PETROLEUM OILS FOR THE CONTROL OF ORCHARD PESTS

By

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# CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreword</td>
<td>3</td>
</tr>
<tr>
<td>Origin of Modern Plant Spray Oils</td>
<td></td>
</tr>
<tr>
<td>Effects of Aromatics</td>
<td>6</td>
</tr>
<tr>
<td>Influence of Molecular Size</td>
<td>6</td>
</tr>
<tr>
<td>Oil Deposit Factor</td>
<td>8</td>
</tr>
<tr>
<td>Structural Composition</td>
<td>8</td>
</tr>
<tr>
<td>Criteria for Selecting Plant Spray Oils</td>
<td></td>
</tr>
<tr>
<td>Chemical considerations</td>
<td>9</td>
</tr>
<tr>
<td>Physical and chemical properties</td>
<td>12</td>
</tr>
<tr>
<td>Oil Spray Limitations</td>
<td>14</td>
</tr>
<tr>
<td>Advantages of Oil Sprays</td>
<td>17</td>
</tr>
<tr>
<td>Outlook</td>
<td>18</td>
</tr>
<tr>
<td>References</td>
<td>19</td>
</tr>
</tbody>
</table>

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FOREWORD

PETROLEUM oils have two advantages over most pesticides. First they pose such a small human health hazard in their use that the Food and Drug Administration exempts them from the requirement of a tolerance. Their second advantage is the apparent inability of insects and mites to develop races or strains resistant to them. This resistance problem has been the undoing of many once potent pesticidal chemicals. Synthetic products introduced since World War II have been the principal casualties to this biological adjustment.

Exploitation of the almost unique advantages of oils is an example of the way this Station is meeting the challenge of finding human-safe and dependable means of controlling certain pests of our food crops. Scientists at this Station have played a major part in advancing plant spray oil technology as the contents of this Bulletin will reveal. It has resulted, for example, in the establishment of physico-chemical specifications for these products which are known and respected throughout the horticultural world.

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About the Author

Dr. Paul J. Chapman is a former head of the Geneva Station's Department of Entomology and has spent a major portion of his research career studying petroleum oils for controlling orchard pests. Dr. Chapman is recognized as a world's authority on this subject.
Figure 1. Applying a 2 per cent oil spray to apple trees with an air-blast sprayer at the half-inch green bud stage.
Petroleum Oils for the Control of Orchard Pests

by P. J. Chapman, Department of Entomology

Petroleum oils have been used in the United States to control certain classes of insect and mite pests of deciduous fruit trees for about 85 years. Only the arsenicals have a longer record of use. Kerosene was the first petroleum product used in any serious way as a pesticide. Around 1880 it became the standard treatment, as a 10 per cent emulsion, for the control of aphids and other soft-bodied insects and at about 25 per cent for the more resistant scale insects (22, 27).

San José scale, Aspidiotus perniciosus Comstock, which was introduced to California from China around 1870, provided a major stimulus for investigating the insecticidal possibilities of crude petroleum and its fractions. Its early activities were so alarming that it appeared to threaten the survival of our deciduous fruit industry. While this fear proved unfounded, San José scale did become a major pest and growers became much in need of a reliable control measure. Extensive tests were made in this connection with kerosene, “distillates,” and crude petroleum. While crude petroleum gave fair to good scale control when used either undiluted or as emulsions ranging down to 25 per cent, it often caused serious injury to the trees (28).

Safer spray oils became available by 1905 (31). These were in the form of proprietary oil spray stocks consisting of emulsifiable mixtures of oil and emulsifying agents. Although these products won some acceptance, the oils saw less use than did liquid lime sulfur for San José scale control during the period 1905–1920.

An important event took place in 1923. This was a report by Ackerman (1) on the successful use of a 2 per cent light lubricating oil against the San José scale. Ackerman’s results had special significance because his tests were conducted in orchards where growers had recently failed to control the pest with lime sulfur. The “new” light lubricating oil introduced by Ackerman was one previously developed by Yothers (49) and successfully used on citrus in Florida. From this time on, petroleum oils gradually became the primary dormant or semi-dormant treatment used in deciduous fruit orchards (Fig. 1). Further strengthening their position was the upsurge in the 1920’s and 1930’s of the fruit tree leaf roller, Archips argyrospila (Walker) (25). The overwintering eggs of this species are readily killed with oil sprays, but are unaffected by lime sulfur.

Origin of Modern Plant Spray Oils

Following Ackerman’s contribution were four developments which account in the main for the kinds of petroleum fractions used today as plant spray oils. These were: (a) the discovery that the hydro-
carbons which cause acute leaf injury—the outright "burning" of the tissues—are the aromatic and other unsaturated components; (b) the finding that both chronic phytotoxicity—the retardation of growth, yellowing, and dropping of leaves, etc.—and pesticidal efficiency are related to oil "heaviness" or its average molecular weight; (c) recognition that regardless of the spray formulation and method used to apply the oil, the amount actually deposited on the plant and pest in treatment is the basis upon which use should be projected to meet both pest control and plant safety objectives; and (d) the discovery that the pesticidal efficiency in oils is related to the dominant basic structural composition of the hydrocarbon molecules present.

The foregoing developments resulted from research conducted on both citrus and deciduous fruit pests. At a time when the oils applied to deciduous fruit trees were designed for use in the dormant or semi-dormant period, primarily, this handling of the evidence would have been subject to question. However, the present trend is to use foliage-type oils on both deciduous and citrus fruit trees. Interestingly, the time seems near when essentially the same oils will be used on both plant classes. However, there may still be a place, regionally, for the older dormant type oils in the treatment of deciduous trees.

Effects of Aromatics

Credit for discovering the oil unsaturate-plant safety relationship apparently should be given to Gray and de Ong (24) from experiments conducted in 1914–16 but not published until 1926. In 1924, Volck (47) filed patent claims based on this principle for a series of plant spray oils of low unsaturate content. He was granted patent right to them in 1929. The degree of refinement in plant spray oils is defined by ASTM test D 483 (3). The percentage of the oil which is unreactive to 37 N sulfuric acid is the "unsulfonated residue." This provides an approximate measure of the percentage of saturated structures present. By inference, the reactive portion gives a rough indication of the percentage of aromatic and other unsaturated structures present. Specifications for modern spray oils intended for use on verdant plants commonly provide a minimum UR of 92 per cent. The more desirable products test out 95–96 per cent.

Influence of Molecular Size

It was early learned that even high UR oils may be harmful to verdant plants if they remain too long on the plant after application (20, 22, 26, 44). The contributions of Smith (44) in this connection are especially noteworthy for he clearly saw the interrelationship of both pesticidal efficiency and chronic forms of phytotoxicity to oil heaviness. He further recommended the use of distillation as the most satisfactory basis for grading spray oil in regard to the heaviness
property. It was largely on the basis of Smith’s research, apparently, that the California Department of Agriculture in 1932 formally established a series of grades of Summer or Foliage Type oils (30). Two key properties were used in these specifications: a minimum UR, ranging from 90 to 94 per cent depending on the grade and the percentage of oil that distilled at 636° F. This cut-off temperature seems to have been an arbitrary selection (29). Under the atmospheric conditions prevailing in the method used, 636° F. was judged to be a good pre-cracking point from which the distillation characteristics of the oils could be described. These California standards represent the first use of distillation in official spray oil specifications. They proved so satisfactory that they have been retained in force in essentially their original form until quite recently (5).

In 1938, specific provision was made by the California Department of Agriculture for regulating the use of dormant spray oils (17). These were intended for use on deciduous trees during the dormant period. Analyses made of dormant oils sold in California at the time revealed their Saybolt viscosity range at 100° F. to be between 100–135 seconds, while UR readings were generally about 70 per cent. The dormant type oils used in Western North America are manufactured from the asphaltic or naphthenic base crudes of California. These are classified as naphthenic compositions. The early dormant type oils used in the East included both naphthenic and paraffinic class products (8). In 1942 Chapman et al. (9) included a distillation condition in their specifications for dormant oils. This consisted of the statement that the oil be “a relatively narrow boiling distillate portion of petroleum.”

In tests involving insect and mite eggs, New York workers (14, 35, 36) have shown there is no pesticidal advantage in using oils above a certain molecular weight. Their studies and those of others indicate this relationship may not be as striking where hatched forms, particularly scale insects, are involved (22, 36, 37, 38, 42, 46). However, there is an obvious plant-safety advantage in using the least persistent oil that will still provide good pesticidal action. It was to attain this objective that led New York workers to abandon their 100 second superior oil for the 70 and 60 second products (13, 14). To provide a more critical characterization of the oils Chapman (13) included a 50 per cent distillation temperature and a 10 to 90 per cent range in specifications issued in 1959. These values were to be determined under atmospheric conditions, using ASTM Test D 447 (3). In 1962, Chapman et al. (14) proposed the use of distillation at 10 mm Hg as provided for under ASTM method D 1160 (3). Because ASTM methods D 447 and D 1160 both lack desired precision, Aczel et al. (2) shortly will propose the use of a gas chromatographic method. It is believed this will not only provide more accurate and definitive information, but will save testing time and expense.
Oil Deposit Factor

The importance of knowing how much oil is deposited on the plant in spraying rests on the fact that the margin between the deposit needed to control the pest(s) and how much the plant will tolerate may be quite narrow. This may be especially critical in using oils on plants in leaf. Smith (44) in 1932, was perhaps the first to recognize the full significance of this principle.

Various factors affect the oil deposition rate. Where the treatment is applied in its most common form, namely, as a dilute emulsion, the more important are: the concentration of oil in the spray mixture, the kind and amount of emulsifying agent used, the kind of equipment used to apply the spray, the quantity of spray applied per tree or plant and the nature of the plant surface(s) treated. (7, 8, 12, 22, 44).

A number of methods have been proposed for measuring oil deposits on plant surfaces (4, 18, 32, 35, 39, 44). Additional references to methods will be found in the papers cited. In 1948, Pearce et al. (35) introduced one in which a dye is added to the oil. The presence of the dye in the sample extract permits a spectrophotometric determination of the amount of oil present. This method, or some modification of it, is the one most commonly used at present. Deposit determinations have proved especially useful in studying the role of the emulsifying agent on deposition. It has been shown, for example, that the deposit may have little relation to the oil content of the spray mixture if emulsions compared have been formulated with different emulsifiers or concentrations of these products (7, 8). Since pesticidal performance is directly related to how much oil is present, regardless of how it may have been laid down, then deposit becomes the best basis for making critical dosage-response studies. The correlation which exists between the oil deposit and pest control has been demonstrated in many studies made at this Station (8, 10, 14, 23, 33, 35, 36). The earliest of these was conducted in 1941 and involved eggs of the fruit tree leafhopper (8).

Structural Composition

Prior to 1942, plant spray oils apparently were selected without regard to their basic chemical composition except for the UR standards imposed for verdant oils (30). In 1942, Pearce et al. (33), demonstrated a correlation between oil paraffinicity and pesticidal efficiency. Subsequently, various workers at this Station have confirmed this finding against pest species representing four unrelated taxonomic groups (10, 19, 23, 35, 36, 45, 48). Riehl and LaDue (38) have shown this relationship also applies to two major pests of citrus in California. In 1942, Chapman, et al. (9), restricted recommended dormant type oils to those which were at least moderately paraffinic in composition. This appears to have been the first official recommendation of par-
affinic oils, as such, for the control of orchard pests. Specifications for a more highly refined and more paraffinic oil were issued in 1947 (34). These were named "superior-type" plant spray oils. To avoid confusion, the paraffinic oil introduced in 1942 was called "regular-type." A more recent innovation (13) was the linkage of viscosity to this common name stem. Thus, since the original superior type oils were of approximately 100 seconds viscosity, these were named 100-second superior oils. Currently, two weights or viscosities of spray oils are recommended in New York, viz., a 60-second and a 70-second superior oil (14, 15). Both grades will continue to be recommended unless practical experience may suggest the elimination of one. Specifications for the two grades are given in Table 1.

Table 1.—Specifications for Two Superior Type Plant Spray Oils.\(^a\)

<table>
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<th>Property(^b)</th>
<th>60-Second Superior Oil</th>
<th>70-Second Superior Oil</th>
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<tr>
<td>Saybolt Universal Viscosity(^1) at 100°F., seconds</td>
<td>56–62</td>
<td>66–74</td>
</tr>
<tr>
<td>Gravity(^2), ° API (minimum)</td>
<td>34</td>
<td>33</td>
</tr>
<tr>
<td>Unsulfonated residue(^3) (minimum)</td>
<td>92</td>
<td>92</td>
</tr>
<tr>
<td>Pour point(^4), ° F. (maximum)</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Distillation(^5) at 10 mm Hg, ° F.</td>
<td>408±10</td>
<td>425±12</td>
</tr>
<tr>
<td>50% point</td>
<td>(645±8)(^6)</td>
<td>(670±10)(^6)</td>
</tr>
<tr>
<td>10 – 90% range</td>
<td>80</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>(75)(^6)</td>
<td>(90)(^6)</td>
</tr>
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\(^a\)As established in 1962 (14).

\(^b\)The following ASTM methods are to be used: (1) O 445–61 and D 446–53; (2) D 287–55; (3) D 483–61T; (4) D 97–57; (5) D 1160–61; and (6) approximate atmospheric distillation temperatures employing D 447–59T.

Criteria for Selecting Plant Spray Oils

The foregoing review establishes that plant spray oils have become rather specialized products. Selection in their manufacture starts with the crude oil. Thus, if a highly paraffinic spray oil is desired, a paraffinic class crude is required. Spray oils are derived from the lubricant fraction.

Chemical considerations

It will simplify matters in an examination of plant spray oil selection from a chemical viewpoint if two questions can be disposed of initially. The first of these concerns the role of the aromatics and other unsaturated hydrocarbons present. With some exceptions, these hydrogen-deficient compounds apparently contribute little if anything to the
pesticidal action of modern plant spray oils (40). On the other hand, they are highly phytotoxic and must be reduced to low levels—probably not exceeding 8 per cent—if they are to be used on verdant plants. The second question concerns how petroleum oils kill insects and mites. It is possibly permissible to say their participation in this action is basically "physical" (20, 21, 41, 43). Smith and Pearce (41) concluded that an oil film over eggs of the oriental fruit moth, Grapholitha molesta Busck, effected kill by interfering with the normal gaseous exchange of respiration.

It is not known, precisely, how oils kill scale insects. The question has been studied by Phillips and Smith (37) in connection with Lecanium corni Bouché, a deciduous fruit pest, and by de Ong et al. (20) and Ebeling (21) on the California red scale Aonidiella aurantii (Maskell) of citrus. De Ong et al. (20) concluded the oil kills the red scale by penetrating the insect's spiracles and plugging the tracheae. Future studies may show the pesticidal action of oils is of a less passive nature than the very limited evidence available on this point now would indicate. On the other hand, there is little basis for the belief that an elusive x component may be found in oils, which accounts for their pesticidal action.

If these two questions can be considered answered, the task of selecting suitable plant spray oil can be reduced to determining what average molecular weight product is desired and the structural composition of the saturated hydrocarbons present. Pearce and Chapman (36) have compared three series of hydrocarbon compositions of varying molecular weight where the percentage of carbon atoms present in the form of paraffin chains was approximately 50, 75 and 100 per cent. The first two series were very narrow boiling petroleum fractions, and the last were isoparaffins which were synthesized at this Station by use of the Grignard reaction.

The authors concluded that pesticidal efficiency starts to decline below an average molecular weight of about 310 regardless of structural composition, and that pesticidal efficiency rises as oil paraffinicity is increased. A summary of the data on which these conclusions were based is reproduced in Figure 2. The LD₉₅ values given represent the oil deposit needed to kill 95 per cent of the winter eggs of the European red mite Panonychus ulmi (Koch).

Figure 3 compares the results obtained with the isoparaffin series against eggs of European red mite and oriental fruit moth and of nymphs of the cottony peach scale, Pulvinaria amygdali Cockerell. While the dosage of oil required to effect kill here varied with the test species, the decline in pesticidal efficiency started at about the same molecular weight.
Figure 2. Correlations between pesticidal efficiency and molecular weight and viscosity of three classes of hydrocarbon compositions. Test species: winter eggs of European red mite. Pearce and Chapman (36).

More recent tests involving winter eggs of the European red mite, which were made at a more susceptible stage than in the earlier test (36), are given in Figure 4. All the oil fractions used in this series were derived from a common source and were highly paraffinic in nature. These data show that the fall-off in pesticidal efficiency may occur at a somewhat lower average molecular weight than was indicated in the earlier tests (Figure 2).

The writer's current thinking is that suitable verdant plant spray oils can be selected from oil fractions having an average molecular weight range from about 290 to 330. The lightest of these would find use in the treatment of the most sensitive plants. There could well be a pesticidal advantage, however, in using somewhat heavier oils if the plants under treatment will tolerate them. The average molecular weights of the 60- and 70-second superior oils currently recommended in New York are approximately 305 and 320, respectively.
Figure 3. Correlations between pesticidal efficiency and molecular weight and of carbon atoms per molecule in a series of isoparaffins against three unrelated test species. Pearce and Chapman (36).

Physical and chemical properties

Plant spray oils as well as petroleum fractions intended for other uses are commonly characterized by use of various physical and chemical properties. The applicability of a number of these to define spray oils has been examined (14, 35, 36, 40). The ones selected to characterize the superior type oils are: viscosity, gravity, unsulfonated residue, pour point, the 50 per cent distillation temperature at 10 mm Hg, and the 10 to 90 per cent range (14). These properties were selected to provide a relatively precise means of defining desired products among oil fractions having quite similar structural compositions. It follows, then, that no single series of standards established under these properties will apply to both naphthenic and paraffinic oils. This situation offers the choices of limiting spray oils recommended either to paraffinic or to naphthenic classes, or of using some other basis for selecting acceptable products.

As already noted, workers in New York decided to limit recommended oils to paraffinic compositions. Traditionally, plant spray oils in Western North America have been manufactured from the asphaltic or naphthenic base crudes of California. These would be classified as naphthenic compositions. As paraffinic spray oils are being used
Figure 4. Correlations between control efficiency and viscosity and of average molecular weight in a series of paraffinic fractions. Test species: winter eggs of European red mite. Pearce and Chapman (36).

In increasing volume in the West, it will be interesting to see whether some means can be developed to accommodate the use of both naphthenic and paraffinic oils in that area in official specifications.

Considerable interest has developed recently in establishing standards which are less restrictive than those used in the superior oil specifications. The object would be to qualify oils manufactured from diverse crudes as acceptable plant spray oils. As pointed out by Chapman et al. (14), oil distillation criteria could be employed as a close approach to this objective. This is not to say distinctly naphthenic oils would be as effective on an equal unit basis as highly paraffinic oils where both exhibit approximately the same distillation patterns. It does appear to mean the difference between the better naphthenic oils—that is, those containing more than about 60 per cent paraffinic structures—and highly paraffinic oils may be so small as to be unfair to exclude them from use in specifications should there be a regional economic reason for including them.

Narrow distillation range products are desirable for both plant safety and pesticidal efficiency reasons. Thus, wide cuts will contain at one end portions which are too light to contribute anything to pesticidal action whereas at the other end the heavier portions could constitute an unnecessary plant injury hazard (Fig. 5).

A current weakness in the use of distillation as the primary basis for selecting plant spray oils is the lack of an official method of sufficient precision. The tolerance limits of values obtained by ASTM methods D
447 and D 1160 are relatively wide. A distinct improvement in this regard is probably available through the gas chromatographic method being proposed (2).

![Distillation Diagram]

*Figure 5.* Showing the 10 to 90% distillation range (bar portion) of a narrow (oil A) and a wide (oil B) fraction plant spray oil and the portions falling into two undesirable "zones." Based on two products of identical 50% distillation points sold as 60-second superior oils in 1965.

In summation, the selection of plant spray oils by specification would be greatly simplified if they could be limited to similar compositions. The preferred type would appear to be paraffinic oils. Limitation of plant spray oils to paraffinic compositions would not seem to penalize actual or potential suppliers unduly, for any major oil company now can either obtain the necessary crudes to produce paraffinic spray oils or can purchase the finished oil from some company manufacturing one. If spray oils are selected from such a single structural class, use can be made of more easily determined properties than distillation. Some of these such as viscosity, gravity, density, etc., are standard determinations in control laboratories of the petroleum industry. They provide measurements of relatively high precision. While it is possible to define fairly acceptable plant spray oils without stipulating distillation standards, the specifications are greatly strengthened if they are included.

**Oil Spray Limitations**

Phytotoxicity and the limited number of pest species which are controllable with oil spray constitute the principal limitations of verdant type spray oils.

The plant injury problems attributable to the oil itself have already
been discussed. These can be reduced to manageable proportions by using high UR oils and products which do not persist too long on the plant after application. The problem of preventing plant injury where oils are combined with other pesticides, however, is in a less satisfactory state. In Eastern North America, especially, growers commonly combine insecticides, fungicides, and acaricides in one spray treatment.

Oils often cannot be added successfully to some of these mixtures because of their incompatibility with one or more of the other ingredients present. Much of the difficulty centers in an oil's solvent and leaf penetrating ability. Thus, an otherwise safe pesticide may cause injury when combined with oil because it becomes partially dissolved in it, and then is conveyed into the leaf where it is brought to bear on the highly sensitive inner tissues. Problems of the foregoing type may be averted either by using the oil alone or by combining it with oil-compatible products. Fortunately, there is a fairly good selection of pesticides which can be used safely with oil. However, the chances of avoiding all unfavorable combinations are so small that oils are not recommended for use generally later in the spring than the pink bud stage in New York (15, 16).

Petroleum oils are not effective in controlling all orchard pests. Currently, they are used to control only certain species of mites and scale insects on any large scale at present. They have proved particularly effective in controlling those species of mites which overwinter in the egg stage, notably the European red mite (Fig. 6), and the San José scale. (Fig. 7). Both of these are major pests in deciduous fruit plantings. While petroleum oils find limited use insofar as the numbers of pest species are concerned, these are of sufficient importance as to assure oil use in most of the nation's orchards.

*Figure 6.* (a) San José scale (enlarged) and (b) infestation of the pest on blossom end of an apple fruit.
Figure 7. (a) Winter eggs and (b) adult females of the European red mite (both enlarged).
Advantages of Oil Sprays

Oils have three principal advantages over competitive pesticides. First, they have been judged to pose such a small human health hazard that the Food and Drug Administration exempts them from the requirement of a tolerance. This is a highly valuable asset. It assumes special importance in the current efforts being made to find means of reducing the human hazards inherent in the employment of all toxic chemicals in pest control.

The second major advantage of petroleum oils is the apparent inability of insects and mites to develop races that are resistant to them. This is a collective major weakness of competitive products, especially among the synthetic organic pesticides introduced since World War II. Many of these have lost their original potency to one or more pest species because of the development of resistant strains. Theoretically, insects and mites should be able to develop resistance to any pesticide, including petroleum oils. However, in 85 years of use, no oil-resistant strain of a pest has appeared. Possibly the mechanism of the killing action in oils may account for this situation. In any event, the apparent "resistance-proof" quality of petroleum oil is an almost unique advantage in a situation where we have come to accept the idea that effective pesticidal action of a given chemical may be of only temporary duration.

Petroleum oils may also win preference over competitive products for their efficiency and low cost. A case in point is their use in the control of the European red mite. In Figure 8 are shown the results obtained with a single 1 per cent petroleum oil spray applied at the tight

![Figure 8. European red mite populations developing in untreated trees and those receiving a 1% 60-second superior oil spray at the tight cluster bud stage. 1964.](image)
cluster bud stage (15, 16). In this instance it gave satisfactory commercial control of the pest for the season. And, this was done at a total cost of about 12 cents per tree. The oil and emulsifier represent about 7 cents of that cost. It should not be assumed from these data that this is the degree of control fruit growers commonly receive from a single oil treatment. It does show what can be done commercially in European red mite control in areas having about the same length of growing season as New York. On the last point, more generations of the mite are produced in latitudes south of New York so that first generation survivors of a control operation may repopulate the trees importantly if sufficient time is available to achieve this end. In long growing season areas it may often be necessary to supplement the early oil spray with some other acaricidal treatment later in the year.

**Outlook**

Petroleum oils have a considerable unrealized potential in the pesticide field. Some of this potential may lie in areas where the oil serves essentially as the carrier of other pesticides. Principal interest, however, is in uses where the oil effects control through its own action. Although oils are used chiefly to control mites and scale insects at present, it seems probable their use could be extended advantageously to other pest groups. One of these would be the fungous diseases. Plant spray oils have already found a place in the control of the Sigatoka leaf spot disease of banana (6) and of the greasy spot disease of citrus in Florida (46).

Oils were formerly extensively used as ovicides (43). They found a definite place in this connection in the control of various lepidopterous species (8, 10, 25) and of at least one plant bug (19). Considering the advantages oils possess over competitive pesticides it appears desirable to reexamine some of these older uses for possible application in today's agriculture. Attention should also be given of course to possible new uses of the oils.

Some excellent plant spray oils are currently available. Even better ones are needed if their full potential is to be realized.

One of the inherent shortcomings of all spray oils is the interference they cause to normal plant functions. At least three means of reducing this hazard merit attention. First, as the unsaturated structures are known to be phytotoxic and even the better spray oils still contain 4 or 5 per cent of these compounds, it should be determined what advantages, if any, would accrue if virtually all of these components were eliminated. The most obvious means of doing this would seem to be through intensive hydrogenation. Another possible means of safening plant spray oils is through the additions of antioxidants or similar inhibiting chemicals. Finally, attempts should be made to produce even narrower oil fractions than are presently available and especially
those which lie at the lighter end of the pesticidal range. Such oils would be safer for their more rapid dissipation after pesticidal action has taken place.

To produce more pesticidally efficient spray oils, again three approaches merit further exploration. Since available evidence shows a correlation between paraffinicity and efficiency, attention should be given to offering more paraffinic compositions. The maximum paraffinic structure content of conventional petroleum fractions is approximately 75 per cent. This level can be increased to 100 per cent through synthesis as in the isoparaffins. It is not certain orchardists would pay the higher price manufacturers would probably have to ask for these synthetic products. In addition to considering means of increasing the gross paraffinicity of spray oils, the influence, if any, of branching in the paraffinic structures on pesticidal efficiency needs critical study.

Pesticidal efficiency can also be improved by eliminating the pesticidally ineffective portions of oil fractions. Ideally we seek the lightest narrow boiling fractions which are essentially 100 per cent pesticidal throughout their distillation range.

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8. Chapman. The use of petroleum oils as insecticides III. Oil deposit and control of fruit tree leaf roller and other apple pests. J. Econ. Entomol. 34 (5);639–647. 1941.


