production at the last harvest. There were no significant differences among treatments for total season harvest. Low yields in plots treated with fluazifop-butyl were believed to be due to competition by pigweed and lambsquarters and not due to phytotoxicity.

Based on weed control and early yield (for which there is often a market advantage), the best treatments overall were napropamide, oxyfluorfen and a combination of Hoe 00661 (0.75 lb. a.i./acre) + DCPA.

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PERSISTENCE OF OIL-SOLUBLE AMINE TYPE 2,4-D IN SOUTH FLORIDA

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Abstract. **Oil-soluble amine type 2,4-D has been found to persist in shell rock for at least 2 yr under south Florida weather conditions. Field observations indicate persistence for at least several months in sandy soils. Pepper plants which were contaminated by either road or field dust containing this type of 2,4-D did not show visible symptoms until exposed to the dust for a period of several months. Only older pepper plants showed evidence of injury. An explanation of this phenomenon is provided. The legal implications resulting from a court decision in which a pepper grower was awarded damages for crop losses are discussed.**

2,4-(dichlorophenoxy) acetic acid (2,4-D) is generally considered to have a short residual life in soil (2, 3, 4) with complete breakdown occurring after a few weeks. Mechanisms by which the chemical is lost from the soil include 1) leaching in the case of water-soluble formulations, 2) volatilization in the case of volatile formulations, 3) photodecomposition, and 4) destruction through microbial activity.

Considerable amounts of oil-soluble amine type 2,4-D are used in south Florida for control of aquatic and canal bank weed species. The 2,4-D is generally used in combination with other herbicides and is usually sprayed as an invert oil emulsion. There has been little or no concern for possible persistence of the 2,4-D.

This report describes two situations in which oil-soluble amine type 2,4-D has caused serious injury to bell pepper plants. In both instances the symptoms of injury were not manisfested until several months after the 2,4-D was released into the environment. The report will also include comments on the legal implications associated with use of persistent-type 2,4-D.

Field Observations

Both fields in which damage occurred were located in Palm Beach County, Florida; one near Boynton Beach, the other near Delray Beach.

In the Boynton Beach plantings, pepper was seeded beginning on August 4, 1977 and continued at approximately weekly intervals until late September (Fig. 1). Injury was first observed on about November 11 with a few plants in the August 4 planting showing foliar symptoms suggestive of phenoxy herbicide injury. As one proceeded west through the plantings the incidence of injury increased to about 5% in the second (August 10) planting and to about 10% in the third (August 17) planting. Later plantings showed no signs of injury (Fig. 1a).

Two weeks later (Fig. 1b), both the number of plants showing injury and the severity of injury in many plants had increased dramatically. The August 4 planting showed about 10% injured plants, the August 10 planting about 25%, and the August 17 planting about 50% injured plants. Injury was now apparent in the August 24 planting but was restricted to the beds located next to Jog Road and extended northward in the field for only about 300 ft. In the August 4-17 plantings the injury was greatest, both in numbers of plants affected and severity of symptoms, immediately adjacent to Jog Road Extension. As one went south from Jog Road Extension the problem lessened, and, by the time a distance of about 500 ft had been traversed, the injury disappeared. Thus, two clear gradients of injury were apparent on the south side of Jog Road Extension, one going south from the road and the other going east along the road. The source of the contamination appeared to have been in the area where Jog Road intersects with Jog Road Extension (Fig. 1).

Because of the alarming rate at which the injury was increasing and the obvious association with the road, it was decided to treat the road surface with a dilute solution of sodium hydroxide. This treatment would have the effect of releasing the 2,4-D from the formulation and should result in a rapid loss of the chemical. Prior to doing this, however, samples of shell rock were taken from the road surface and submitted for chemical analysis. The road was treated with a dilute solution of NaOH (100 lb. dissolved in several thousand gallons of water) in late November.

By December 13 the extent of injury became maximal with the August 4 planting showing about 25% injured plants, the August 10 planting about 50%, and the August 17 planting about 90% injured plants. The August 24 planting showed about 50% injured plants in the relatively small area where injury was present. There was also some injury to plants located next to Jog Road Extension in the September 8 planting. Later plantings remained free of injury.

Symptoms of Injury

Early foliar symptoms in pepper were typical of those caused by phenoxy herbicides with leaves showing narrowness, heavy veinal development and epinasty in the terminals. There was not as much axillary shoot development as one usually finds with 2,4-D injury in pepper. Fruit symp-

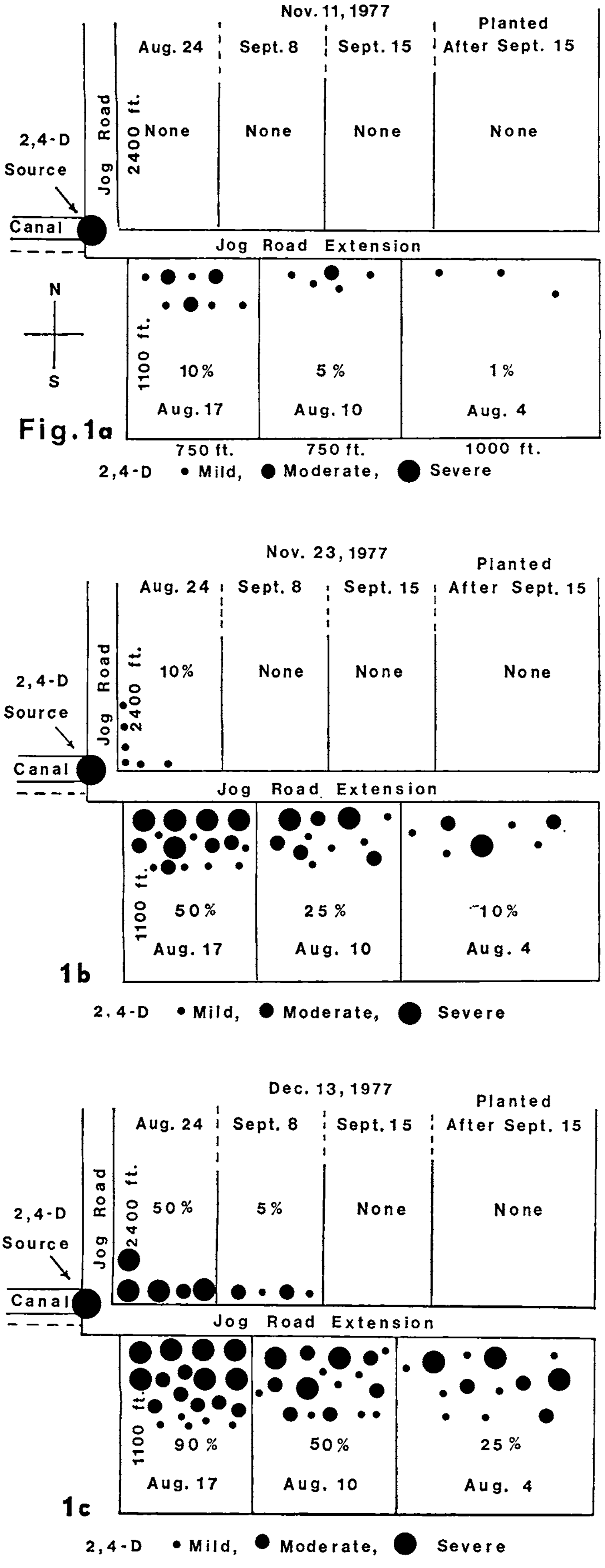

Fig. 1. Diagram of pepper field showing palnting dates and incidence of 2,4-D injury on a) November 11, 1977; b) November 23, 1977; and c) December 13, 1977.

toms ranged from roughness and elongation to occasional fruits which were globose in shape and very scarred. This unusual symptom of 2,4-D injury in pepper fruit was likely the result of the cumulative buildup of the chemical in the plant. Most weeds in the field and along the road remained symptomless although some nightshade plants in the field showed mild symptoms. Pine trees growing along the road showed significant injury.

Evidence for the Presence of 2,4-D

A number of commonly used herbicides cause symptoms in pepper which are similar to those caused by 2,4-D. We are certain that 2,4-D was involved here because laboratory analysis of pepper foliage and fruit showed 2,4-D to be present in them and analysis of the shell rock road also showed 2,4-D to be present. Plant samples were taken about mid-November and the road surface was sampled about a week later.

Observational and Experimental Evidence for the Persistence of 2,4-D

Two observations of the pattern of injury strongly indicated persistence of 2,4-D. First, new plants continued to come down for over 6 wk after the original discovery was made. Second, younger plantings remained free of injury even though young plants are more susceptible to 2,4-D than are older ones.

Of the several types of 2,4-D which are used commercially there is only one which would appear to have a likelihood of persisting under environmental conditions found in south Florida. This is the oil-soluble amine which is neither water-soluble nor volatile. Like other forms of 2,4-D it is subject to biological degradation. However, shell rock, which is primarily calcium carbonate, is a poor medium for biological activity and could well represent a substrate in which an oil-soluble amine type 2,4-D could persist for many months.

Investigation as to the use of 2,4-D in the area where the damage occurred revealed that this type of 2,4-D (Visko Rhap A3-D) had been used for canal bank weed control in June 1977. It had been applied as an invert emulsion at that time. No other use of 2,4-D in the area could be verified.

Thus, the persistence of Visko Rhap A3-D in shell rock was investigated. In August 1980 a 30-gal sample of shell rock was taken from Jog Road and brought to Vero Beach, Florida. Two 24 inch square frames constructed from 1 inch by 4 inch boards were placed in an open area and filled with the shell rock. The shell rock was tamped to compress it and treated as follows—1) One qt of Visko Rhap A3-D (36.14% 2,4-D) was uniformly sprinkled over the shell rock, and 2) one quart of Visko Rhap A3-D diluted in five quarts of diesel oil was uniformly sprinkled over the other shell rock surface. The second treatment was used because in commercial practice Visko Rhap A3-D is mixed with diesel oil in a 1:5 ratio prior to being sprayed as an invert emulsion. We hypothesized that the 2,4-D had been spilled on the road in 1977 and it could have been either straight formulation or the diluted material.

The boxes were located in a well-drained area and were exposed to direct sunlight most of the day. Beginning one month later, and continuing at 2, 3, 6, 9, 11, 12, 15, 18, 21 and 24 months later, assays for 2,4-D were made. The procedure followed was to take a pinch of shell rock from the top quarter inch and distribute this over the upper leaves of a small (4-6 leaf stage) pepper plant. Three plants were used for each of three treatments in each trial. Treatments were 1) shell rock with undiluted Visko Rhap A3-D, 2) shell rock with diluted Visko Rhap A3-D, and 3) untreated control. In the first two assays the untreated control was sprinkled with uncontaminated shell rock. Results have been consistent—plants in treatments 1 and 2 have developed severe epinasty within a few hours after exposure to the contaminated shell rock. The shell rock from treatment 1 has been consistently more toxic than from treatment 2 as would be expected. No symptoms have been observed in the control plants. During the 2-yr period of testing over 100 inches of rain has fallen and the 2,4-D is still found in the top quarter inch of the shell rock.

A second incident involving persistence of 2,4-D in the form of Visko Rhap A3-D was observed during the fall of 1980 near Delray Beach, Florida. In this case the only use of 2,4-D on the farm was application of Visko-Rhap A3-D in combination with other herbicides during June, 1980. The herbicide mixture was applied as an invert emulsion to ditch banks. During late October the senior author observed typical phenoxy herbicide injury on peppers with the majority of affected plants being on beds adjacent to the canal banks. Interestingly, in many instances the row of peppers on the inside of the bed (there were two rows on each bed) was much more damaged than the row which was proximal to the canal bank. As in the Boynton Beach situation only the older plantings seemed affected. Laboratory analysis of pepper plants showed that 0.25 ppm 2,4-D and 0.20 ppm Banvel (dicamba) were present. The unusual distribution pattern of the injured plants would indicate that windborne dust particles emanating from the non-plastic covered alleys were the source of the chemicals. Injury appeared about 2 wk after a hot, dry and windy period in late September. Most of the plants eventually outgrew the symptoms although the fruit showed evidence of 2,4-D injury. The grower was advised to keep the water table high so as to minimize dust and this appeared to resolve the problem. It should be noted that occasional pepper plants with typical 2,4-D injury symptoms were observed a year later on this farm even though no 2,4-D had been used for over 17 months.

Cumulative Uptake of 2,4-D

It seems appropriate to comment on the nature of cumulative uptake of 2,4-D by plants since this is not a common phenomenon with this chemical. Observations of more and more plants being involved over a period of 6 wk coupled with the failure to observe symptoms in young plants provide strong evidence for a cumulative response. The reasons for this happening can be explained.

All of the plants within a few hundred feet of Jog Road Extension were being subjected to a continuing exposure to 2,4-D through the medium of contaminated road dust. During dry periods the dust cloud caused by vehicular traffic on an old shell rock road is so thick as to seriously reduce visibility. The chance of a 2,4-D contaminated dust particle settling on a pepper plant is determined primarily by two factors 1) the proximity to the source of contamination, and 2) the cross-sectional area of the plant. It is simple to calculate the rate of accumulation of particles as related to the size of the target area if one assumes a constant rate of particle emanation from the road. It is known (3) that 2,4-D which is absorbed by the plant does not breakdown rapidly but rather is accumulated in the growing areas of the plant. Thus, it is possible to integrate the rate of accumulation (dustfall x cross-sectional area of the plant) with the increase in the volume of the plant (growth) and gain a measure of the net accumulation rate of 2,4-D in the plant. It works out that very small plants would probably not be hit by contaminated dust, and, as the plants increase in cross-sectional area to where they are certain to be struck by contaminated dust, the increase in volume of the plant proceeds at a rate which is faster than the increase in cross-sectional growth, thus the net concentration of 2,4-D in the plant does not increase rapidly (Fig. 2). Only after the plant has ended the growth phase of its development can a rapid buildup in 2,4-D concentration occur. And, it is then of course that the injury symptoms begin appearing.

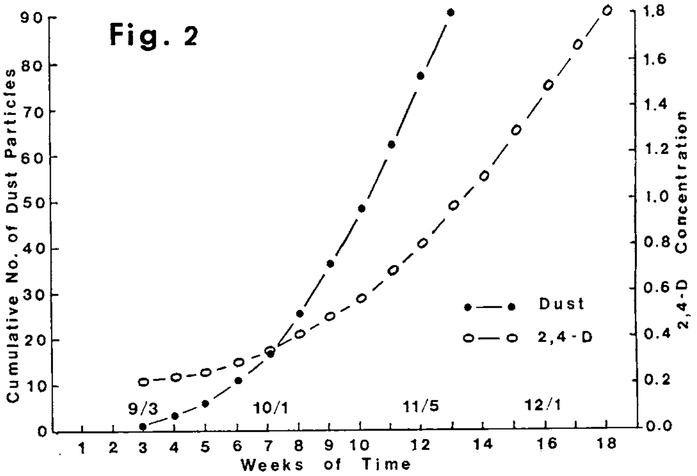

Fig. 2. Accumulation of 2,4-D in a plant when the plant is being subjected to a constant bombardment of contaminated dust particles over a period of several months. Although the number of dust particles accumulates on an exponential basis (solid circles), the increase in concentration of 2,4-D in the plant (open circles) proceeds at a much slower rate because of the effect of plant growth in diluting away the 2,4-D thus preventing a toxic concentration from being present during much of the vegetative phase of growth of the plant.

Legal Discussion Concerning Use of 2,4-D

Since the commercial introduction of 2,4-D in the U. S. in the 1940's, both its toxicity, as well as the hazards associated with its use in causing unintentional exposure to sensitive non-target plants has been well-documented (4, 7). Attention to the hazards giving rise to legal liability has focused on its application through aerial and ground spraying (1, 8, 9).

The most common lawsuit has resulted from aerial spraying where the injury occurs from drift to susceptible non-target crops. Lawsuits arising from damage to sensitive crops such as pepper, tomato and eggplant, both in the state of Florida and in other areas of the country, have been traditionally based on negligence in the use and application of the herbicide by the applicator. Less often, claims have been made against the manufacturer of the herbicide for failure to properly label the product so as to warn of drift and other use hazards.

Physical factors apart from the chemical formulation such as particle size, wind velocity and direction and other atmospheric phenomena also influence the likelihood of harm to sensitive crops through drift. Upon finding that the application of herbicides is an ultrahazardous activity, the highest courts of three states have adopted the concept of strict liability caused by the use of pesticides (including herbicides) thereby rendering applicators, users and farmers liable for damage caused by use of 2,4-D without regard to negligence (5).

The Florida Supreme Court has not directly addressed the issue, but, in the Boynton Beach case discussed in this report, the trial court held that 2,4-D use was an inherently dangerous activity and adopted strict liability against the 2,4-D user (6). Therefore, the sole question before the jury was whether the 2,4-D use in June caused the injury to the pepper in November.

Legally and factually the implications of the Boynton Beach observations and the experimental work reported in this paper are unique. The unique facts were the nonuniform pattern of injury to plants of similar age, the evidence of continuing exposure over a several week period of time and the observation that younger plants were less injured than older ones. All of these factors differ from the injury pattern observed in cases in damage incidental to spray operations where evidence of 2,4-D injury appears within hours or days after application.

Additionally, one of the issues in the lawsuit involving the Boynton Beach pepper focused on the persistence of 2,4-D. An inquiry into the persistence of 2,4-D was necessary because, although chemical injury to the pepper was first noted in November, a thorough investigation revealed no spray activities in the vicinity and no 2,4-D use on neighboring farms in the preceding months.

The legal implications are two-fold. First, assuming that Florida courts continue to find 2,4-D use to be an inherently dangerous activity, whether that use occurs incidental to the spraying or at a time subsequent to the application of the 2,4-D, users and applicators could be held legally responsible for damage caused as a result of the persistence of the 2,4-D. It is now generally assumed that it is safe to plant sensitive crops in close proximity to where 2,4-D has been used within a short period of time after 2,4-D has been used. Studies (2, 3, 4) cite 2,4-D persistence in soil to be one month or less and do not refer to any significant difference in persistence with regard to the formulation used.

Second, assuming the validity of the assumption that oil-soluble amine 2,4-D creates a potential hazard to sensitive crops due to persistence over many months (years), the failure to recognize and warn of the potential hazards created by oil-soluble amine 2,4-D and oil-soluble amine 2,4-D in its invert emulsion form could create liability on the part of the manufacturer under both theories of negligence and strict liability. Thus, the question posed to manufacturers of oil-soluble amine 2,4-D and to promoters of the invert emulsion is whether in addition to the benefits of the formulation in reducing drift, evaporation and run-off, has not an unexpected and injurious side-effect been created which could be hazardous to sensitive plants.

The field observations and experimental evidence suggesting persistence of 2,4-D in oil soluble forms under south Florida conditions would seem to warrant further study and analysis by herbicide manufacturers with regard to the potential hazard from persistence of 2,4-D and therefore the need to warn users of this hazard.

One final comment, for the reader who may have been wondering how the 2,4-D got down the length of Jog Road Extension, we are very suspicious that the grower's road grader was the culprit.

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INSECTICIDE EVALUATION FOR PEPPER WEEVIL CONTROL[1]

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Additional index words. Insect, pod injury, *Anthonomous eugenii.*

Abstract. **Several insecticides significantly reduced the number of observed adult pepper weevils** (Anthonomous eugenii **Cano) to less than 0.4 weevil per plant in 1975-79 tests. The number of adult weevils from the check averaged 0.4 to 1.0 per plant during the same period. In the 1979 test, fenvalerate and methomyl reduced the total number of larvae, pupae and adult weevils found in dropped pods from 7500 in the check plots to 200-1,000 per acre.**

The pepper weevil is a serious pest because oviposition may cause flower drop, or the larva can cause pods to drop before maturity or it makes the infested part unfit for human consumption. In 1972, Genung and Ozaki (1) reported that the pepper weevil was found on the lower east coast of Florida for the first time.

The report describes the national and Florida distribution, pod damages, life stages, biology, ecology and preliminary insecticide evaluations on pepper weevils. Carbaryl, methomyl, endosulfan, chlorinated camphene, leptophos, acephate, and chlorodimeform reduced the number of weevils. Poe (2) reported that the 1972 infestation on the Florida west coast was the highest in many years. Winsberg (President, Green Cay Farm, Route 1, Box 331B, Boynton Beach, FL 33437; personal communication) reported that an 80-acre field of bell pepper plants in Lantana, FL was disked when weevils infected the limb pods in 1973. In 1979, Subramanya (Univ. of Florida, P.O. Drawer A, Belle Glade, FL 33430-1101; personal communication) also found pepper weevils in Belle Glade, FL.

The purpose of this investigation was to evaluate several insecticides for reducing pepper weevil populations on bell peppers.

Materials and Methods

Insecticidal tests were conducted from 1973-1979 at the University of Florida, Morikami Farm, Delray Beach.

Bell pepper plants were sprayed mostly with a power sprayer with 8.8 kg/cm² (125 psi) pressure applying 935 liters/ha (100 gal/acre). The pyrethrins in 1975 were sprayed with a compressed air sprayer with 3.5 kg/cm² (50

[1]Florida Agricultural Experiment Stations Journal Series No. 4373.
[2]Deceased.