two and one-half and five pounds of five percent gamma-isomer content per 50 gallons of starter solution, as used on tomatoes, injured tomato plants. DDT has been safe to plants in soil applications at dosages up to 200 pounds per acre. Aldrin has been safe to potato plants up to four pounds active ingredient per acre in combination with fertilizer.

TOXIC INSECTICIDE RESIDUES OF VEGETABLES

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The hearings conducted by the Food and Drug Administration on chemicals used for pest control in fruit and vegetable production were completed in late September. It is expected that tentative tolerances will be announced during the early spring of 1951. The promulgation of these tolerances is of primary interest to every one connected with fruit and vegetable production, from the grower to the distributor and manufacturer of pesticides. These hearings and the restrictions on the amounts of insecticides to be tolerated on fruits and vegetables have served to focus attention upon the means of avoiding excessive residues. It is generally conceded that the use of insecticides is absolutely essential in the economic production of market-acceptable fruits and vegetables. Entomologists' efforts are directed toward developing effective means of insect control which require a minimum amount of poisonous insecticides.

When a new chemical is under investigation as a possible insecticide it is necessary to conduct a lengthy and detailed study of the chemical before it is released for experimental trial. Among the factors which are studied during the preliminary investigations are: (1) the effectiveness of the chemical against several different types of insects, (2) the reaction of plants to the chemical, that is, whether or not plants are injured by the material under a variety of conditions, (3) the compatibility of the chemical with other insecticides and fungicides, and (4) the acute and chronic toxicity of the chemical to small animals and man. If the chemical still shows promise after the preliminary investigations it is released for experimental trials under a wider range of weather conditions against a large number of insects on many crops. After it has passed these tests the chemical is ready to be placed on the market for general use. Thus the development of a new insecticide is a long and expensive process. We may then define the ideal insecticide as one which has a high toxicity to a wide range of insects, will not injure plants, can be readily mixed with other insecticides and fungicides, has an optimum degree of persistence and is not toxic to human beings. The insecticides which have come into use in recent years have many of the desirable characteristics of an ideal insecticide, but most of them are highly toxic to human beings. For this reason these insecticides must be used cautiously in order to avoid injury to those who apply the insecticides and those who consume the treated vegetables.

If the necessary precautions are observed the possibilities of acute poisoning are rather remote. But the possibilities of chronic poisoning, resulting from the consumption of foods contaminated with small quantities of cumulative poison over a long period of time, are of great concern to everyone. Thus it becomes important to know the amount of these various insecticides which may be expected to remain on vegetables treated for the control of insect pests. There are a number of factors which influence the amount of residues found on treated vegetables and a knowledge of these factors will assist in the avoidance of excessive residues.

One of these factors is the chemical nature of the insecticide itself. For example, tetra ethyl pyrophosphate (TEPP) hydrolizes rapidly in the presence of water so that within twenty-four hours very little or no TEPP is present. On the other hand, parathion, another of the phosphate insecticides, is stable in the presence of water and is much more persistent than TEPP. In the case of the chlorinated hydrocarbon insecticides, Decker et al. (2) have shown that the volatility of the insecticide has a considerable influence upon the amount of the original deposit of the insecticide and thus influences the amount of residue. Of the insecticides they worked with, DDT gave the greatest original spray deposit, followed, in the order named, by toxaphene, dieldrin, aldrin, chlordane, parathion and lindane. In the selection of an insecticide, especially in cases where it is to be used during the latter part of the growing season, the chemical nature of the material should be given consideration.

Another important factor which influences the amount of residue that may be found on treated vegetable crops is the physical nature of the insecticide. Decker (2) and his co-workers, in the paper already referred to, also reported that chlordane and toxaphene are much more resistant to the washing effects of heavy rainfall than DDT, dieldrin and aldrin. In a duplicate series of tests on alfalfa a heavy rain of 2.33 inches fell on the third day on one series of plots, while there was no rainfall for seven days on the other series of plots. As was to be expected, all of the insecticides showed a greater loss following the rain than where there was no rain. This ability of chlordane and toxaphene to resist the washing effect of heavy rains was attributed to the fact that DDT, dieldrin and aldrin are drier than chlordane and toxaphene.

A third factor, which influences the amount of residue, is the formulation used. Most present day insecticides are prepared as dusts, wettable powders and emulsifiable concentrates. In each of these types of formulations there is a wide range of diluents, wetting agents, deposit builders, solvents, etc. which may be used. The materials which are used in the manufacture of an insecticide have chemical and physical properties that will affect the amount of the original deposit of the insecticide and its weathering characteristics. Hoskins (4), reporting on work in California, shows that residues following the use of dust formulations are much lower than following the use of wettable powder sprays. Similar results were reported from Illinois by Decker et al (2).

Under weather conditions may be grouped rainfall, light and temperature conditions. The washing effects of rainfall have already been mentioned in connection with the physical properties of the insecticide. It is also obvious that the amount and the rate of rainfall will affect the amount of insecticide residue. Lindquist et al. (5) studied the effect of ultraviolet light and sunlight on solutions, emulsions and suspensions of DDT. Exposure to both ultraviolet light and sunlight materially reduced the effectiveness of the DDT. This reduction in effectiveness was greatly accelerated when high-boiling auxiliary solvents were used as contrasted wth the low-boiling solvents. Xylene emulsions and water suspensions were less affected by light than solutions. As a result of their study of the effect of temperature and humidity upon residues of DDT, Burgess and Sweetman (1) concluded that high temperatures and high humidity markedly, reduced its effectiveness against house flies. Treated screens, held at 23° C. and 25 to 40 percent relative humidity, remained highly toxic to house flies for a period of thirty-nine months, whereas similarly treated screens, held at 37° C. and 60 to 75 percent relative humidity, caused a very low mortality of flies at the end of this period. Gaines and Dean (3) used the boll weevil as the test insect to study the effect of temperature and humidity upon the toxicity of calcium arsenate, toxaphene, chlordane and a mixture of 3 percent gamma benzene hexachloride—5 percent DDT. High temperature and high humidity affected the toxicity of toxaphene less than the other organic insecticides. High temperature alone reduced the toxicity of all the insecticides, with the toxicity of clordane being reduced more than the toxaphene or the mixture of benzene hexachloride and DDT. At constant temperatures and high humidity the toxicity of both toxaphene and chlordane were reduced.

Robinson (6) has presented data to show that the processing required in the preparation of certain vegetables for market will reduce the amount of insecticide residue. For example, beans treated four days before harvest with 3 percent DDT at the rate of thirty pounds per acre carried a residue of 1.1 p.p.m. of DDT, while beans receiving the same treatment and canned by the usual cannery process carried 0.7 p.p.m. of DDT. Cauliflower treated with 0.5 percent parathion dust at fifty pounds per acre, seven days before harvest, carried a residue of 0.21 p.p.m., while cauliflower receiving the same treatment and washed and blanched for freezing carried 0.04 p.p.m. of parathion.

The time elapsing between the last application of the insecticide and harvest is the most important of all the factors which influence the amount of residue. The longer the time period the smaller the amount of residue remaining because of decomposition, volatilization and erosion.

During the past year determination of residues on Florida grown vegetables was started at the Central Florida Experiment Station. It was necessary to spend last year in preliminary studies and for this reason only a very limited amount of data on insecticide residues on Florida grown vegetables is available. This work is being continued at the main Station in Gainesville. The available data is from a small number of samples of pepper, cabbage, and celery from plots treated with parathion sent to the American Cyanamid Company Laboratory and samples of celery from plots treated with toxaphene sent to the Hercules Powder Company Laboratory. Results of these analyses are presented in table 1 and table 2. The first sample of pepper was taken from a plot treated by means of hand duster and the second sample from a field treated by means of a six row power duster. Eight hours after the power duster application a heavy rain fell on this field and a second rain fell twenty-four hours later. The cabbage received two applications of 1 percent parathion dust on March 16 and April 8 by means of a hand duster. The parathion and toxaphene were applied to celery by a six row power sprayer. The pepper and cabbage samples were not washed. Part of the celery samples were taken to a commercial packing house and given the usual washing and part of them were unwashed. Although the number of samples is small the data on parathion is in accord with published data from other sections showing that when there is a period of as much as thirteen days between the last application and harvest very little parathion residue is found. The toxaphene residues on celery given in table 2 show the effect of washing as the washed and unwashed samples at each dosage level were taken from the same plot.

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TABLE 1.
RESIDUES OF PARATHION ON PEPPER, CABBAGE AND CELERY. ANALYSES BY AMERICAN CYANAMID COMPANY.

Crop	Insecticide Applied	Lbs. per Acre, Toxicant Applied	Number Applications	Interval Between Last Application and Analysis, Days	Residue in P.P.M.
Pepper	1% Parathion Dust	0.8	2	13	None
Pepper	"	0.18	1	2	None
Cabbage	1% Parathion Dust	0.9	2	3	3.7
Cabbage	"	"	"	13	0.4
Cabbage	"	"	"	21	0.2
Celery	½ lb. 25% Wettable Parathion	0.25	2	3	0.5
Celery	"	"	"	20	0.1
Celery	"	0.37	3	55	0

TABLE 2.
RESIDUES OF TOXAPHENE APPLIED AS A SPRAY OF THE 40% WETTABLE POWDER TO CELERY. ANALYSES BY HERCULES POWDER COMPANY.

Lbs. per Acre of Toxicant	Number Applications	Interval Between Last Application and Harvest, Days	Residue in P. P. M.			
			Unwashed		Washed	
			Stalk	Foliage	Stalk	Foliage
14.4	10	12			1.6	9.8
10.3	9	13	2.6	19.7	1.8	6.5
1.8	2	47	0	0.2	0	0
6.0	3	31	0.2	2.9	0	0
4.2	3	31	0	0	0	0