, lime-sulfur is poured in a glass cylinder and then tested with the hydro-
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meter. In the following table are given the relative amounts of lime-sulfur to use to obtain the concentrations required by different formulas.

### Dilution Table for Lime-Sulfur

<table>
<thead>
<tr>
<th>Hydrometer reading (Degrees Baume)</th>
<th>Quantity needed for 50 gallons of spray in the following dilutions:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-7</td>
</tr>
<tr>
<td></td>
<td>1-40</td>
</tr>
<tr>
<td></td>
<td>1-50</td>
</tr>
<tr>
<td>34</td>
<td>6</td>
</tr>
<tr>
<td>33</td>
<td>6 ¼</td>
</tr>
<tr>
<td>32</td>
<td>6 ½</td>
</tr>
<tr>
<td>31</td>
<td>6 ¾</td>
</tr>
<tr>
<td>30</td>
<td>7</td>
</tr>
<tr>
<td>29</td>
<td>7 ¼</td>
</tr>
<tr>
<td>28</td>
<td>7 ½</td>
</tr>
<tr>
<td>27</td>
<td>8</td>
</tr>
<tr>
<td>26</td>
<td>8 ¼</td>
</tr>
<tr>
<td>25</td>
<td>8 ¾</td>
</tr>
<tr>
<td>24</td>
<td>9 ¼</td>
</tr>
<tr>
<td>23</td>
<td>9 ½</td>
</tr>
<tr>
<td>22</td>
<td>10 ¼</td>
</tr>
<tr>
<td>21</td>
<td>11</td>
</tr>
<tr>
<td>20</td>
<td>11 ½</td>
</tr>
</tbody>
</table>

Fig. 12. — Courtesy Tennessee Agricultural Experiment Station.

- **WETTABLE SULFUR**: Whenever the sulfur is used for spraying, a wetting agent must be added to it, so that it can be mixed with water. For home-made wettable sulfur as a wetting agent, calcium caseinate or lingnin pitch (of various trade names — “Goulac”, “Bindex”, and others) is recommended, at the rate of 1 pound to each 16 pounds of sulfur. The sulfur and wetting agent first are thoroughly mixed, then with a little water a paste is made, placed on strainer, and washed through with the remaining water required by the formula. To avoid the necessity for adding a wetting agent to each batch of sulfur, the desired lot of wettable sulfur may be prepared at one time for the entire season. For this purpose, use a 325-mesh sulfur powder, add to it dry lingnin pitch, or any other good wetting agent, at the rate of 3 pounds to 50 pounds of sulfur, thoroughly mix the materials, and keep dry until needed Wettable sulfur differs from dry-mix sulfur-lime only in that it contains no lime.

There are on the market several commercial brands of wettable sulfur, such as Flotation, Micronized, Mike, Sulfrox, Microsulfur, Microspray, Mist, Colloidal Sulfur, and Grasselli Wettable. Essential
FUNGICIDES

ally each is a fine sulfur powder — 325-mesh or finer — with a wetting agent added. Some of the sulfurs contain certain impurities, making them wettable, as in the case of Flotation sulfur. The paste form of this material is finer than the 325-mesh sulfur flour, and hence, less of it is needed to give the same fungicidal efficiency. 201

• DRY LIME-SULFUR: By evaporation of lime-sulfur concentrate, usually under a vacuum or in presence of an inert gas, a dry powder is obtained. This product is not identical chemically with lime-sulfur in solution, and the addition of water does not exactly reproduce the original material. If the powder soaks for several hours, or better, at an elevated temperature, the resulting liquid more nearly resembles liquid lime-sulfur. Increased efficiency is secured by removing the insoluble residue. On account of this complicated behavior, dry lime-sulfur is seldom used, liquid lime-sulfur or oil being preferred. 60

• DRY-MIX SULFUR-LIME is a mechanical mixture of sulfur, lime, and a wetting agent. It is radically different from lime-sulfur, in which the two substances are chemically combined. Lime-sulfur and sulfur-lime, differ greatly in their effects on diseases and on plants. As a rule neither should be used in place of the other. The usual formula for dry-mix is 8-4-½-100; that is, 8 pounds of sulfur, 4 pounds of lime, ½ pound of a wetting agent, to 100 gallons of water. The sulfur, lime, and wetting agent should be thoroughly mixed. A rotating barrel with a crank should be used for this mixing if a considerable quantity is to be prepared. A few small stones placed in the barrel will help in the mixing. 201

• LIQUID LIME SULFUR: This is the most effective sulfur fungicide. It is very caustic, however, and is injurious to some plants, especially peach and grape foliage, even in dilutions of 1 to 50 parts of water; to young fruit of some varieties of apples, notably Golden Delicious; and to all apple varieties in hot weather. Its use in strong concentration — 1 to 10 — is limited entirely to dormant and delayed-dormant spraying of all varieties; and in low concentrations — 1 to 40 or 50 — for early foliage sprays on most varieties of apples.

Lime-sulfur in concentrated form — 1 part to 10 parts of water — for dormant spray of trees has been the commonly recommended scalecide and fungicide. However, oil emulsion used for dormant spray has been found more effective and more convenient to use as a scalecide, and now completely replaces lime-sulfur for control of scale. When a fungicide is needed in this spray, as for control of peach leaf curl, Bordeaux mixture is used, together with oil emulsion.

At present commercially manufactured lime-sulfur is used almost to the exclusion of home-made material. If the product is not available, or is inconvenient to obtain, it can be prepared at home without too much trouble. For home-made lime sulfur, use rock lime, 50 pounds;
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sulfur flour, 100 ponds; and water, 50 gallons. At first the lime is slaked with only a little water, and when it becomes boiling hot the sulfur is added and mixed with the lime. To the paste thus obtained the rest of the 50 gallons of water is gradually added, and the whole is boiled for 1 hour in a loosely covered vat. Use of live steam, if available, is a very convenient method of cooking the mixture, which should be kept agitated all the while during the boiling. 201

COMPLETE DUSTS: A number of commercial materials are advertised as complete dusts. These are mixtures of stomach and contact poisons, together with fungicides for plant diseases. They are available on the market under various trade names such as "three-in-one", "all-in-one", etc. Complete dusts are quite convenient for use by the home gardener. They are less significant to the commercial grower. Care must be taken, however, to note on the labels whether one or more ingredients may constitute a poisonous residue hazard if the dust is applied to leafy vegetables soon to be eaten. 167

S. R. 406 is a new synthetic organic fungicide which has been produced by the Standard Oil Development Company. This fungicide is now manufactured and distributed by the California Spray Chemical Corporation, Richmond, California and Elizabeth, New Jersey. The active ingredient of SR 406 is N-trichloromethylthio-tetrahydrophthalimide. The material has undergone extensive field tests and is said to be effective against many plant diseases including apple scab, tomato and potato blights. It is also effective against banana and coffee diseases in Central America. Preliminary tests indicate that SR 406 appears not to be toxic to warm blooded animals. 250

CRAG 341 B & C: Crag 341 C and Cherry Fungicide 341 B are trade names for certain glyoxalidine derivatives which have been undergoing extensive field tests since 1946 in various countries. Glyoxalidine derivatives were first introduced to the public by Wellman McCallan and Thurston in 1946. Field tests began in 1942 and indicated that glyoxalidine would control scab as well or better than currently used fungicides and that it was the best material for the control of leaf spot defoliation.

According to Hilborn and Lathrop 250 Crag 341 C in addition to controlling scab on apples, prevented a serious build up of European red mite. Glyoxalidine contains neither sulfur nor metal, thus it can be used successfully with many insecticides and other fungicides. Crag 341 C is a solution of glyoxalidine acetates in isopropanol. To each 100 gallons of water is added 1 quart of the isopropanol solution. The glyoxalidine is precipitated by the addition of ½ pound of spray grade hydrated lime. Foliage injury occurred during tests when spraying was done under relatively high humidity and temperatures of over 90 degrees. It should be recommended that glyoxalidine is a preventative or protective fungicide rather than an eradicant.
FUNGICIDES

Getting to the Under Side of Leaves

The major problem in air application is that of getting to the underside of the plant foliage. For example: Control of leaf blights cannot be expected unless both surfaces of the leaves are covered, as a fungus may enter the leaf on either side. A poison placed on the upper surfaces of bean leaves is wasted, as the insect feeds on the lower surfaces and only material placed there will be eaten by the beetle larvae.

The dust should form an even protective film on the under surfaces as well as on the top surfaces of the leaf. But whether spraying or dusting, the fungicides or insecticides should be applied to healthy plants to keep them healthy. Fungicides should be applied before the attacking organisms are expected to make their appearance and before rains. Most diseases start when the plants are wet, so spraying after a rain may be too late. (Keep in mind that you are protecting the plants from invasion.) It is extremely difficult and almost impossible to "burn out" or eradicate the casual organisms once they have become established within the fruit or leaf tissues. 187

VERIFY ALL DOSAGE RECOMMENDATIONS WITH LOCAL AUTHORITIES BEFORE USING
Sterilants and fumigants are those chemicals that form gases that kill insects, larva, pupa, on vegetable growth. Usually it is necessary to confine the gases to enclosures such as green-houses and grain storage houses. Fumigants may also be used effectively in the soil by depositing the chemical in liquid or solid form beneath the earth surface. Brief descriptions of the most common fumigants, although obviously not applicable by airplane, are included in this book to round out the Air-Applicator’s general information on agricultural chemicals.

Carbon disulfide, chloropicrin, DD, ethylene dibromide, formaldehyde or methyl bromide are some of the common chemicals used to destroy disease causing organisms and insects in the soil. 179

BORON: Compounds containing Boron have been used for a long time to sterilize the soil and thus prevent weed growth. Application of 20 to 25 pounds of borax per square rod has been used satisfactorily as a soil sterilant. Borox is somewhat insoluble in water so some time must elapse between application and the time it is effective. The amount of boron applied, kind of material used, kind of soil, species present and amount of rain-fall will determine the length of time the area will be sterilized. Boron is less toxic to grasses than to other species of plants. This property makes it a good chemical to use on Klamath Weed (also known as goat weed), a serious weed in some of our range areas. From four to eight pounds of boron per square rod has given good control of Klamath weed and has in no way injured the grass — in fact the grass appeared to be somewhat stimulated. Mixing a small amount of sodium chlorate with the boron will hasten the “knockdown” of Klamath weed. About ½ pound of sodium chlorate in four pounds of boron is a good mixture. There is not much fire hazard in using this mixture. Commercial products are on the market having two chemicals — boron and sodium chlorate mixed together and ground the same size. The latter is important in securing a uniform mix of the two chemicals. 179

CARBON DISULFIDE is a liquid which evaporates quickly when exposed to the air, forming a heavy and inflammable vapor of great penetrating power. In using the material for the control of insects infesting stored products — for example, granary weevils — it must be placed near the top of the chamber in a shallow container in order that the heavy vapors as they are given off may thoroughly diffuse through the air contained in the space to be fumigated. The proper amount to use depends upon the type of room being fumigated and ranges from 10 pounds to about 30 pounds per 1,000 cubic feet in
ordinary rooms where the walls and floor have not been made especially tight. The best results are obtained by doing this work when the temperature is above 70°F. Since the vapors of carbon disulfide are very inflammable, precaution must be taken to keep all flames and sparks away.

- **CARBON DISULFIDE EMULSION**: This is a rather unstable emulsion which is a valuable soil fumigant for the control of certain pests. In the San Francisco Bay region, it has proved effective in killing the garden centipede in the soil. "Good results have been obtained by diluting the emulsion 1 part to 300 parts of water and applying it to the surface of the soil at the rate of 5 gallons per square yard". 60

- **FORMALDEHYDE**: A 37% solution of formaldehyde is used to disinfect seed beds, flats and greenhouse soils. The soil may be planted as soon as the formaldehyde odor has left. Soil treatment may be made at the rate of 2 1/2 tablespoonsfuls per bushel of soil.

- **ETHYLENE DIBROMIDE** in 5% strength is a liquid fumigant used for the control of stored grain insects. For fumigation in mills, a formulation containing 15 per cent ethylene dibromide is also available. Ethylene dibromide is toxic to man even in dilute form, and should be handled accordingly. While there may be little danger out-of-doors, care should be taken not to breathe the vapor. For use as a soil fumigant, ethylene dibromide is available in solution in a light petroleum oil. The commercial product contains either 20 per cent or 40 per cent ethylene dibromide by weight. Ethylene dibromide is the best immediate liquid fumigant for the control of wireworms in the irrigated regions of West coast states known at the present time, according to the Federal Bureau of Entomology and Plant Quarantine. This is used at the rate of 10 gallons of a 40 per cent solution per acre. According to Lane, 1 ethylene dibromide is the best liquid fumigant known for the control of wire worms at the present time. It is applied at the rate of 10 gallons of 40% solution per acre. Practically all of the wire worms in the soil are killed at the time of application.

Ethylene dibromide, at the rate of 2 gallons actual material per acre, is effective for wire worm control. The material is available in 10, 20, and 85 per cent concentrations. It is necessary to dilute high concentrations for effective distribution in the soil. It may be applied with a power soil applicator or a plow-sole injector to a depth of 8 or more inches. Good soil moisture and tilth are pre-requisites for satisfactory control. The material is hazardous to plants and animals, and directions on the label should be closely followed. 167

Most wire worms live from 3 to 15 inches below the surface. Consequently, the ethylene dibromide should be placed at least 8 inches in the soil. Applied from a tank attached to a plow or tractor, the liquid flows by gravity directly to the bottom of the furrow. Practice-
ally all the wire worms in the soil are killed at the time of application. Two weeks should elapse before planting in fall and spring, following soil applications of ethylene dibromide. In summer, the time can be cut to 7 or 10 days.

- ETHYLENE DICHLORIDE: This is a colorless liquid with an odor similar to that of chloroform. Mixed with carbon tetrachloride in the proportion of three to one, this chemical has some advantages as a fumigant, especially because of its freedom from fire hazard and relatively low toxicity to human beings. Boiling points of the two substances are about the same, and consequently they volatize at nearly equal rates. Under the name of Dowfume 75, Dow Chemical Company formulates a product described as “an all-purpose grain and spot fumigant mixture” composed of ethylene dichloride 75 per cent carbon tetrachloride, 25 per cent.

Ethylene dichloride has proven useful in killing peach tree borers. This method of control was developed in Georgia by Oliver I. Snapp, Bureau of Entomology and Plant Quarantine and further investigated in the Pacific Northwest by A. W. Anthon. Potash fish-oil soap was first used as an emulsifier, but monothanolamine and triethanolamine have proven more satisfactory.

- PROPYLENE DICHLORIDE: This is a clear, colorless liquid, with an odor similar to that of ethylene dichloride. Most satisfactory for peach tree borer control because of greater penetration, propylene dichloride appears to be quite as efficient even at concentrations from one-fourth to one-third lower than that required for ethylene dichloride emulsions.

A mixture of propylene dichloride (1-2 dichloropropane) and 1-3 dichloropropene, most commonly known under the trade name of DD, is used extensively for the control of nematodes. DD is the name used by the Shell Company to designate their product. Eston Chemicals utilize the trade name Nemafume, while the Dow Chemical Company uses the name Dowfume N for a similar product.

This fumigant is corrosive and inflammable. Equipment used for its application should be made of corrosion-resistant metals. Such equipment should be thoroughly cleaned and flushed with kerosene after use. The fumigant itself should be kept away from open flames. Because of its toxicity to human beings, workers should not breathe heavy concentrations of the vapor. In contact with the skin, the liquid may cause serious inflammations. If any of the fumigant is spilled on clothing or skin, the clothing should be removed and the body thoroughly washed with soap and water wherever contacted by the liquid. Whenever spilled on or into shoes, these should be removed and not used again until the odor of the fumigant is all gone.

From 200 to 300 pounds per acre are recommended for nematode-infested soil. The fumigant is injected into the soil in rows 12 inches
SOIL STERILANTS

apart and at a depth of at least 8 inches. Several weeks should elapse before planting. Where 200 pounds per acre have been applied and the soil temperature is above 60° F., there should be a 2 week interval between treatment and any seeding, and 3 weeks in case of transplants. For every additional 100 pounds per acre, an additional week should elapse before planting. 105

PARADICHLOROBENZENE is useful as a fumigant to control downy mildew in tobacco seed beds. It is a white crystal insoluble in water but readily soluble in alcohol, benzene, ether, carbon disulfide and chloroform. Its most popular use in agriculture is against the peach tree borer. (Ground application.)

SOIL STERILANTS are used for controlling all vegetative growth on such areas as driveways, fence rows, road sides, ditch banks, railroad rights-of-way, and firebreaks. Soil sterilants are classified loosely as permanent or temporary, depending upon the length of time they will control vegetative growth. Permanent control seldom extends beyond the fourth or fifth year, although growth-retarding effects may be noticeable for several years after that time.

Sterilants readily soluble in water, such as ordinary salt (sodium chloride), sodium chlorate, ammonium sulfamate, and ammonium thiocyanate, as well as some of the relatively soluble arsenicals, are frequently applied as a spray, with standard spraying equipment. Sterilants which are insoluble, or relatively so, such as arsenic trioxide and borax, are applied dry, either by hand or with a mechanical spreader. Ordinary fertilizer distributors or lime spreaders are sometimes used. Frequently, the weed growth is cut off level with the ground and the sterilant applied to the bare surface, for maximum effectiveness.

In using carbon bisulfide (or other soil fumigants) prepare the ground as for a seed bed about June 1 - 10. Mark off rows every 18 inches and apply two ounces of carbon bisulfide in holes every 18 inches. Holes in adjacent rows should be staggered. Seal the hole up immediately after putting the material in it. After the area has been completely treated harrow with the harrow laid flat or roll the ground to prevent the rapid escape of the gas from the soil. Be sure and treat several feet beyond the margins of the patch. Carbon bisulfide usually sterilizes the soil for sixty to ninety days. Carbon bisulfide fumes are very inflammable. Keep all forms of fire away when using carbon bisulfide.

PROCHLOR is a mixture of propanes and propenes. It can be used under drier conditions than carbon bisulfide and earlier in the spring and later in the fall. The reason for this is that the material does not volatilize as rapidly. Best results, however, are obtained in moist soil. Preparations of the ground is the same as for carbon bisulfide. However, the rows should be spaced 12 inches instead of 18 inches. Stagger
the holes in adjacent rows. Put $\frac{1}{4}$ to one-half teaspoonful of prochlor in each and close the hole immediately. Depth of injection of soil fumigants varies with moisture content of the soil and species to be controlled. In general injections for Canadian thistle should be five inches to seven inches; Bindweed, white top and Russian Knapweed four inches to six inches; quack grass two to three inches deep. Prochlor also sterilizes the soil for sixty to ninety days on the average. Prochlor is not inflammable which is a point in its favor but the fumes are disagreeable.

VERIFY ALL DOSAGE RECOMMENDATIONS WITH LOCAL AUTHORITIES BEFORE USING
PART SIX

GROWTH REGULATORS

The most interesting and important use of growth regulators to fruit growers is the prevention of fruit drop. It was first observed that some of the hormones retarded the dropping of leaves from woody cuttings. Stimulated by these observations, Drs. F. E. Gardner, P. C. Marth, and L. T. Batjer, of the Pre-fruit Experiment Station, Washington, conducted experiments on the prevention of fruit drop, by treating the fruit stems with hormones. Results were rather striking and found almost immediate large-scale application in commercial orchards.

Dr. Gardner states that naphthalene acetic acid and naphthalene acetamide are the most successful plant hormones in preventing apple drop. They are effective when applied in extreme dilutions, at the rate of only 1 to 2 level teaspoons of the pure substance to 100 gallons of water. At present the workers recommend that the spray should be applied only when needed — best not until the fruit begins to drop. The effect lasts from 1 to 2 weeks, so that one application usually is sufficient. If it is necessary to delay the drop longer, a second spray may be put on after the effect of the first begins to wear off.

The effect of spraying to control fruit drop is not the same with all varieties, and perhaps not in all locations. In general, however, tests in widely separated localities, and on various early and late varieties of apples, gave strikingly good results. The spraying has been used extensively by practical growers, and deserves a fair trial whenever it would be of advantage to keep the fruit hanging on the trees either for better development of color or for a more favorable picking season. The grower should remember, however, that the prevention of fruit drop does not delay maturity of the fruit; hence, there is danger that sprayed fruit will be left on the trees until it becomes over ripe.

All of the hormones in concentrated form are potent poisons, and should be handled with great care. They are used in extremely small amounts and when pure are hard to dissolve. For convenience and ease in dissolving and for safe proportioning, the manufacturers put them up in combination with carriers, under various names, such as "Parmone" and "Fruittone".

Treatment with the hormones prevents fruit, flower, and leaf drop apparently by preventing disintegration of the abscission layer, a layer of plant tissues connecting a stem to the branch on which it is borne. The disintegration of the abscission layer takes place in nature under the influence not only of the maturity of the fruit, but of cold, disease, insect injury, sterility, and desiccation.
One year's test at Cornell Agricultural Experiment Station with naphthaleneacetic acid spray used to reduce the pre-harvest drop of apples indicates that the application of the substance in the form of dust controls the pre-harvest drop just as well as in the form of spray. This is important since dusting requires considerably less time and labor. 201

NAPHTHALENE - ACETIC ACID: Some of the commercial materials, claimed to promote the rooting of plant cuttings and retard the forming of the abscission layer of apple stems are called Stop-Drop, Parmone, Apple-set and Fruit-tone. Naphthalene-acetic acid retards the formation of the ring of cells at the base of the stem thus delaying the time at which the apple normally would fall.

The following information is taken from the report of an experiment by L. P. Batjer and A. H. Thompson, Tree Fruit Experiment Station, Wenatchee, Washington. 186 The data presented, while admittedly limited, seem to establish clearly the foliage as the chief means of transporting the spray stimulus responsible for retarding fruit drop. Under conditions of this experiment, applications made solely to fruit stems and cluster bases had only a slight effect, although when these tissues in addition to the foliage were treated the reduction in fruit drop was greater than when the foliage alone was sprayed.

Regarding the transmission of effect from one fruit to another when one component of a compound spur was treated, fruit drop from the other component seemed to be appreciably reduced though the degree of reduction was considerably less than on the treated portion. Since a very minor proportion of the fruit of most apple varieties is borne on compound fruiting spurs, very little practical significance can be placed on this type of stimulus transmission. 186

Air-Application is Advantageous

Airplane application of hormone chemicals to fruits was first tried in the Pacific Northwest during the season of 1944. In this area in 1945 it is estimated that 15,000 to 20,000 acres of apples and pears were treated with hormones by this method. A. H. Thompson and L. P. Batjer, Tree Fruit Experiment Station, Wenatchee, Washington, made studies during the 1945 season: (a) to compare the efficiency of the airplane application with that of the conventional application of naphthalene-acetic acid, (b) to study time of application as a possible factor in the success of the airplane method, and (c) to determine the relationship of concentration to effectiveness of hormone sprays when applied by airplane.

In order to determine whether or not the concentration of airplane sprays could be reduced without limiting the effectiveness of the
spray, a one-half strength (1200 ppm) airplane spray was compared with full strength airplane (2400 ppm) and conventional (10 ppm) sprays in a block of 20-year-old Delicious apple trees. After 21 days the drop on all treated trees was significantly lower than that of the check trees, but no one treatment was clearly better than any of the other treatments. The one-half strength airplane spray seems to have given essentially the same control of fruit drop as the other airplane treatments.

Airplane application of hormone sprays is clearly an advantageous method from the point of view of orchard management. The large acreage covered during the 1945 season is ample evidence of the interest in this method of applying hormones. Results of these studies show clearly that airplane sprays are effective in reducing fruit drop. In some of the experiments reported the conventional method seemed to give significantly greater intensity of effect while in others little or no difference was obtained. From these data it is apparent that the magnitude of the differences between the two methods is not large, but further testing is necessary in order to establish more definitely their comparative relationship.

While these data are somewhat limited, they do suggest that the spraying of spur leaves alone on a fruiting spur is sufficient to delay fruit abscission. This is contrary to the popular conception in which it is deemed necessary to actually make contact with the stem in order to achieve control of fruit drop with hormone sprays. Thus in airplane spraying, while many fruits and stems are missed by the spray, it is rare that at least one of a group of spur leaves is not reached by several droplets of spray material.

In the test described above, a solution of only 10 ppm applied to leaves only on fruiting spurs was sufficient to control drop. This would seem to indicate the possibility of drastically reducing the concentration of airplane sprays without sacrificing effectiveness. It has been shown in these experiments that concentrations considerably lower than 2400 ppm (airplane method) were effective in delaying fruit drop. However, further work is necessary before the extent to which concentrations might be reduced can be definitely established.

Dust Treating Effective

Taken from the report of an experiment by P. C. Marth, L.P. Batjer, and H. H. Moon, U.S. Department of Agriculture, Beltsville, Maryland.

Much interest has been manifested in the use of dusts for harvest-drop control because of the rapidity and uniformity with which applications can be made. Hoffman et al. (1) have reported that results with dusts on McIntosh apples were generally as good under New
York state conditions as with liquid sprays. Under conditions prevailing in Massachusetts, Southwick, however, found dusts to be generally less effective than sprays in controlling apple fruit drop. The present report contains results comparing the effect of aqueous sprays containing naphthalene-acetic acid with the effect of naphthalene-acetic acid in different types of dust carriers or in aerosol form, in controlling the harvest-drop of Stayman Winesap apples.

Under the conditions of these experiments, application of naphthalene-acetic acid in dust form was at least as effective if not more effective in retarding fruit drop than were liquid sprays. In this instance, doubling the amount of naphthalene-acetic acid contained in the dust slightly increased the effectiveness, but the small added benefit would not seem to be sufficient to justify the added expense.

**2,4-D Equally Effective as NAA**

(Experiment by L. P. Batjer, A. H. Thompson and Fisk Gerhardt, Tree Fruit Experiment Station, Wenatchee, Washington)

The high degree of effectiveness of 2,4-D acid in preventing fruit drop of Winesap and Stayman winesap apples has been reported. Likewise attention has been called to the selective nature of this chemical with its failure to have any appreciable effect in preventing drop on a number of important commercial apple varieties. The purpose of this report was to present the results of a 3-year comparison of 2,4-D and naphthalene-acetic acid (hereafter written NAA) in retarding the pre-harvest drop of bartlett pears.

The tenacity with which the fruit was held as a result of the sprays is further indicated by the greatly reduced amount of fruit which was knocked off by pickers during routine harvest operations. No evidence of injury was observed on trees receiving either the 2,4-D or NAA at 2 1/2 ppm. However, at harvest time every tree sprayed with 10 ppm of NAA exhibited a moderate number of premature yellow leaves throughout the inner portion of the tree.

In all the three years tested, 2,4-D proved to be as effective as NAA in reducing the drop of bartlett pears. In the 1945 experiment, injury which was roughly proportional to the concentration was obtained with all 2,4-D sprays stronger than 2 1/2 ppm. The latter concentration caused no injury in any of the experiments and its very high degree of effectiveness would suggest that 2,4-D might be effective on bartletts when used at even a weaker strength. While the present experiments indicate 2,4-D to be promising as a pre-harvest spray for bartlett pears, more extensive work is needed before the use of this chemical on bartletts can be adequately evaluated.
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2,4-D FOR WINESAP DROP: 2,4-D is effective against fruit drop in certain varieties of apples according to the 1948 memo released by Chelan County Extension Service. “During the past four years extensive experiments with 2,4-D have shown this chemical superior to the standard hormone spray (naphthalene-acetic acid) when used on Winesap and Stayman winesap to prevent dropping. This material is not effective on other varieties. 2,4-D has advantages over the regular hormone in being much cheaper, more effective and longer lasting, and can be applied on Winesaps before Delicious harvest is under way. In applying 2,4-D on Winesap, the following schedule must be strictly observed:

(a) Use only the sodium salt form of 2,4-D at a concentration of 8 ppm (4/5ths standard strength).

(b) Apply between September 10 and 20, preferably about September 13. Do not apply sprays earlier than September 10. If applied later than the 20th, full effectiveness may not be obtained.

(c) Do not use oil of any type with 2,4-D sprays, nor any other material except a non-petroleum wetting agent or spreader if desired.

(d) Apply 2,4-D sprays only with a standard conventional spray system.

(e) Do not overspray. Apply about one-half the gallonage generally used with a mite spray. A wetting of the foliage (with a mist spray when possible) is sufficient. Avoid over spraying of the lower weaker limbs.

The use of the sodium salt of 2,4-D on Winesaps is complicated by the fact that there is no product on the market prepared especially for convenient use on apples. Many different forms and concentrations of 2,4-D are available in both powder and liquid form. All of these are prepared specifically for use as weed sprays. Send to Tree Fruit Experiment Station, Wenatchee, Washington for experimental report on fruit drop.

2,4-D Promising for Grapefruit Drop

(Experiment work by W. S. Stewart and E. R. Parker, Citrus Experiment Station, Riverdale, California.)

Two field experiments are described in this report in which water sprays containing 5 to 225 parts per million 2,4-D were applied to nearly mature grapefruit for control of preharvest fruit drop. Up to the middle of the normal harvest period fruit drop was reduced 52
to 78 per cent, the percentage of reduction depending on the concentration of 2,4-D. The reduction in fruit drop persisted after the usual harvest season.

No undesirable effects on the quality of the juice were noted as a result of the use of any of the sprays applied on the nearly mature fruit. Dilute sprays of 2,4-D appeared to have no commercially significant effects on the quality of the following year’s fruit; but sprays containing 225 parts per million 2,4-D caused undesirable growth modifications in these fruits, as well as a reduction in yield.

**BLOSSOM THINNING**

Blossom thinning is another use of hormone sprays. Like many other of the hormone uses blossom thinning is still in its experimental stages. Indications are favorable and the progress of these experiments should be followed carefully and studied by the air-applicator.

**Thinning with Chemicals Saves Money**

Hand thinning is one of the most costly operations in growing a crop of apples. Experiments carried on by Leif Verner, Horticulture, and D. F. Franklin, Parma Branch Station, during the past five years have shown that thinning of apple blossoms by the use of caustic spray materials is both cheaper and more effective than hand thinning of the fruit. A chemical sold under the name of “Elgetol 30” has been used in this work.

Best results have been obtained with Rome Beauty and Jonathan. Delicious has been successfully thinned in some cases and overthinned in others. A concentration of 1½ pints per 100 gallons of spray seems best for Rome Beauty and Delicious; 2 pints per 100 gallons for Jonathan. The spray should be applied when the trees reach about 90 per cent full bloom, or not later than 3 days thereafter. These sprays thin the crop at about one-tenth the cost of hand thinning. In addition, they help to break up alternate bearing; that is, the habit of producing a heavy crop one year and little or none the next. Over a two-year period the spray-thinned trees have produced up to 52% more apples than hand-thinned trees.

Blossom thinning sprays must be used with caution, Verner and Franklin advise. They should not be used when trees have a light bloom, if there has been much frost damage to blossoms, or if conditions are not favorable for good pollination. Trees having much apple mildew should not be sprayed for blossom thinning. 129

Some varieties of apples set more fruit than the trees can develop to desirable size every year, and unless artificial thinning is done,
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early in the season, the trees become biennial bearers. Most varieties, in fact, frequently bear too heavily, so that in spite of the expense, the practice of thinning by hand is followed by many of the best growers.

Recent tests by Cornell Agricultural Experiment Station, with sodium salt of dinitrol-cresol, showed, however, that a spray with 0.2 per cent of the substance kills open apple blossoms if applied before pollination and fertilization: "But spraying with this material after the first flowers have been exposed to good pollination for one day to insure a commercial set, the remaining flowers can be eliminated and thus reduce the cost of thinning. Wealthy apple trees treated in this way in the spring of 1941 had an excellent crop of large fruits and required very little hand-thinning. Check trees set so heavily that the fruits were practically worthless. In 1942 the treated trees have enough bloom for a set, an unusual occurrence for such a biennial-bearing variety as the Wealthy. The check trees have no bloom."

"This new method promises to greatly reduce the cost of thinning fruits by hand to insure development of satisfactory size. This is the first practical means of inducing annual bearing in varieties usually biennial in their fruiting habit." 201

Are Thinning Sprays Practical?

(Taken from the Report of experimental work of L. P. Batjer and A. H. Thompson, Tree Fruit Experiment Station, Wenatchee, Wash.)

This past season marks the fourth of extensive experiments with chemical thinning of apples under conditions prevailing in the Northwest. These thinning sprays at the present time are in general commercial use on Golden Delicious and Yellow Newton, and, in Idaho on Rome Beauty. Also many growers, particularly in the Wenatchee area, are successfully using the sprays on Jonathan, Winesap and Delicious. In 1948 it has been estimated that approximately 3,000 acres were chemically thinned in north central Washington alone. Some growers using thinning sprays for the first time sprayed only small experimental blocks, while others sprayed all or a substantial portion of their acreage. One organization alone chemically thinned approximately 300 acres of Winesap, Golden Delicious, Jonathan and Delicious.

While the concentration of the active ingredient used for chemical thinning may vary depending upon varieties and conditions, the amount generally used is about one and one-third pints of Elgetol 20 or its equivalent per 100 gallons of water. Time of application of these sprays ranges from the full bloom stage to 1 to 3 days past the full bloom stage. Even though a heavy set occurs during a cool,
humid bloom period, thinning sprays are more likely to thin heavily than in seasons when generally warm, dry conditions prevail.

Experience has shown that chemical thinning sprays are usually more effective in reducing fruit set on young trees. Also trees under 10 or 12 years of age are likely to be more vigorous and frequently fail to set fruit in proportion to the amount of bloom they produce. Only by trial under one's own condition can it be determined whether these sprays can be used safely on such trees. There seems to be less risk involved on young trees in the case of Golden Delicious and Yellow Newton than with Delicious and Winesaps of comparable age.

Thinning sprays are not fool proof and for this reason can never be universally recommended. Because of one reason or another, as has been outlined above, some orchards are not adaptable to the use of thinning sprays. But a good many are adapted and it remains for each grower to appraise his own situation and determine to what extent chemical sprays might possibly be used. It is suggested that the grower without previous experience proceed on a trial basis until he learns how his trees respond. Within the same orchard response may vary from year to year depending upon weather conditions prevailing during the bloom season.

We regret that it is not possible to recommend chemical thinning unconditionally. However, if the orchardist can employ this method successfully, it is possible to realize as much as $150 to $200 per acre increase in revenue (present day cost and prices) through savings in hand thinning and from increased yields. This should go a long way toward fulfilling the goal of most growers — to grow more and better apples cheaper. 216

Sprays Applicable to Certain Varieties: (Taken from the report of experimental work of L. P. Batjer and A. H. Thompson, Tree Fruit Experiment Station, Wenatchee, Washington). Hand thinning of apples represents a major item in cost of production. Among other disadvantages hand thinning cannot generally be accomplished early enough and heavy enough to accomplish one of its chief purposes; that is, to avoid the tendency of the tree to more or less alternate in its fruiting habit. Also, ultimate fruit size is directly related to the time and thoroughness of this operation. It is, therefore, obvious that any substitute which could effectively overcome some of these drawbacks would be highly desirable.

For best results generally sprays should be applied as near the full bloom stage as possible. By full bloom is meant that stage at which an occasional petal will fall from the earlier opening blossoms when a small branch is gently shaken. At this stage most of the center of “king” blossoms have been open for 12 to 36 hours, and under favorable pollinating conditions have been pollinated and fertilized. When the king blossom has reached this stage it has a greater tendency to
survive spray treatment than the freshly opened or side blossoms, many of which are killed by the spray. If the spray is applied after the freshly open blossoms have become pollinated and fertilized, less thinning may result. Considerable thinning seems to result from "spray shock", however, and many side blossoms, even though fertilized, will fail to stick.

King blossoms resist this shock to a far greater degree. Actually treatment as late as one to three days (of normal weather) following full bloom have been only slightly less effective than the full bloom stage. Timing, therefore, is not too critical and allows from 1 to 3 days in which to make applications. This is a sufficient period for most growers to cover a sizable block of a given variety.

On a number of materials tested for the past several years, the sodium salt of dinitro-cresol (Elgetol) has proven generally the most effective. Other DN chemicals in powder form have proven about as toxicant. An interesting feature of blossom thinning spray is the very noticeable increase in fruit size resulting from these sprays. This difference becomes readily apparent within a few weeks after blossoming.

In one Golden Delicious orchard the fruit from sprayed trees on June 15 (at the close of the June drop period) was 37 per cent larger than fruit from unsprayed trees. The ultimate fruit size in five different Golden Delicious blocks averaged 61 fruits per loose box for the blossom thinned trees. In six Winesap and Delicious blocks the sprayed trees averaged 13 fruits less per box than the unsprayed trees.

It is easy for anyone who has worked with blossom thinning sprays to become enthusiastic over their possibilities. However, from the foregoing discussion it seems obvious that no specific or general recommendation can be made regarding their use. As pointed out above, success with these sprays is based upon the assumption that fruit set will be heavy.

With such varieties as Delicious and Winesap it, therefore, becomes necessary for the fruit grower to decide whether under his conditions the use of these sprays is justified. With Golden Delicious, particularly, there would seem to be little or no risk involved on normal vigorous trees. In many orchards of this variety it would probably require two sprays rather than one to approach the desired amount of thinning. While our work has not included Yellow Newton it probably falls in the same class as Golden Delicious. Vigorous Jonathan and Rome Beauty trees under many conditions respond favorably to blossom thinning sprays.

Without question blossom thinning sprays on some varieties and under some conditions are worthy of serious consideration. Much of the basic work has been accomplished. If this section is to take full
advantage of this practice and the opportunity it affords in cutting the cost of production, it remains for the individual grower to test the feasibility of these sprays under his own particular conditions. 112

**COMPARISON OF MATERIALS IN THINNING:** During the past 10 years the use of various types of chemical sprays applied during the bloom period for the purpose of reducing fruit set of apples have been reported by many investigators. In general, results obtained have varied so widely as to preclude the possibility of applying the methods and techniques developed in one area to that of another. The experiments herein reported were particularly designed to evaluate the commercial feasibility of chemical sprays for apple thinning under conditions prevailing in the Wenatchee district of the Northwest. According to the reports of the Wenatchee Tree Fruit Experiment Station most of the treatments applied in the three years of experimental work in apple blossom thinning resulted in an appreciable reduction in fruit set.

All factors considered, Elgetol seemed to be the most consistent and effective. Used at equivalent toxicant concentration, DN No. 2 resulted in a slightly greater reduction in fruit set than Elgetol, though it generally produced somewhat more injury to foliage. However, injury from any of the treatments was not regarded as commercially important.

Results with naphthalene-acetic acid were more erratic than with Elgetol, and in several instances fruit size was less than might be expected on the basis of the amount of thinning accomplished. This probably was because the fruit attained considerable size (as was pointed out) before dropping. Nevertheless, results in the present experiments as well as those reported by Hoffman et al would indicate promise for this material for thinning apples during the bloom period as well as two or three weeks later. In several tests on Winesap morpholine thiram disulfide (MTD), an organic fungicide, proved about as effective as Elgetol in reducing fruit set. 218

**PREHARVEST SPRAYING**

The purpose of spraying a seed crop such as Ladino clover and alfalfa a few days prior to harvest is to aid the drying up and maturing of the crop prior to fall rains. This method permits the crop not only to be harvested ahead of possible early rains but eliminates the wind rowing, allowing direct combining. It also eliminates green weeds in the harvesting and makes for a cleaner seed. “Dow General” manufactured by the Dow Chemical Company, is said to be very useful in pre-harvest spraying. The spray is usually applied 2 to 5 days prior to harvest depending upon the temperature and humidity.
GROWTH REGULATORS

DEFOLIATION

(Following information — courtesy National Cotton Council)

Your attention is directed to the brochure, Fig. 14, published by the National Cotton Council 261 (See Bibliography, Volume VI). Write for this 24 page booklet which treats in considerable detail cotton defoliation. The following paragraphs are quoted:

Nature of Defoliation

The process of defoliation is a very natural one for cotton which belongs to that group of plants that are inherently deciduous, losing their leaves by a natural process when they have become mature or senescent. This state of senescence or old age is not always related to age in days or months. It is more often a reflection of the conditions under which the cotton plants have developed. Once having attained ample structure the leaf can become senescent, and subsequently shed from the plant, through the influence of a number of natural causes. Drought, nutrient starvation, insect and fungus attacks, cold weather and even light frosts may produce a condition of the leaf that is essentially senescent and thereby contribute to defoliation. These causes of senescence may all be considered as injuries, or unfavorable alterations of vital plant processes, and the use of chemicals for the purpose merely involves use of an applied injury that ultimately induces the plant to cut off (abscise) its leaves.

Fig. 14.

Chemical Defoliation Of Cotton

Normally the function of cotton leaves will be interrupted as soon as there is any evidence of injury following application of the chemicals. Even before leaves fall there is a curtailment of manufacture and transport of leaf reserves to the bolls. The effect must then be judged in terms of the time of application rather than time when the plants are entirely defoliated. Consequently, any bolls found immature at the time of application may contain immature seed and fibre at time of harvest. Bolls that are mature, but unopened at this time, will open more rapidly. If the majority of bolls are mature there will be little loss in quality of yield.

Usually the cotton fibre attains its full length within 20 to 21
days. The boll attains full size a short time later but fibres con-
tinue to strength and seed reserves accumulate up to the time the
boll splits and seeds are no longer receiving supplies from the plant.
This background prepares us for what has been ascertained about
early defoliation. 261

Advantages of Defoliation

Several of the benefits of defoliation have been under-emphasized.
Its effect on insect control has been mentioned often this year and it
is considered of sufficient importance by entomologists to warrant their
making a definite statement in the 1949 Conference Report on Cotton
Insect Research Control, as follows:

"Defoliation of cotton with chemicals has a direct relation to cotton
insect control. Defoliation of the cotton has been found to cause boll
weevils to leave such fields almost immediately. It also reduces the
percentage of locks infested by weevils. Damage to open cotton by
heavy aphid populations and late cotton leafworm infestations has
been prevented by chemical defoliation."

"Proper defoliation checks the growth of the cotton plant and
accelerates opening of the bolls. The crop may thus be harvested
earlier thereby permitting earlier destruction of the stalks. Where
cotton has been defoliated, a much smaller number of weevils were
found the following spring." Reduction of boll rot and prevention of
weathering damage have long been considered major benefits of de-
foliation, particularly in the Southeast.

Defoliation is often a necessity if machine harvesting is to be utilized.
With both spindle pickers and mechanical strippers, defoliation assists
in at least three valuable functions: (1) removal of the bulk of leaves
that interfere with machine efficiency, (2) prevention of green leaf in
the lint, and (3) elimination of a source of dry leaf trash which is
difficult to remove at the gin. 261

Factors Limiting Efficiency

The condition of the plant and the prevailing weather at time of
application will be the major factors that limit efficiency of the de-
foliation process regardless of the defoliant used. Present defoliants
have only minor differences relative to the plant condition most con-
ductive to efficient defoliation. They differ markedly, however, as to
what might be called the most ideal weather condition for application.
In general, efficiency seems highest when plants have become veget-
atively dormant and reproductively mature; when the moisture con-
tent of leaves is high; and when both temperature and humidity are
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high. In fact, some defoliants are directly dependent upon dew for most efficient activation. Before abscission can take place, the leaf must be in a condition of activity that will allow the proper degree of reaction to the chemical. There also must be sufficient activity to allow for the biological processes that accompany cell multiplication and eventual separation in the abscission region.

Defoliation efficiency has been found directly related to age of leaves, providing the plants have been in a continuous state of growth up to the time of application. As fruiting progresses it usually is found that the lower leaves and the leaves subtending the mature bolls are easy to remove whereas the leaves of the newer growth are removed with difficulty. Where this continuous growth and fruiting are maintained up to defoliation time, complete defoliation is difficult especially since the younger leaves have not developed the state of senescence or old age needed for rapid abscission. 261

Chemicals used as Defoliants

(Recommendations of the National Cotton Council)

Wide variations exist relative to needs and specific requirements for use of the defoliation process, and knowledge of exact local requirements may not be satisfied by this presentation. The conference group strongly advocates supplementing the general knowledge contained in this report through consultation with local agricultural authorities — particularly if specific needs do not seem to be answered by these generalized guides. Defoliants may be applied either as dusts or sprays. Local condition of humidity, amount of dew present, turgidity of plant, stage senescence, etc., largely determine the particular defoliant which is best.

• CALCIUM CYANAMIDE (dust) may be used when and where dews occur. The rate required will depend upon variations in climate and status of plant growth. Use 20 pounds when plants are mature and active, when weather is warm, humidity high, and heavy dews are expected — even when growth is moderately rank. Use 25 to 30 pounds under the above conditions but when growth is very dense and leaves tend to be toughened. Use 35 to 40 pounds when plants are droughty, leaves tough, humidity low and weather cool — particularly when dews are of short duration. Rates in excess of 40 pounds are not recommended and their use may tend to burn the leaves so severely that defoliation will be delayed or prevented.

• MONOSODIUM CYANAMIDE (X-10) (dust): This defoliant is not dependent upon dews. It becomes liquid on the leaf by drawing moisture from the air or the leaf itself. It may not be efficient in drought stressed cotton or when humidity is low. Use 30 to 35 pounds per
acre where plants are active and mature, where foliage is turgid and not too dense, and when humidities (at least during the night) will exceed 40 percent. Use 40 to 45 pounds per acre when growth is rank and foliage is excessively dense or where plants have low activity and when humidities are very low. 261

**SODIUM MONOCHLOROACETATE:** This material may be applied in the complete absence of dews and at relatively low atmospheric humidities. It has been under widespread experimentation for only one season and its strict activity, maturity and climatic requirements are yet to be worked out.

For Use in Airplanes: Dissolve one pound in each gallon of water. Apply this solution at 4 to 6 gallons per acre for the plant and environmental conditions favoring defoliation; 7 to 10 gallons per acre for very tall, dense, and drought-stressed cotton. For Use in Ground Machinery: Apply the pounds stipulated below in sufficient water to wet the foliage. These rates will be: 4 to 6 pounds per acre where conditions favor defoliation; 7 to 10 pounds per acre where defoliation is difficult. Rates in excess of 10 pounds per acre will tend to kill and freeze leaves — particularly the less mature leaves.

**MONOSODIUM CYANAMID, (X-5), E. C. 3504 and sodium thiocyanate are defoliants still in the experimental stage. 261

**SODIUM CHLORATE - SODIUM PENTABORATE:** This defoliant has been used in a formulation containing 42 percent sodium chlorate and 58 per cent sodium pentaborate, and all information here pertains to the use of this specified mixture. The chlorate content may be considered as an index of active ingredient. The borate is included as a suppressant of fire hazard. Because of this hazard, sodium chlorate is not recommended for use as a defoliant without an adequate suppressant.

Sodium chlorate-sodium pentaborate is effective in the complete absence of dews and at very low humidities, but, like all other defoliants, it works best with high leaf turgor and complete reproductive maturity. For use in airplanes dissolve 1 pound in each gallon of water. Apply this mixture at the rate of 5 gallons per acre, where foliage is not too dense, activity high, and plants are mature; 7 gallons per acre, where growth has been rank and/or cotton is very droughty.

For use in ground machinery apply 6 to 8 pounds per acre dissolved in 10 to 20 gallons of water — or sufficient water to obtain complete coverage. Use the 6 pound rate for conditions where 5 gallons are stipulated for airplane use. Use the 8 pound rate for the rank growth and particularly for the water stressed conditions. 261
POTATO VINE KILLING

(Taken from Paper No. 226, Department of Vegetable Crops, Cornell University)

Summary: The killing of potato vines has become a desirable or necessary practice with many growers and the question of when and how to destroy top growth is a pertinent one. Field experiments were conducted in 1946 and 1947 in an attempt to gain additional information on this problem. With the procedure followed, Penite 6 plus activator resulted in the most efficient kill observed. Dowspray 66 Improved, Penite 6 without activator, Sizz flame, and Sinox General gave satisfactory kills. Cyanamid X-5 and X1 gave fairly satisfactory kills, especially of leaves.

Yields were lower in rapidly killed plots than in controls or poorly killed plots. Differences between killing dates indicate that increase in tuber size during late stages of maturity warrant delaying the application of vine killers as long as possible unless greater size is objectionable. Discoloration of the vascular region was decidedly increased by killing injury to top growth. Specific gravity readings were lower in vine killed plots than in controls with the most rapidly killed plots giving lowest readings. Sprouting and shrinkage loss other than sprouting was not significantly affected by killing agents. Early kill resulted in significantly greater loss than later kill. Neither killing agents employed nor killing dates appeared to have a significant effect on the value of tubers as a source of seed.

VERIFY ALL DOSAGE RECOMMENDATIONS WITH LOCAL AUTHORITIES BEFORE USING
There are ten or more important plant foods. Phosphorus, nitrogen, potash and calcium are well known as major commercial soil fertilizers. Other plant foods used in much smaller amounts but just as essential are carbon, hydrogen, oxygen, magnesium, iron, sulfur, boron, zinc, silicon and copper.

Trace Elements

As indicated by the term trace elements, some plant foods are needed in only very small amounts. Some plants will tolerate a surplus of the trace elements. For example, alfalfa will tolerate large amounts of Boron whereas beans will tolerate only trace amounts. There is some danger in too much of certain trace elements. For example, certain plants may tolerate excessive amounts of molybdenum which, however, may be dangerous as cattle forage.

MAJOR AND MINOR PLANT FOODS: There are ten plant food elements required in considerable quantity for growth: Carbon, calcium, hydrogen, magnesium, oxygen, iron, phosphorus, nitrogen, potassium, and sulfur. Phosphorus, nitrogen and potash are usually added to the soils in commercial fertilizers. Calcium and magnesium are usually added in the form of lime or dolomite and sulfur in the form of sulfate radical in fertilizer salts.

Minor or trace elements are required in smaller amounts. Trace elements are to plant life what vitamins are to human life. These are: Manganese, boron, copper, zinc, and cobalt (silicon). The absence of these elements produces deficiency diseases in plants similar to the vitamin deficiency diseases in animal and human nutrition. Sulfur in addition to being a major plant food serves also to act as a carrier for the other food elements.

Effects of Deficiencies

- **BORON**: Heart and dry rot in beets and turnips; cracked stem in celery; Brown heart of Cauliflower.
- **COPPER**: Slow or complete cessation of growth. Plants are weak and unproductive. "Heather moor Disease" of oats and barley. Disappearance of better grasses on land in sod.
- **MANGANESE**: Brittle leaves. "Gray speck" of oats; wheat, barley, potatoes, turnips, kale, beans, peas, flax, clover, spinach, and many grasses.
• Zinc: Stunted growth and reduction of buds. "Rosette" in pecans and apple trees; "mottle-leaf" of citrus; "yellows" of walnuts and "white bud" of corn plants.

• Magnesium: Brittle leaves and discoloration of leaf. Non-uniform produce and delayed maturity in tobacco and most crops.

• Silicon: Concentration of minerals within plant, interfering with utilization of the nutrients.

SOIL DEPLETION OF MINOR ELEMENT: Intensive farming, heavy cropping, high yield varieties, all have contributed to a heavy drain on the minor element plant foods. Minor elements formerly were returned to the soils in animal manures.

• Calcium Cyanamide: Calcium cyanamide has strong weed killing characteristics, ultimately breaking down into a nitrogenous fertilizer. It also can be used as a vine killer.

Since alfalfa has become depleted in many Washington orchards (principally because of arsenic toxicity) zinc deficiency has become widespread in many fruit areas. The best known method of correcting zinc deficiency is by means of dormant sprays at the rate of 25 to 40 pounds of zinc sulfate per 100 gallons.

During the past year a considerable amount of acreage received zinc sulfate spray applied with the airplane during the dormant period in a concentrated solution at the rate of 40 to 100 pounds of zinc sulfate per acre. In an experimental block of Bartlett pears the airplane (40 pounds per acre) was highly effective in correcting acute zinc deficiency.

Zinc deficiency on pears is generally easier to correct than on apples; on sweet cherries it is particularly difficult. On the latter fruits it is not definitely known whether an acute condition can be corrected with the airplane method. It seems likely, however, that this method will prove effective in maintaining the zinc requirements and correcting a sub-acute deficiency on both apples and cherries.

A relatively weak zinc sulfate spray on apples and pears applied as soon as possible after harvest in the fall offers considerable promise of correcting a mild zinc deficiency and maintaining the zinc requirements. The Washington Tree Fruit Branch Station reports good results with no injury when not over four pounds per 100 gallons is used. For best results with the least chance of injury, zinc sprays during the dormant period (whether applied with the airplane or conventional method) should be applied within a few weeks prior to growth initiation in early spring.
PLANT FOODS

It is difficult, if not impossible, to correct a zinc deficiency if it exists in combination with chlorosis or iron deficiency. These two deficiencies frequently occur in combination since the same soil condition is essentially responsible for each. In such cases it is suggested that iron citrate injections precede by one year a zinc spray application. 73

BORON DEFICIENCIES IN APRICOTS: Boron deficiencies have become apparent in many areas. According to the published reports of R. M. Bullock and N. R. Benson of the Tree Fruit Experiment Station of Wenatchee, Washington: Apricots, produced in certain orchards in the Wenatchee Valley of Washington during recent years, have shown fruit malformations that have made the affected fruit unmarketable. During the 1946 season, several orchards produced fruit that was severely cracked. In other orchards, the fruit was shriveled, cracker, deformed and discolored with internal browning and corky tissue developing near the stone. These symptoms were found even more widely distributed in the 1947 season. 40

During the season of 1946 when these disorders in apricots were brought to the attention of these experts soil applications of borax were made at the rate of ½ pound per tree to four trees in two different orchards showing the symptoms described above. The fruit produced on all of the trees treated with borax in 1946 were free of any of the symptoms in 1947, while the untreated trees again produced fruit showing all of the symptoms. 40 Plants can be over borated. Boron can be tolerated in large amounts by such plants as alfalfa but only in trace amounts by such plants as beans.

AERIAL FERTILIZATION

Because of the airplanes ability to operate at any time of the year regardless of surface conditions the distribution of fertilizers by airplane has a big potential. This method of fertilization is growing rapidly. Distribution of nitrogen fertilizers from airplanes has been practiced extensively on the rice lands of California and Texas. In Texas, Dr. Fudge estimates that three times as much rice acreage was fertilized from the airplane in 1949 as was seeded by this method. Fertilization by aerial methods has also been used extensively in Indiana, Illinois, Washington and Oregon. Any fertilizer material that can be drilled could be distributed from an airplane.

One very important item that should be considered is fertilizer replacement in soil. Over the past 25 years much research work has been done to determine the best method of fertilizer placement. In general, the placement of phosphatic fertilizers is highly important, while the placement of nitrogen is relatively unimportant, so long as 103
it does not damage the seed or plants. In fertilizing small grains with phosphorus the best method is to place the fertilizer in the row with the seed broadcasting the material decreases the efficiency by about one-half. Airplane application is a broadcast treatment, thus we should not expect as good results from airplane placement of phosphorus as we get from the use of the best ground equipment. With nitrogen, the placement problem being relatively unimportant, we should expect about equally good results from airplane application as from application by means of surface equipment, providing the aerial application results in uniform distribution of the fertilizer. The big question then is one of relative economy.

The place where aerial application of fertilizers will have its greatest place is: (a) where the area to be fertilized is extensive, and (b) where the area is relatively inaccessible to ground equipment. In Kansas the area having the greatest need for fertilization is in the eastern part of the state where the fields tend to be small. In the large fields of central and western Kansas the need for fertilizers is much less than in the eastern part of the state. 172

Granulated Fertilizers

The granulation process converts the finely ground chemically processed fertilizer to relatively large spherical particles. The small powdered particle is left as such would tend to leach rapidly in the soil solutions. The large granules therefore tend to remain in readily available form for a longer period of time. In addition to the longer lasting quality of the superphosphate granules the spherical particles are non-caking, dustless and non-corrosive to farm machinery. 250

Traditionally we have always thought of phosphate, nitrogen, potash, and calcium as the only soil fertilizers required. Now we know that a well balanced soil must have other elements in lesser amounts. These four are the main fertilizing elements but not the only ones.

Alfalfa Liming

Alfalfa is a heavy consumer of lime, therefore, acid soils require liberal applications to insure success. Liberal applications of phosphate and potash are also essential to satisfactory growth if the soil is deficient in these elements. 141

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AGRICULTURAL AUTHORITIES

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The air-applicator must constantly keep in mind the basic concepts of chemical crop treatment. He must know that:

(a) Crops *stage* and *mature* differently in different geographical areas.

(b) That various species of the same plant *react* differently to the same chemical.

(c) That *growth conditions* materially affect toxicity.

(d) That *dry, warm weather* tends to toughen plant foliage.

(e) That the *carriers* used affect the effectiveness of the chemicals.

(f) That *timing* has much to do with results.

(g) That *temperature* has much to do with results.

(h) That the potential hazard of drift must always be kept in mind.
NOTE:—
This is but one of six volumes prepared to aid you in the techniques of air application.

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