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Meeting the Spray Material Shortage

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FOREWORD

In the present situation it should be assumed that shortages of any material may occur at any time, that nothing should be wasted and that maximum benefit should be obtained from even the cheapest and most plentiful materials.

On the basis of the facts already available, sizeable shortages of spray materials can be met without serious losses in production of essential foods. Among the important ways of conserving materials are (1) accurate diagnosis of troubles, so that ineffective treatments are avoided, and (2) selection of important food and vitamin crops for treatment, and elimination of "luxury" crops.

Careful consideration of the whole problem shows that the best answer now is to stretch the supplies of materials commonly used, rather than to depend too heavily on possible substitutes or alternates. Manufacturing facilities are available for the common materials, but the facilities for making new materials may be impossible to procure.

The greatest single saving in the common materials can be made by reducing the dosage applied. The amounts of these materials suggested in the past can be reduced by half without sacrificing much control. The data available on 16 diseases and insects indicate that the use of half the "standard" dosages would result in only about 5 percent decrease in control.

In Connecticut, 0.5 percent rotenone dust is the *maximum* dosage suggested and 4-2-50 the *maximum* strength of Bordeaux mixture for late potatoes. In any case, the materials available, however short, should be spread over all the acreage, rather than treating only a small portion of the crop and leaving the rest to the ravages of pests.

On the basis of recent research, suggestions are offered for improving the coverage of the plants, that is, for improving efficiency of application so that equal control may be maintained with less material. Contrary to expectations the results indicate savings in materials may be large.

Suggestions are offered also on timing treatments and on timing the planting of crops to escape pests. In general treatments for diseases should be applied just before a rain and for insects just after the rain has stopped. Intervals between disease treatment can be extended safely in dry weather.

The methods outlined above should meet most of the shortages. In addition some alternate materials are available to supplement supplies. In the insecticide field, the most important are (1) impregnated pyrethrum dust, (2) impregnated rotenone dust and (3) synthetic organic thiocyanates added to rotenone dust. These are all excellent insecticides to supplement rotenone dusts. Some organic fungicides may be available to supplement mercury and copper materials for both seed treatment and use on foliage.

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The war has affected control of pests both directly and indirectly. Supplies of several materials needed in large quantities have been cut off by invasion of the producing countries. Other materials, such as steel, copper and rubber, are vital war needs and their conservation in pest control becomes a necessity. At the same time more food must be produced, and an important factor in production is pest control. The problem, then, is one of doing the best job of pest control with the minimum of vital materials, and not of increasing the control by use of more material.

The Experiment Station has long been engaged in research on insecticides and fungicides and on the factors governing their efficiency when used on fruits and vegetables. Many of the facts developed by recent research can be applied to provide much more efficient control than obtained in the past. Other information bearing on the subject has been included in this publication because, for one reason or another, these facts have not been used up to the present time.

AVAILABILITY OF MATERIALS

Exact estimates of the amounts of insecticides and fungicides available for 1942 or any succeeding year cannot be given with any accuracy at present. Fortunately, such information is not necessary for a discussion of conservation. In an emergency situation it should be assumed that shortages of any material may occur at any time, that nothing should be wasted and that maximum benefit should be obtained from even the cheapest and most plentiful materials.

It is on this basis that the following discussion is presented. Farmers may rest assured that production of food ranks second in importance only to production of actual munitions. Therefore, manufacturers and the War Production Board will make every effort to provide a supply of insecticides and fungicides.

CONSERVATION

The means for saving materials are legion. Perhaps the most important of these are (1) to use them on troubles than can be controlled, (2) to treat only plants that are likely to be most in need, (3) to improve the efficiency of distribution over the plants and (4) to give careful attention to the dosages.

ACCURATE DIAGNOSIS OF TROUBLES

Accurate diagnosis of a plant pest must precede adequate treatment. Too often mistakes in diagnosis are made and material is applied where no treatment would do any good or when another type of treatment is needed.

For instance, eggplants and tomatoes affected by wilt diseases are often sprayed under the supposition that they are afflicted with a leaf spot disease. In both cases the leaves die, but a careful observation in the case of wilt would show that the leaves wilted first and then died. On the other hand, in cases of the leaf spots, the leaves become spotted before dying. Applying a fungicide would have no effect on the wilt fungus, but would protect foliage from the leaf spot disease.

As another example, bean foliage may turn "rusty." Since rust diseases are combated with fungicides, the tendency might be to spray or dust with copper. However, beans react to many pests by turning a reddish color. Red spiders on the undersides of the leaves may be responsible, in which case all fungicides and many insecticides would be of no value.

Exact diagnosis is difficult sometimes even for the expert, but it is at least possible to distinguish between fungous and insect troubles. Various bulletins are available to help growers in diagnosis. The Extension Service and Experiment Stations are glad to help when possible. It will be impossible for experts to visit farms to diagnose all troubles, and home diagnosis and use of the mails will have to be increased. Specimens mailed in should represent various stages of the trouble. They should be collected just before mailing, packed in moist cotton, wrapped in waxed paper, and mailed in a substantial container that will not be crushed or broken in transit. The whole plant is preferable unless the size prevents. There should be an accompanying letter with information on the history of the trouble, a complete description of the symptoms, the fertilizer practices, variety, weather information and any suggested causes.

SELECTION OF IMPORTANT CROPS FOR TREATMENT

A distinction can be made between those insects and diseases that affect quality only and those that actually reduce the yield of crops. Many of our control measures deal entirely with quality of the crop, and in some cases it is possible to sacrifice some of this quality and thus save materials for use in increasing quantity production of other crops. Apples with some curculio and scab damage are entirely acceptable. On the other hand, quality cannot be sacrificed in some cases without destroying the value as food. Broccoli, spinach and similar crops infested with aphids are not acceptable to the average consumer. The same is true of cabbage, cauliflower and broccoli heavily infested by worms, corn by the corn borer or corn ear worm, apples damaged by the apple maggot, or peaches infested by the fruit moth.

Arsenate of lead is used in sprays on ornamental plants and as a soil insecticide in lawns to control the Japanese beetle. If a shortage of this material occurs, elimination of such a non-agricultural use would free large quantities for farmers.

With only a limited quantity of materials available, each grower can obtain the most benefit by applying them where they will do the most good. First choice can be made for those crops requiring treatment to produce a normal yield. Next should be included those that affect quality in such a way as to destroy or greatly reduce the sale value. Any surplus available after these treatments have been made can be saved for future use.

In actual practice in Connecticut the following food crops are first choice for treatment:

Spraying or dusting	**Seed treatment** (chiefly to save seed)
Potatoes	Spinach
Green beans	Peas
Cabbage	Lima beans
Celery (where leaf diseases are bad)	Potatoes
Squash and cucumbers	Cucumber family

The crops which require foliage treatment to produce a quality that can be sold are:

Apples
Peaches
Broccoli (aphids and worms)
Carrots (leaf blight)
Spinach (aphids)

ELIMINATION OF UNNECESSARY TREATMENTS

The use of an "all-purpose" dust on vegetables has been practiced by many growers. Such a dust contains both a fungicide and an insecticide, and its use has avoided the necessity of selecting the proper material for each pest. This practice was wasteful in time of plenty and should be discontinued now. The use of copper with rotenone on beans to control the bean beetle adds nothing to effectiveness and may do some harm. The same is true of copper-containing dusts for striped cucumber beetles. The pest control schedules now published for fruits and vegetables can be followed by eliminating use of "all-purpose" dusts except where they are necessary.

The following "luxury" crops that are dusted or sprayed can be replaced by more essential ones:

Extra early sweet corn
Muskmelons and watermelons

Crops now treated on which elimination of treatment would cause little reduction in yield are:

Tomatoes (for defoliation diseases)
Hubbard squash (for leaf diseases)
Onions (for onion thrips)

DOSAGE

Dosage is used here in the sense of the amount of toxicant (active ingredient) applied per plant unit (per acre, bushel of seed, tree, plant, etc.). For example, 24 pounds of copper sulfate per acre may be applied in 150 gallons of 8-8-50 Bordeaux. Half this dosage would be 12 pounds of copper sulfate per acre or 150 gallons of 4-4-50 Bordeaux mixture. Use of 75 gallons of 8-8-50 Bordeaux to reduce the dosage of copper sulphate to 12 pounds per acre would introduce the complication of coverage, which is discussed below. All discussions of dosage in this paper are based on experiments where all factors except dosage have been held constant.

The basis for deriving the recommended dosages of spray materials has been—produce maximum control. In an era of plentiful materials, these recommended dosages have crept upward as a sort of insurance against a pest epidemic and against inefficient methods of application. Seldom has the improved control been counted in terms of the quantities of materials required.

Now that farmers are confronted with an unaccustomed shortage of materials, a study of the quantity problem is necessary. The problem now is not to boost control without regard to how much material is required, but rather to learn how little spray material can be used without serious sacrifice of control.

A rather extensive study of this problem has already been made at this Station.[1] As would be expected the law of diminishing returns operates. The amount of control increases ever more slowly as dosage increases. The problem is to obtain a general idea as to how far above the shoulder of this curve the generally recommended dosages are. This knowledge would tell how far dosage can be reduced without seriously reducing control. Dosage experiments covering a wide enough range are available at this Station or in the literature.

Data on a large number of materials used on a wide range of pests have been assembled in the accompanying table where they are expressed on the basis of the reduction in percent control for a reduction in dosage to one-half and to one-tenth. The actual figures were usually obtained from curves plotted.

It seems unlikely now that supplies of any material will be cut to less than one-half. From the table it is clear that this amount of reduction in dosage has seldom reduced control by more than 4 or 5 percent, irrespective of the pest concerned. This gives the general indication that this is the "expectancy" in the future.

From this finding it follows that if a farmer were able to obtain only half his normal supplies he would be using them more efficiently by covering all his normal acreage with half normal dosage than by covering half his acreage with normal dosage.

Likewise it follows that dealers and manufacturers can make the most effective distribution of materials to their regular customers by prorating their supplies.

These data seem startling at first. A decision to reduce quantities of fungicides and insecticides by half seems fraught with unforeseen dangers. Clearly all evidence on 16 diseases and insects indicates the strong possibility that no serious results would ensue. It may be thought that an inefficient grower might be in more danger than an efficient grower. This is true to some degree because the reduction in percent control is greater per unit of dose in the middle range than

[1] See Dimond et al. Conn. Agr. Expt. Sta. Bul. 451, 1942.

SUMMARY OF INFORMATION ON RELATION OF DOSE TO CONTROL FOR 16 DISEASES AND INSECTS.

Chemical	Crop	Disease or insect	% Reduction in control for 50% reduction in dose	Control for half dose	% Reduction in control for 90% reduction in dose	Source[1]
Yellow copper oxide	Tomato foliage	Alternaria leaf spot	2.0	58.0	9.0	B
Yellow copper oxide	Muskmelon foliage	Macrosporium leaf spot	6.5	75.0	30.0	L
Yellow copper oxide	Pea seeds	Pythium seed decay	6.0	69.0	27.0	F
Semesan	Pea seeds	Pythium seed decay	4.0	74.0	39.0	L
Chloranil (Spergon)	Pea seeds	Pythium seed decay	9.0	68.0	34.0	L
Tetramethyl thiuram disulfide	Pea seeds	Pythium seed decay	4.0	75.0	18.0	L
Mercaptobenzothiazole	Pea seeds	Pythium seed decay	8.0	54.0	32.0	L
Zinc oxide	Spinach seeds	Pythium seed decay	5.0	44.0	17.0	A
Red copper oxide	Muskmelon foliage	Macrosporium leaf spot	9.0	63.0	37.0	L
Red copper oxide	Pea seeds	Pythium seed decay	12.0	55.0	34.5	F
Red copper oxide	Wheat seeds	Bunt	2.0	95.0	12.0	B
Bordeaux mixture	Peach twigs	Peach leaf curl	0.7	96.5	....	D
Wettable sulfur	Apple foliage	Apple scab	1.5	98.8	5.5	B
Sulfur dust	Soil	Wheat bunt	6.0	57.0	20.0	G
Organic copper compound	Celery foliage	Septoria leaf spot	5.0	80.0	22.0	B
Copper carbonate	Wheat seeds	Bunt	2.5	97.5	30.0	K
Rotenone	Cabbage	Imported worm	7.0	78.8	26.9	J
Rotenone	Cabbage	Looper	12.0	61.1	42.5	J
Pyrethrum	Cabbage	Imported worm	none	48.1	18.4[2]	J
Pyrethrum	Cabbage	Looper	3.1	36.1	33.6[2]	J
Elgetol	Snowball	Snowball aphid	3.6[3]	96.4[3]	10.4[4]	C
Elgetol	Spruce	Spruce gall aphid	7.2[3]	97.8[3]	....	C
Nicotine sulfate (with oil)	Apples	Bud moth	8.0	70.0	....	E
Nicotine sulfate (with lime-sulfur)	Apples	Bud moth	6.0	67.0	....	E
Lead arsenate	Apples	Codling moth	5.2	89.8	....	H
Lead arsenate	Apples	Codling moth	10.4	62.2	....	H
Lead arsenate	Woodland	Gipsy moth	6.0	91.4	....	I

[1] See references as follows:
A. Cook. Va. Truck Expt. Sta. Bul. 96. 1937.
B. Dimond et al., Conn. Bul. 451, 1942.
C. Gambrell, N. Y. Geneva Bul. 698, 1942.
D. Groves. Phytopath. 28, 1938.
E. Hartzell. N. Y. Geneva Bul. 698, 1942.
F. Heuberger and Horsfall, Phytopath. 29, 1939.
G. Mackie and Briggs, Calif. Bul. 364, 1923.
H. Newcomber and Yothers, U.S.D.A. Tech. Bul. 281, 1932.
I. Potts, U. S. Bur. Ent. Series E. 515. 1940.
J. Reid et al. U.S.D.A. Tech. Bul. 782, 1941.
K. Twentyman, Jour. Dept. Agr. Victoria 28, 1931.
L. Unpublished data.

[2] 1/8 original dose
[3] 1/4 original dose
[4] 1/15 original dose

in the higher ranges of control but, even so, the effect is small. The effect, in practice, is to reduce control by only a small percentage for a reduction of 50 percent in dosage.

Another possibility is that infestation or inoculation level may suddenly increase and disturb these figures. An increase in this level operates in the same fashion as increase in dosage. The control level drops progressively less as the population increases. Twentyman, working on wheat smut, has shown that the control with copper carbonate seed treatment drops only 9 percent as the smut load doubles. This would indicate a not too serious effect of infestation level.

Dusts containing rotenone have been used in much greater strength than necessary. Probably this was done because of the inconvenience of having two or three strengths of dust on hand. The proper maximum strengths for various pests are as follows:

.4 percent rotenone	Mexican bean beetle
.5 percent rotenone	Imported cabbage worm
	Cabbage looper
	Striped cucumber beetle
	Potato flea beetle

If growers or dealers have dusts of greater strength on hand, these should be re-mixed with a filler to the percentage of rotenone indicated above.

On potatoes, 4-2-50 Bordeaux mixture applied thoroughly should be considered the maximum strength to use at present.

IMPROVED COVERAGE

Available supplies of materials can certainly be stretched by efficient coverage of the plant or insect, but unfortunately, little is known about the subject. Considerable research has been directed at the general problem but the objective again has been to hoist the control another notch or two. Such an experimental design provides little of value to measure the efficiency in terms of dosage saved.

It should be emphasized that sprays and dusts are applied to plants to kill some pest living there, such as aphids, bean beetles or powdery mildew, or to lay down a layer over all the foliage so that no pest arriving afterward can attack the foliage without being killed. Accordingly, the important consideration is to be sure that the materials are so applied that they cover all tissues without wastage.

Finally, this is the problem of covering the lower and inner foliage of plants without unduly overspraying the outside so that material runs down on the ground.

Sprays. This field of research is being explored at this Station. Use of comparatively large nozzle openings results in a coarser spray which penetrates the inner critical leaves better than fine nozzle openings producing a "mist." Of course the larger nozzles apply more gallons per acre, but this effect can be offset by reducing the concentration in the tank. It has been found in the case of tomato spraying (see Bulletin No. 456) that equal control of leaf diseases can be obtained with one-third the amount of copper per 100 gallons, provided the nozzle opening is increased enough in size to apply 150 gallons per acre instead of 60 gallons. One-tenth of the copper is enough if the nozzle size is further increased to provide 375 gallons per acre. Similar results have been reported for citrus spraying in California. It seems likely that similar results would be obtained on other crops, especially potatoes. Experiments of this type will be made on potatoes in 1942.

Dusts. Little work has been done on the effect of nozzle size on distribution of dusts. Several important facts affecting coverage by dusts are known, however. Dust will not stick well to dry foliage. Except for dusts applied for aphids, in which case a cloth trailer is used, all dusts should be applied either at night or in the early morning hours when the dew is on the plants. If no dew is there, dusting should be postponed to another day. Otherwise material will be wasted. *This fact has been known for at least 100 years and it is high time to apply it.*

Improved coverage by dusts cannot be obtained by simply increasing the amount of dust applied. Twenty to 30 pounds per acre of vegetables is sufficient if it is applied where it belongs. Neither dusts nor sprays can be "drifted" onto the foliage, particularly the under surfaces. They must be directed there.

IMPROVED TIMING OF APPLICATIONS

Protective treatment of crops, that is, application to prevent trouble later, can be wasteful. Diseases do not develop much during dry weather, and application by a set time schedule, such as once a week, is unnecessary. Celery may require dusting every three days during a wet spell, and not at all during a drought. Potatoes sprayed thoroughly have enough residue to prevent leafhopper damage during drought because little unprotected new growth occurs. Applications for disease protection are best made just before a rain and for insect protection just after a rain.

Insecticides should be applied after insects appear but before they have destroyed much of the crop. Often the grower waits too long and until too much injury has been caused. He then wastes much of what he applies. In such cases the materials can be used to better advantage on a crop that can be saved. Fungicides are better applied before the diseases appear, but often material can be saved by waiting until a few spots appear. In any case timing involves eternal watchfulness of the plants.

Potatoes are often oversprayed with Bordeaux mixture, which is deleterious to them if no pests are present. The applications therefore should be timed with care. Cobblers planted for an early crop should not be sprayed at all with Bordeaux mixture, but may be dusted with insecticides to control flea beetles. Neither Green Mountains nor Cobblers for a late crop should be sprayed with Bordeaux mixture before July 1 in Connecticut. Tomatoes and muskmelons often go down with the birds-eye spot or so-called early blight. Actually these crops are never attacked by these diseases until the fruits begin to set. Accordingly, protective sprays should not be applied before four or five blooms actually set fruit. The timing should be based more on the stage of the plant than on the calendar.

In addition to improved timing, the interval between treatments can be extended in many cases without reducing control seriously. Three applications at intervals of 10 days are only slightly less effective than four at weekly intervals. Potatoes, for example, yield almost as many bushels per acre sprayed six times as sprayed eight or even 10 times during the same period. The same is true of cover sprays for apples during the summer. Further, applications of arsenate of lead with adhesives prolongs the effectiveness on fruit and eliminates later treatment.

TIME OF PLANTING

Insects usually appear at definite times of the year. Often damage can be reduced or even eliminated by planting the crop so that it does not reach the susceptible stage when the insects are around. Corn picked during August is usually not seriously damaged by the European corn borer. Beans planted between June 1 and 25 are not seriously damaged by the Mexican bean beetle. Early Irish Cobbler potatoes mature before leafhoppers and late blight become destructive. Cabbage planted after June 1 usually escapes the cabbage maggot. Hubbard squash planted early can sometimes produce a good crop in spite of the squash vine borer.

ALTERNATE MATERIALS

At present most of our shortage can be met by more efficient use of materials. The rest will have to be met by use of alternate materials. Fortunately, recent research has developed many of these and the information is available.

Copper, the most seriously affected of all metals, can be saved by using two new organic fungicides. Tetramethyl thiuram disulfide (TMTD) and ferric dimethyl dithio carbonate (FTC) have shown promise on apples for scab and cedar rust, and on tomatoes and roses for leaf diseases. Enough information is available to justify use of either of these in the field.

For seed treatments TMTD and chloranil (Spergon) can be used to replace copper.

Mercury for seed treatments can be replaced by hot water except on potatoes. Hot water treatment requires most careful handling and should be done by seedsmen rather than by individual growers. Chloranil can be used as an alternate material.

For cabbage maggots, tar paper discs may be substituted for calomel or bichloride of mercury. In fact, mid-western growers prefer the discs to the chemical treatment.

TMTD seems promising as a substitute for calomel and corrosive sublimate on golf greens.

Formaldehyde for soil treatment can be replaced by chloropicrin if the latter is available. A very recent material, 1-1-dichlor-1-nitroethane (Ethide) seems promising as a soil treatment. TMTD can replace formaldehyde for control of onion smut by seed treatment. It seems possible that sulfur dioxide may be useful as an alternate in storage house fumigation.

Rotenone products can be saved by using pyrethrum for squash bugs, cabbage worms, cucumber beetles, flea beetles and leafhoppers. Pyrethrum in the form of an impregnated dust (Pyrocide and Stimtox) is a thoroughly satisfactory insecticide in its own right and not just because derris and cubé are scarce. The impregnated type of rotenone dusts (Agicide) are more economical of material than the dusts made by using pure ground roots with fillers.

The synthetic organic thiocyanates, such as Lethane may be used with small dosages of rotenone (such as .25 percent) to produce dusts having the killing power of .5 percent rotenone.

Lead arsenate on fruit trees is difficult to replace. Efforts to find an alternate material to avoid residue on fruits have not been highly successful. Lead arsenate can be saved for use on fruits by using alternate materials for Japanese beetle sprays on ornamentals and by discontinuing during the war soil treatment to kill Japanese beetle larvae in lawns.

MACHINERY

Ample publicity in regard to farm machinery care has been issued by various agencies. A few suggestions can be added to apply to sprayers and dusters.

Sprayers operating at lower pressures last longer than if used with highest pressure. Spray hose is more frequently ruined by misuse than by age. Dragging hose over rocks, allowing it to rub on wheels, and allowing kinks to form damage hose seriously.

The chief point of wear on dusters is the fan bearings. These can be replaced or repaired in many supposedly worn-out dusters.

There are not enough good efficient power dusters in Connecticut to supply each grower with one for his own use. In some localities cooperative groups have been formed to share equipment. Such an arrangement could be advantageous for many vegetable growers in this State.

During the spraying and dusting of row crops nozzles sometimes become clogged. In spite of the trouble of stopping and making repairs wherever this happens, this is the only way that the plants can be covered properly.