I believe we can also agree that if these pesticides, which are so valuable and essential to us and our well being, are correctly used they are harmless to those who apply them and also to those who consume the products protected. It is my belief that this goal can best be attained through education, a field to which the Extension Service is dedicated. To this end we pledge to you our complete support.

THE BEHAVIOR OF PURPLE SCALE POPULATIONS ON CITRUS TREES IN FLORIDA *

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During the past 50 years in Florida, purple scale, *Lepidosaphes beckii* (Newm.), has been the primary scale problem on citrus trees in Florida. The amount of damage due to this pest has varied from year to year and from decade to decade, but, in a general sort of way, the first half of the 20th Century may be divided into the three periods as defined by distinct differences in the problems which have been encountered with this insect. Prior to 1925 scale infestations were fairly common, and some control measures were undertaken. However, regular spray programs for scale control were not applied, because satisfactory means did not exist. From 1925 to 1935, definite changes took place in citrus groves in Florida. Plantings were shifted to the sand hills of central Florida, and there was a change from organic to inorganic fertilizers. As a result of improper feeding, magnesium, manganese, copper and zinc deficiencies developed. In the early 1930's, trees grown in the sandy soils were in very poor growing condition, deficiency symptoms were common, and scale populations were at a very low ebb. Although oil emulsion sprays were available during this period, very few sprays were applied for scale control. Beginning in 1936, new fertilizer practices were instituted. These involved the use of magnesium, manganese and copper in the fertilizer, and the use of copper, zinc and manganese sprays, with copper and zinc sprays being applied regularly. The change in fertilization practice resulted in increased yields and improvement in the general size and the vitality of the

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trees. Accompanying this, there was a marked change in the insect picture on citrus trees in Florida. Zinc and copper sprays were partially responsible for increased insect injury, but the increased shade and tree vigor seemed to offer better living conditions for both insects and mites. Where it had previously been unnecessary to control scale, scale insects now became a major problem for the citrus grower. Today, scale insects represent the primary source of tree damage in the state of Florida. Purple scales are distributed throughout the citrus area and are a major problem wherever they occur.

At the present time, in the state of Florida, another change in the general production picture appears to be taking place. In the 1940-50 season more than 50 percent of the citrus crop will be canned as single strength juice or as frozen concentrate. This means that the external quality of much of the fruit need not meet the fresh fruit standards as in the past, and this subsequently means a change in general spray programs and spray practices. An effort is being made to evolve a spray program for canning plant fruit which will necessitate a minimum of spray applications, but which at the same time will maintain yields and internal fruit quality as high as they have been previously. Reductions in the amounts of copper and zinc to be used as sprays can probably be made. The use of copper for the control of melanose (a fungus disease which affects external quality) will probably be almost eliminated on fruit which is to be canned. Since zinc has been used for more than 10 years, citrus groves are generally free from zinc deficiency. Therefore, it is possible that trees can be maintained with soil applications, or at least maintained without an annual zinc spray. Lower mite and scale populations should follow a reduction in the amounts of zinc and copper. This fact has been substantiated most recently by Griffiths and Fisher (1, 2).

For the past three years rather careful records have been kept of scale infestations in a number of citrus groves. More complete records have been kept during the past two years, and most of the following discussion will be centered about the 1948 and 1949 seasons.

It is the purpose of this paper to demonstrate the behavior of scale insect populations on citrus trees in Florida as observed where some different spray programs were in effect. A complete spray program includes the use of compounds of copper, zinc, sulfur, DN (40% dinitro-o-cyclohexyl phenol) and oil emul-
sions. Scale population behavior under such a program is compared with that where certain or all of the materials have been eliminated from the spray program.

**Behavior of Scales in Unsprayed Groves**

Figures 1 and 2 present data from September 1947 through November 1949, for four groves in or near Lake County and for three plots located on the Citrus Experiment Station grounds in Polk County. The two sets of data are separated because general behavior patterns appear to have been somewhat different in these two areas. In general, Lake County will experience slightly colder weather during the winter than Polk County, and it is possible that this may explain some of the differences.

In these and subsequent graphs, some irregularities occur. These are often present during the spring of the year and may be accounted for by inaccuracy in sampling methods. Scale counts were made by a method previously described by the authors (3). This involves taking 50 leaves per tree and examin-
Purple Scale Population Changes in Unsprayed Groves
In Polk County

Figure 2

ing them for living scales. In the spring, the major leaf flush occurs just prior to bloom. Usually, this period coincides with a time of maximum egg deposition by the infesting scale insects and scale crawlers tend to migrate to new foliage. Thus, there is a general exodus to new growth. Sampling is complicated by this shift in population, and counts made during this time are apt to present a slightly inaccurate picture of the infestation. The total scales per tree may have increased considerably, but the percentage of leaves infested may appear to have decreased if new foliage has been picked.

In Figs. 1 and 2 it will be noticed that, for three years, during the period from August through November, scale populations attained a minimum. They regularly decreased during the summer, but by late fall were again increasing. In this connection, it should be noted that prior to the introduction of present day spray schedules, oil sprays were often applied as fall clean-up sprays. Growers of citrus for many years often comment upon the effectiveness of such sprays for scale control. The fact that they were spraying populations at the lowest
density during the entire year was undoubtedly an important factor in the excellent scale control which often resulted.

The amount of increase in the fall and the rate of increase throughout the winter months is probably a factor related to winter temperatures. During the fall and winter of 1946-47, 1947-48, and 1948-49 temperatures were generally high throughout the entire period. This resulted in scale increases throughout the winter months. The past three years have been exceptional, in that purple scale populations have been high, and excessive damage has resulted in many groves. The application of two oil sprays for scale control has been necessitated in many individual holdings. It will be noted in the graph on groves in Lake County that higher scale populations were generally attained during the 1948 season than in 1949. The opposite is true of the groves shown from Polk County. The Lake County groves probably reflect a truer picture of the situation throughout the state. In general, scale populations have been much lower during the summer of 1949 than during the preceding two years. It will be noted that, in the Polk County groves, maximums were reached in February and March of 1949, and that populations continued to decrease from that time on. This represents an abnormal situation when compared to the past. In general, scale populations in unsprayed groves reach their minimum in the fall of the year, either stabilize or increase slightly throughout the winter months, and finally attain a maximum during June and July of the following summer. Decreases caused by natural control agencies become evident in July, August, or September and minimums are again reached during the fall of the year. The 1949 season seems to offer an enigma as far as decreases throughout the spring and summer are concerned. These decreases were experienced throughout the entire citrus belt, in spite of the fact that weather was dry in the spring and was not what would normally be considered advantageous for the functioning of scale fungi. In fact, dry weather has always been considered to be a major factor in scale population increases, and the 1949 season was in direct opposition to this presupposed thesis.

It will be noted that one of the four Lake County groves shown has consistently had higher populations than the other three. This was true also in the 1946-47 season. All four groves are treated with occasional sulfur dusts for the control of the citrus rust mite, but copper, zinc, and oil emulsion sprays
are not used. In Fig. 1 the three groves with lower scale infestation also have populations of the tree snail, *Drymacus dormani*. The claim has been made by many growers that the presence of these snails will result in reduced scale populations. The authors have never been able to substantiate this on the basis of good data. Tendencies are certainly evident here, but it should also be noted that groves which are satisfactory for growth and reproduction of snails are also groves which tend to have high humidity factors and which are planted in such a fashion that good shade is present throughout the entire year. As opposed to this situation, the grove with the greater scale population (Fig. 1) has smaller trees which are planted far apart, so that the same type of shade and moisture conditions are not present. It would be expected that entomogenous fungi might not function as satisfactorily in the latter grove as in the three groves where snails are present. Another factor must be mentioned, however. When snails are present in large numbers, the trees attain a very sick appearance due to the removal of sooty mold from the foliage and fruit. Where this condition exists almost no residue of any type is present on the foliage. It is to be expected that residue-free leaves would be relatively unsatisfactory for the settling of scale crawlers, since they seem to prefer dirty leaves to extremely clean ones. How much of a factor this is in the reduction of scale populations in these groves cannot be determined at the present time. It should also be noted that the grove listed as having both oranges and grapefruit was almost completely defoliated in February of 1948. Most of the snails had died by November of 1947, and it was not until the late summer and fall of 1949 that high snail populations were again attained in this grove. In spite of this fact, scale populations seem to follow similar trends to those in other snail groves. This would appear to be an argument against the fact that snails are major factors in causing reduced scale populations in citrus groves. In addition to this, the groves which attained the second highest infestations both in 1948 and again in 1949 as shown on Fig. 1 has not been properly fertilized for the past two years. The trees are in a very hard condition, growth flushes have been very much below normal, and such trees are not trees which are satisfactory for the development of maximum scale insect infestations. These factors must be considered in attempting to evaluate the possible value of snails in citrus groves in Florida.
THE BEHAVIOR OF SCALE POPULATIONS IN SPRAYED GROVES

Figure 3 shows the difference in behavior of scale infestations on three separate spray programs from plots at the Citrus Experiment Station in Polk County. One plot represents unsprayed controls where no sprays or dusts of any kind are applied; one represents a plot in which copper, zinc and sulfur are used, but where no scalicides are applied; and the third represents a standard spray program as practiced throughout most of the citrus area. This latter program includes the use of copper, zinc, sulfur, and DN (40% dinitro-o-cyclohexyl phenol) as well as an oil spray for scale control. The unsprayed control plot was not started until 1948 and counts were not initiated until the late summer of that year. Certain trends are evident in this graph, and based on general observations throughout the citrus area represent conditions which would be expected to occur under the various spray programs involved. It will be noted that maximum populations are found, of course, on the trees where copper and zinc are used and where no oil spray follows.
The oil sprays in the complete spray program were applied on the first of July and resulted in the decreases in infestation between July and August in both years. The unsprayed control has lower populations than the trees containing copper and zinc sprays. At times, the populations on this program are actually lower than where oil sprays are applied. It will be noted that during the fall of 1948 this situation existed, and according to the last counts made in 1949, this group of trees again has less scale than was found on the other two programs. These data again illustrate the same thing noted in Figs. 1 and 2 in that for most groves, maximum populations in 1949 were attained during the early, spring months. Regardless of the program, the scale population decreased throughout the late spring and the summer. This has resulted, during the fall of 1949, in a general condition over the entire state where purple scale populations are at a minimum.

**DISCUSSION**

Figure 4 is a theoretical situation designed to demonstrate the difference in scale insect populations resulting from several types of spray programs. This is hypothetically drawn from data such as that presented in Fig. 3, and is based upon observations from many groves throughout the entire citrus area. If we assume that three programs are instituted where initial scale infestation is identical, certain things would be expected to occur. On those trees where copper and zinc is included in the spring of the year, greater increases would be experienced than on the unsprayed controls. These increases would continue up until late summer or early fall, in the case of the plot which received copper and zinc. In the case of the unsprayed control, decreases would begin in July or August. A spray applied for scale control in July would reduce the population in those plots to almost zero, but increases would start immediately after the oil spray and would continue throughout the fall, and if weather conditions were satisfactory, on through the winter months. As noted on the graph, groves on the oil, copper, zinc, sulfur program would often have more scale in the spring of the year than would those on no spray program at all. They would have less during the latter part of the summer, but during the fall and winter months the populations might be very similar to those of the unsprayed controls. The trees receiving copper, zinc and sulfur, but no oil would end the season with much
higher populations than either of the other two programs. This points up the fact that the addition of copper and zinc in the spray program necessitates sprays for scale control. Thus, if copper and zinc are eliminated from spray programs, it may be possible to also eliminate sprays for scale control in some years, but at the same time maintain maximum yield with minimum tree damage from scale insects.

In support of the thesis that it may be possible to eliminate sprays for scale control in some years if no copper and zinc sprays are used, the following data on dead wood cut from trees is pertinent. In a Pineapple orange block at the Citrus Experiment Station several spray programs are present. One is a complete spray program which includes zinc, copper, sulfur and oil. The oil is applied about July 1; second program is identical, except that no oil is used; and a third set of plots receives no sprays or dusts at all. In March, 1949, dead wood was cut from those trees. An average of 12 pounds were removed from the unsprayed control as compared with 26 pounds on the copper-zinc-sulfur-oil program and 36 pounds on the copper-zinc-sulfur-no oil program. The introduction of parathion as a spray for
scale control on citrus (4) may mean that scale can be controlled without damaging results from oil sprays so that there will probably be less dead wood not only from scale, but also from oil damage. In the parathion sprayed plots (includes copper-zinc-sulfur) in this same series of experiments only 12 pounds of dead wood was removed in 1949. It may be possible that, where groves receive little or no copper and zinc, parathion sprays will further reduce scale populations to such a level that even greater yields might be attained.

SUMMARY AND CONCLUSION

Data are presented to show the behavior of purple scale populations in groves in Florida where only sulfur is used as a spray or dust program. In these groves, maximum infestations are usually attained during the late spring or early summer, and minimum infestations occur during the months of September and October. Data also compare the difference between the trees receiving copper, zinc, sulfur and oil against copper, zinc, sulfur and no oil, and against no sprays or dusts at all. These findings may serve as a basis for attaining short-cut spray programs which will meet requirements of fruit for canning plant operations.

LITERATURE CITED


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