NEWS AND REVIEWS

THE CHANGING ROLE OF SOIL PESTS ATTACKING POTATO TUBERS[1]

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When crops are grown intensively, insect pests frequently become a serious problem. Over 100 insect species are reported to be injurious to potatoes, (Dudley, Landis and Shands 6). Some of these insects have been introduced from foreign countries; others are native pests which have adapted to new host plants.

A classic illustration of a potato insect that changed its feeding habits is the Colorado potato beetle, *Leptinotarsa decemlineata* (Crosby and Leonard 5). This species was described by Say in 1824 as feeding on buffalo-bur. In 1859, it was found feeding on cultivated potatoes in Nebraska. From that date, its migration eastward was steady and rapid and 15 years later it reached the Atlantic seacoast.

Potato pests can be classified roughly as (A) foliage feeders, such as the Colorado potato beetle; (B) root or tuber feeders, such as wireworms or garden symphylans, and (C) both foliage feeders and tuber feeders, such as various species of flea-beetles. Some of these are discussed separately in this paper.

FLEA BEETLES

Damage to potatoes by flea beetles is often caused by adult beetles eating small pin-point sized holes in the foliage. Excessive feeding causes leaves to wither and die, resulting in a reduction in tuber size and yield. Certain diseases such as spindle tuber, brown rot, curly dwarf and blight may inter wounds caused by adult feeding (Dudley et al 6).

More serious than the adult leaf feeding is damage caused to tubers by larvae of various species of the genus *Epitrix*. This damage is usually of two types: "Tracks" or serpentine-like tunnels just beneatth the surface of the skin (Fig. 1), and "pits" or "splinters" caused by larvae burrowing into the flesh of the tuber at right angles to the surface, sometimes to a depth of one eighth inch or more (Figs. 2, 3). Suberization in the entrance of these burrows may cause the tuber to have a pimple-like appearance. At times soil organisms may enter these wounds, resulting in a scab-like growth on the surface of the tuber.

Investigators differ in their opinion concerning flea beetle tuber damage on potatoes. Anderson and Walker (1) and Jewett (12) report tuber damage caused by larvae of the potato flea beetle *Epitrix cucumeris* in Virginia and Kentucky. Harding (11) discussed the distribution of seven species of *Epitrix* in Maryland and mentioned tuber damage of *E. cucumeris* in Virginia and Kentucky. Gui (10), reporting on tuber damage by *E. cucumeris*, stated that under Ohio conditions tuber damage rarely occurred. In personal correspondence with R. N. Hofmaster in January of 1966, it was learned that during certain seasons in Virginia

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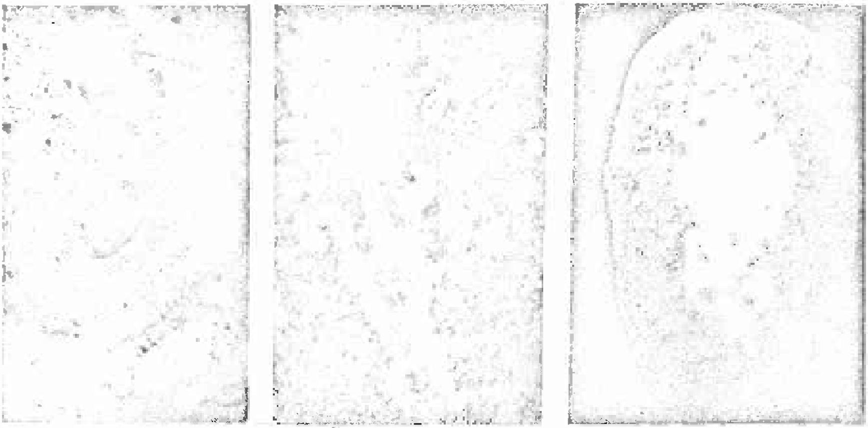

FIG. 1.—Flea-beetle "tracks" just beneath skin surface. (Left)
FIG. 2.—Tuber flea-beetle entering tuber. (Center)
FIG. 3.—Flea-beetle "pits" on peeled tuber caused by flea-beetle larvae. (Right)

E. cucumeris caused both foliage and tuber damage. In other years, the potato vines were almost totally defoliated, yet little tuber damage occurred.

About 1925 a flea beetle, believed to be *E. cucumeris*, caused considerable damage to potato tubers in both Oregon and Washington. Gentner (9) described it as a new species, the tuber flea beetle, *Epitrix tuberis*. Further discussion of this species in Oregon will refer to it as *E. tuberis*.

Gentner was of the opinion that *E. tuberis* was a native of Colorado where it fed on wild hosts such as ground cherry, buffalo-bur and nightshade. About 1904 it invaded cultivated potato plantings near Greeley, Colorado, and gradually spread through western Nebraska and South Dakota to the east, and also moved westward until it reached Washington and Oregon in 1917. Thus, 45 years after the migration of the Colorado potato beetle, a second potato insect pest changed its feeding habits and moved both eastward and westward to become a serious potato pest.

Gray and Schuh (7), working with what was thought to be *E. cucumeris* and now known to be *E. tuberis*, found it to be generally distributed in the Willamette Valley of western Oregon, along the Columbia River in Columbia and Hood River Counties and near Redmond, Prineville and Madras in central Oregon. Although it was suspected to be in Malheur and Klamath Counties of eastern and southeastern Oregon, these reports could not be authenticated.

Where found, *E. tuberis* is closely associated with the western potato flea beetle, *E. subcrinita*, which is distributed throughout western and northwestern United States. Gray and Schuh (7) found the two species about equally distributed. In 1940 *E. tuberis* varied from field to field, sometimes comprising 100% of the adult population. In other instances, 20 to 93% of the adult population was identified as *E. tuberis*.

In appearance *E. tuberis* is very similar to *E. subcrinita*, but is dull black in color while *E. subcrinita* is black with a brassy sheen. Both species feed readily on potato foliage. Gray and Schuh (7) reported that *E. tuberis* was the species cousing most of the tuber damage, and that *E. subcrinita* was of little importance. Jones (13) agreed with this observation, but stated that when adult populations reached 15 to 45 per 25 sweeps of an insect net, tuber damage by *E. subcrinita* was likely to occur. There was no indication of whether *E. subcrinita* would cause "pits" or "tracks" but a picture in his article indicates that most of the injury was of the "pit" type.

In Oregon, Gray et al (8) directed their efforts to the control of the adult of *E. tuberis* and attempted to hold populations at or below the level of 10 beetles per 50 sweeps of an insect net. This, in effect, was designed to minimize egg deposition and subsequent tuber damage. Depending on the time of planting and exact timing of applications, satisfactory tuber flea beetle control was obtained with five to seven applications of insecticide. Three percent calcium arsenate plus 0.5% rotenone, or three percent DDT dust were found effective and were recommended. By 1950, DDT dust was commonly accepted as the most satisfactory control for *E. tuberis*.

Morrison and Crowell (16) initiated a study on the longevity of soil insecticides in 1949. As a result of this study, aldrin was recommended as a soil treatment for tuber flea beetle control in 1953. This recommendation was also useful for the control of the western spotted cucumber beetle, *Diabrotica undecimpunctata undecimpunctata,* which sometimes caused serious potato tuber damage in western Oregon. Morrison and Crowell (18) later revised the recommendations to include dieldrin and heptachlor. Chlordane and toxaphene, as used in these trials, were generally considered less effective than aldrin, dieldrin and heptachlor. DDT as a soil treatment was never satisfactory in controlling larvae of *E. tuberis*.

The longevity study started in 1949 was terminated in 1960. Summaries of the unpublished yearly reports appeared in the abstracts of the Pacific Northwest Vegetable Insect Conferences 1949-1960. At termination of the study, the aldrin, dieldrin and heptachlor treated potato plots were still showing a high degree of protection from damage by larvae of *E. tuberis*.

Almost coincidental with the termination of the longevity trials came reports on August 15, 1960, that aldrin as a soil treatment near Oregon City was not controlling *E. tuberis* larvae. Investigation in 1961 revealed that larvae of *E. tuberis* were entering potato tubers growing in aldrin treated soil. Chlordane, dieldrin and diazinon soil treatment trials in 1962 failed to control *E. tuberis* in this field. From these 1961 and 1962 tests, it was concluded that *E. tuberis* in this field had developed a tolerance for cyclodiene soil nisecticides. This was characterized during the growing season by a very heavy adult "population explosion." At times irrigation puddles in the field assumed a bluish-black luster, from the massed bodies of countless dead beetles.

In 1962, in cooperation with the USDA, ARS, Forest Grove, Oregon endosulfan (1 lb) carbaryl (1 lb) and DDT (2 lbs) toxicant per acre were applied with a trailing boom sprayer to potato foliage in replicated plots. Satisfactory tuber protection from *E. tuberis* was obtained in these trials, but five spray applications were required. Carbaryl seemed to promote population increases of the green peach aphid, *Myzus persicae,* in these trials. Endosulfan gave satisfactory aphid control but was inferior to DDT in controlling flea beetles. The grower cooperator, using the trailing boom sprayer and parathion (0.5 lbs toxicant/acre per application), controlled both aphids and flea beetles with five applications during the season.

Also, in 1962, it was learned that in some instances potato tubers grown in soil treated with aldrin contained residues in excess of established tolerances. A special study showed that these residues could not be correlated with (i) the method of applying the insecticide; (ii) the amount of insecticide used, or (iii) the amount of insecticide present in the soil when potatoes were harvested nor could it be concluded that excessive residues resulted from misuse of the insecticide.

Because of the above-tolerance residues found in potato tubers and the threat of increasing resistance of the tuber flea beetle to soil insecticides, Oregon State University withdrew recommendations (Morrison, Crowell and Avery 19) for use of aldrin, dieldrin, and heptachlor for control of the tuber flea beetle. Instead, the use of foliage applications of DDT, endosulfan, carbaryl or parathion was advocated. A trailing boom sprayer was recommended as the best method of application.

Studies, initiated in 1963 and continued through 1965 and 1966, were aimed at the identification of the problems existing in potato growing areas of Oregon. The results are summarized as follows:

1. Flea beetles, *Chaetocnema* n. sp. or *Longitarsus oregonensis* were sometimes collected in sweeping potato fields. They are of no importance to potatoes. *Phyllotreta albionica* and *P. cruciferae* were also collected from potato fields, probably feeding on wild cruciferous plants growing in or near potato fields. *P. albionica* and *P. cruciferae* sometimes caused alarm among growers because of their resemblance to *E. tuberis* or *E. subcrinita.* They can be distinguished easily by the dark color of their legs. *Epitrix* has yellowish legs.

2. The collection of several specimens of the hop flea beetle, *Psylliodes punctulata,* in Klamath County potato fields was of interest. This species appeared in British Columbia in 1894 and became economically important to hops in 1903. Chittenden (4) and Parker (20) in 1910 reported that flea beetle was damaging 75% of the hop yards. After 1910, the species began to decline in numbers and few could be found in Oregon hop yards in 1937. Parker was of the opinion that parasites or predators were responsible for its rapid decline in numbers. It has not been seen in Oregon hop yards for over 20 years.

3. The western potato flea beetle, *E. subcrinita,* was sparsely scattered in the potato growing areas of eastern, central and western Oregon, but was not considered to be of sufficient magnitude to contribute to tuber damage.

4. The tuber flea beetle, *E. tuberis,* was found only in certain potato fields of western Oregon. In areas such as Columbia County, where intensive aphid control was practiced, only a few specimens were collected. In Clackamas County, certain fields showed 100% of flea beetle adults collected to be *E. tuberis.* Resistance to soil insecticides seemed to be common to certain fields near Oregon City, but not at Wilsonville, about 20 miles distant. In potato fields near Corvallis, Oregon, the tobacco flea beetle, *E. hirtipennis,* comprised about 35% of the adult flea beetle population. In this area *E. hirtipennis* seemed to be declining in 1965 and 1966. This species is of little importance to potatoes.

5. Although *E. tuberis* was well established in Crook, Deschutes and Jefferson Counties of central Oregon in 1944, a survey in 1963 of more than 30 potato fields failed to yield a single specimen. This has held true in 1964, 1965 and 1966, although surveys were not extensive. Workers from Washington State also report that *E. tuberis* is not abundant.

The case of the "missing *Epitrix*" is both perplexing and challenging. The population decline suggests the action of unknown biological agents. Two brachonid wasps, *Microctonus pusillae* and *M. gastroctonus* are known to be flea beetle parasites and were collected by Gray in 1935 on potatoes and strawberries. However, a decline of insect populations as a result of parasites or predators generally results in a resurgence of the host within a relatively short time. This has not happened with *E. tuberis* in four years of this study 1963-66.

A nematode (Family Allantonematinidae) is also reported by Steinhaus (22) and Sweetman (23) as parasitic in the digestive or reproductive system of female flea beetles, *Phyllotreta* sp. If these were the causative agents in the decline of *Epitrix* or *Psylliodes punctulata,* they could be expected to behave in a manner similar to modern chemosterilants, and result in a major decline or almost an extinction of a species. Continued studies may uncover more convincing information concerning the decline of flea beetle populations. Studies of this kind will be difficult. This is especially true in certain areas where adult tuber flea beetles no longer seem to exist.

Wireworms

Several species of wireworms are common to the Pacific Northwest. The Great Basin wireworm, *Ctenicera pruinina,* is found in areas where the annual rainfall does not exceed 15 inches. In intensively irrigated lands, this species is replaced by the Pacific coast wireworm, *Limonius canus*; the sugarbeet wireworm, *L. californicus*; the western field wireworm, *L. infuscatus*; or the Columbia Basin wireworm, *L. subauratus.* From two to six years may be required to complete the life cycle of *Limonius,* but an average of three years is expected.

Cook et al (2), Cook (3) and Lane and Stone (14) advocated ethylene dibromide and D-D mixture as soil fumigants for wireworm control. Lane and Stone (14) also recommended DDT for the same purpose. They advocated deep and thorough mixture of DDT with the soil, and discussed the use of chlordane, heptachlor, dieldrin, aldrin and lindane, for wireworms.

Morrison and Crowell (16), in their longevity studies, found aldrin, dieldrin and heptachlor effective for wireworm control and later (1954) recommended them. The identity of the check plots in this longevity study was maintained for the duration of the study (1949-1960). Wireworm tuber damage in the check plots is indicated as follows:

Period	Wireworm holes per 100 tubers	Range
1949-51	247.0	332-294
1952-54	126.0	130-122
1955	1.3	....
1956-58	103.0	136-72
1959	6.0	....

No reason is suggested for the extremely low tuber damage in 1955.

Little attention was given to wireworms in recent years until 1963 when reports of poor performance of aldrin, dieldrin and DDT were received. Some of these fields were visited in 1963-64 and an unexpected number of *L. canus* and *L. californicus* were collected from potatoes growing in chlorinated hydrocarbon treated soil. They often occurred in new land where information concerning the history and control measures was meager. The possibility of wireworms developing a tolerance to the soil insecticides has been considered. This has been reported for the southern potato wireworm, *Conoderus falli*, a species which has two or more generations each year in southeastern United States (Reid and Cuthbert 21).

In contrast to a normal frequency distribution the 1963 survey of potato pests in eastern Oregon indicated that wireworms tend to have a contagious or negative binomial type of field distribution. This tends to confuse and confound the use of randomized and replicated field plots, especially when insecticidal performance is measured in terms of tuber injuries. Studies indicated that at times only a portion of a field was seriously infested with wireworms, the remainder of the field being relatively uninfested.

The Garden Symphylan

In eastern United States, the garden symphylan, *Scutigerella immaculata*, has been reported as a potato pest (Fig. 8). In 1955, B. F. Coon of the Southeastern Branch Station, Pennsylvania, State College sent samples of symphylan damaged potatoes for study (Fig. 4). The close similarity of flea beetle and symphylan damage was immediately recognized. However, the importance of this similarity was not appreciated until August, 1963, when several potato fields in eastern Oregon failed to meet commercial grade because of 'flea beetle" damage. Since *E. tuberis* was not found in the surveys in this area and *E. subcrinita* populations were extremely light, these fields were checked for other causes of damage. Symphylans were found at depths of about 18 inches. Some could be found eating on potatoes at shallower depths where the soil was moist.

The "pits" or "splinters" caused by symphylan or flea beetle feeding can be readily peeled from the potato (Fig. 5). However, in some instances the blemish caused by symphylan feeding tends to return to the flesh of the tuber as a "darkened area" (Fig. 6), suggesting that perhaps a hormone or toxin was injected at the time of feeding. After allowing the damaged potato to suberize for several days, the symphylan blemish reappears as a "dermal vent" (Fig. 7). Efforts to remove the darkened symphylan blemishes from the flesh of the tuber with chemical bleaches have not been successful.

The discovery of the serious nature of the symphylan problem to potatoes in both eastern and western Oregon was the most disturbing aspect of the 1963 survey. In western Oregon both tuber flea beetles and symphylans are now found in the same fields. In general, injury by flea beetle larvae is of both "track" and "pit" types. Symphylans leave only "pits."

There is a need for more extensive surveys, particularly when it is necessary to determine what control measures should be undertaken. Morrison (15) recommended such non-persistent soil insecticides as para-

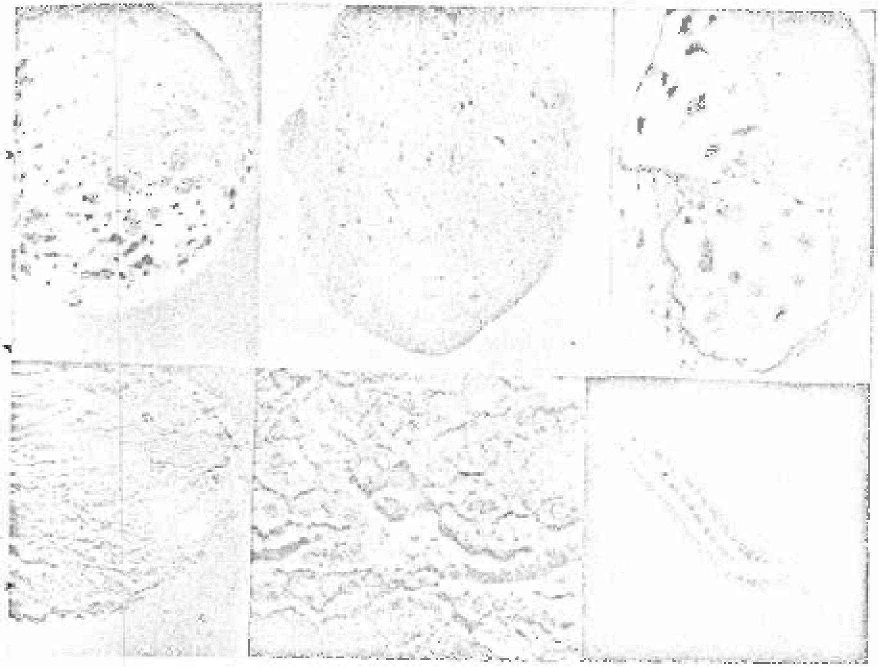

FIG. 4.—Symphylan damage to potato tuber from Pennsylvania. (Top left)

FIG. 5.—Symphylan damage to potato from Oregon. (Top center)

FIG. 6.—Darkened areas surrounding points of symphylan feeding on potato. (Top right)

FIG. 7—"Dermal Vents" on suberized tuber corresponding to areas caused by symphylan feeding on potato. (Bottom left)

FIG. 7A—"Dermal Vents," an enlargement of Fig. 7. (Bottom center)

FIG. 8.—The garden symphylan. (Bottom right)

thion and Zinophos as being helpful in establishing a good root system on leafy and fruiting vegetable crops grown in symphylan infested soil. In many instances, howeevr, these materials did not have sufficient persistence to protect tuber or root crops. He reported that good crop protection was accomplished with the use of soil fumigants such as Telone, Vorlex, D-D mixture or Vapam. To accomplish this the application had to be properly timed with good equipment on well prepared soil. Under these conditions, symphylan control has lasted for a period of four or more years.

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