CONTROL AND SEASONAL DEVELOPMENT

OF THE GREEN PEACH APHID AND THE

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PREFACE

Spinach and cruciferous greens crops have been grown on a commercial scale in the Arkansas River Valley of Oklahoma for over twenty years. During the early period of development of the industry serious infestations of insect pests were apparently infrequent and local in range. By 1946 insect outbreaks had become more common and in that year several canners and growers in the industry requested assistance from the Department of Entomology of the Oklahoma Agricultural Experiment Station. Research in progress by the writer on vegetable insect control was expanded in 1946 to include an investigation of insect pests on greens crops. The investigation remains in progress at the present time. This paper, however, is limited to a report on the results of studies made from 1946 to 1952 inclusive on the control and seasonal development of the two important aphid species occurring as pests on greens crops.

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INTRODUCTION

The production of greens crops for canning and for the fresh market is an important industry in the Arkansas River Valley of Oklahoma. The crops in order of importance are spinach, mustard, turnips, and kale. Observations made during 1946 to 1949 indicated that the combined acreage planted to mustard, turnip and kale was almost equal to the spinach acreage. The greater part of the production of these crops is canned. During the past ten years the acreage planted to these crops has increased; and as production has become more intensified in this area, insect problems have become more acute. At certain times plant injury by insects may become a limiting factor in production. However, the most important damage due to insects is the contamination of food products caused by the presence of insect bodies, cast skins, and other debris. Rigid enforcement of regulations prohibiting insect contamination of products on sale makes a high level of insect control mandatory if the industry is to survive.

Aphids constitute the most important insect pests of greens crops in Oklahoma on the basis of average annual losses. The presence of living host plants throughout the year and the type of climatic conditions existing during the fall, winter and spring, when these crops are grown, cause certain aphid species to be particularly well adapted to the environment. The species of chief importance are the green peach aphid, *Myzus persicae* (Sulz.), and the turnip aphid, *Rhopalosiphum pseudobrassicae* (Davis). The green peach aphid is the only species of importance on spinach. The turnip aphid was collected from spinach a number of times but it was not observed to establish colonies there. It was considered as having "over-flowed" from infested crucifers. Both species infested the cruciferous crops but in all cases observed the turnip aphid was the dominant species on these crops. The relatively low populations of the green peach aphid on crucifers was of importance, however, in that they appeared to frequently act as a source of infestation by this species of spinach.

Other insect pests of importance on these crops included the diamonback moth larva, Plutella maculipennis (Curt.) on the crucifers and the seed-corn maggot, Hylemya cilicrura (Rond.), on spinach. Although a considerable amount of data were obtained concerning the control and seasonal history of these species the data presented in this paper were limited to those concerning the aphid species.

REVIEW OF LITERATURE

The Green Peach Aphid

The accepted common name of the green peach aphid, (Muesebeck, 1950), was apparently first applied to *Myzus persicae* by Taylor (1908). The species was originally described in the genus *Aphis* (Sulzer, 1776 p. 105). It has a very extensive synonomy due to its cosmopolitan distribution, many host plants, and variation in the summer and fall forms. The summer and fall forms possess swollen cornicles characteristic of the genus *Rhopalosiphum* but the members of the spring generation exhibit cylindrical cornicles which constitutes a characteristic of the genus *Myzus*. The synonomy of *Myzus persicae* (Sulz.), according to Essig (1948) is as follows:

Aphis persicae Sulzer (1776)
Aphis dianthi Schrank (1801)
Aphis vulgaris Kyber (1915)
Aphis furcipes Rafinesque (1817)
Aphis rapae Curtis (1842)
Aphis vastator Smee (1846)
Aphis cyanoglossi Walker (1848)
Aphis egressa Walker (1849)
Aphis redundans Walker (1849)
Aphis aucta Walker (1849)
Aphis persicaecola Boisduval (1867)
Siphonophora achyrantes Monell (1879)
Rhopalsiphum tulipae Thomas (1879)
Myzus malvae Oestlund (1886)
Myzus pergandii Sanderson (1901)
Rhopalosiphum solani Theobald (1912)
Rhopalosiphum betae Theobald (1913)
Rhopalosiphum lactucellum Theobald (1915)
Rhopalosiphum tuberosellae Theobald (1919)

Essig (1948) and Mason (1940) give technical descriptions of the various forms produced. Essig (1948) states:

> . . . The green peach aphid is without doubt the most important economic species in the entire Family Aphididae. It is not only cosmopolitan in distribution and feeds on more varieties of host plants, but it is also capable of transmitting more kinds of plant viruses than any other insect known at the present time.

Gillette and Taylor (1908) stated it was the most abundant species on peach in Colorado. Chittenden (1909) pointed out that the damage to cabbage, spinach, celery, and lettuce in the Norfolk, Virginia trucking section in 1907 was estimated at $750,000. Wilson (1913) reported M. persicae as damaging peach blossoms and leaves in Oregon. Smith (1917), Gould (1930), Isely (1946) and many others have reported serious damage to truck crops in many sections of the country during the first half of the century. The earliest published record of M. persicae as occurring in the United States appears to be by Thomas (1876). The green peach aphid has caused damage to potatoes, especially as a vector of disease (Simpson and Shands, 1949; Davis and Landis, 1951). In recent years it has occurred as a pest on tobacco (Chamberlin, 1949; Creighton, 1947; Turner, 1949).

Myzus persicae has an unusually long and varied list of host plants. Horsfall (1924) listed one hundred and six plants in this category. Patch (1938) reported three hundred and twenty-two species and varieties of host plants belonging to sixty-eight different families. Essig (1948) recorded three hundred and fifty-one species and varieties from California. Taylor (1908) studied the biology and seasonal development of the species in Colorado. The peach, nectarine, plum, prune, cherry, chokecherry, willow and rose were found to serve as winter hosts. During the summer aphids fed on such herbaceous plants as potato, turnip, rape, cabbage, tomato, false-mallow, yellowdock, redroot, mustard, shepherd's purse, eggplant, snapdragon, carnation and rhubarb. The fall migrants returned to the winter hosts by mid-September to early October. Stem-mothers began hatching by mid-February to early March. Migration was well under way to other hosts by early May. Horsfall

(1924) made similar observations in Pennsylvania. Patch (1925) concluded the peach tree was the true overwintering host. Davis and Landis (1951) studied the relation of green peach aphid infestations on peaches to outbreaks on potatoes in Washington. It was found that the presence of peach trees in the potato growing districts was associated with early infestations on potatoes. Simpson and Shands (1949) reported species of wild plum were satisfactory winter host plants. Sanborn (1904), Wadley (1922), and King (1952) recorded collections from peach in Kansas. King observed deposition of eggs on peach and made a series of observations of the species on winter and summer hosts.

By 1876 M. persicae was widely distributed over the United States on peaches but was not classed as doing important damage. Thomas (1876) suggested infested plants be drenched or sprinkled with strong soapsuds, weak lye solution, tobacco water, or a mixture of soapsuds and tobacco water. Townsend (1891) recommended, in addition to the above, the use of sprays or dusts containing pyrethrum or hellebore. By 1908 M. persicae had become a serious pest on peaches in Colorado. Taylor (1908) recommended kerosene emulsion, tobacco decoction, or "Black Leaf Extract of Tobacco in water. Within the next few years standardized nicotine concentrates were developed and control practices for the green peach and other aphids on a number of crops became very general. Until the introduction of the synthetic organic insecticides in the 1940's nicotine remained the leading aphicide. A few workers recommended either rotenone or pyrethrum as substitutes for nicotine (Cory and Eaton, 1929; deJung, 1929; Chupp and Leiby, 1942).

Beginning in 1944, a number of workers reported on the effects of DDT on the green peach aphid (Wiegel, 1944). Hill (1945) and

Simpson and Shands (1949) reported satisfactory control on potatoes and Gyrisko et al. (1946) found DDT to be superior to nicotine or rotenone. Sylvester (1949) rated DDT and parathion as equal in effectiveness. DDT was effective on M. persicae on apples (Newton, 1947) and superior to nicotine on peaches (Yothers and Carlson, 1948).

Isely and Miner (1946) obtained 96 to 100 percent mortality of M. persicae with dusts containing benzene hexachloride in hand application tests on spinach. They attributed much of the effectiveness of the benzene hexachloride to its fumigating action. Srivastava (1947), in laboratory tests, demonstrated the fumigative action on several aphid species. Bacon and Walz (1947) reported 3 percent nicotine, 3 percent hexaethyl tetraphosphate and benzene hexachloride (1 percent gamma isomer) to be approximately equal in tests on spinach.

The Turnip Aphid

The common name, turnip aphid, appears to have been first applied to Rhopalosiphum pseudobrassicae (Davis) by Paddock (1915). The species was described as Aphis pseudobrassicae by Davis (1914, p. 231). Because of its close resemblance to the cabbage aphid, Brevicoryne brassicae (Linnaeus), the two species were no doubt often confused prior to 1914. Essig (1948) listed Lipahis pseudobrassicae (Davis) and Aphis mathiolellae Theobald as synonyms.

By 1915 the turnip aphid had been reported from New York, Indiana, Minnesota, Oklahoma, Texas, Louisiana, and Florida (Paddock, 1915). At the present it is widely distributed in the United States and causes heavy losses to growers of cruciferous crops, especially in the South. The estimated average annual loss in Texas, Louisiana, Mississippi, Alabama, Florida, Georgia, and South Carolina is about $2,800,000 (Allen and Harrison, 1941).

R. pseudobrassicae has a much shorter and much more restricted list of host plants than M. persicae. Patch (1939) listed 26 species of food plants belonging to five families. Twenty of these belonged to the mustard or Cruciferae Family. Essig (1948) reported 30 species and varieties of hosts in California. Twenty-four of the hosts were crucifers. All host species reported to date are herbaceous plants. Harrison and Allen (1943) listed turnip, mustard, and radish as the favorite food plants. They reported that the highest populations and the greatest damage occurred during November to March in Louisiana. They were of the opinion that the very low populations found during the summer months did not account for all of the fall population. This condition has been observed by other workers but no satisfactory explanation has been proposed.

Paddock (1915) collected the species from turnip, radish, cabbage, cauliflower, mustard, kale, rutabaga, lettuce, bean, rape, kohl-rabi, and collard in Texas. He found aphids remained active on their food plants throughout the winter. In the northern part of the state at Wichita Falls, reproduction was suppressed for several days or weeks during periods of sub-freezing temperature. He found the aphids preferred both turnip and radish to mustard. Paddock also reported difficulty in finding aphids during the summer months. No sexual stages of the species were found. Davis and Satterthwait (1916) studied the life history and seasonal history in Indiana. Harrison and Allen (1943) stated that: "On December 23, 1932, L. B. Reed collected from mustard at Chadbourn, North Carolina, specimens of wingless and oviparous female aphids which were identified by P. W. Mason as R. pseudobrassicae."

For control of R. pseudobrassicae on crucifers, early workers (Paddock, 1915; Davis and Satterthwait, 1916) suggested the use of soap solutions or soap solutions plus nicotine. Hull (1929) found standard treatments with nicotine and pyrethrum to be unsatisfactory because of low temperatures and high winds in tests in Texas. Harrison and Allen (1943) conducted an extensive testing program on crucifers in Louisiana during 1932 through 1938. The most successful material was one percent rotenone with tobacco dust and dusting sulphur as diluents. Dusts containing 3 percent nicotine also gave good initial control but provided only a brief period of protection, and where repeated several times, caused stunting and reduction in plant quality. Sprays were less effective than dusts containing the same toxicants. Plants grown in rows could be more effectively treated than those planted broadcast. Howard (1944) found 3 percent nicotine dust to be slightly better than one percent rotenone and considerably more effective than one percent DDT dust. Isely and Miner (1946) as a result of work in Arkansas, stated dusts containing benzene hexachloride appeared to give effective control of the turnip aphids on mustard. In laboratory tests, Brooks (1947) found one percent hexachloride dust gave better control of R. pseudobrassicae on kale than 3 percent nicotine dust. Wene (1949a) conducted an extensive series of dusting test in southern Texas with hand equipment on turnip, mustard, and radish. One percent dusts of either parathion or lindane gave excellent results. Nicotine dusts gave high initial kills, but the surviving aphids rapidly increased. Combinations of pyrethrins, rotenone and piperonyl cyclohexenone and pyrethrins with DDT did not give satisfactory control. In other tests on radish (Wene, 1949b) parathion and lindane gave higher kills than rotenone or nicotine at 24 hours but counts made at the end of seven days showed rotenone to be as effective as the first two materials.

Because of its relation to public health, the amount of insecticidal residues remaining on parts of treated plants used for food is of special importance. A review of the literature reveals that a number of factors affect the amount of insecticidal residues remaining on plants at harvest time. These include the time between treatment and harvest, rate of application, rate of decomposition or degradation as determined by the type of insecticide and formulation, the amount of plant growth following treatment, field environmental conditions, and processing of the food products. Hamilton (1929) showed the amount of residue on apple foliage was inversely proportional to the rate of leaf growth. When the growth rate was slow, weathering was the most important factor in residue reduction. Decker (1946) concluded from a review of publications that the time between treatment and harvest was more important than the rate of application on the amount of residue present. Arant (1948) found that four to five weeks of weathering plus the process of bailing removed nearly all of DDT residues on peanut hay. Fleck (1944) reported the rate of volatilization of DDT was too slow to be important in reducing its residues. Allen and Berck (1950) showed DDT residues on celery increased with the rate of application.
Sloan et al (1951a and 1951b) showed that: (a) the amount of DDT residue on lettuce increased with the rate of application and the number of applications — this trend was less consistent in the case of parathion residues (b) weathering reduced the residues of DDT and parathion by 80 and 90 percent, respectively (c) plant growth, alone, reduced DDT

residues by 73 percent. Ginsburg et al. (1949) stated rainfall decreased residues. An increase in spray concentrations or decrease in time between treatment and harvest resulted in an increase in parathion residues on apples (Westlake and Fahey, 1950). Stansbury and Dahm (1951) found commercial dehydration reduced spray residues on alfalfa as follows: parathion, 84 percent; chlordane, 81 percent; aldrin, 69 percent; toxaphene, 66 percent.

Decker et al. (1950) determined the residue loss at certain intervals after treatment from mature apple and peach foliage. The percent loss at seven days for each compound was as follows: parathion, 97; lindane, 90; toxaphene, 72; DDT, 59; aldrin, 55. By the twenty-first day the respective reductions in percent were: 100, 99, 82, 77, 84. Aldrin was completely dissipated by the 27th day but toxaphene and DDT were decreased by only 88 and 83 percent by the 42nd day. Barnes et al. (1950) reported that during 30 days residues of parathion and DDT on peaches declined 98 percent and 84 percent, respectively. Hopkins et al. (1952) found that negligible residues of parathion, aldrin, lindane, BHG, and DDT, remained on alfalfa at the end of 30 days even when applied at a rate of 6 pounds of toxicant per acre. The order of materials as listed above was the order of disappearance of their residues. Teotia and Dahm (1950) showed that parathion had a significantly longer period of residual toxicity to house flies than either lindane or aldrin.

Zeid and Cutkomp (1951) found parathion persisted as a translocated insecticidal material in beans for about two weeks. Mote (1950a) reported the parathion residue on hop foliage, resulting from treatment with 40 pounds of one percent dust per acre, at the end of two weeks was 0.6 ppm. At the same time the residues from foliage treated with

0.25 percent dust was only 0.05 ppm. Mote (1950b) reported unprocessed samples of spinach treated with 1.0 percent and 0.5 percent parathion dust at a rate of 30 pounds per acre had residues at the end of one week of 0.93 ppm and 0.05 ppm, respectively. Processed samples of the same treatments tested at the same time showed residues of 0.46 ppm and 0.05 ppm, respectively.

Bacon and Walz (1947) found spinach samples treated with a benzene hexachloride dust containing one percent gamma isomer possessed a decided musty off-flavor. Smith et al. (1949) reported that all fresh and canned samples of peaches which had been sprayed with benzene hexachloride were off-flavored. Chandler (1949) obtained similar results with benzene hexachloride on peaches, but found that lindane sprays did not impart an off-flavor to the peaches. Samples of potatoes and tomatoes treated with lindane in the greenhouse were associated with slight off-flavor but did not differ significantly from the untreated check samples. (Rodriquez et al., 1950).

METHODS AND MATERIALS

Descriptions were made in this section for only those methods or materials which were used in several tests. Where they were used in one or only a few tests, the methods or materials were described in the "application data" under the table presenting the test's results or in the text where the results were discussed.

Losses of Crops

During the period 1946 to 1950 data were secured on losses of greens crops caused by aphids and by all insect infestations. Quantitative records were obtained from five individual truck farms, which included a commercial farm in each of the four important production areas of the Arkansas River Valley, and the Oklahoma Vegetable Research Farm at Bixby. The commercial farms selected were representative of the industry in cropping systems, operation and size but produced a higher proportion of spinach to cruciferous greens than ordinarily occurred. The combined acreage in the study consisted of 7,662 acres, composed of 61 percent spinach and 39 percent crucifers. The crucifers in order of importance were curled mustard, turnips and kale. The farms ranged in size from average annual planting of 250 to 1100 acres.

The majority of the data on losses were based on reports compiled by the farm operator although in a few instances they were recorded by the author. In all cases losses were recorded within one year after the losses occurred. The losses were recorded as the acreages of crops abandoned because of insect infestations. Losses were classified as "caused by all insects" and as "caused by aphids." In addition to aphids, important insect pests causing losses were the diamondback moth larva, Plutella maculipennis (Curt.), on crucifers and the seed-corn maggot, Hylemya cilicrura (Rond.), on spinach. Supplementing these quantitative data from specific farms, a considerable number of observations on insect damage were made at irregular periods and varying locations.

Seasonal Development

Information on the seasonal development of aphids was obtained by three types of investigations. One investigation, designed to study the seasonal development of the two species on greens crops, included consecutive population counts made in specific fields during the two years of 1949-1950 and 1950-1951. The second source of information consisted of estimates and counts of the aphid population made at irregular times and in various fields of greens crops in the Bixby area during the five-year period of 1946-1951. Records of collections made from host plants other than greens crops served as a third source of information. The population trends in the specific study fields were based on counts of aphids on the leaves selected at random at each of four counting stations in each field. Counts were made at intervals of five to seventeen days. Each year during the period of 1946 to 1951 a few observations were made at irregular intervals in each of several fields in the Bixby Area. These observations consisted of population estimates and counts, date of observation, notes on predator-parasite activity and plant condition. The results are summarized and expressed as the estimated intensity and date of occurrence of the peak population during the different seasons. The intensity of the peak populations were classed on four categories. These categories were as follows: "very light," less than one aphid per leaf; "light," from one to ten aphids per leaf; "moderate," from eleven to twenty-five aphids per leaf; and "heavy," more than twenty-five aphids per leaf. Collections of aphids were made from a considerable number of host plants other than the commercial greens crops. These included both cultivated and weed plants and a few ornamental species. Collections were made at irregular intervals and largely incidental to other phases of the investigations. Collections were recorded only when aphid colonies were observed.

Control with Insecticides

A total of twenty-five field and laboratory tests were made in the investigation of various insecticidal methods for aphid control. Fourteen insecticidal toxicants and synergists were tested. These included nicotine sulphate, rotenone, pyrethrum, sabadilla, piperonyl butoxide, piperonyl cyclohexenone, DDT, methoxychlor, chlordane, benzene hexachloride, lindane, toxaphene, tetraethyl pyrophosphate, parathion, and methyl parathion. Most of these toxicants were tested in several different formulations. Table 1 gives a description of each formulation including the manufacturer or processor. The materials, in the form of dusts and sprays, were applied by hand equipment, power ground equipment, and airplane. The majority of hand applications of dusts were made with Root rotary dusters with a single straight outlet tube equipped with a "fishtail" attachment. In a few tests dusts were applied with small plunger-type dusters. Hand application of sprays were made with a Champion knapsack sprayer. Power application of dust was made with a YB, six outlet,

Table 1. Formulations and sources of insecticides tested

Number	Formulation and Source
1.	BHC (1,2,3,4,5,6-hexachlorocyclohexane) Spray: 4 pounds Lexone 50 (50% wettable powder concentrate containing 5.0% gamma isomer) per 100 gals. water. E. I. duPont de Nemours & Company.
2.	BHC Spray: 8 pounds Lexone 50 per 100 gals. water.
3.	BHC 1.0% Dust: Lexone 50 diluted with talc to form a dust containing 1.0% gamma isomer.
4.	BHC 2.0% Dust: Lexone 50 diluted with talc to form a dust containing 2.0% gamma isomer.
5.	Chlordane (not less than 60% 1,2,3,4,5,6,7,8,8-octachloro-4,7-methano-3a,4,7,7a-tetrahydro-indane) 3.0% Dust: Velsicol Corporation.
6.	DDT [2,2-bis (p-chlorophenyl)-1,1,1-trichloroethane] 5.0% Dust: Gesarol V-D50 (50% DDT dust concentrate) diluted with talc. Geigy and Company.
7.	DDT 10.0% Dust: Gesarol V-D50 diluted with talc.
8.	DDT 1.0% and pyrethrins 0.12% Dust: P-M No. 10 Dust. McLaughlin-Gormley King Company.
9.	Lindane (not less than 99% gamma isomer of 1,2,3,4,5,6-hexachlorocyclohexane) 1.0% Dust: Isotox No. 10 Dust (gamma isomer 1.0%). California Spray Chemical Corp.
10.	Lindane Spray: 1½ pints Isotox (lindane 20% emulsifiable concentrate) per 100 gals. water.
11.	Lindane Spray: 2½ pints Isotox 20% concentrate per 100 gals. water.
12.	Lindane Spray: 2 pints Isotox 20% concentrate per 10 gals. water.
13.	Methoxychlor [2,2-bis (p-methoxyphenyl)-1,1,1-trichloroethane] 5.0% Dust: E. I. duPont de Nemours & Company.
14.	Methoxychlor Spray: 4 pounds Marlate 50 (50% methoxychlor wettable powder) per 100 gals. water. E. I. duPont de Nemours & Company.

Table 1. (Continued)

15. Methyl Parathion (0,0-dimethyl-0-p-nitrophenyl thiophosphate)-parathion (0,0-diethyl-0-p-nitrophenyl thiophosphate) Spray: 1 2/3 pints Metacide (methyl parathion 24.5%, parathion 6.2%) per 100 gals. water. Geary Chemical Company.

16. Methyl Parathion-parathion Spray: 2 pints Metacide per 10 gals. water.

17. Methyl Parathion-parathion Spray: 1 pint Metacide per 10 gals. water.

18. Nicotine sulphate 3.0% Dust: Black Leaf 40 in hydrated lime. Tobacco By-Products and Chemical Corporation.

19. Nicotine 1.5% rotenone 0.2%, piperonyl cyclohexenone 0.8% Dust: Tobacco By-Products and Chemical Corporation.

20. Parathion 0.5% Dust: Thiophos American Cyanamid Company.

21. Parathion 1.0% Dust: Thiophos.

22. Parathion 1.0% Dust: Vapophos (Parathion 15% wettable powder) diluted with talc. California Spray Chemical Corp.

23. Parathion Spray: 1½ pounds Vapophos 15% wettable powder in 100 gals. water.

24. Parathion Spray: 1½ pints Thiophos (parathion 25% emulsifiable concentrate) per 12 gals. water.

25. Pyrethrins 0.05%, rotenone 0.25%, piperonyl cyclohexenone 0.5% Dust. (CPR Dust). U. S. Industrial Chemicals Co.

26. Pyrethrins-rotenone Spray: 3 pints Pyrenone [pyrethrins 0.19%, rotenone 1.0%, piperonyl butoxide (3,4-methylenedioxy-6-propylbenzyl butyl diethylene glycolether) 2.8%] per 100 gals. water. U. S. Industrial Chemicals Company.

27. Rotenone 0.5% Dust in talc. Thompson-Hayward Chemical Co.

28. Rotenone 0.75% Dust in talc. Thompson-Hayward Chemical Co.

29. Rotenone 1.0% Dust in talc. Thompson-Hayward Chemical Co.

30. Rotenone 1.0%, sulphur 40% Dust. Thompson-Hayward Chemical Co.

31. Sabadilla 10% Dust in hydrated lime. John Powell and Co., Inc.

Table 1. (Continued)

32.	TEPP (Tetraethyl pyrophosphate) 0.5% Dust: Vapotone Dust. California Spray Chemical Corporation.
33.	TEPP 0.66% Dust: Vapotone Dust.
34.	TEPP 0.75%. Grisham Seed Company, Oklahoma City.
35.	TEPP 1.0% Dust. Vapotone Dust.
36.	TEPP Spray: 1 quart Vapotone concentrate (20% tetraethyl pyrophosphate) per 50 gals. water.
37.	TEPP Spray: 3 gals. Vapotone concentrate (20% tetraethyl pyrophosphate) per 45 gals. water.
38.	Toxaphene (chlorinated camphene) 20% Dust. California Spray Chemical Corporation.
39.	Toxaphene Spray: 5.6 pounds toxaphene 40% wettable powder per 100 gals. water. California Spray Chemical Corporation.

Root power duster. Each outlet was equipped with a "fish-tail" attachment. Except as otherwise specified, the outlets were spaced laterally at intervals of two feet and at a height of approximately 18 inches above the tops of the plants. No drag sheets were used. Dilute sprays were applied by a high volume power sprayer at a pressure of 250-300 p.s.i. and at rates of 50 to 125 gallons per acre. Concentrate sprays were applied by means of a low-volume power sprayer at pressures of 60- to 100 p.s.i. and at rates of 4 to 15 gallons per acre. Except as otherwise specified sprayer nozzles were arranged at lateral intervals of 30 inches and at a height approximately 18 inches above the tops of the plants. In two tests, Stearman airplanes were used to apply dust and spray. Descriptions of the methods used are given in the "application data" of the tests.

Residues on Greens Crops

The determination of the amounts of insecticide residues on greens crops was made by chemical analysis by the Department of Agricultural Chemistry Research of Oklahoma A. and M. College. Residues of parathion and methyl parathion were determined by the colorimetric method of Averell and Norris (1948). Residues of the chlorinated hydrocarbon insecticides were measured by an adaptation of the total organic chloride method by Carter (1947). Samples were extracted with benzene and the extract freed from the solvent. The extract was taken up in isopropanol and refluxed with sodium metal for one-half to two and one-half hours. Water was added and the alcohol removed by evaporation. The organic chloride thus converted to inorganic chloride was determined by the method of McLean and Van Slyke (1915). In all tests untreated samples were analyzed as controls.

The method of sampling used on spinach and radishes differed from that employed on mustard and tender-greens. On the first two crops the plant stem was cut at a point immediately below the bottom leaves and the entire foliage was included in the residue sample. On the other crops the foliage was cut off at a height of two to six inches above the ground depending on the size and height of the plant. This method resulted in the major portion of the petioles and most of the young leaves being left in the field. The two different methods of sampling were used because they coincided with the methods of harvesting used on commercial plantings of the respective crops.

Samples of 6 to 20 pounds were collected and placed in large paper bags. The bags were closed at the top and securely tied. Residue samples were taken to the laboratory within three hours after collection and were then extracted in benzene or placed in refrigeration at temperatures of 36 to 40 degrees until processed. All samples treated with lindane, BHC, or parathion were extracted in benzene or processed within 12 hours after collection. Benzene extractions which were not immediately analyzed were stored in refrigeration in airtight containers until analyzed.

The Effect of Processing on Residues.--Tests were made to determine what effect certain processes had on residues on greens crops. The processes included washing, canning, cooking in an open vessel, cooking under pressure, freezing, and drying. Before processing, the foliage clusters of the spinach plants which were collected in the field as units were separated into individual leaves. In washing a sample placed in a large pan and immersed in fresh tap water. The sample was stirred thoroughly with the hands for two to three minutes and then lifted out and placed in fresh water. These processes were repeated until the sample had passed through three lots of water. On removal from water the sample was allowed to drain and was then extracted with benzene for analysis or was further processed. Two methods of canning were used. These were the standard method employed by commercial canneries in packing these crops, and a home canning method. The latter process included washing, as described above, blanching, sealing, and cooking under pressure. Blanching was performed by immersing the sample in water at a temperature near the boiling point. At the end of three to five minutes the sample was placed in cans or jars and sealed. A sufficient amount of the blanching water was added to the container to cover the sample. The canned greens were cooked under a pressure of 15 p.s.i. for 30 minutes. To test the effect of cooking in an open vessel, unwashed samples were boiled in their own juices for a period of 5 minutes. Unwashed samples were also cooked under a pressure of 15 p.s.i. for 30 minutes. To test the effect of freezing on residues, unwashed samples were frozen and stored at a temperature of 0 degrees for 60 days. Unwashed samples were also dried in the open air and sunshine for five days.

LOSSES OF GREENS CROPS CAUSED BY APHID INFESTATIONS

The data on losses, presented as crop acreages abandoned because of insect infestation (Tables 2 to 8), do not necessarily indicate the presence of short-lived or light infestations. Neither do they distinguish between intensities of infestation, since moderate infestations caused abandonment in the same manner as heavy infestations. Furthermore, these data do not measure insect damage in its entirety. Insect damage in the form of reduction in yield, usually caused by stunting and mortality of young plants, is not included. As previously stated, however, the important damage to these crops is largely limited to contamination of the food products by insects and their debris. Considering this fact, it appears that these data are of value as a measure of the important losses caused by aphids and other insects.

Table 7 presents the percent of acreage losses caused by aphids each year on all five farms. The same losses caused by all insects (aphids included) are shown in Table 8. Aphids constituted the most important type of insect pest for both spinach and cruciferous crops. The average annual loss of spinach due to aphids (Table 7) ranged from 9 percent in 1948 to 48 per cent in 1946, with the average loss for the five-year period being 21 percent. Similar losses of crucifers (Table 7) varied from 11 percent in 1947 to 46 percent in 1949. The average loss for the period was 28 percent.

The relative amount of losses caused by aphids and by other insect pests can be determined by comparing Table 7 with Table 8.

Table 2. Acreage of greens crops abandoned because of insect infestations, Lee Tyler Farm, Keota, 1946 to 1949.

	Total Crop Planted	Crop Loss Due To			
		Aphids		All Insects	
Year	Acres	Acres	Per Cent	Acres	Per Cent
		- Spinach -			
1946	760	100	13	115	15
1947	575	45	8	45	8
1948	650	0	0	0	0
1949	780	90	12	140	18
Total	2,765	235	—	300	—
Average	691	59	9	75	10
		- Mustard, Turnips and Kale -			
1946	425	90	21	105	25
1947	455	95	21	190	42
1948	345	90	26	110	32
1949	470	210	45	250	53
Total	1,695	485	—	655	—
Average	424	121	28	164	38

Table 3. Acreage of greens crops abandoned because of insect infestations, Griffin Grocery Company Farm, Muskogee, 1947 to 1950.

Year	Total Crop Planted	Crop Loss Due To			
		Aphids		All Insects	
	Acres	Acres	Per Cent	Acres	Per Cent
		- Spinach -			
1947*	125	0	0	0	0
1948	150	0	0	0	0
1949*	145	0	0	0	0
1950	120	30	25	70	58
Total	540	30	—	70	—
Average	135	8	6	18	15
		- Mustard, Turnips and Kale -			
1947	120	40	33	65	54
1948	120	0	0	80	67
1949	120	60	50	90	75
1950	100	40	40	0	0
Total	460	140	—	235	—
Average	115	35	31	59	49

*Fall crop plowed under in early winter because of failure to mature before the advent of freezing weather.

Table 4. Acreage of greens crops abandoned because of insect infestations, T. E. Moore Farm, Bixby, 1947 to 1950.

Year	Total Crop Planted Acres	Crop Loss Due To Aphids Acres	Crop Loss Due To Aphids Per Cent	Crop Loss Due To All Insects Acres	Crop Loss Due To All Insects Per Cent
		- Spinach -			
1947	100	36	36	36	36
1948	120	20	17	20	17
1949	80	40	50	40	50
1950	60	15	25	30	50
Total	360	111	—	126	—
Average	90	28	32	32	38
		- Mustard, Turnips and Kale -			
1947	60	0	0	0	0
1948	60	10	17	10	17
1949	40	30	75	40	100
1950	40	10	25	20	50
Total	200	50	—	70	—
Average	50	13	29	18	42

Table 5. Acreage of greens crops abandoned because of insect infestations, Willis Farm, Haskell, 1946 to 1949.

Year	Total Crops Planted	Crop Loss Due To			
		Aphids		All Insects	
	Acres	Acres	Per Cent	Acres	Per Cent
- Spinach -					
1946	450	350	78	350	78
1947	100	25	25	25	25
1948	260	60	23	90	35
1949	225	40	18	65	29
Total	1,035	475	—	530	—
Average	259	119	36	133	42
- Mustard, Turnips and Kale -					
1946	200	80	40	100	50
1947	80	0	0	20	25
1948	225	75	33	100	44
1949	240	20	8	100	42
Total	745	175	—	320	—
Average	186	44	20	80	40

Table 6. Acreage of greens crops abandoned because of insect infestations, Oklahoma Vegetable Research Station, Bixby, 1946 to 1950.

Year	Total Crop Planted Acres	Crop Loss Due To: Aphids Acres	Aphids Per Cent	All Insects Acres	All Insects Per Cent
		- Spinach -			
1946	28	15	54	20	71
1947	42	0	0	0	0
1948	40	2	5	2	5
1949	49	10	20	10	20
1950	30	0	0	20	67
Total	189	27	—	52	—
Average	38	5	16	10	32
		- Mustard, Turnips and Kale -			
1946	4	2	50	2	50
1947	4	0	0	0	0
1948	7	2	29	2	29
1949	8	4	50	8	100
1950	8	2	25	4	50
Total	31	10	—	16	—
Average	8	2	31	3	46

Table 7. The per cent acreage of greens crops on five farms abandoned because of aphid infestations, eastern Oklahoma, 1946 to 1950.

Farm	1946	1947	1948	1949	1950	5-Year Average
			- Spinach -			
Tyler	13	8	0	12	—	9
Griffin	—	0	0	0	25	6
Moore	—	36	17	50	25	32
Willis	78	25	23	18	—	42
Station	54	0	5	20	0	16
Average	48	14	9	20	17	21
			- Mustard, Turnips and Kale -			
Tyler	21	21	26	45	—	28
Griffin	—	33	0	50	40	31
Moore	—	0	17	75	25	29
Willis	40	0	33	8	—	20
Station	50	0	29	50	25	31
Average	37	11	21	46	30	28

Table 8. The per cent acreage of greens crops on five farms abandoned because of insect infestations, eastern Oklahoma, 1946 to 1950.

Farm	1946	1947	1948	1949	1950	5-Year Average
			- Spinach -			
Tyler	15	8	0	18	—	10
Griffin	—	0	0	0	58	15
Moore	—	36	17	50	50	38
Willis	78	25	35	29	—	42
Station	71	0	5	20	67	32
Average	55	14	11	23	58	28
			- Mustard, Turnips and Kale -			
Tyler	25	42	32	53	—	38
Griffin	—	54	67	75	0	49
Moore	—	0	17	100	50	42
Willis	50	25	44	42	—	40
Station	50	0	29	100	50	46
Average	42	24	38	74	33	43

The loss of spinach due to all insect infestations (Table 8) varied from 11 percent (1948) to 55 percent (1946) with an average loss for the entire period of 28 percent. The comparative loss by aphids of 21 percent was approximately three-fourths of all insect losses.

Losses of cruciferous crops on all farms due to all insects ranged from 24 percent (1947) to 74 percent (1949) with an average of 43 percent for the five-year period. Approximately two-thirds of this total or 28 percent was caused by aphids. The total loss of all crops on all farms due to insects was 2374 acres or 30 percent. The corresponding loss due to aphids was 1738 acres or 23 percent.

CROPPING PRACTICES

The cropping practices employed in the production of greens crops result in various plantings being in the field during nine to twelve months of the year. Since the presence of these crops in the field affects the aphid population, a knowledge of the cropping practices is essential for an understanding of seasonal development of the pest species.

Table 9 presents in somewhat simplified form a summary of seeding and harvest dates of spinach and crucifers such as mustard, turnips and kale. The relative losses due to aphids is indicated for the different dates of planting. The information given represents average estimates. Certain specific cases have deviated considerably from these estimates.

Spinach is usually planted during September, October, November and February-March. Plantings made in September and October produced the "early" and "late" fall crops, respectively. The "carry-over" crop was usually planted in November and the spring crop in February or March. In actual practice where weather and other conditions permit, plantings may be made in a community at intervals of a few days from early September until late November. As a usual practice, however, a single grower spaces the different plantings at intervals of two to four weeks. Typically, August is characterized by low soil moisture content and high temperatures. Soil moisture and soil temperature conditions favorable for the germination of spinach and crucifer seed determine when the first plantings can be made in late summer or early fall.

Table 9. Seeding and harvest periods of greens crops with comparative losses caused by aphid infestations.

Date Seeded	Date Harvested	Extent of Losses Usually Occurring
	- Spinach -	
September	November	Light to Moderate
October	December	Heavy to Moderate
Late Fall ("Carry-Over" Crop)	February-March	Moderate to Heavy
February-March	April-May	Heavy to Moderate
	- Cruciferous Greens -	
August-September	October	Moderate to Heavy
October	November	Heavy to Moderate
March	May	Moderate to Heavy
April	May-June	Heavy to Moderate

Usually, rains occur in late August or September and produce favorable conditions. In some years, however, because of drouth and high temperatures, seeding may be delayed until October. A few growers have used overhead irrigation equipment to add moisture to the soil and thus secure successful early seedings.

The rate of growth of these crops depends on the factors of fertility, moisture and temperature. Because of temperatures being usually slightly higher in the spring than in the fall, growth is generally more rapid at the former season. Under optimum conditions the period between seeding time and harvest has been as short as four weeks for cruciferous crops and five weeks for spinach. As a general rule, however, an additional two to three weeks period is required for plants to attain marketable size. When temperatures remain low for extended periods, 90 days or more may be required for crop maturity.

It is indicated in Table 9 that spinach planted in late fall is not harvested until the following February or March. Occasionally, spinach planted in October, due to unfavorable growing conditions or to insect infestations, is not in condition to harvest before the advent of freezing weather. Infrequently, the foliage may be harvested in the fall or early winter and the cut-over plants allowed to remain in the field until the following spring. All spinach crops that are left in the field during the winter are classed as "carry-over" spinach in this paper. The "carry-over" crop sustains more or less injury from low temperatures. Injury varies from slight "burning," due to a moderate frost, to a degree where a majority of the plants are killed as a result of a prolonged period of sub-freezing temperatures. Ordinarily injury to the foliage is sufficient to make it unmarketable but not extensive enough to kill the majority of leaf tissues. The bud cluster and root system of the plants are seldom seriously impaired. When temperatures favorable for continued plant growth return in the late winter the plants develop new foliage. The semi-dormant "carry-over" plants become active and produce a marketable crop earlier than can be obtained from spring-seeded spinach.

SEASONAL DEVELOPMENT

Among the factors that affect the seasonal trends of aphid populations are food plants and shelter, predators and parasites, and climatic conditions. A number of workers, including Horsfall (1924), Broadbent and Hollings (1951), and Harrison and Allen (1943), have found that temperature was a very important influence on the seasonal development of the aphid species concerned in this investigation. Temperature influences aphid development indirectly through its effect on food plants, and on predators and parasite populations. It also affects aphids directly by regulating their life processes, including feeding, metabolism, and reproduction (Broadbent and Hollings, 1951).

Lady beetle larvae and adults and parasitic wasps of the genus *Aphidius* appeared to be the most important aphid enemies in greens fields during the period of the investigation. Syrphid fly larvae and aphid lions of the genus *Chrysopa* occasionally were very effective against aphids but usually occurred in effective numbers less frequently than did the lady beetles and parasitic wasps.

The results given in Figures 1 and 2 and Tables 10 and 12, in certain cases, reflect the direct effects of temperature on the seasonal trends of the aphid populations. During the fall, winter, and spring, when the greens crops are grown, minimum temperatures would appear to be one of the limiting factors in aphid development. A study of maximum mean temperatures in relation to the population trends showed that

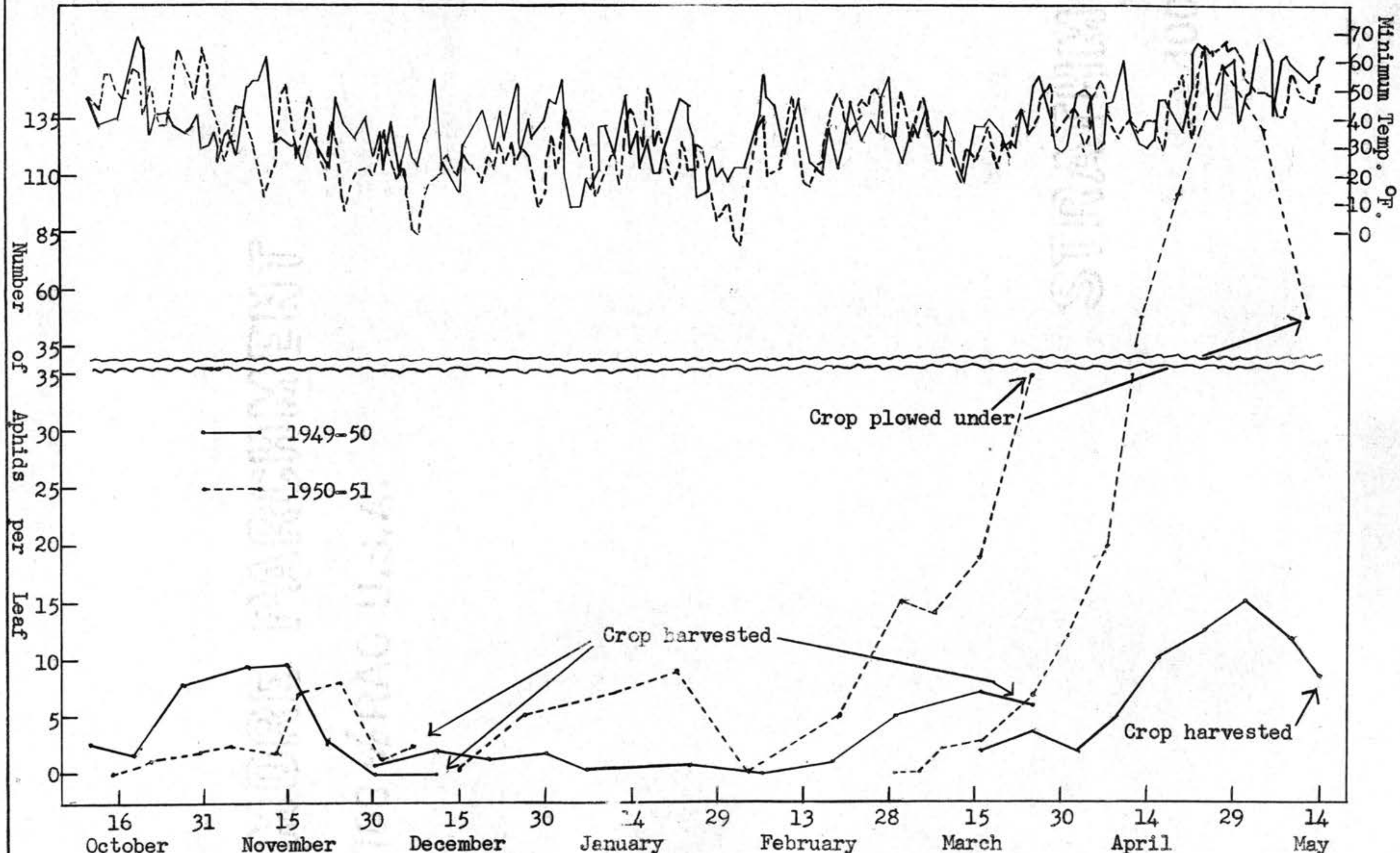

Figure 1. Population trends of green peach aphid on fall, "carry-over" and spring spinach crops, Vegetable Research Station, Bixby, 1949-51.

daily minimum and mean minimum temperatures were more closely correlated with such trends than were the maximum and mean temperatures. The daily minimum temperatures are charted in Figures 1 and 2 and the mean minimum temperatures are given in Tables 10 and 12.

The Green Peach Aphid on Spinach

The green peach aphid is apparently active in and around the spinach production areas of Oklahoma during the entire year. This species is ordinarily present on spinach throughout the winter and feeding, growth, and reproduction generally occur during a major portion of this period. Normally, minimum temperatures are not sufficiently low nor prolonged to prevent the survival of a portion of the nymphs and adults on this crop.

The trends of the population on the fall, "carry-over," and spring spinach crops during 1949-50 and 1950-51 are shown in Figure 1. Population counts were made at intervals varying from five to seventeen days. Because critically low temperatures seldom occurred and also because of the presence of other influential factors there were few instances in the population trends during 1949-50 and 1950-51 (Figure 1) that clearly reflect the effect of minimum temperatures on the infestation.

During the last half of November in 1949 there was a general decline in the mean temperatures which was correlated with a decline in the population on the fall crop. The situation in 1950 was in certain respects, similar. An early cold period on November 12, 13, and 14 with temperatures of 23, 13, and 20 degrees respectively, seemed to check the increasing population. After a period of warmer weather, the infestation reached a peak of 8 aphids per leaf by November 24. On November 31, after a week in which the minimum temperatures ranged from 10 to 28 degrees, the population declined to about one aphid per leaf. The crop was harvested a few days later.

The population trends on the "carry-over" crop differed greatly in the two years during December and January. In 1949-50 the level was never above 2 aphids per leaf in December and was almost at the zero point during January. In 1950-51, on the contrary, the population level began to rise after mid-December and continued to increase until a peak of approximately nine aphids per leaf was reached by January 23. Following a cold period from January 26 to February 3, when the minimum temperatures ranged from -3 to 21 degrees, the infestation was reduced to a very low point. Prior to this time, the December-January temperatures in the two years differed little.

The population levels on the "carry-over" crop in the two years differed greatly in February and March. In 1950 a peak of 6 to 7 aphids per leaf was reached by March 16 to March 25. In contrast, in 1951 the infestation reached a level of 15 aphids per leaf by March 1 and continued to increase to a level of 35 aphids per leaf by March 25 when the crop was plowed under. This difference in the populations in the two years appears to be due in part to the fact that the minimum temperatures from February 19 to March 10 averaged approximately ten degrees higher in the second year than in the first. The mean minimum temperature for the period in 1951 was 42 degrees compared with approximately 32 degrees in 1950. During March 11 to May 12 the mean minimum temperature in 1950 was 44 degrees and that for 1951 was 41 degrees.

The aphid infestation on the spring crop was much higher in 1951 than in 1950. This was probably due in part to the abundant population present on the "carry-over" crop and to the lower temperatures which would tend to slow the development of the aphid enemies. However, in both instances predator and parasite populations developed during the latter part of April to the extent that the aphid infestations were sharply reduced.

In summary, the population trends during the two years were basically similar. Beginning in early October the infestation in the fall crop approached a moderate level in November or early December. On the "carry-over" crop aphid populations increased in December and January but by early February they were again at a very low level. As the mean temperatures rose in February and March the population increased until late March. Infestations of the spring crop appeared in early March and increased until late April or early May. Infestations during the spring were significantly higher than those in the fall or winter. Predators and parasites were effective in reducing aphid infestations during May in both years.

These seasonal trends of the green peach aphid population on spinach at the Vegetable Research Station Farm resembled in general the seasonal development in the Bixby area during the entire period of investigation. The results are summarized in Table 10, expressed as the estimated intensity and date of occurrence of the peak populations during the different seasons. The trends during the six-year study period are in general agreement with those presented in Figure 1 which were based on population counts made throughout the season in certain specific fields.

Table 10. Estimated intensity and occurrence of peak populations of the green peach aphid on spinach at different seasons, Bixby.

	Fall Crop		"Carry-Over" Crop		Spring Crop	
Year	Intensity	Occurrence	Intensity	Occurrence	Intensity	Occurrence
1945-46	—	—	heavy	late March	moderate	early April
1946-47	light	—	light	early April	light	early May
1947-48	very light	late November	very light	early April	very light	early May
1948-49	light	early December	light	late March	moderate	early May
1949-50	light	mid-November	moderate	mid-March	moderate	early May
1950-51	light	mid-December	heavy	mid-March	heavy	late April

The aphid populations in the fall crops were low compared with those usually present in the "carry-over" and spring crops. During four of the five years in which observations were made on the fall crop the average peak population was estimated to be "light." Almost all of the fields included in the "light" category had peak populations of only one to three aphids per leaf. In 1946-47 the peak was estimated to be "very light."

On the "carry-over" crop considerably higher infestations generally occurred. In the six-year period the peak populations were classed as "heavy" during two years, "moderate" one year, "light" two years and "very light" one year.

On the spring crop the peak population intensities were approximately equal to those on the "carry-over" crop. Two moderate deviations from this trend occurred in 1945-46 and 1948-49 when populations on the "carry-over" crop were "heavy" and "light", respectively, while corresponding infestations on the spring crop were both classed as "moderate."

The occurrence of the peak population varied over a period of approximately one month on the different crops. On the fall crop the peaks during the various years occurred from mid-November to early December. On the "carry-over" crop the range was from mid-March to early April. Population peaks on the spring crops occurred from early April to early May.

An attempt was made to determine if the estimated peak populations (Table 10) were correlated with mean minimum temperatures. Little correlation was found but this was not surprising considering the fact that detailed population trends were not shown nor determined. Little variation in peak population intensities on the fall crop occurred in the different years. The population intensities ranged only from "very light" to "light." In contrast, the mean minimum temperatures in the fall months varied greatly in the different years, ranging from 44 to 58 degrees in October, from 31 to 40 degrees in November, and from 22 to 36 degrees in December.

In the case of the "carry-over" crop there appeared to be a moderate degree of correlation between peak population intensities and the mean minimum temperatures for the period of January and February. In the three years, 1945-46, 1949-50, and 1950-51, when population intensities were "moderate" or "heavy," the mean minimum temperatures were from two to seven degrees higher than in the three years, 1946-47, 1947-48, and 1948-49 when the peak population intensities were classed as "very light" to "light." In the "moderate" to "heavy" years the mean minimum temperatures (degrees F.) of the January-February period, were as follows: 1945-46, 32.5; 1949-50, 31.5; 1950-51, 29.5. Corresponding temperatures in the "very light" to "light" years were as follows: 1946-47, 26.5; 1947-48, 25.5; 1948-49, 27.5. It can be noted (Table 14) that the February temperatures in the "moderate" to "heavy" years ranged from 31 to 35 degrees while in the "light" years they varied from 25 to 29 degrees. January temperatures showed less differences, ranging from 28 to 30 degrees in the first group and from 23 to 28 degrees in the second group.

The peak population intensities did not appear to be associated with mean temperatures for March. Similarly, there seemed to be no correlation of population intensities on the spring crop with mean temperatures for March, April, May or for any period of thirty days or longer during the three-months period.

The Green Peach Aphid on Other Host Plants

During the course of the investigation, collections of both species of aphids were made from crop plants and uncultivated species. Most collections were made at irregular intervals and largely incidental to other work. Tables 11 and 13 present lists of plants from which the indicated species was collected and on which it was observed to feed.

The green peach aphid was collected from a total of forty-seven species belonging to twenty-one families (Table 11). Thirty-five of the species were cultivated crop or ornamental species. Sixteen of the host plants were crop species which were grown on a commercial scale in each of the greens crops production areas. The horticultural crops in this category were spinach, mustard, turnip, kale, radish, cabbage, bush bean, tomato and peach. The field crop species included corn, alfalfa, vetch, mungbean, soybean and cotton. Collections were made from eight species of weeds all of which were more or less common in and around greens crops fields. These were lambs-quarter, pokeweed, purslane, peppergrass, shepherd's purse, evening primrose, henbit, horse nettle and wild lettuce.

The leading host plant groups were the Mustard Family (Cruciferae) and the Pulse Family (Leguminosae), from each of which eight species and varieties were listed as food plants. Other groups of importance were the Goosefoot and the Gourd Families.

As previously described, spinach is present as a food plant from September to June, inclusive. The cruciferous greens crops are subject to infestation during the fall and spring. A weed species appears to serve as a host during a longer portion of the year than any other plant. This species is known as henbit (Lamium amplexicaule L.) and

Table 11. Host plant list of *Myzus persicae* (Sulzer) in Oklahoma

Plant	Family	Date of Collection
1. Cat-tail (*Typha latifolia* L.)	Cat-tail (Typhaceae)	June 5, 1947; May 27, 1949
2. Corn (*Zea mays* L.)	Grass (Gramineae)	May 10, 1947
3. Asparagus (*Asparagus officinalis* L.)	Lily (Liliaceae)	April 7, 1949
4. Iris (*Iris* Sp.)	Iris (Iridaceae)	May 10, 1949
5. Gladiola (*Gladiolus* Sp.)	Iris (Iridaceae)	May 10, 1949
6. Canna (*Canna* Sp.)	Canna (Cannaceae)	May 10, 1949
7. Black Willow (*Salix nigra* Marsh.)	Willow (Salicaceae)	June 5, 1947
*8. Cottonwood (*Populus deltoides* Marsh.)	Willow (Salicaceae)	May 10, 1949
*9. Pecan (*Carya illinoensis* Wang.)	Walnut (Juglandaceae)	June 5, 1947
*10. Chinese Elm (*Ulmus pumila* L.)	Nettle (Urticaceae)	July 3, 1950
11. Beet (*Beta vulgaris* L.)	Goosefoot (Chenopodiaceae)	April 7, 1949; May 10, 1949
12. Lamb's Quarter (*Chenopodium album* L.)	Goosefoot (Chenopodiaceae)	April 7, 1949; May 10, 1949; June 5, 1949; July 3, 1950
13. Spinach (*Spinacia oleracea* L.)	Goosefoot (Chenopodiaceae)	Late August to early June
*14. Pokeweed (*Phytolacca decandra* L.)	Pokeweed (Phytolaccaceae)	April 17, 1949; May 10, 1949
15. Purslane (*Portulaca oleracea* L.)	Purslane (Portulacaceae)	May 10, 1949
*16. Peppergrass (*Lepidium virginicum* L.)	Mustard (Cruciferae)	May 10, 1949; June 5, 1947; July 3, 1950; August 6, 1950
17. Shepherd's Purse (*Capsella bursa-pastoris* L.)	Mustard (Cruciferae)	May 10, 1949; June 5, 1947; July 3, 1950; August 6, 1950
18. Cabbage (*Brassica oleracea* L. var. *capitata*)	Mustard (Cruciferae)	Early March to August
19. Kale (*Brassica oleracea* L. var. *acephala*)	Mustard (Cruciferae)	Late August to early December; late March to June
20. Turnip (*Brassica rapa* L.)	Mustard (Cruciferae)	Late August to early December; late March to June
21. Mustard (*Brassica juncea* L.)	Mustard (Cruciferae)	Late August to early December; late March to June

Table 11. (Continued)

Plant	Family	Date of Collection
22. Chinese cabbage (Brassica chinensis L.)	Mustard (Cruciferae)	Late August to early December; late March to June
23. Radish (Raphanus sativa L.)	Mustard (Cruciferae)	Late March to June
*24. Alfalfa (Medicago sativa L.)	Pulse (Leguminosae)	March 20, 1947; April 7, 1949; June 5, 1947; October 19, 1950
*25. Sweet Clover (Melilotus officinalis Lam. L.)	Pulse (Leguminosae)	April 7, 1949
*26. Sweet Clover (Melilotus alba Desr.)	Pulse (Leguminosae)	April 7, 1949
27. Crotalaria (Crotolaria Sp.)	Pulse (Leguminosae)	April 7, 1949
28. Vetch (Vicia sativa L.)	Pulse (Leguminosae)	May 10, 1949
29. Bush bean (Phaseolus vulgaris L. var. humilis)	Pulse (Leguminosae)	May 10, 1949; June 5, 1947
*30. Mung bean (Phaseolus aureus L.)	Pulse (Leguminosae)	July 21, 1950
31. Soy bean (Glycine mas L. Merr.)	Pulse (Leguminosae)	July 21, 1950
32. Box Elder (Acer negundo L.)	Maple (Aceraceae)	June 5, 1947
33. Cotton (Gossypium herbaceum L.)	Mallow (Malvaceae)	June 5, 1947
*34. Evening Primrose (Oenothera biennis L.)	Evening Primrose (Onagraceae)	April 7, 1949
35. Sweet Potato (Ipomaea batatas L.)	Convolvulus (Convolvulaceae)	May 10, 1949; June 5, 1947; July 21, 1950
*36. Henbit (Lamium amplexicaule L.)	Mint (Labiatae)	September to July
37. Tomato (Lycopersicon esculentum var. comme Baily)	Nightshade (Solanaceae)	May 10, 1949; June 5, 1947; July 21, 1950
38. Potato (Solanum tuberosum L.)	Nightshade (Solanaceae)	March to July
39. Eggplant (Solanum melogena L.)	Nightshade (Solanaceae)	June 5, 1947
40. Horse Nettle (Solanum carolense L.)	Nightshade (Solanaceae)	May 10, 1949; June 5, 1947
41. Summer Squash (Cucurbita pepo L.)	Gourd (Cucurbitaceae)	May 10, 1949; June 5, 1949; July 21, 1950
42. Squash (Cucurbita maxima Duchesne)	Gourd (Cucurbitaceae)	May 10, 1949; June 5, 1949; July 21, 1950
*43. Cucumber (Cucumis sativus L.)	Gourd (Cucurbitaceae)	May 10, 1949; June 5, 1949; July 21, 1950

Table 11. (Continued)

Plant	Family	Date of Collection
44. Cantaloupe (*Cucumis melo* L.)	Gourd (Cucurbitaceae)	May 10, 1949; June 5, 1949; July 21, 1950
45. Watermelon (*Citrullus vulgaris* Schrad.)	Gourd (Cucurbitaceae)	May 10, 1949; June 5, 1949; July 21, 1950
46. Wild Lettuce (*Lactuca canadensis* L.)	Composite (Compositae)	April 7, 1949; May 10, 1949
47. Head Lettuce (*Lactuca sativa* var. capitata)	Composite (Compositae)	March 4, 1948; April 7, 1949; May 10, 1949

*Species not listed by Patch (1938)

Table 12. Estimated intensity and occurrence of peak populations of the turnip aphid on fall and spring crops of crucifers, Bixby.

	Fall Crop		Spring Crop	
Year	Intensity*	Occurrence	Intensity	Occurrence
1947-48	light	———	moderate	early May
1948-49	light	late October	light	early May
1949-50	heavy	early November	moderate	mid-May
1950-51	light	early October	heavy	mid-May

*light, from 1 to 10 aphids per leaf
moderate, from 11 to 25 aphids per leaf
heavy, more than 25 aphids per leaf

belongs to the Mint Family. It is a serious weed pest in spinach fields and, being cold resistant, ordinarily shows a considerable degree of survival after periods of sub-freezing temperatures. Living foliage of this weed is present in the field throughout the year and collections were made during the entire year except in late July and August.

During the spring and early summer light infestations of M. persicae occurred on a considerable number of cultivated and weed species. However, during the last half of July, all of August, and early September, aphid populations were extremely low and were found on only a few plants.

The leading spring and summer host appeared to include alfalfa, potato, lamb's quarter, peppergrass, shepherd's purse, sweet potato, and cucurbits. Aphids were found on alfalfa during the spring and again in the fall. Potatoes usually were lightly infested from early spring to harvest time. No collections were attempted on fall-grown potatoes. Aphids were present on lamb's quarter during the same period as on potatoes. The wild mustards (peppergrass, and shepherd's purse) appeared to be lightly infested from mid-spring to late summer. Sweet potatoes appeared to be infested from late spring until mid-summer.

Some of these plants were apparently of little importance as secondary host because of their limited occurence in the greens production areas. Those that ordinarily occurred in or around most production units included the three weed species (lamb's quarter, peppergrass, and shepherd's purse), alfalfa, and cucurbits as a group.

Seasonal Development of the Turnip Aphid

The records obtained on the seasonal development of the turnip aphid on crucifers were similar to those made for the green peach aphid on spinach. The four-year period of study extended from the fall of 1947 through the spring of 1951. The study was limited to the fall and spring crops since no "carry-over" planting of cruciferous greens are made in the area.

The results of a series of population counts made during 1949-50 and 1950-51 in three fields of curled mustard are given in Figure 2. The highest infestation of turnip aphids observed during the entire investigation occurred in the fall of 1949. Populations of less than ten aphids per leaf increased steadily to peaks of about four hundred per leaf by early November. Adequate moisture and favorable temperatures enabled the plants to make almost normal growth until mid-October despite the increasing infestation. In the following month aphid damage increased to the point that all plants were severely injured and many were killed. During November 15 to 25 the population greatly declined, chiefly due to deterioration of the food supply and the activity of predators and parasites.

In 1950 a moderate infestation developed on the spring crop. From a low level on April 18 the population reached a peak of fifteen aphids per leaf by May 10. During the succeeding nineteen days a subsidence occurred followed by a second incline in the population. In late May the field was harvested after it was treated with a dust containing tetraethyl pyrophosphate.

In 1950-51 the infestation level in the fall crop field did not exceed seven aphids per leaf. By September 30 a moderate predator population was present and apparently accounted for the decline in the light population. In the spring crop field a heavy infestation developed. A

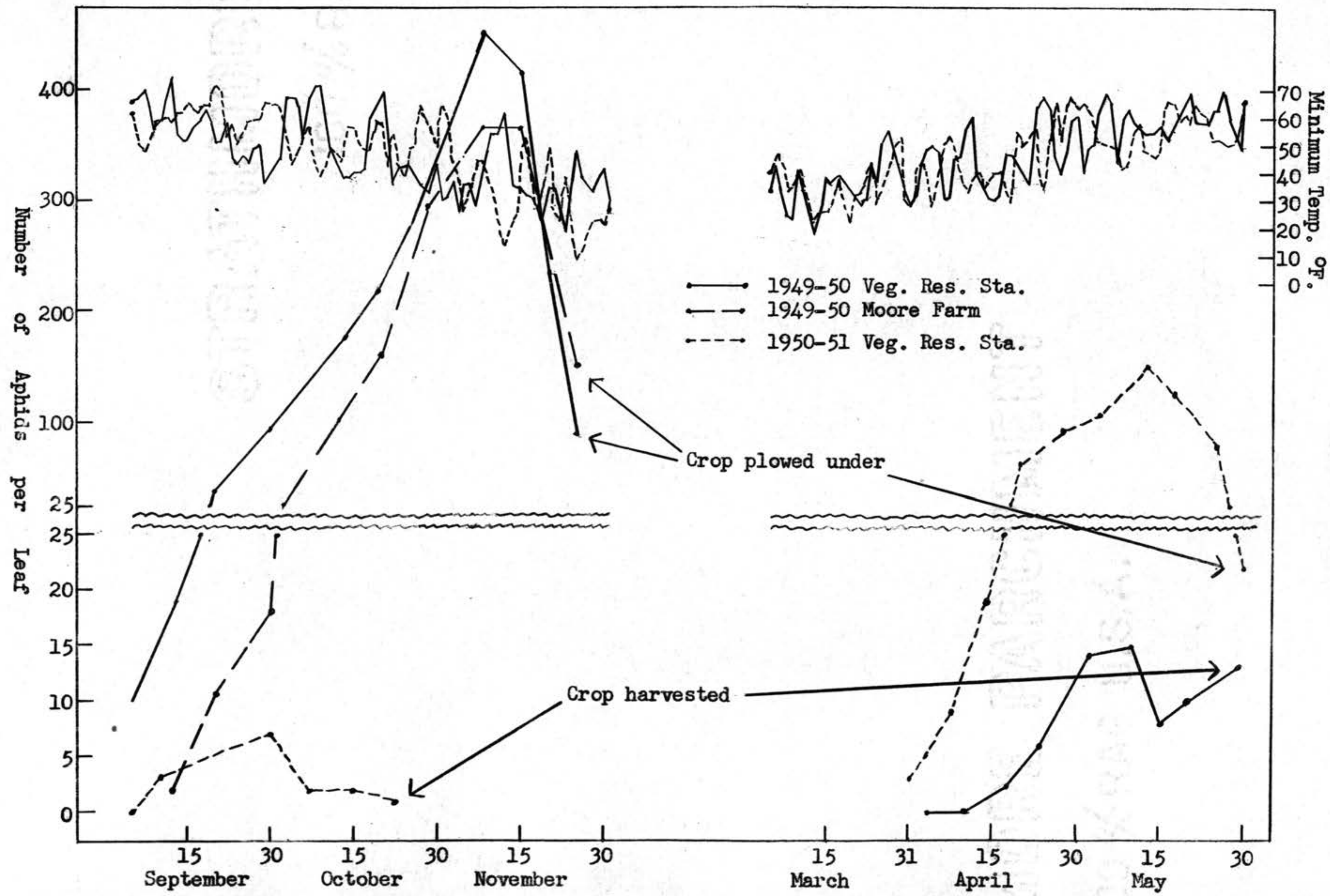

Figure 2. Population trends of turnip aphid on fall and spring curled mustard crops, Bixby, 1949-1951.

very light population in late March increased to a peak of over 150 aphids per leaf by May 12. Heavy predator-parasite population reduced the numbers of aphids in the following three weeks. Because of much insect debris adhering to the foliage no attempt was made to treat and harvest the field. The crop was plowed under in late May.

In addition to the population trends in fields where specific counts were made (Figure 2), estimates of infestation intensities and the occurrence of population peaks during the four-year period of 1947 to 1951 are given (Table 12). As in the case of the green peach aphid (Table 10) the estimates are based on a few counts and observations in each of several fields in the Bixby area. These estimates and the data presented in Figure 2 show that serious outbreaks of turnip aphids may occur in either the fall or spring. Although the heaviest outbreak recorded occurred in the fall, the four years' estimates indicate that the population is more likely to reach the "heavy" or "moderate" level in the spring than in the fall. During the four years the spring crop population was classed as "heavy" one time, as "moderate" two times, and as "light" one time. By comparison, the infestation in the fall crop was rated as "heavy" once and as "light" three times.

The effects of temperature on the seasonal development of the turnip aphid were demonstrated only to a small extent by the data presented in Figure 2, Table 12 and Table 14. The great difference between the population levels in the fall of 1949 and in the other three years, appeared to be due at least in part to the abnormally low temperatures in September of the former year. The mean minimum temperature was 55 degrees (Table 14) which was approximately 5 degrees below normal for the month. Corresponding temperatures for September in the other years, when aphid infestations were low, ranged from 59 to 64 degrees. This indication that lower temperatures tended to favor aphid outbreaks, was supported to some degree by infestation records on the spring crop (Figure 2 and Table 12). In 1951, when a "heavy" population developed, the mean minimum temperature for the last half of April and the first half of May was 4.5 degrees below the corresponding temperature in 1950 when the infestation was at a "moderate" level (Figure 2). The mean minimum temperature for the three-month period of March, April and May was 46 degrees in 1951 when the population was "heavy" and ranged from 47 to 50 degrees in the other three years when the population levels were "light" or "moderate."

The turnip aphid was collected from a smaller number of plants than the preceding aphid species (Table 13). The host listed consisted of nine species belonging to three families. The Mustard Family (Cruciferae) included six species, the Composite Family (Compositae) two species and the Pulse Family (Leguminosae) one species. Seven of the nine host plants were commercially-grown crop species and the remaining two were weed species quite common in road and field margins of the area. R. psuedobrassicae usually occurred on mustard and turnips from late August to December and from early spring to mid-summer. Kale was similarly infested except that it was seldom allowed to remain in the field after early June. Radishes usually served as host plants only in the spring, fall plantings of this crop seldom being made. Collections were made from the wild crucifers from early May to August. The turnip aphid, like M. persicae, was difficult to find during late summer, only occasional individuals or small colonies being observed.

Table 13. Host plant list of _Rhopalosiphum pseudobrassicae_ (Davis) in Oklahoma

Plant	Family	Date of Collection
1. Peppergrass (_Lepidium virginicum_ L.)	Mustard (Cruciferae)	May 10, 1949; June 5, 1947; August 6, 1950
2. Shepherd's Purse (_Capsella bursa-pastoris_ L.)	Mustard (Cruciferae)	May 10, 1949; June 5, 1947; August 6, 1950
3. Cabbage (_Brassica oleracea_ L. var. capitata)	Mustard (Cruciferae)	March to August
4. Kale (_Brassica oleracea_ L. var. acephala)	Mustard (Cruciferae)	August to December; late March to June
5. Turnip (_Brassica rapa_ L.)	Mustard (Cruciferae)	August to December; late March to July
6. Mustard (_Brassica juncea_ L.)	Mustard (Cruciferae)	August to December; late March to July
7. Radish (_Rhaphanus sativa_ L.)	Mustard (Cruciferae)	Late March to June
8. Bush bean (_Phaseolus vulgaris_ L.)	Pulse (Leguminosae)	May 10, 1949; June 5, 1947
9. Lettuce (_Lactuca sativa_ L. var. crispa)	Composite (Compositae)	March 4, 1948; April 7, 1949; May 10, 1949
10. Head Lettuce (_Lactuca sativa_ L. var. capitata)	Composite (Compositae)	March 4, 1948; April 7, 1949

Table 14. Mean minimum temperatures (°F.), Vegetable Research Station, Bixby, 1945 to 1951.

Year	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
1945-46	—	—	—	—	30	35	47	54	55
1946-47	60	53	40	36	28	25	34	49	55
1947-48	64	58	37	30	23	28	35	52	57
1948-49	59	44	35	32	26	29	42	49	61
1949-50	55	49	36	31	29	34	36	46	59
1950-51	60	52	31	22	28	31	36	46	56

CONTROL WITH INSECTICIDES

The results of the tests to control the green peach aphid in spinach are given in Tables 15 to 21 and in Tables 30 and 31. The data on the control of the turnip aphid on cruciferous crops are presented in Tables 22 to 27 and in Table 29.

Comparative Effectiveness of Toxicants

Six of the toxicants showed promise for aphid control. These were parathion, a mixture of parathion with methyl parathion, tetraethyl pyrophosphate, lindane, benzene hexachloride and nicotine sulphate. Toxicants which gave generally unsatisfactory results were DDT, chlordane, toxaphene, rotenone, sabadilla and mixtures of piperonyl compounds with pyrethrins and rotenone.

Tests on the Green Peach Aphid on Spinach. In a laboratory test (Table 15) nicotine sulphate dust gave 98 percent control compared with 93 and 87 percent control by rotenone dusts and 82 percent by DDT dust. In a preliminary field test (Table 16), at application temperatures of 57 to 61 degrees F., DDT, rotenone, sabadilla, and nicotine sulphate dusts all failed to prevent great increases in the aphid populations by the fifth day after treatment. In a second field test (Table 17) dusts containing benzene hexachloride gave 96 and 94 percent control compared to 58 and 52 percent respectively, by chlordane and rotenone dusts. In a comparison of dusts and sprays of organic phosphates and lindane (Table 18), all treatments appeared to have given good

Table 15. Effectiveness of insecticidal dusts in a laboratory test to control the green peach aphid on spinach, Stillwater, January 9, 1946.

Form. No.	Materials	Aphids Per Leaf at Treatment[1]	Aphids Per Leaf 3 Days After Treatment	Per Cent Decrease in Population
17	Nicotine sulphate 3%	13	0.2	98
28	Rotenone 1%	12	0.8	93
26	Rotenone 0.5%	13	1.7	87
6	DDT 5%	15	3.7	82
	Untreated check	13	15.1	21[2]

Application data: mean temperature of test period, 78° F.; temperature at application, 84°F.; method of application, single plants in flower pots dusted by use of plunger-type hand guns.

[1]Based on an examination of 4 leaves of each of 4 plants per treatment.

[2]Increase.

Table 16. Results of a preliminary field test to control the green peach aphid on spinach with insecticidal dusts applied by a power duster, Haskell, March 10 to 15, 1946.

Form. No.	Materials	Pounds Actual Toxicant Per Acre	Estimated Per Cent Increase of Aphid Population March 10 to 15
7	DDT 10%	2.00	200
29	Rotenone 1%-sulphur 40%-talc	0.44	300
28	Rotenone 1%-talc	0.40	300
30	Sabadilla 10%	3.00	350
17	Nicotine sulphate 3%	0.50	350
	Untreated check	—	400

Application data: date, March 10; temperature, 57°-61°F.; wind velocity, 2-4 mph; plant diameter, 8-12 inches; water on foliage, slight; estimated population at application, 8-10 aphids per leaf; plot size, ½ acre; number plots per treatment, 1; method of application, power duster.

Table 17. Effectiveness of benzene hexachloride and other insecticidal dusts applied by hand dusters in a field test to control the green peach aphid on spinach, Bixby, March 6 to 9, 1947.

Form. No.	Materials	Pounds Actual[1] Toxicant Per Acre	Population 3 Days After Treatment: Aphids Per Leaf[2]	Population 3 Days After Treatment: Per Cent Control
4	BHC (2% gamma isomer)	1.00	0.7	96
3	BHC (1% gamma isomer)	0.53	1.2	94
5	Chlordane 5%	2.20	8.4	58
25	Rotenone 0.75%	0.36	9.4	52
	Untreated check	—	19.8	—

Application data: temperature, 55°-57°F.; wind velocity, 2-4 mph; plant diameter, 8-14 inches; water on foliage, slight; aphid population, 17.6; aphids leaf; plot size, 20' x 20'; number plots per treatment, 4; method of application, rotary hand gun.

[1]The amount of gamma isomer given for dusts containing benzene hexachloride.

[2]Based on an examination of 100 leaves from each of 4 plots per treatment.

Table 18. Effectiveness of sprays and dusts of organic phosphates and lindane applied by power equipment in a test to control the green peach aphid on spinach, Bixby, November 17 to December 8, 1949.

			Aphid Population[1]			
		Pounds	November 28		December 8	
Form. No.	Materials	Actual Toxicant Per Acre	Aphids on 100 Leaves	Per Cent Control	Aphids on 100 Leaves	Per Cent Control
12	Methyl parathion-parathion spray	0.15	22	78	32	70
19	Parathion 0.5% dust	0.13	18	82	42	61
22	Parathion spray	0.15	24	78	34	68
9	Lindane 1% dust	0.20	16	84	27	75
10	Lindane spray	0.22	25	76	31	71
	Untreated check	—	102	—	107	—

Application data: date, November 17; temperature 63°-60°F.; wind velocity, 1-2 mph; plant diameter, 8-12 inches; water on foliage, slight; number of aphids on 100 leaves on untreated plants, 81; plot size, 0.12 acre; number plots per treatment, 4; methods of application, power duster and power sprayer delivering 65-70 gals. per acre at 300 pounds pressure.

[1]Based on an examination of a 100-leaf sample composed of 25 leaves from each of 4 plots per treatment.

control by the third day after treatment. Population counts made eleven days after treatment (November 28) showed the percent control to range from 76 to 84. On December 8 the corresponding range was 61 to 75 percent. In a test made at an application temperature of 54 degrees (Table 19) parathion dust caused 98 percent control compared with 93 percent and 83 percent, respectively, by dusts containing lindane and tetraethyl pyrophosphate. In a spinach field which was treated with a spray containing tetraethyl pyrophosphate, the percent control obtained was 92 (Table 20). Parathion dust gave 92 per cent control (Table 21) when parathion spray, tetraethyl pyrophosphate dust and lindane produced 86, 87 and 87 percent control, respectively.

Tests to Control the Turnip Aphid on Crucifers. The toxicants showed about the same comparative effectiveness on the turnip aphid as in the cases cited above from tests on the green peach aphid. When applied to kale (Table 22) dusts containing tetraethyl pyrophosphate caused 99 and 98 percent control of aphids on the open leaves as compared with 82 percent control by a dust containing a mixture of nicotine, rotenone and piperonyl cyclonene. The difference in the degree of control of aphids on the terminal bud clusters by the two types of dusts was much greater, ranging from 78 to 75 percent by the phosphate dusts to only 33 percent by the mixture. A comparison of organic phosphates and mixtures of piperonyl compounds with pyrethrins and rotenone (Table 23) showed the percent control obtained by October 18, five days after treatment, to be as follows: methyl parathion-parathion spray, 99; tetraethyl pyrophosphate dust, 96; parathion dust, 93; parathion spray, 92; lindane dust, 84; lindane spray, 75; piperonyl butoxide-pyrethrins-rotenone spray, 44; piperonyl cyclohexenone-pyrethrins rotenone dust,

Table 19. Influence of water on foliage on the effectiveness of dusts of organic phosphates and lindane applied by hand dusters to spinach to control the green peach aphid, Bixby, November 18, 1949.

Form. No.	Insecticide	Pounds Actual Toxicant Per Acre	Foliage Dry (Temp. 54°F.)		Foliage Wet (Temp. 51°F.)	
			Aphids Per 100 Leaves	Per Cent Control	Aphids Per 100 Leaves	Per Cent[1] Control
21	Parathion 1% dust	0.4	2	98	8	90
9	Lindane 1% dust	0.4	6	93	8	91
35	TEPP 1% dust	0.4	11	83	32	62
	Untreated check	0.0	84	—	84	—

Application data: plant diameter, 8-12 inches; wind velocity, 2 mph; plot size, 20' x 20'; number plots per treatment, 2; method of application, rotary hand dust guns.

[1]Based on an examination of 100 leaves from duplicate plots on the third day after treatment.

Table 20. Effectiveness of a concentrate spray containing tetraethyl pyrophosphate, applied by airplane, to control the green peach aphid on spinach, Porter, April 6 and 7, 1951.

Sampling Station	Untreated: At 4 Hours: Aphids Per Leaf	Treated: At 4 Hours: Aphids Per Leaf	Treated: At 4 Hours: Per Cent Control	Treated: At 24 Hours: Aphids Per Leaf	Treated: At 24 Hours: Per Cent Control[1]
1	6.5	2.4	63	0.5	91
2	5.2	1.2	77	0.3	94
3	7.3	2.9	60	0.7	90
4	8.1	2.8	65	0.8	90
Average	6.8	2.3	65.6	0.6	91.5

Application data: date, April 6; temperature, 76°-77° F.; wind velocity, 2-4 mph; plant diameter, 8-12 inches; water on foliage, none; airplane application, Stearman applying approximately four gallons spray containing about 0.4 pound toxicant (Formulation 35) per acre at 40 p.s.i. at a height of approximately 20 feet and covering a width of approximately 40 feet.

[1] Based on an examination of 10 leaves selected at random at each station.

Table 21. Effectiveness of organic phosphates and lindane in a test to control the green peach aphid on spinach planted broadcast and in rows, Bixby, May 7-10, 1951.

		Broadcast Spinach			Rowed Spinach		
Form. No.	Materials	Pounds Toxicant Per Acre	Aphids Per Leaf[1]	Per Cent Control at 3 Days	Pounds Toxicant Per Acre	Aphids Per Leaf	Per Cent Control at 3 Days
22	Parathion 1% dust (applied by hand duster)	—	—	—	0.34	0.1	99
22	Parathion 1% dust	0.33	2.3	87	0.30	1.8	92
24	Parathion spray	0.35	3.5	80	0.35	3.2	86
32	TEPP 0.5% dust	0.25	4.0	79	0.27	3.1	87
9	Lindane 1% dust	0.35	4.3	77	0.30	3.1	87
	Untreated	—	18.4	—	—	23.1	—

Application data: date, May 7; temperature, 75°-77°F.; wind velocity, 3-5 mph; plant diameter, 8-12 inches; row width, 18 inches; water on foliage, none; plot size, approximately one-fourth acre; plots per treatment, one; methods of application, power duster and power sprayer delivering 10-12 gallons per acre at 100 p.s.i.

[1]Based on an examination of 10 leaves, selected at random, at each of four points in each plot.

Table 22. Effectiveness of tetraethyl pyrophosphate dust and a nicotine-rotenone-piperonyl cyclohexenone dust mixture applied by hand dusters in a field test to control the turnip aphid on kale, Spiro, April 5-6, 1948.

Form. No.	Materials	Pounds Toxicant Per Acre	Aphid Population at 24 hours: On Open Leaves[1] Aphids Per Leaf	Per Cent Control	On Terminal Bud Cluster[2] Aphids Per Leaf	Per Cent Control
33	Tetraethyl pyrophosphate 0.66% dust	0.20	0.3	99	1.8	78
32	Tetraethyl pyrophosphate 0.50% dust	0.16	0.6	98	2.0	75
19	Nicotine 1.5%-rotenone 0.2%-piperonyl cyclohexenone 0.8% dust	0.75	5.2	82	5.5	33
	Untreated check		28.3	—	8.2	—

Application data: temperature, 87°F.; wind velocity, 6-7 mph; leaf length, 6-10 inches; water on foliage, none; plot size, 30' x 15'; number plots per treatment, 4; method of application, rotary hand guns.

[1]Based on an examination of 100 leaves from each of 4 plots per treatment.

[2]Based on an examination of 10 developing leaves from each of 4 plots per treatment.

Table 23. Effectiveness of insecticides applied by power equipment in a test to control the turnip aphid on curled mustard, Bixby, October 13 to November 8, 1949.

			Aphid Population					
			October 18		October 27		November 8	
Form. No.	Materials	Pounds Toxicant Per Acre	Volume,[1] cc	Pct. Control	Volume, cc	Pct. Control	Volume, cc	Pct. Control
15	Methyl parathion-parathion	0.50	0.1	99	0.4	97	2.5	87
21	Parathion 1% dust	0.25	0.6	93	1.2	91	4.5	76
23	Parathion spray	0.19	0.7	92	0.9	93	4.2	78
9	Lindane 1% dust	0.50	1.5	84	3.6	73	6.0	68
11	Lindane spray	0.47	2.3	75	3.2	76	5.3	72
35	Tetraethyl pyrophosphate 1% dust	0.23	0.4	96	3.7	72	10.1	47
26	P.B.-P.R. spray	0.28	5.1	44	10.0	24	16.1	15
25	P.C.-P.R. dust	0.42	5.6	38	10.6	20	17.0	10
	Untreated check	—	9.1	—	13.2	—	18.9	—

Application data: date, October 13; temperature, 73°-75°F.; wind velocity, 3-4 mph; plant height, 12-14 inches; water on foliage, none; plot size, 0.15 acre; number plots per treatment, 1; methods of application, power duster and power sprayer delivering 100-125 gallons spray per acre at 250 pounds pressure; volume of aphids on 10 leaves preceding application, 7.0 cc.

[1]Volume of aphids measured in gasoline on sample of 10 leaves. Four samples taken per treatment.

38. In a comparison of lindane, toxaphene and methoxychlor (Table 24) the percent control obtained by the seventh day after treatment was: Lindane dust, 84; lindane spray, 72; toxaphene dust, 70; toxaphene spray, 55; methoxychlor dust, 53; methoxychlor spray, 45. At the end of seven days, in a test comparing sprays of organic phosphates and lindane (Table 25), methyl parathion-parathion produced 99 percent control compared with 94 percent by parathion and 84 percent by lindane. In a later test (Table 26) at the end of nine days methyl parathion-parathion sprays gave 95 and 91 percent control while that due to lindane spray and parathion dust were 91 and 89 percent, respectively.

Due to certain characteristics of plant growth, adequate coverage of the foliage of spinach and cruciferous greens crops was extremely difficult, if not impossible, to obtain with most of the toxicants tested. The preferred varieties of spinach, mustard and kale, in this area, are of the savoy-type with highly convoluted and wrinkled leaf surfaces. Under the conditions ordinarily existing, spinach of the savoy-type develops a compact, rosette type of foliage with closely overlapping leaves. A high plant density generally occurs in plantings of mustard and turnip greens. As these two crops approach maturity, a tall, dense mass of foliage ordinarily develops. These plant growth characteristics of spinach and cruciferous crops, particularly the former, produce serious barriers to the effective placement of toxicants. Most of the aphid pooulation normally is found in the more inaccessible situations on the lower surface of leaves, on leaflets nearest the ground, and in wrinkles and pockets formed by the convolution of the leaf surface. The facts that aphids do not injest materials from the foliage surface, and that their movement on the plants

Table 24. Effectiveness of lindane, toxaphene and methoxychlor, applied by hand equipment, in a test to control the turnip aphid on curled mustard, Bixby, October 4 to 11, 1949.

Form. No.	Materials	Pounds Toxicant Per Acre	Volume[1] of Aphids Per 10 Leaves, cc	Per Cent Control at Seventh Day	PPM Toxicant[2] Recovered From Canned Greens
9	Lindane 1% dust	0.56	0.9	84	0.0
10	Lindane spray	0.25	1.6	72	0.1
38	Toxaphene 20% dust	7.20	1.7	70	0.7
39	Toxaphene spray	2.24	2.6	55	0.9
13	Methoxychlor 5% dust	2.06	3.2	45	0.3
14	Methoxychlor spray	2.75	2.7	53	0.2
	Untreated	—	5.8	—	0.0

Application data: date, October 4; temperature 74°-76° F.; wind velocity, 1-2 mph; water on foliage, slight; plant height, 6-8 inches; plot size, 20' x 20'; number plots per treatment, 4 (randomized block); methods of application, rotary hand duster and knapsack sprayer; approximate increase in plant weight during test, 80 per cent.

[1] Based on the volume of aphids on 10 leaves selected at random, from each of four plots per treatment.

[2] Based on analyses of greens which were canned on the seventh day after treatment.

Table 25. Effectiveness of parathion and lindane emulsions applied as concentrate sprays in a test to control the turnip aphid on curled mustard, Kenneth Stone Farm, Porter, May 1 to 13, 1950.

Form. No.	Materials	Pounds Toxicant Per Acre	At 7 Days: Aphids Per Leaf	At 7 Days: Per Cent Control[1]	At 12 Days: Aphids Per Leaf	At 12 Days: Per Cent Control
16	Methyl parathion-parathion	0.25	0.01	99	0.06	86
24	Parathion	0.25	0.05	94	0.09	76
12	Lindane	0.25	0.12	84	0.20	47
	Untreated check	0.00	0.75	—	0.38	—

Application data: date treated, May 1; time, 4:30-5:00 p.m.; temperature, 60°F.; wind velocity, 10-12 mph (N-W); plant height, 3-5 inches; method of application, Yellow Devil sprayer (hollow-cone nozzles at 12" spacing 24" above ground, 60 pounds pressure, 5.5-6.0 gallons spray per acre); plot size, 200' x 36'; replication, 2; water on foliage, none; increase in weight of plants, May 1-13, 90-100 per cent.

[1] Based on an examination of 100 leaves from each of two plots.

Table 26. Effectiveness of parathion and lindane, applied by power equipment, in a test to control the turnip aphid on curled mustard, Bixby, September 19 to October 5, 1950.

Form. No.	Materials	Pounds Toxicant Per Acre	Aphids Per 10 Sweeps	Per Cent Control At 9 Days[1]	PPM Toxicant Recovered From Greens Canned on 4th Day
16	Methyl parathion-parathion spray	0.50	0.5	95	0.03
17	Methyl parathion-parathion spray	0.25	0.9	91	0.00
12	Lindane spray	0.30	0.9	91	0.00
22	Parathion 1% dust	0.25	1.1	89	0.02
	Untreated check	—	9.8	—	0.00

Application data: date, September 19; temperature, 83°-82° F.; wind velocity, 6-10 mph; plant height, 8-10 inches; water on foliage, none; spray application, 8.0 gallons per acre at 100 p.s.i.; dust application, power duster; increase in plant weight September 19 to 23, approximately 25 per cent.

[1]Based on four 10-sweep samples from each of duplicate plots.

is greatly limited, necessitate the actual bringing of the insecticide into contact with the aphid in order to produce mortality.

Each of the six toxicants which have been the most effective--methylparathion, parathion, tetraethyl pyrophosphate, lindane, benzene hexachloride and nicotine sulphate - possesses relative high volatility or "fuming action." Conversely, the ineffective materials - DDT, methoxychlor, toxaphene, rotenone, pyrethrins, the synergistic piperonyl compounds and chlordane - are only slightly volatile. This suggests that the superiority of the more volatile toxicants is due to a considerable extent to their greater ability to penetrate to the more inaccessible foliage surfaces and make contact with the aphids.

Factors that Influence the Effectiveness of Insecticides

The insecticide control tests were made under varying factors and conditions. These variables included foliage characteristics of the crops, size of plants, arrangement of plants, type of formulations, method of application, temperature level, wind velocity, and amount of water on the foliage. Each of these factors appeared to have some influence on the effectiveness of treatment.

Foliage Characteristics of Spinach and Crucifers. It has been pointed out in an earlier section that the growth characteristics of spinach plants, in particular, as well as that of the savoy-type crucifers presented serious barriers to the effective placement of insecticides. The results of certain of the tests suggest that effective treatment is more difficult to secure on spinach than on the cruciferous crops. Since a different species of aphids occurred on each of the two crops, the results are not directly comparable and, therefore, do not justify a definite conclusion. In three tests on crucifers a methyl parathion-parathion spray gave an average control of the turnip aphid of 96 percent (Tables 23, 25, and 26). This compared with a control of the green peach aphid of 78 percent by the same material in a test on spinach (Table 18). Parathion 1 percent dust gave an average control of 91 percent in two tests on crucifers (Tables 26 and 29) compared to 84 percent in two tests on spinach (Tables 18 and 21). Similarly, lindane 1 percent dust produced 85 percent control of the turnip aphid in two tests on crucifers (Tables 23 and 24) and 80 percent control of the green peach aphid in a pair of tests on spinach (Tables 18 and 21).

Plant Size and Arrangement. Limited data were secured on the influence of plant size and plant arrangement or location on control measures. Table 27 summarizes the results of a test to measure the effects of plant height and the lateral distance of plants from duster outlets on the effectiveness of tetraethyl pyrophosphate dust in controlling the turnip aphid on broadcast turnips. The method was more effective on plants 12 inches in height than those 16 inches tall. Further, the effectiveness of the method decreased as the lateral distance of the plants from the outlets increased. In a zone within 6 inches of the outlet the control on the short plants was 99 percent as compared with 96 percent on the tall plants. At a lateral distance of 6 to 12 inches from the outlet the level of control decreased to 85 percent on short plants and to 68 percent on tall ones. In the zone 12 to 18 inches from the outlet control dropped to 65 percent on short plants and to the very low level of 17 percent on tall plants.

Table 27. The influence of plant height and the lateral distance of plants from duster outlets on the effectiveness of tetraethyl pyrophosphate dust applied by power duster in a test to control the turnip aphid on broadcast turnips, Spiro, May 20-21, 1948.

	Control[1] at Lateral Distances From Outlets		
Approximate Height of Plants	Within 6 Inches	Within 6 to 12 Inches	Within 12 to 18 Inches
12	99	85	65
16	96	68	17

Application data: date, May 20; temperature, 86°F.; wind velocity, 5-6 mph; foliage moisture, slight; number aphids per leaf on untreated plants, 9.2; rate, 30-35 pounds tetraethyl pyrophosphate 0.5% dust per acre; method, power duster with outlets set at 36 inch intervals and at a level of 16-20 inches above the plants.

[1]Based on an examination of 10 leaves at each of four points per treatment.

Some additional information concerning the influence of plant arrangement or plan location on the effectiveness of treatment was obtained in a test on spinach. Table 21 shows the comparative effectiveness of sprays and dusts on the green peach aphid when applied to broadcast spinach and to rowed spinach. The sprayer and duster outlets were spaced at lateral intervals of 18 inches. In treating the rowed spinach a single outlet was placed directly above each row. In the case of each treatment the level of control was higher on the rowed spinach than on broadcast spinach, the increase in effectiveness ranging from 5 to 10 percent.

Comparative Effectiveness of Dusts and Sprays. Table 28 gives a summary of results showing the comparative effectiveness of dusts and sprays. The results of five comparisons between dusts and sprays of parathion and lindane are given. Three of the comparisons were made on spinach and the others on cruciferous crops. In four of the comparisons, dusts gave from 4 to 9 percent higher control than their corresponding sprays. In the other case the percent control for parathion dust and spray were 93 and 92, respectively. The average for the dusts was 85 percent compared to 80 percent for the sprays.

Hand Dusters Compared with Power Dusters. Hand dusters were definitely more effective for applying dusts containing parathion, lindane and tetraethyl pyrophosphate to greens crops than power dusters. In a direct comparison (Table 21), parathion 1 percent dust applied with a rotary hand duster gave 99 percent control of the green peach aphid as compared to 89 percent by the same material applied by power duster. In a total of five treatments applied by hand duster in the

Table 28. Summary of results showing comparative effectiveness of dusts and sprays.

			Dusts		Sprays	
Table No.	Toxicant	Pounds Per Acre	Per Cent Conc.	Per Cent Control	Gallons (P.S.I.)	Per Cent Control
(Green peach aphid on spinach)						
4	Parathion	0.15	0.5	82	70 (300)	78
7	Parathion	0.34	1.0	87	12 (100)	80
7	Parathion	0.32	1.0	92	12 (100)	86
4	Lindane	0.20	1.0	84	70 (300)	76
(Turnip aphid on crucifers)						
12	Parathion	0.25	1.0	93	112 (250)	92
12	Lindane	0.48	1.0	84	112 (250)	75

various tests on spinach the average control obtained was 93 percent. In these and similar tests four treatments applied by power duster averaged 84 percent.

In a direct comparison of hand duster application of tetraethyl pyrophosphate dust on turnips with power duster application (Table 29) the former gave 98 percent control and the latter 88 percent control. The average control of three treatments by hand application to crucifers was 98 percent while the average of seven similar treatments applied by power duster was 91 percent.

The Influence of Temperature on Control. The effects of temperature on the action of volatile insecticides was reflected in the results of certain tests. Table 30 presents a summary of the results of four tests, two of which were made at temperatures within the range of 54 to 59 degrees F. and the other two at temperatures within the range of 76 to 84 degrees. In the case of nicotine sulphate dust, the control cited for 84 degrees (98 percent) was obtained in the laboratory. Therefore, the great difference between this figure and the very low control level of 13 percent should not be attributed entirely to the effects of temperature. The two results, however, do indicate that the effectiveness of the insecticide is adversely affected by temperatures as low as 59 degrees. The comparative results presented for the other materials were obtained in two tests made April 23, 1951, and May 7, 1951. The only important difference known to exist in the conditions of the tests was the variation in temperature levels. Tetraethyl pryophosphate dust was affected most by the drop in temperature, decreasing from 79 percent control at 76 degrees to 58 percent at 54 degrees. Lindane dust appeared to be affected almost as much, decreasing

Table 29. Influence of water on foliage on the effectiveness of tetraethyl pyrophosphate dust[1] applied by power duster to control the turnip aphid on curled mustard, Keota, May 18-20, 1948.

Method of Application	Per Cent Control[2] Obtained at 48 Hours: Most of Plant Wet; Temperature 78°-80°F.; 9:00 a.m.	Plant With Approximately Lower Half Wet; Temperature 83°F.; 2:00 p.m.	Plants With Almost All of Foliage Dry; Temperature 85°F.; 5:00 p.m.
Hand gun	29.3	85.2	98.1
Power duster	18.7	71.0	87.6
Airplane	21.2	—	80.3

Application data: wind velocity, 3-5 mph; plant height, 10-12 inches; number aphids per leaf on untreated plants, 14.1; airplane application, Stearman with venturi spreader, operated at approximately 10 feet above the ground and covering a swath of approximately 30 feet.

[1]0.5 per cent tetraethyl pyrophosphate dust (Formulation No. 32) approximately 30 pounds per acre.

[2]Based on an examination of 25 leaves selected at random at each of 4 points in single plots.

Table 30. Summary of results of several tests to show the influence of temperature levels on the effectiveness of volatile insecticides on the green peach aphid on spinach.

		54° to 59°F.			76° to 84°F.		
Form. No.	Materials	Test Date	Appli. Temp., °F.	Per Cent Control	Test Date	Appli. Temp., °F.	Per Cent Control
18	Nicotine sulphate 3% dust	March 10, 1946[1]	59	13	Jan. 9, 1946[2]	84	98
34	Tetraethyl pyrophosphate 0.75% dust	April 23, 1951[3]	54	58	May 7, 1951[4]	76	79
22	Parathion 1% dust	April 23, 1951[5]	54	72	May 7, 1951	76	87
9	Lindane 1% dust	April 23, 1951[6]	54	59	May 7, 1951	76	77

[1]See Table 16.

[2]Laboratory test, Table 15.

[3,5,6]All dusts used in test on April 23, 1951, applied to broadcast spinach with power duster. TEPP used at a rate of approximately 0.25 pounds actual toxicant per acre. Parathion and lindane applied at rates of 0.30 to 0.35 pounds toxicant per acre.

[4]See Table 7.

from 77 percent at 76 degrees to 59 percent at the lower level of temperature. Parathion dust exhibited a smaller reduction, declining from 87 percent control to 72 percent.

The Effects of Wind Velocities on Insecticidal Treatment. Since in nearly all tests, treatment was applied during periods when the wind velocity was low, no quantitative data were obtained on the influence of moderate velocities in control methods. However, the results of one test showed that velocities of 25-30 miles per hour greatly decreased the effectiveness of dusts and sprays containing tetraethyl pyrophosphate (Table 31). Tetraethyl pyrophosphate 0.75 percent dust, applied with a power duster at a rate of 45 to 50 pounds per acre, produced only 29 percent control of the green peach aphid. In the same test tetraethyl pyrophosphate spray applied at 300 p.s.i. and a rate of approximately 0.4 pound of toxicant per acre, gave a similarly low level of control of 27 percent. In a previously discussed test (Table 21), tetraethyl pyrophosphate dust, applied when the wind velocity was only 3 to 5 miles per hour, gave 79 percent control of aphids. In this second test, the temperature at application was 75-77 degrees compared with a temperature of 72-73 degrees in the first test. This slight advantage in temperature was probably offset by the fact that the application rate in the second test was but 0.25 pound of toxicant per acre compared to 0.35 pound in the first test; therefore, it would appear that the comparatively low level of control in the first test was chiefly due to the high wind velocities.

The Influence of Water on Foliage on Effectiveness of Insecticides. Results in at least two tests showed that treatments of certain

Table 31. Control of the green peach aphid on spinach with tetraethyl pyrophosphate dust and spray under high wind velocities, Stone Farm, April 19-22, 1951.

Station No. In Field	Untreated	Treated			
		Dust (Form. No. 35) 0.35 Pounds Per Acre		Spray (Form. No. 36) 0.40 Pounds Per Acre	
	Aphids Per Leaf[1]	Aphids Per Leaf	Per Cent Control	Aphids Per Leaf	Per Cent Control
1	77	51	34	54	30
2	53	40	25	34	36
3	61	48	21	54	12
4	48	31	35	33	31
Mean	59.9	42.6	28.9	43.8	27.3

Application data: date, April 17; temperature, 72°-73° F.; wind velocity, 25-30 mph; water on foliage, none; dust application, power duster; spray application, power sprayer delivering 45-50 gallons per acre at 300 p.s.i.; plant diameter, 7-10 inches; plant arrangement, 12-inch rows.

[1]Based on an examination of 10 leaves, selected at random, at each station on third day after treatment.

insecticides made on wet foliage were less effective than similar treatments applied to foliage on which moisture was not easily visible. The data indicated that the effectiveness of dusts containing tetraethyl pyrophosphate was markedly reduced and that parathion dust was also impaired in effectiveness although to a lesser extent. Lindane dust did not appear to be seriously affected. In a test on spinach (Table 19) tetraethyl pyrophosphate 1 percent dust gave 83 percent aphid control when applied to foliage which appeared to be dry but caused only 62 percent control when applied to wet foliage. On dry foliage parathion 1 percent dust produced 98 percent control but its use on wet foliage obtained only 90 percent control. Lindane 1 percent was about equally effective on dry and wet foliage, the degree of control being 93 and 91 percent, respectively. In a test to control the turnip aphid on turnips with tetraethyl pyrophosphate dust (Table 29) the level of control was closely correlated with the amount of moisture on the foliage. This trend was quite marked in the case of each of the methods of application employed. In plots treated by means of a hand duster, the degree of control obtained was 98 percent on plants classed as "dry," 85 percent on plants with approximately the lower half of the foliage wet, and 29 percent on plants with most of the foliage wet. The corresponding data for plots treated by means of a power duster were 88 percent, 71 percent and 19 percent. The application by airplane resulted in 80 percent control on "dry" plants and 21 percent on "wet" plants.

These data were obtained from field tests which included the variable factor of temperature. The temperature at time of application of treatment to dry foliage ranged from 3 to 6 degrees above the temperature when treatment was made to wet foliage (Tables 19 and 29). Therefore, the differences in effectiveness of treatment cannot be attributed entirely to the factor of water on foliage. Data presented earlier on the effects of temperature (Table 30), however, indicate that differences of 3 to 6 degrees in the temperature at time of application are not sufficiently influential to cause the relatively great differences in control levels obtained on wet and dry foliage. It appears therefore, that the major portion of difference in effectiveness were due to the factor of water on foliage.

RESIDUES OF INSECTICIDES ON GREENS CROPS

Some information was obtained on the comparative amounts of residues that resulted from the use of certain toxicants on these crops.

Parathion and Lindane

A majority of the residue data were obtained from samples collected from plots treated with parathion and lindane. Table 32 shows the amount of toxicant recovered from unwashed and unprocessed samples collected in tests on spinach, mustard and radish tops. In these tests similar formulations of the two toxicants were applied at approximately the same rate. In all comparable cases of comparison the amount of lindane recovered was considerably greater than the amount of parathion found. In many instances the amount of lindane recovered exceeded that of parathion by two to six times. These large differences occurred between samples of the two toxicants collected shortly after treatment as well as between those collected several days later. No satisfactory explanation for the large differences in the amounts recovered of the two toxicants is known. Nothing was observed or known that indicated the parathion formulations possessed such physical qualities that less of the material adhered to the foliage than in the case of lindane formulations. Because of the data from samples collected shortly after treatment, the differences cannot be attributed to differential rates of deterioration.

The results of the test on spinach (Table 32) give information

Table 32. Amounts of toxicants recovered from unwashed and unprocessed samples of mustard, spinach, and radish collected from plots treated with parathion and lindane.

Date of Test	Formulation	Period After Treatment	Pounds Toxicant Applied Per Acre	PPM Toxicant Recovered Parathion	PPM Toxicant Recovered Lindane
		- Spinach -			
11-25-51	dust	1 hour	0.7-0.9	28.8	64.7
11-25-51	dust	4 days	0.7-0.9	3.5	9.6
11-25-51	dust	9 days	0.7-0.9	2.4	5.1
11-25-51	emulsion	1 hour	1.4-1.9	11.3	69.2
11-25-51	emulsion	4 days	1.4-1.9	6.3	11.4
11-25-51	emulsion	9 days	1.4-1.9	1.4	6.9
11-25-51	wet powder	1 hour	1.2	24.0	67.1
11-25-51	wet powder	4 days	1.2	5.6	29.6
11-25-51	wet powder	9 days	1.2	0.9	
		- Mustard -			
12-13-51	dust	1 hour	0.3	5.5	12.9
12-13-51	emulsion	1 hour	0.3	5.5	25.3
		- Radish -			
5-1-51	dust	16 hours	0.3-0.4	0.0	8.0
5-1-51	emulsion	16 hours	0.3	2.8	7.0

on the rate of decrease of residues on plants in the field. Data are presented for samples collected at one hour, four days, and nine days after treatment. Amounts of the two toxicants decreased at about the same rate. By the fourth day after treatment the residues had declined by 45 to 88 percent by comparison with the levels present at one hour. By the ninth day they had decreased by 88 to 96 percent.

Table 33 presents the amounts of toxicants recovered from canned samples. Samples were collected at intervals after treatment ranging from twelve hours to ten days. The processing incident to and included in canning apparently eliminated a high percentage of insecticidal residues. The largest amount of toxicant recovered was 0.4 ppm. In 12 of the 15 samples analyzed, the amount of toxicant recovered was less than 0.2 ppm and in 4 of these 12 samples no insecticide was found. These data indicate that at rates ordinarily required for aphid control (0.2 to 0.4 pound toxicant per acre) the amount of toxicant that will appear in greens canned shortly after treatment will be less than one ppm. Greens canned ten days after treatment would be expected to contain only traces or no toxicant at all.

Toxaphene, Methoxychlor, DDT and Aldrin

Analyses were made on a few samples taken from plots treated with toxaphene, methoxychlor, DDT and aldrin. These results are shown with the results of an aphid control test (Table 24) and in Tables 34 and 35. Each of these chemicals has been shown by many studies to persist as residues on plants for long periods as compared to parathion and lindane. A small amount of information was obtained in one test (Table 34) on the persistence of these chamicals on spinach during a period

Table 33. Amounts of toxicant recovered from canned samples of spinach, mustard and tendergreens collected from plots treated with parathion, lindane and methyl parathion.

Date of Test	Formulation	Period After Treatment	Pounds Toxicant Applied Per Acre	PPM Toxicant Recovered: Parathion	Lindane	Methyl Parathion
			- Spinach -			
10-21-50	dust	3 days	0.25	0.04		
10-21-50	dust	3 days	0.50	0.14		
10-21-50	emulsion	3 days	0.50	0.40		
11-6-50	emulsion	4 days	0.50	0.04	0.20	
			- Mustard -			
9-19-50	emulsion	4 days	0.25-0.3		0.00	0.00
9-19-50	emulsion	4 days	0.50			0.03
9-19-50	dust	4 days	0.25	0.00		
10-4-49	emulsion	7 days	0.25		0.01	
10-4-49	dust	7 days	0.56		0.00	
			- Tendergreen -			
5-25-50	emulsion	12 hours	0.50			0.05
5-25-50	emulsion	5 days	0.50			0.01
5-25-50	emulsion	10 days	0.50			0.03
5-25-50	emulsion	10 days	0.25			0.02

Table 34. Amounts of toxicant recovered from unwashed, unprocessed spinach collected at stated intervals after field treatment with chlorinated hydrocarbons and parathion, Bixby, November 25 to December 3, 1951.

Materials	Pounds Toxicant Applied Per Acre	PPM Toxicant Recovered at 1 Hour	4 Days	9 Days	Per Cent Decrease in Residue by 9th Day
DDT dust	7.5	92.4	68.4	32.8	65
DDT wettable powder	9.4	168.4	122.0	88.8	47
DDT emulsion	9.7	216.4	197.0	76.4	74
Toxaphene dust	14.2	205.1	101.5	54.6	73
Toxaphene wettable powder	16.5	156.2	104.5	85.7	45
Toxaphene emulsion	15.9	209.9	112.3	—	—
Aldrin dust	2.1	15.3	8.9	4.5	70
Aldrin wettable powder	1.9	46.3	28.3	—	—
Aldrin emulsion	1.6	24.7	15.4	—	—
Lindane dust	0.7	64.7	9.6	5.1	92
Lindane wettable powder	1.2	67.1	29.6	—	—
Lindane emulsion	1.9	69.2	11.4	6.9	90
Parathion dust	0.9	28.8	3.5	2.4	92
Parathion wettable powder	1.2	24.0	5.6	0.9	88
Parathion emulsion	1.4	11.3	6.3	1.4	96

Table 35. Residues of insecticides recovered from spinach in a test to control the seed corn maggot, Bixby, November 6 to 10, 1950.

Materials	Pounds Toxicant Applied Per Acre	PPM Toxicant Recovered From Spinach Harvested 4 Days After Treatment	
		Canned	Unwashed
Toxaphene 20% dust[1]	7.5	2.80	above 79
Toxaphene emulsion spray[2]	2.8	2.60	
Toxaphene emulsion spray[3]	3.0	2.60	above 79
Lindane emulsion spray[2]	0.5	0.20	
Parathion emulsion spray[2]	0.5	0.04	

Miscellaneous data: conditions at application; temperature, 68°-62°F.; wind velocity, 3-6 mph; water on foliage, none; plant diameter, 8-12 inches. Precipitation during November 6 to 10, none. Increase in plant weight, November 6 to 10, 10 to 15 per cent.

[1]Applied by power duster.

[2]Applied by power sprayer at 20 gallons per acre at 75 psi.

[3]Applied by power sprayer at 100 gallons per acre at 300 psi.

of nine days after treatment. Each insecticide was applied in the form of a dust, wettable powder spray, and emulsion spray. Because of the lower level of toxicity to most insect species, toxaphene and DDT were applied at rates several times that of the other materials. These greater application rates naturally result in correspondingly higher residue levels. By comparison, the amount of toxicant recovered from samples collected one hour after treatment with toxaphene and DDT ranged from 92 to 216 ppm., greatly exceeding levels of 11 to 69 ppm. found on samples treated with the other chemicals. Residues recovered from samples collected on the ninth day after treatment give a measurement of the rate of decrease of the different toxicants on the plants. The three DDT formulations showed decreases ranging from 47 to 74 percent. Records on toxaphene dust and wettable powder spray showed decreased of 73 to 45 percent, respectively. Aldrin dust residues decreased 70 percent. Records were not obtained on the wettable powder and emulsion sprays of aldrin for the ninth day, but the rates of decrease of residues of these two formulation during the first four days were roughly equal to that of the dust for the same period. By the ninth day decreases of 92 and 90 percent were shown by lindane dust and emulsion spray, respectively. Similar residue decreases for parathion ranged from 88 to 96 percent.

The required rate of application of parathion and lindane is seldom above and usually less than one pound per acre as contrasted with a rate of several pounds per acre necessary for effective use of DDT and toxaphene. The rate of disappearance of parathion and lindane residues from plants is considerably greater than that of DDT and Toxaphene. Therefore, the use of the former insecticides on greens crops results in less residue hazards than would the use of the latter.

The Effect of Processing on Residues

A moderate amount of information was obtained on the effect of certain processes on residues of parathion and lindane. The most important process involved was canning which consisted of sub-processes of washing, blanching, and pressure-cooking. In addition, the specific processes of washing, cooking in an open vessel, cooking under pressure, freezing and drying were tested separately.

An indication of the general effects of canning on residues of parathion and lindane can be seen by comparing certain data from Tables 32 and 33. Table 32 gives the residues found on unprocessed samples while Table 33 shows those found on canned samples. At four days after treatment unprocessed samples (Table 32) had residues ranging from 3.5 to 29.6 ppm. At 3 to 4 days canned samples (Table 33) showed 0 to 0.4 ppm. In Table 35 two comparisons are presented which involve toxaphene treatments. Unwashed and unprocessed samples were found to have residues of over 79 ppm. at four days after treatment. Canned samples collected from the same treatments at the same time had residues of only 2.6 to 2.8 ppm. One other comparison to illustrate the effect of canning on residue levels is given in Table 36. From unprocessed samples to which a known amount of parathion had been added, 182 MMG of toxicant were recovered. Canned samples of the same lot of mustard was found to contain only 16 MMg. On the basis of these three direct comparisons presented in Tables 35 and 36, canning reduced residue levels 91 to 96 percent.

Table 36. The effect of certain processes on the amount of parathion recovered from samples of curled mustard to which 200 mmg of parathion had been added in the laboratory, Stillwater, November 1950.

Treatment Process	MMG Parathion Recovered
Analysed immediately without processing	182
Boiled 1 hour in open vessel	42
Dried 5 days in open air and sunshine	6
Canned[1] and immediately analysed	16

[1]Washed, blanched in boiling water, placed in can and sufficient blanching water added to cover, and cooked 30 minutes at 15 psi.

Freezing

Tables 37 and 38 present data that indicate the effect of certain specific processes on residues of parathion and lindane. Freezing had the least effect of any of the processes. In four treatments (Tables 37 and 38) the average reduction in residue, compared to unprocessed samples, was 34 percent.

Washing

The results of a total of 16 comparisons between washed and unwashed samples treated with dusts and sprays are given in Tables 37 and 38. The average reduction of parathion residues on spinach was 45 percent. In three comparisons on mustard the average decrease was 55 percent. In two comparisons on spinach (Table 37) washing reduced lindane residues an average of 37 percent. In three comparisons on mustard the average reduction of lindane residue was 90 percent. The effect of washing on residues on radish tops is given in Table 39. Residues of parathion emulsion were reduced 25 percent, from 2.8 to 2.1 ppm. On lindane treated samples the reductions were 37 percent for the dust and 57 percent for the emulsion. The difference in the effect of washing on DDT residues was very great. The dust residue was reduced 93 percent but the spray residue was reduced only 13 percent.

Cooking

Cooking reduced insecticidal residues to a greater extent than any of the processes (Tables 36, 37 and 38). Cooking spinach in an open vessel reduced parathion residues 93 percent. Cooking under pressure reduced the same toxicant by 96 percent. In a test on mustard (Table 38), parathion residues were reduced 79 and 95 percent by cooking

Table 37. The effect of certain processes on the amount of insecticidal residue recovered from spinach harvested at different periods after insecticidal treatment, Bixby, November 25 to December 3, 1951.

Date Collected	Process	PPM Parathion Dust	PPM Parathion W. P. Spray	PPM Parathion Emul. Spray	PPM Lindane Dust	PPM Lindane W. P. Spray	PPM Lindane Emul. Spray
11-25	Washed	8.1	—	9.6	—	—	—
	Cooked[1]	0.1	1.6	1.6	—	—	—
	Pressure Cooked[2]	0.5	1.5	0.5	—	—	—
	Frozen[3]	—	7.0	11.0	—	—	—
	Not Processed	28.8	24.0	11.3	64.7	67.1	69.2
11-29	Washed	2.3	5.3	5.1	—	—	—
	Not Processed	3.5	5.6	6.3	9.6	29.6	11.4
12-3	Washed	1.0	0.1	0.5	4.0	5.7	3.3
	Not Processed	2.4	0.9	1.4	5.1	—	6.9
Pounds Toxicant Applied Per Acre		0.88	1.18	1.41	0.69	1.20	1.88

[1]Boiled in open vessel for 5 minutes.

[2]Cooked at 15 psi for 30 minutes.

[3]Frozen and stored at 0°F. for 60 days.

Table 38. The effect of certain processes on the amount of insecticidal residue recovered from curled mustard which was harvested immediately after receiving insecticidal treatment, Stillwater, December 13, 1951.

Process	PPM Parathion Dust	PPM Parathion W. P. Spray	PPM Parathion Emulsion Spray	PPM Lindane Dust	PPM Lindane W. P. Spray	PPM Lindane Emulsion Spray
Washed	2.5	5.0	3.5	0.6	0.0	5.6
Cooked[1]	0.5	4.5	2.0	0.0	0.4	0.8
Pressure Cooked[2]	0.4	0.6	0.6	—	—	—
Frozen[3]	3.1	19.6	—	—	—	—
Not Processed	5.5	24.5	5.5	12.9	1.1	25.3
Pounds Toxicant Applied Per Acre	0.28	0.33	0.33	0.29	0.33	0.33

Miscellaneous data: method of dust application, plunger-type hand duster method of spray application, weighed amounts of insecticide mixed in 1 gallon of water and applied by a knapsack sprayer. Plot size, 150 by 5 feet.

[1]Boiled in open vessel for 5 minutes.

[2]Cooked at 15 psi for 30 minutes.

[3]Stored 0°F. for 60 days.

Table 39. Residues of insecticides recovered from washed and unwashed samples of radish tops in a test to control the false chinch bug, *Nysius ericae* (Schill.), Leonard, May 1951.

Materials	Pounds Toxicant Applied Per Acre	PPM Toxicant Recovered	
		Washed	Unwashed
(Test No. 1[1] samples collected 16 hours after treatment)			
Parathion 1% dust	0.35	0.0	0.0
Parathion emulsion spray	0.25	2.1	2.8
Lindane 1% dust	0.40	5.0	8.0
Lindane emulsion spray	0.25	3.0	7.0
DDT emulsion spray	1.25	7.0	8.0
DDT 10% dust	2.60	12.0	165.0[2]
(Test No. 2[3] samples collected 72 hours after treatment)			
Lindane 1% dust	0.25	0.5	2.0

[1]Dusts applied by rotary hand duster and sprays applied by knapsack sprayer.

[2]Analysis repeated three times.

[3]Applied by Stearman airplane.

in open vessel and under pressure, respectively. In the same test lindane residues were reduced 87 percent by cooking in an open vessel. In another test (Table 36) cooking in an open vessel reduced the parathion residue 77 percent.

Drying

In the same test (Table 36) drying samples for five days in the open air and sunshine caused a decrease of 93 percent in the parathion residue.

The data on the effects of these processes on residue show much variation, indicating considerable experimental error. Therefore they cannot be used as a basis to predict specific reductions that can be expected to occur from the use of the processes. They do indicate, however, that each of the processes investigated does materially reduce residues of parathion and lindane on these crops.

The Effect of Type of Insecticidal Formulation on Residues

A study of the data obtained on residues did not reveal any consistent trends that would indicate the type of formulation affected the amount of residue occurring on the plant. Generally the residue levels were apposimately the same where dust and sprays were applied to put on the same amount of toxicant per acre. Furthermore, the type of formulation did not appear to affect the rate of reduction of residue levels by the various processes used.

RESULTS OF FLAVOR TESTS

Three tests were made to determine if certain insecticides affected the flavor of spinach. Table 40 gives the results of a taste test made on spinach treated twice with dust and sprays containing benzene hexachloride. Samples were collected at 15 days and 31 days after the last treatment. While still warm, moderate servings of cooked spinach were placed on plates and tasted and sniffed for off-flavors. All three treatments were judged to have affected the flavor of samples collected at 15 days after treatment. Samples treated with dust or spray at a rate of 4 pounds of benzene hexachloride per acre were classed as having slight off-flavor. Those which received 8 pounds per acre were classed as having moderate off-flavor. Thirty-one days after treatment samples from plots treated with the lower rate were described as possessing normal flavor. However, those from plots treated with 8 pounds per acre were classed as having slight off-flavor.

In two later tests (Tables 41 and 42) flavor tests were made on two varieties of spinach canned at 10 and 20 days after treatment. The insecticides involved included a mixture of methyl parathion and parathion, lindane, and parathion. The materials were applied at the slightly low rates of 0.13 to 0.20 pound of toxicant per acre. The taste test panels consisted of 7 to 10 persons. In no instance in either of the tests did more than two persons of a panel fail to class a sample as normal in flavor. In several cases one or two persons classed a sample as having a trace of off-flavor. It should be pointed

Table 40. The effect of benzene hexachloride on the flavor of freshly cooked spinach in a field test, Bixby, January 31 to March 15, 1947.

Materials	Total Pounds BHC Per Acre	Total Pounds Gamma Isomers Per Acre	Total Pounds Other Isomers Per Acre	Off-Flavor in Spinach Harvested[1]	
				March 1	March 15
Benzene hexachloride dust	4.0	0.4	3.6	Slight	None
Benzene hexachloride spray	4.0	0.4	3.6	Slight	None
Benzene hexachloride spray	8.0	0.8	7.2	Moderate	Slight
Untreated	—	—	—	None	None

Application data: application dates, January 31 and February 13; plant diameter, 5-8 inches; plots per treatment, 2 (sprays) and 4 (dusts); plot size, 20' x 20'; methods of application, rotary hand dust gun and knapsack sprayer. Total rainfall during test period, 1.85 inches.

[1]A master sample was obtained for each treatment by combining samples taken from all plots receiving the treatment. Spinach was cooked at a pressure of 15 pounds for 30 minutes. Samples were identified by numbers and taste-tested by a panel of 6 persons.

Table 41. Results of taste tests[1] on Bloomsdale spinach[2] treated with insecticides to control the green peach aphid, Bixby, November 17 to December 8, 1949.

Form. No.	Materials	Pounds Actual Toxicant Per Acre	Normal	Number of Tasters Checking Each Flavor Classification: Off-Flavor Trace	Off-Flavor Def.	Lack of Flavor Trace	Lack of Flavor Def.
Spinach harvested and canned November 28 (10 days after treatment)							
	Untreated check	—	7				1
1	Methyl analog of parathion-parathion spray	0.15	8				
9	Parathion dust	0.13	7	1			
4	Lindane dust	0.20	8				
Spinach harvested and canned December 8 (20 days after treatment)							
	Untreated check	—	7				
1	Methyl analog of parathion-parathion spray	0.15	7				
9	Parathion dust	0.13	6	1			
4	Lindane dust	0.20	7				
3	Parathion spray	0.15	6				1
5	Lindane spray	0.22	5	1			1

Application data: date, November 17; temperature, 63°-60°F.; wind velocity, 1-2 mph; water on foliage, slight; methods of application, power duster and power sprayer (300 lbs. pressure); rainfall during November 17 to December 8, none; plant diameter: November 17, 8-12 inches; November 28, 10-14 inches; December 8, 10-14 inches.

[1]Conducted by National Canners Association Research Laboratories.

[2]Canned by standard commercial methods excepting insect-damaged material was not removed.

Table 42. Results of taste tests[1] on Viking spinach[2] treated with insecticides to control the green peach aphid, Bixby, November 17 to December 8, 1949.

Form. No.	Materials	Pounds Actual Toxicant Per Acre	Normal	Off-Flavor Trace	Off-Flavor Def.	Lack of Flavor Trace	Lack of Flavor Def.
			Number of Tasters Checking Each Flavor Classification				
Spinach harvested and canned November 28 (10 days after treatment)							
	Untreated	—	8	2			
1	Methyl analog of parathion-parathion spray	0.15	9	1			
9	Parathion dust	0.13	9	1			
4	Lindane dust	0.20	9	1			
Spinach harvested and canned December 8 (20 days after treatment)							
	Untreated	—	7				
1	Methyl analog of parathion-parathion spray	0.15	6	1			
9	Parathion dust	0.13	5	1		1	
4	Lindane dust	0.20	7				
3	Parathion spray	0.15	6	1			
5	Lindane spray	0.22	5	2			

Application data: date, November 17; temperature, 63°-60° F.; wind velocity, 1-2 mph; water on foliage, slight; methods of application, power duster and power sprayer (300 lbs. pressure). Rainfall during November 17 to December 8, none; plant diameter: November 17, 6-8 inches; November 28, 8-10 inches; December 8, 10-12 inches.

[1]Conducted by National Canners Association Research Laboratories.

[2]Canned by standard commercial methods excepting insect-damaged material was not removed.

out, however, that one of the samples thus described was an untreated check (Table 42). None of the members of a panel classed any of the samples as having a definite off-flavor.

SUMMARY AND CONCLUSIONS

This investigation of aphids infesting commercial greens crops was made during 1946 to 1952, inclusive. The objectives, in order of importance, were (a) to develop satisfactory methods of control with insecticides, (b) to study the seasonal development of the species of aphids, and (c) to determine the losses caused by these insects. Losses were recorded from a total of 7,662 acres of crops grown on five farms during 1946 to 1950. Data on seasonal development of the green peach aphid and the turnip aphid were based on (a) a two-year study of populations of each species in specific fields of greens, (b) supplemental data taken in several other fields in the Bixby Area during 1946 to 1951, and (c) observations and collections of the species of aphids on host plants other than greens crops. Twenty-five field and laboratory tests, made on insecticidal methods of control, involved the testing of fourteen toxicants and synergists in a total of thirty-nine different formulations. The results included information on the effects of certain plant and weather factors on the effectiveness of insecticide treatments. In nine of these tests a total of 166 greens samples were analyzed chemically for residues. Data were obtained in five tests which showed the effects of processing on residues. Spinach was examined to determine if the flavor were impaired by insecticide treatment in three tests.

The leading commercial greens crops of Oklahoma, in order of importance, are spinach, mustard, turnips, and kale. Aphids are the chief insect pests, having caused a loss of 23 percent of the entire acreage, as compared with 7 percent due to all other insects, during the period 1946 to 1950. The important species of aphids are the green peach aphid, *Myzus persicae* (Sulz.), on spinach, and the turnip aphid, *Rhopalosiphum pseudobrassicae* (Davis), on crucifers. *M. persicae* appears to be active in and around the spinach production areas during the entire year, being present on spinach from October to May, inclusive, and occurring in light infestations during the summer on a large number of cultivated and wild plants. The heaviest infestations generally occur on the "carry-over" and spring crops of spinach. The turnip aphid usually occurs on cruciferous greens crops from August to December and during the spring. Serious outbreaks may occur during either the fall or spring. Collections of *R. pseudobrassicae* were limited to the members of the Mustard Family, lettuce, and bush beans. Below normal temperatures in the early fall, mid-fall and spring, and above normal temperatures in the late fall and winter, appeared to favor aphid development. Sub-freezing temperatures did not seem to cause an immediate reduction of the population unless they were near or below 0 degrees F.

Six toxicants, possessing relatively high volatility, showed promise for aphid control. Parathion and a mixture of parathion with methyl parathion, followed by lindane, were the most satisfactory of these materials. Tetraethyl pyrophosphate was highly effective when applied under dry and warm conditions but was much less effective when applied to wet foliage or when temperatures were below 60 degrees F. Nicotine sulphate was similarly affected by temperatures. Benzene hexachloride was effective as an aphicide but imparted an off-flavor to food products. A number of relatively non-volatile materials, including DDT, methoxychlor, chlordane, toxaphene, rotenone, sabadilla and mixtures of piperonyl compounds with pyrethrins and rotenone were generally ineffective.

The presence of more convolutions and inaccessible cavities on spinach foliage appeared to explain lower levels of control obtained on this crop as compared with those secured on turnips and mustard. The effectiveness of dusts declined with increases in the size of the plant and the lateral distance of the plant from the duster outlet. Hand dusters were more effective than power dusters. Dusts were more effective than sprays containing the same toxicants. The effectiveness of tetraethyl pyrophosphate dusts and sprays was greatly reduced at wind velocities of 25 to 30 mph as compared with that of treatments made at velocities below 10 mph. Water on foliage markedly reduced the effectiveness of tetraethyl pyrophosphate but affected parathion and lindane much less. Tetraethyl pyrophosphate and lindane were much less effective than parathion at temperatures below 60 degrees F.

Residues of parathion or lindane on unprocessed samples at nine days after treatment ranged from 1 to 6 ppm. Residues of DDT and toxaphene under similar conditions varied from 33 to 89 ppm. Residues of parathion and lindane on canned samples collected three to four days after treatment ranged from 0.0 to 0.4 ppm. Canned samples collected ten days after treatment contained only traces of or no toxicant. Each of the processes of washing, cooking, freezing, and drying markedly reduced residues of insecticides on greens crops.

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THESIS TITLE: CONTROL AND SEASONAL DEVELOPMENT OF THE GREEN PEACH APHID AND THE TURNIP APHID ON COMMERCIAL GREENS CROPS

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