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An Annotated Bibliography of Potato/Tomato Psyllid, Paratrioza Cockerelli (Sulc) (Homoptera; Psyllidae)

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AN ANNOTATED BIBLIOGRAPHY OF THE POTATO/TOMATO PSYLLID *PARATRIOZA COCKERELLI* (SULC) (HOMOPTERA: PSYLLIDAE)[1]

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INTRODUCTION

The potato (tomato) psyllid, *Paratrioza cockerelli* (Sulc), is a key insect pest of potato and tomato in many of the growing areas of western North America. Attention was first drawn to the species as a threat to the regional potato crop following a period of widespread outbreaks in the late 1920's. Although it was later recognized to have caused similar outbreaks of uncertain diagnosis during several earlier seasons, B.L. Richards described it as "a new disease of potato which appeared suddenly in 1927 and purports to become the outstanding disease problem of the intermountain states. In its rate of spread and its degree of destruction it would seem that nothing has been more startling in American agriculture." Once its association with the potato psyllid was recognized, the term "psyllid yellows" was suggested for a description of the disorder induced by the feeding activities of the insect.

Distribution of the potato psyllid includes Minnesota, North and South Dakota, Nebraska, Kansas, Oklahoma, Texas and all states west except for Oregon and Washington. Canadian records include Alberta and Saskatchewan and it has been reported from as far south as Mexico City and Rio Frio, Puebla. In recent years, damage to potatoes has been most consistent in Colorado, Wyoming, and Nebraska, although severe crop injury has also been reported from Montana, Texas, New Mexico, Arizona, Utah, and California. Significant injury to tomatoes, the other economically important crop damaged by this insect, has also occurred recently in more southern regions, including both the central and Baja regions of Mexico.

This bibliography was constructed by a search of citations in existing computer data bases and cross checking all citations in retrieved articles. With the exception of Extension and popular press articles, it is felt that this bibliography is complete as of December 1992.

With each citation in this bibliography is a description of the citation's content. When available, the abstract of the article was used for this annotation. For many technical bulletins and experiment station reports the summary was used. Minimal editing of the original abstracts and summaries was undertaken, limited to subject matter that did not directly relate to the potato/tomato psyllid. For the remaining articles a brief description was constructed by the authors, based on a review of the article. In a few cases, the article was not able to be retrieved, but had been previously cited by at least two other authors. In these cases (marked ref.) no description follows the citation.

ACKNOWLEDGMENT

This production of this bibliography has been a process that has taken several years and involved numerous students at Colorado State. I wish to particularly acknowledge the efforts of Rella Abernathy and Darryl Patrick.

AN ANNOTATED BIBLIOGRAPHY OF THE POTATO/TOMATO PSYLLID *PARATRIOZA COCKERELLI* (SULC) (HOMOPTERA: PSYLLIDAE)

Abernathy, R. L. 1991. Investigations into the nature of the potato psyllid toxin. *M.S. Thesis. Colorado State University.* 54 pp.

Using tissue-cultured potatoes, potato psyllids [*Paratrioza cockerelli* (Sulc)] caused dramatic injury to all four tested cultivars. Varietal responses showed that early maturing cultivars had less damage than later cultivars. However, tubers from early varieties showed a greater percentage of sprouting from premature breakage of dormancy. Eight varieties of tomatoes evaluated in field trials all showed significant yield loss from psyllid injury. However, psyllid populations were not consistently related to yield loss when comparisons were made between cultivars. For example Jubilee sustained a high loss of yield from fairly light psyllid infestations while Roma was less damaged although psyllid populations were high. Peppers showed a much different response to psyllid injury, with generally marginal effects from infestation and even a yield increase with the cultivar Anaheim. A membrane feeding system was developed to collect the salivary secretions of psyllid nymphs. Several attempts were made to develop a bioassay for the psyllid toxin, using tomato cotyledons, but results were inconsistent. Potato minitubers were topically treated with psyllid salivary secretions collected in membrane feeding systems and with psyllid excrement to assay effects on tuber sprouting; treatment effects were not significantly different from the controls.

Allen, T. C. 1947. Suppression of insect damage by means of plant hormones. *J. Econ Entomol.* 40(6): 814-817.

Psyllid yellows is mentionned as an example of a type of insect injury that shows evidence of having effects similar to those of plant hormones.

Altstatt, G. E., P. A. Young and A. L. Harrison. 1940. Tomato diseases in northeast Texas in 1940. *Plant Disease Reporter.* 24(14): 291-297.

There were no reports of psyllid yellows in the state.

Anonymous. 1932. Potato psyllid investigations. *Bienn. Rept., Utah Agr. Expt. Sta. Bull. 235*: 55-59.

Three to four generations of *Paratrioza cockerelli* (Sulc) developed in the field at Logan during 1931. Apparently, matrimony vine, *Lycium halimifolium*, is one of the principal plants upon which the potato psyllid breeds in the early spring; many plants are used as a source of food early in the season, but eggs are not laid on most of these. Potato psyllids were rather scarce in northern Utah during the season of 1931 and were observed in only a few fields in this area. On May 6, 1932, 228 adult *P. cockerelli* (139 males) were collected in 100 sweeps of the net from matrimony vine at Plain City. The mortality in hibernation cages was much higher where the adult psyllids were allowed to become wet than in cages where they remained rather dry. No parasitism of *P. cockerelli* has been observed, but adults and larvae of ladybird beetles, chrysopid larvae, and one adult anthocorid bug have been observed to be predaceous upon this psyllid. Extreme hot weather in summer appears to be an important factor in retarding the development of large numbers of psyllids during July and August. It is planned to determine, if possible, the more important fall and spring host plants of the potato psyllid.

-------- 1940. *Thirty-fourth Annual Report of the Department of Agriculture (British Columbia) for the Year 1939.* 146 pp.

In the report of the Provincial Entomologist (pp. B62-B63), M. H. Ruhmann gives records of the prevalence of the principal pests observed during the year. *Paratrioza cockerelli* Sulc, which has been reported as crossing the boundary from Alberta, was not recorded in British Columbia during the year.

-------- 1943. Spraying and dusting potatoes. *Bull. N. Dak. Agr. Exp. Stn. no. 319*, 19 pp.

The potato Psyllid [*Paratrioza cockerelli* Sulc] is of only slight importance in North Dakota, and control measures are rarely necessary.

Arslan, A., Bessey, P. M., Matsuda, K. and Oebker, N. F. 1985. Physiological effects of psyllid (*Paratrioza cockerelli*) on potato. *Amer. Potato J.* 62:9-22.

Feeding by psyllid nymphs causes "psyllid yellows", a characteristic yellowing of shoots which results in a dramatic loss of tuber yield. If psyllid infestation is not controlled, the onset of shoot yellowing and growth reductions can occur within two weeks. When insecticides are applied after yellowing, recovery of plants often is not complete. In this study comparisons were made of the physiology and growth of tops and tubers of recovered and permanently injured potatoes of the cultivars 'Denali', 'Kennebec', and 'Norgold Russet'. Permanently injured plants senesced rapidly, developed less shoot growth, aerial tubers and shortened and thickened internodes. They had lower tuber yields than plants that recovered. Permanently injured 'Denali' developed shoots on old flowering stems. In samplings made during tuber growth, dry weight percentages of total soluble sugars, sucrose and glucose of tubers from permanently injured plants were found to be the same as those of recovered plants. In all cultivars, starch percentages of tubers from permanently injured plants were higher than that of the recovered, but the pattern of carbohydrate content changes was similar for permanently injured and recovered cultivars.

Babb, M. F. and Kraus, J. E. 1937. Tolerance of certain potato varieties to psyllid yellows. *Nebraska State Board of Agr. Rept. 1937*: 694-698. (Also in Nebraska Potato Improvement Association, 1937:26-30). (Ref.)

Binkley, A. M. 1929. Transmission studies with the new psyllid-yellows disease of solanaceous plants. *Science.* 70(1825): 615.

An apparently new disease of potato and other solanaceous plants, the characteristic symptom of which is the upward cupping of the leaves and dwarfing of the plants, was extremely destructive in Colorado in 1926-28 and was believed to be associated with the psyllid, *Paratrioza cockerelli* Sulc. Nymphs hatching from eggs laid by infective psyllids and allowed to feed on healthy tomato plants until they became adult did not produce the disease, which is not, therefore, transmitted through the egg, but nymphs transferred from diseased to healthy potato plants produced the symptoms in 7 to 10 days. It has also been transmitted from diseased tomato to healthy potato plants, and vice versa, and also to the common garden pepper [*Capsicum*], eggplant [*Solanum melongena*] and the ornamental Jerusalem cherry [*S. pseudocapsicum*]. The disease is very destructive and the psyllid is difficult to control, owing to its habit of feeding on the lower surface of the leaves and the strength of the spray necessary to kill it.

Binkley, A. M. and Metzger, C. H. 1929. Psyllid yellows (cause undetermined). USDA Bur. Plant Ind., *Plant Disease Reporter, Supplement*. 68: 29.

Blood, H. L., Richards, B. L. and Wann, F. B. 1933. Studies of psyllid yellows of tomato. *Phytopathology*. 23(11): 930.

Psyllid yellows of tomato [caused by *Paratrioza cockerelli* (Sulc)] is of importance only in so far as it becomes a confusing element in investigations of curly-top, the symptoms of which are similar, though distinguished by more intense yellowing and leaf-curling and more rapid death. Symptoms of yellows were not induced by inoculation with less than 30 psyllids and were only maintained by the continued feeding of the latter, the plants recovering if the insects were removed. These results support the theory that this disease is caused by an insect toxin.

Burks, B. D. 1943. The North American parasitic wasps of the genus *Tetrastichus* - a contribution to biological control of insect pests. *Proc. U. S. Natl. Museum*. 93(3170): 505-608.

In this revision, *Epitetrastichus* Gir., and *Neomphaloidella* Gir., are among the genera not considered distinct from *Tetrastichus*. Specific synonyms include *T. thripophonus*, Wtstn. (*tatei* Doz.) and *T. nimutus* How. (*blepyri* Ashm., *detrimentosus* Gah.). *T. gibbone* Gir., is transferred from *Ootetrastichus*, and *T.whitmani* Gir., from *Aprostocetus*. Among the new species described are *Tetrastichus triozae* reared from nymphs of *Paratrioza cockerelli* Sulc.

Caldwell, J. S. 1941. Preliminary survey of Mexican Psyllidae (Homoptera). Ohio Journal of *Science*. 41(6): 418-424.

A key is given to the genera of the psyllids of Mexico along with the location of the potato psyllid (*Paratrioza cockerelli* Sulc) discovered in Mexico.

Carter, R. D. 1950. Toxicity of *Paratrioza cockerelli* (Sulc) to certain solanaceous plants. *Ph.D. Dissertation, University of California*. 128 pp.

An investigation was made of some aspects of toxicity of potato psyllids, *Paratrioza cockerelli* (Sulc), to certain solanaceous plants. All of the work was done in the greenhouses of the University of California at Berkeley. A method of distinguishing the sexes in nymphs was devised, and a technique for handling psyllids and radioactive material was developed. Symptoms were described for *Physalis angulata* L., *P. floridana* Rydberg, *Nicotiana tabacum* L., *Lycopersicon pimpinellifolium* (Jusl.) Mill., and *L. esculentum* (Mill.). Some factors affecting symptoms in tomato were investigated. Foliage mass appeared to be a critical element in plant susceptibility. Tests of minimum feeding periods indicated that disease could be caused readily in 2-leaf seedlings in 2 hours' feeding, and that a single nymph could cause disease in as little as 6 hours' feeding. It was also shown that psyllids confined to 1 side of a plant might affect severely only that side of the plant. Feeding tracks or sheaths left in the plant by the psyllids were studied. Tracks are of small diameter and irregular occurrence for early instar nymphs, but later instar nymphs as well as adults leave thick, well-defined tracks. Tracks begin at the point of puncture and are of uniform diameter throughout their length. The path of the tracks is decidedly intercellular, even after the track becomes ramified in the cortex or vascular tissues. Examination of tracks revealed that nymphs and adults both feed deep in the plant, in the region of the phloem. Both nymphs and adults can penetrate to the phloem in 1 hour. However, for every 2 tracks left in 3 hours of feeding, a total of only 3 tracks may be left when the feeding period is extended to 24 hours. This increase in the number of sheaths is far less

than the increase in severity of symptoms caused when the feeding period is increased from 3 to 24 hours. Toxicity in a psyllid is dependent, therefore, upon continued feeding in 1 or a few punctures rather than upon leaving a great quantity of sheath material in numerous punctures. It appears that the toxin is released near the phloem, in which it moves and through which it affects the plant. The feeding rates of nymphs and adults were compared by counting feeding tracks and by use of feedings upon radioactive material. Adults do not feed readily in darkness, and teneral adults feed less readily than mature adults. In light, adults and nymphs can feed at about the same rate. None of these feeding characteristics can account for the usual absence of toxicity in the adult psyllid. Toxicity in third-instar and older nymphs and in adults was tested in serial, 48-hour feedings. Some nymphs were never toxic, and even when fed in groups these non-toxic nymphs caused no disease. Other nymphs caused disease for a short time, then became non-toxic. The remaining nymphs were toxic up to about the time of final molting. Many nymphs exhibited temporary declines in toxicity at the end of the fourth and fifth instars. Toxicity tests suggested that toxicity levels in a pair of nymphs may be reflected later in their progeny. In one test 3 of 66 adults were apparently toxic when tested singly for 48 hours during the first 72 hours after emergence as adults. Two of 15 lots of 10 adults were apparently toxic when fed for 48 hours during the first 72 hours after emergence. Other trials involving many psyllids the same age fed for shorter periods or older psyllids fed for longer periods were negative or inconclusive. Variations found in potato psyllid mycetomes were not correlated with variations in toxicity. Certain shortcomings in the techniques used in attempting to correlate the variations are evident. Pleiomorphic symbiotes were described from mycetome smears in a preliminary study. Numerous injections of extracts of macerated psyllids were made into tomato plants. No disease developed in these tests, although plants used were of a susceptible size. Some injections were made into Russet Burbank potato, but neither the injected plants not the psyllid-infested checks developed disease.

-------- 1961. Distinguishing sexes in nymphs of the tomato psyllid, *Paratrioza cockerelli*. *Annals Entomol. Soc. Am.* 54:464-465.

Means of distinguishing sexes in immature insects are useful in the laboratory where sexes must be treated separately for mating of adults is to be controlled, and in the field where a knowledge of sex ratio is important. The yellowish coloration of the developing testes is sufficiently intense in fourth- and fifth-instar nymphs of the tomato psyllid, *Paratrioza cockerelli* (Sulc), to permit in vivo segregation of the sexes under the dissecting microscope. Examination of cleared, whole-mounted nymphs reveals that all bear internally a yellowish-orange, roughly U-shaped body, lying almost entirely in the basal half of the abdomen. This is the mycetome, as illustrated by Rowe and Knowlton. In male nymphs, the spindle-shaped testes extend caudad along and beyond the mycetome lobes, forming with the mycetome the H-like marking shown by Essig (1917) and described by Hartman (1937) as characterizing the tomato psyllid nymph. In the female nymphs a pair of hyaline bodies may be seen posterior to the mycetome. These apparently are developing ovaries, such as Brittain has shown to occur in *Psylla mali* Schmidberger. In third-instar and younger tomato psyllid nymphs, the testis is often so weakly colored as to be almost invisible. In older nymphs, weak coloration of the testes is the exception. Among more than 200 live, fourth- and fifth-instar nymphs examined under the dissecting microscope, the presence of testes was questionable for only 5% of the individuals. Nymphs for which the presence or absence of testes appeared certain were re-examined as adults and found to have been sexed correctly. Occasionally the mycetome lobes of females nymphs part prematurely. These nymphs will not be mistaken for males, even in rare instances when the parted lobes appear spindle-shaped and a vestige of the central mass of the mycetome remains. The different coloration and location of the mycetome prevents its being confused with the testes.

Male nymphs of *Paratrioza maculipennis* (Crawford) and *P. lavaterae* (Van Duzee) also have an H-marking cast on the abdomen by the testes and mycetome. Formation of this mark is dependent on a linear arrangement. According to Brittain (1923) and Witlaczil (1885), the testis of other psyllid species may be V- or Y-shaped. Transformation zones and efferent ducts of the tubules are commonly separate. Lacking the linear testis projecting caudad beyond the mycetome, nymphs of these psyllids do not have an H-marking cast upon the abdomen.

Carter, W. 1939. Injuries to plants caused by insect toxins. *Bot. Rev.* 5(5): 273-326.

This disease of the potato and tomato was first described by Richards in further detail in 1931, and in collaboration with H. L. Blood in 1933. The disease has been recorded in the United States from Utah, Colorado, Idaho, California, New Mexico, Arizona, Wyoming, Kansas, Nebraska and in Canada from Alberta. Psyllid yellows belongs to the small group of complex toxicoses in which the effect of the toxic secretion of the insect is systemic. The systemic effects are probably more highly developed in this disease than in any other of its type since the entire plant is affected. The symptoms include the rolling and cupping, with marginal yellowing of younger leaves, with subsequent necrosis and degeneration. Stem elongation in aerial shoots is hindered and axillary tubers, or small rosettes of leaves malformed in witch's broom fashion, may develop at the internode. Underground, a characteristic response is the formation of numerous small potatoes, many of which are prematurely sprouted. Aerial tuber formation in potato has resulted in confusion of this disease with that of Rhizoctonia, while in the tomato the symptoms produced are similar to those of curly top of beet. There is a single reference to natural transmission of this disease but the record has not been confirmed. The insect concerned in the production of psyllid yellows, *Paratrioza cockerelli* Sulc, is primarily a feeder on solanaceous plants, but Knowlton lists 40 species of host plants on which the insect can complete its life cycle. In addition, a large number of plants other than Solanaceae can serve as temporary hosts. The association between the insect and the disease, which was referred to by Richards in his first note on the disease, is unique in the fact that only the nymphs are capable of producing the disease, and the use of populations of adults numbering up to 1000 to a single plant has failed to produce psyllid yellows. When nymphs are applied, the time required to produce symptoms, as well as the intensity of these symptoms, is related to the number of nymphs used. Although the first symptoms appear after three days' feeding, a complete symptom picture is not obtained unless the nymphs feed continuously for 36 days. If the feeding period is less than 26 days, the attacked plants recover. An important datum is that of infectivity of nymphs reared from eggs removed from healthy plants. Richards and Blood found that such nymphs were more intense in their infectivity than nymphs of the same age which fed on diseased plants, which indicated that the insect was inherently toxicogenic. This positive evidence of the infectivity of nymphs hatched from eggs from a healthy plant negatives the findings of Binkley, who declared that it was necessary for a nymph to be transferred from diseased potato plants in order to produce the disease. This finding of Binkley's which appeared to be confirmed by Eyer and Crawford was, no doubt, due to experimental conditions which did not permit the expression of symptoms and one of the latter authors agrees with original statement of Richards and Blood when he says that "Nymphs need not have fed previously on infected plants in order to produce typical symptom." Eyer and Crawford have shown that most of the feeding by *P. cockerelli* occurs in the border parenchyma surrounding the vascular bundles. The authors found nothing that would indicate that psyllid yellows symptoms were induced by either mechanical plugging or destruction of the vascular tissues. Daniels reported that the vascular system in the diseased plants was broken down, and that the abnormal quantities of starch present in the pith indicated the disturbance of translocation. Eyer has made a significant contribution to the physiology of the disease. The injury to the border parenchyma is extended laterally since necrosis of the phloem is found in both midrib and petiole. In the regions of injury the cell proteins are broken down. Nitrate nitrogen content of healthy potato plants is definitely higher than that of diseased plants. The same is true also of the chlorophyll and carotin content, both being decreased in the diseased plant. Control of this disease is based primarily on the facts previously mentioned, that nymphs only are capable on inducing symptoms, the number required is considerably greater than unity and recovery follows the removal of the insect. It follows logically that reduction of the insect population should reduce the incidence of the disease. List and List and Daniels have shown that lime sulphur sprays and dusts were effective in giving field control, with the sprays showing a definite superiority over the dusts. According to Blood, Richards and Wann the disease has not affected the economic production of tomatoes, since not less than 30 psyllid nymphs, continuously feeding, are necessary for the production of symptoms.

-------- 1962. *Insects in Relation to Plant Disease.* Interscience Pub. New York. 705 pp.

On pages 230-237 psyllid yellows of potatoes and tomatoes is discussed as an example of a systemic phytotoxemia. He reviews the history of work on the the effects of psyllid yellows on plants and their relationship to the causal organism, *Paratrioza cockerelli.*

Compere, H. 1915. *Paratrioza cockerelli* (Sulc). *Monthly Bull. Calif. State Commiss. Hort.* 4(12): 574.

Paratrioza cockerelli (Sulc), a psyllid attacking a large range of plants, has been found to be injuring *Solanum capsicastrum* in the Golden Gate Park at San Francisco, and also in the Capitol Park at Sacramento, where it has become a pest necessitating measures of control.

-------- 1916. Notes on the tomato psylla. *Monthly Bull. Calif. State Commiss. Hort.* 5: 189-191.

The psyllid, *Paratrioza cockerelli* Sulc, is distributed throughout the southwestern part of the United States and has been recorded on the following host plants: - *Capsicum annuum* (pepper), *Solanum lycopersicum* (tomato), *S. tuberosum* (potato), *Purshia* sp., *Thuja occidentalis* (arborvitae), *Picea* sp. (spruce), *Pinus monophylla*, *Medicago sativa* (lucerne); the specimens under consideration were taken from *S. capsicastrum* (Jerusalem cherry). In Sacramento broods are continuous throughout the year. During January the mortality among the newly-hatched nymphs may reach 50 per cent. if the temperature is very low. Adults in captivity were extremely active and lived more than a month. Oviposition began three days after pairing and continued for three days. Eggs were deposited on any part of the leaf; the average number laid by one female was thirty-six. The incubation period in a hot-house was 15 days, while the nymphs reached maturity in about 30 days. Suitable methods of control were spraying with water and Black Leaf 40, at a strength of 1 to 1,500 (for thinleaved ornamental plants), or kerosene emulsion and 1 to 20 U.S. gals. water (for more resistant plants).

-------- 1943. A new species of *Metaphycus* parasite on psyllids. *Pan Pacif. Entomol.* 19(2): 71-73.

Descriptions are given of the adults of both sexes of the Encyrtid, *Metaphycus psyllidis*, sp. n., which was bred from nymphs of *Paratrioza cockerelli* Sulc, on chili pepper (*Capsicum* sp.) in California. All the other species of this genus have been reared from Coccids.

Cranshaw, W.S. 1985. Control of potato psyllid and green peach aphid, Ft. Collins, CO, 1984. *Insecticide and Acaricide Tests.* 10: 132.

Foliar sprays of diazinon, endosulfan, permethrin, and acephate were among the superior treatments for control of potato psyllid. Ineffective treatments included carbaryl, Safers Insecticidal Soap, methoxychlor, and Pyrenone.

Cranshaw, W.S. 1985. Control of potato insects with soap sprays, Greeley, CO, 1984. *Insecticide and Acaricide Tests*. 10: 133.

In a comparison between a commercial dishwashing detergent (Ivory Dishwashing Detergent) and Safers Insecticidal Soap, the dishwashing detergent was superior in controlling potato psyllid.

Cranshaw, W.S. 1985. Control of potato insects with soil applied systemic insecticides, Greeley, CO, 1984. *Insecticide and Acaricide Tests*. 10: 133.

In a comparison of soil-applied systemic insecticides, all carbamate insecticides (aldicarb, carbofuran, cloethiocarb) not only failed to control potato psyllid but caused significantly higher populations to occur on foliage foliage of treated plants, compared to the untreated check.

Cranshaw, W.S. 1989. Potato insect control, 1986. *Insecticide and Acaricide Tests*. 14: 136.

All pyrethroid insecticides (esfenvalerate, fenvalerate, cyfluthrin, bifenthrin) provided good control of potato psyllid in this trial.

Cranshaw, W.S. 1989. Potato insect control, 1987. *Insecticide and Acaricide Tests*. 14: 136.

All pyrethroid insecticides (esfenvalerate, fenvalerate, cyfluthrin) provided good control of potato psyllid in this trial.

Cranshaw, W.S. 1989. The potato/tomato psyllid as a vegetable insect pest. *Proc., 18th Ann. Crop Prot. Inst., Colo. St. Univ.* pp 69-76.

A review of the biology of potato tomato psyllid and its relationship with the toxicogenic condition psyllid yellows is given. An evaluation of psyllid populations on different potato cultivars found only modest differences with WC 230-14, thought to be a psyllid-tolerant cultivar, being the most heavily infested in both study years. Among potato cultivars, psyllid populations were not well correlated with yield suppression effects from psyllids, suggesting a tolerance mechanism in potato cultivars to psyllid yellows. Populations on tomatoes showed several different patterns of infestation. In addition to cultivars which were consistently infested at high, moderate, or low levels, some showed seasonal shifts, e.g., being little infested early in the season but being heavily infested at the seasons end, or vice versa. As occurred with potatoes, there appeared to be a wide range in tolerance to psyllid yellows among 8 tomato cultivars tested in 1987. Peppers showed very little response to psyllid injury, although they are regularly the most heavily infested plant during the early season. One cultivar (Anaheim) had greatly increased yields when infested with psyllids, compared to the psyllid control plots. Most organophosphates, pyrethroids, and endosulfan products appear to give acceptable psyllid control, provided application to leaf undersides is thorough. However, soil applied carbamate insecticides have not been consistently effective in test plots and have also been involved in reports of field failures.

Cranshaw, W.S., and Liewehr, D.J. 1990. Effects of colored sprays on aphid and psyllid colonization of potatoes. *Southwestern Entomologist* 15 (2): 205-209.

Sprays that leave a visibly colored reesidue were applied to potato foliage to determine effects on potato insect pest populations. Fungicides used in the studies included yellow-colored wettable powder fungicides, maneb (Dithane M45, Maneb 80) and a white-colored flowable fungicide, chlorothalonil (Bravo 500). Additional treatments were a limestone based whitewash and the white-colored inorganic insecticide sodium fluoaluminate (Kryocide 96W). In 1984 and 1985 no significant differences were observed in green peach aphid, *Myzus persicae* Sulzer, and potato psyllid, *Paratrioza cockerelli* Sulc, captures in alighting traps or in insect populations on plants following fungice treatments. Kryocide treatment was associated with a significant increase in apterous green peach aphid populations in 1985 and 1987. Significant increases in potato psyllid and *Empoasca* sp. leafhoppers also occurred on Kryocide treated plots in 1987.

Cranshaw, W. S. and Knutson, K. 1987. Potato or tomato psyllids in home gardens. *Colo. State Univ. Service-in-Action 5.540.* 2 pp.

A simplified description of potato psyllid injury and its prevention is given in this Extension circular. Diazinon and insecticidal soaps are recommended as controls.

Crawford, D. L. 1910. American Psyllidae I. (Triozinae). *Pomona Journal of Entomology.* 2(2):228-237. (Ref.)

-------- 1911. American Psyllidae III. (Triozinae). *Pomona Journal Entomology.* 3:[421]-453. (Ref.)

Given is a synopsis of the genus *Paratrioza.* Also, a description of *Paratrioza cockerelli* morphology is presented.

-------- 1914. A monograph of the jumping plant-lice or psyllidae of the new world. *U.S. Natl. Mus. Bull.* 85, 186 pp.

Paratrioza cockerelli is described. Since describing *P. ocellata* (Crawford '11a: 447) as a new species closely related to *cockerelli,* the author has had an opportunity to examine many more specimens from many localities, and has come to the conclusion that all these represent but one species more or less variable in some respects. The variation in degree of coloration is so marked and continuous that it seems useless to try to distinguish the varietal forms *nigra* and *flava.*

-------- 1935. Some reports on potato diseases. *Plant Disease Reporter.* 19(12):202.

Psyllid yellows is one of the most important diseases attacking potatoes in New Mexico and was especially severe this season.

Daniels, L. B. 1934. The tomato psyllid and the control of psyllid yellows of potatoes. *Colo. Agr. Exp. Stn. Bull. no. 410.* 18 pp.

An account is given of the bionomics and distribution of *Paratrioza cockerelli* Sulc, which has been known to cause psyllid-yellows of potatoes in Colorado since 1927. It shows a preference for wild and cultivated solanaceous plants. Hot, dry seasons have been considered most favorable for Psyllid injury, and the result of attack is a poor yield composed largely of small potatoes. During feeding, the stylet-like mouth parts of the Psyllid penetrate the cells of the leaf, and a secretion from the salivary glands is probably forced in. The agent causing the changes in the growth of tomato and potato plants is still undetermined, but field and laboratory work suggested that it may possibly be an enzyme. Histological examination of stems from infested plants showed that the vascular system, by which food materials are transported from the leaves to the roots, is broken down and the destruction of internal phloem leaves a yellowish-brown or black mass. The large quantity of starch present in the pith of the stem indicated that the transfer of sugar from the leaves to the tubers had been interrupted. In control experiments in various districts during 1932 and 1933 lime-sulphur (1 gal. lime-sulphur, 30-33° Be., to 40 gals. water) gave the most satisfactory results. In 1933, tests on fields of early and late potatoes showed that the yield was always increased and sometimes trebled by treatment. Spraying should be carried out at sufficient pressure to cover the lower surfaces of the leaves completely, and should begin very soon after the Psyllids appear in the fields. At least two applications should be made, the second about two weeks after the first. If leaf-eating beetles are present, 2 lb. zinc arsenite may be added to each 40 U.S. gals. lime-sulphur. Against the psyllid on tomatoes 1 gal. lime-sulphur to 45 or 50 gals. water may be used, but care is needed because tomatoes are more sensitive to this spray than potatoes.

——— 1937. Controlling Colorado potato pests. *Colo. Expt. Stn. Bull. no. 437.* 35 pp.

An account is given of the bionomics of *Paratrioza cockerelli* Sulc. The Psyllid is best controlled by a spray of 1 gal. liquid lime-sulphur (which should have a high polysulphide content and a specific gravity of 32° Be.) in 40 gals. water, delivered at a pressure of 200-300 lb. During the last two or three years, a combination spray of 2 lb. zinc arsenite, 1 U.S. gal. lime-sulphur and 40 U.S. gals. water has been extensively and successfully used against all these pests in Colorado. An account of spraying and dusting equipment is appended.

——— 1939. Appearance of a new potato disease in northeastern Colorado. *Science* 90(2334):273.

During the summer of 1939, many fields of potatoes in northeastern Colorado were affected by the feeding of the pentatomid, *Chlorochroa sayi* Stal. The symptoms were very similar to those of psyllid yellows, caused by *Paratrioza cockerelli* Sulc, and consisted in wilting of the leaves and tips, a basal curling and yellowish discoloration of the terminal leaves, and, in cases of severe infestation, malformation of the tubers. Plants attacked by 3-4 bugs were only mildly affected, but those on which about 20 occurred showed extreme symptoms. In one area the percentage of plants affected amounted to 50 to 60.

——— 1939. One of the worst outbreaks of psyllid yellows known in Colorado. *Plant Disease Reporter*. 23(1):3-4.

In 1938 we experienced the worst outbreak of psyllid yellows in the history of the State, as far as we have history of the past years in the potato industry. The epidemic has been widespread, not only through the northeastern part of the State but through the mountainous sections, the San Luis Valley, and in Montrose County of the Western Slope. It is interesting to note that no heavy infestation occurred at Grand Junction where the disease was first noted in 1927. General spraying in the heavier infested areas aided in checking the disease to the point where good yields were obtained. Unsprayed fields in many cases were not dug this season. The estimated damage in the San Luis Valley, our most important potato section, has been particularly fortunate in being prepared for just such an epidemic through our experience with the disease since 1927. Spray equipment and an adequate supply of spray materials has made it possible to obtain at least a partial crop of potatoes.

——— 1941. Colorado potato pests. *Bull. Colo. Exp. Stn. Bull. no. 465.* 28 pp.

Summary:

1. The years 1911 and 1931 were the worst psyllid years recorded to date in Colorado.
2. Psyllids are most injurious during dry, hot years.
3. The green, scale-like nymphs are the direct cause of psyllid yellows.
4. In a favorable year there may be from 8 to 10 generations of psyllids.
5. The number of psyllids on a plant determines the extent to which it is diseased.
6. Patches of wild native groundcherry are the early season breeding grounds for psyllids.
7. A power sprayer is necessary for the most satisfactory control of psyllids.
8. For psyllid control a sprayer should develop from 200 to 300 pounds pressure and deliver material at a rate sufficient to thoroughly cover the plant.
9. It is important to reach the under sides of the lower leaves.
10. A standard grade of liquid lime-sulphur is most satisfactory.
11. Liquid lime-sulphur should have a high polysulfide content and a specific gravity of 32 degrees Baume, and should be low in sludge.
12. Dry lime-sulphur may be substituted for liquid, but the grower should be well informed as to its disadvantages.
13. The formula for control of psyllids on potatoes is 1 gallon of liquid lime-sulphur, or from 4 to 5 pounds of dry lime-sulphur, to 40 gallons of water.
14. Two applications of lime-sulphur spray are necessary. The first application should be made when plants are from 6 to 8 inches high. The second application should be made from 2 to 3 weeks after the first.

-------- 1954. The nature of the toxicogenic condition resulting from the feeding of the tomato psyllid *Paratrioza cockerelli* (Sulc). *Ph.D. Dissertation. Univ. Minnesota.* 119 pp.

There are five important solanaceous hosts other than tomato and potato which serve as breeding hosts for the tomato psyllid *Paratrioza cockerelli* (Sulc). Matrimony vine *Lycium halimifolium*, a perennial, and buffalo bur *Solanum rostratum*, an annual, occur with very high populations during the epidemic seasons in Colorado. The ground cherries *Physalis* have a wide distribution and are of secondary importance as hosts for psyllid. Psyllids occur annually. Appearance of adults in the spring has been recorded as early as April 30th, but usually they have been taken during the month of May, on ground cherry, cull potatoes, or matrimony vine. The numbers per 100 sweeps have been found to indicate what may be expected. Numbers from 20 to 60 for 100 sweeps portend an outbreak of considerable severity. The sudden excessive numbers appearing on certain dates indicate that there is a migration or movement under way. The presence of available hosts such as early potatoes, matrimony vine, and other solanaceous plants provides the necessary requirements for propagation and reproduction. The adult psyllid, is an insect of small size with well developed wings for flight and well developed legs with powers for jumping, is ably equipped for withstanding the hazards of wind dissemination. The fecundity of the females and the promptness with which they begin to lay eggs are responsible for psyllid yellows. The presence of a number of nymphs in the early stages of development on a susceptible plant results in a disturbance in plant growth. The setal apparatus in the psyllid will measure two-thirds the length of the body. A secretion from the salivary glands is pumped into the tissues of the plant in the vicinity of the phloem. After the setal elements are introduced into the plant, the individual nymph has a tendency to keep them inserted, except at the time of molting, when it moves to a new site. The secretion must be acceptable in some degree to the plant, otherwise there would be evidence of more disturbance at the feeding site. From the point of introduction, mainly in leaves, it is carried throughout the plant. When it reaches the meristem, disturbances begin to appear. A symptom pattern develops and a typical syndrome of effect is observed. The effect is systemic and the pathological disturbance is closely related to the growth promoting hormones of the plant. Psyllid yellows has occurred with sufficient frequency and intensity within the past twenty-five years to be termed epidemic. The epidemic effect is noticeable in fluctuating potato yields. Twelve seasons since 1929 have been rated as severe or very severe for northern Colorado. The use of insecticidal measures has been effective since 1935, however, the influence of psyllid yellows can be recognized notwithstanding protective measures. Four years of observation with experimental epidemics have shown that the average length of time for psyllid yellows to appear is 18 days. The maximum incidence is reached in 48 days. Tall plants with the most foliage are infested first. The symptom pattern will vary, depending upon the number of nymphs feeding and the length of feeding time. Very intense reactions of rosetting, hyperplasia, and aerial tubers result from populations of over a hundred and up to one thousand per plant. Basal cupping of the leaflets accompanied by reddish coloration is a primary and important diagnostic character for the disease in potatoes. The presence of psyllid nymphs has been considered as a necessary criterion for positive identification under field conditions where environment influences symptom expression. The cumulative effect of retarded growth on the vines, the production of many small tubers in chains, with dormancy broken, result from psyllid yellows in potatoes. Tomatoes are more susceptible to psyllid feeding. The symptom pattern, though similar in many respects to that in potatoes, differs in that flower and fruit production are stimulated. The retarded growth, clusters of prematurely ripened small fruit, and malformed, narrow terminal foliage are characteristic. Symptom expression is dependent upon host susceptibility. Potatoes and tomatoes are susceptible. Peppers occasionally infested do not show psyllid yellows. The other solanums may show an effect from large populations in the form of a mild chlorosis or retarded growth. The age of the plant, its stage of development at the time of infestation influence symptom expression. Plants well along in their growth dissipate the effects of the psyllid toxin and the symptoms are milder. The number of psyllids feeding is a factor in symptom expression. Low numbers produce mild symptoms, large numbers very severe. The influence of environment on the host and the manner in which it affects the development of psyllid populations determine the intensity and the symptom pattern of psyllid yellows. Temperature, light, soil moisture, and soil alkalinity influence the syndrome and the appearance of disease. High light intensity and low temperatures found in the mountain valleys of Colorado are conducive to extreme forms of psyllid yellows. Overirrigation stimulates symptom expression. Critical experiments with psyllid nymphs on tomatoes have shown that there is a very definite phytotoxic effect, beginning with retarded growth, an erectness in the foliage, with chlorosis progressing into a reddish pigmentation and malforming of the foliage. The nymphs and adults both have the ability to cause these disturbances. The intensity and recovery are determined by the number feeding, length of time allowed to feed and the age of the plant. The larger number of nymphs or adults produced higher PY ratings in their host, and the host was less likely to recover. With lower numbers the effect was milder and recovery was more noticeable. Replicated adult feedings, with numbers as low as five for a 96 hour period, have shown strong phytotoxic reactions. Relative potency tests using single nymphs followed through to adulthood and allowing the adult to feed a corresponding length of time on nine day old tomato plants gave striking similarities in PY ratings. However, there appeared to be some difference between individual nymphs in relative potency. In 66 paired nymphal and adult feedings, the symptoms varied from mild to severe. Seventeen were given ratings of PY4. Five pairs had nymphal ratings of PY4 and adult ratings of PY5. Fifteen pairs reached a severity of PY5. Thirty-one pairs were mild, with PY1 to PY3. Tests with plants heavily laden with psyllid toxin have shown that tissue grafts into healthy plants carry over the phytotoxic principle in sufficient amount to cause psyllid yellows, but subsequent grafts indicate a gradual recovery in the form of a reversible reaction. Experiments on defoliation with heavily laden plants result in intense display of the influence upon the meristematic tissues. Vegetative propagation experiments have demonstrated further the subsequent dissipation of phytotoxic principle and gradual recovery. The feeding of psyllids on leaf-roll and aster yellows infected plants has failed to show positive evidence of transmission. The similarities in symptoms of the two diseases with psyllid yellows, and the high incidence with which they occur in association with it have made it necessary to contrast their characteristics.

Davis, A. C. 1937. Observations on the life history of *Paratrioza cockerelli* (Sulc) in southern California. *J. Econ. Entomol.* 30(2):377-378.

The following observations upon the potato psyllid, *Paratrioza cockerelli* (Sulc), were made at Santa Anna, Calif., during April and May 1931, while the writer was employed as assistant in entomology and parasitology at the University of California. The insects were kept in lantern-globe cages having tops of cheesecloth or fine-mesh wire screen. A twig of pepper (*Capsicum*) or tomato (*Lycopersicum*) plant was inserted through a hole in a cork which was fitted in a small bottle of water, the space between the stem and the cork was plugged with cotton, and the whole was placed in the cage. Under these conditions the twigs kept fresh for a long time. Pepper twigs were used in most cases, since it was found that the female did not deposit so many eggs and the young nymphs did not seem to be able to do so well on the pubescent surface of tomato leaves. The cages containing the insects were placed in the insectary under natural conditions of humidity and temperature. This insect has been cited a number of times in literature since its description in 1909. Most of the references deal with its systematic position or are brief notes on its presence and relation to the potato yellows disease. The most important references to the life history of the insect are the papers of Compere (Calif. Mo. Bull. 5:189-191. 1916), Essig (Jour. Econ. Ent. 10:(3)433-9. 1917), and Knowlton & Janes (Ann. Ent. Soc. Amer. 24:283-290. 1931), all of which describe and figure the various stages. The eggs are elongate, yellow, and supported upon a short stalk or stipe. On pepper foliage they are laid along the edges of the leaves, relatively few being scattered over the leaf surface, but upon tomato they are laid by several females, 92, or 11.67 per cent, did not hatch. The incubation period for 91 eggs ranged from 7 to 11 days, with an average of 8.7 days. When the nymph hatches it is attached to the egg by a very fine coiled thread, presumably to prevent it from being blown away or shaken from the plant before it can make its way down the egg stalk and secure a hold upon the leaf surface. In spite of this, mortality is very high among nymphs in the first stadium. Of the 696 eggs that hatched, only 388, of 55.75 per cent, survived to enter the second stadium. Once the nymphs have undergone the first molt the mortality decreases although it remains high. Of 176 eggs from various females, 52 adults were reared, a total loss of 70.5 per cent from egg to adult. Judging from the limited data at hand, there appear to have been but three nymphal instars, but although the observations were carefully made, it is possible that one molt might have been missed. There is a great deal of variation among individuals, even in nymphs kept upon the same twig, in the time required for development from egg to adult. Eggs that hatched upon the same day required from 29 to 34 days to complete the life cycle. Of 267 adults reared in the insectary, this period ranged from 19 to 42 days, with an average of 31.2 days. There seems to be little or no difference in the length of time required by the two sexes. Of 545 adults reared in the insectary, 339 were males and 206 females, giving a sex ratio of 62 to 37, or approximately 3 to 2. Oviposition data on 11 females reared in the insectary are given in table 1. Females will sometimes mate within an hour or two after emergence, but it is believed that normally 24 hours or more elapse before mating. Females reared in the insectary were placed in cages, each with a male, and mating usually occurred the second or third day after emergence. The first eggs were laid two to eight days after emergence, or from 1+ to six or seven days after mating, the average number of days from the time of caging pairs together until the first egg was found being six days.

Edmundson, W. C. 1940. The effect of psyllid injury on the vigor of seed potatoes. *Am. Potato J.* 17(2):315-317.

Psyllid yellows was first described by Richards in 1927. It is one of the most serious maladies affecting potatoes in the Rocky Mountain region and adjoining states, and is produced by a tiny insect known as the potato or tomato psyllid. In order to determine the effect of psyllid injury on the vigor of seed potatoes, studies were conducted in 1939, using seed tubers that had been produced the previous season on plants showing a wide range of psyllid symptoms. In 1938 the variety Triumph was planted at Greeley and Estes Park. In each location one series of plots was sprayed and one unsprayed. One gallon of liquid lime sulphur was mixed with forty gallons of water. The sprayed plots at Greeley were power sprayed three times, using 450 pounds pressure. The plants and tubers developed normally, giving no indication of psyllid yellows and producing 360 bushels of U. S. No. I tubers on each acre. The unsprayed plots at Greeley produced a normal set of tubers, but the plants developed medium severe vine injury, producing only 190 bushels per acre of U.S. No. I tubers. The sprayed plots at Estes Park received two applications. Tractor equipment was used which developed about 250 pounds pressure. A large population of psyllids was present at Estes Park, resulting in severe vine injury and although there was a fairly normal set of tubers in the sprayed plots, the yield was very low. The unsprayed plots at Estes Park were very heavily infested with psyllids, several hundred nymphs being found per plant. Vine injury was very severe and on each plant a large number of tubers was set, all of which were small at time of harvest. In seasons when psyllid injury occurs in the Rocky Mountain region, these insects are usually more abundant in the mountainous area than in the prairie area. This was especially true during the season of 1938. All the plots were harvested during the last week of September. Tubers weighing from 1 1/4 to 1 1/2 ounces were selected for planting the test plot the following year. These were stored in the potato house at Greeley until the first of April, then placed in cold storage until the first of June. The tubers from the unsprayed plants at Estes Park began to sprout in November. On December 10, the sprouts were removed. There was also some sprouting of the tubers from the sprayed plots at Estes Park. The sprouts were again removed when the tubers were placed in cold storage on the first of April. Tubers from the unsprayed plots had the most sprouts and the longest. The rest period appeared to be broken entirely,-- soon after harvest; there was no apical dominance and the sprouts were rather weak. The tubers from the sprayed and unsprayed plots at Greeley gave no evidence of sprouting at the time the seed was placed in cold storage. Plantings to test the vigor of the seed tubers were made at Greeley on the 12th of June. Each plot was a single row planted with thirty whole tubers spaced fourteen inches apart in the row. There were eight blocks and the plots were randomized in each block. Plots planted with seed tubers from sprayed and unsprayed plants at Greeley are designated as "No vine injury" and "Medium severe vine injury," and those planted with seed tubers from sprayed and unsprayed plants at Estes Park are designated "Severe vine injury" and "Very severe vine injury" as you will note in table 1. The plants in all plots were carefully examined during the summer of 1939, but no evidence was found of any disease carried by the seed tubers that could be connected in any way with psyllid yellows. The mean stand in the no vine injury plot was 99.1 per cent; medium severe vine injury, 97.9; severe vine injury, 87.9; and very severely injured plots 89.6 per cent. The seed pieces from plants having severe and very severe vine injury produced a significantly lower stand than seed pieces from vines showing medium severe or no injury. The analysis of variance shows that the difference in number of stems per plant is significant but not highly so. The size of the plant was determined by measuring the height and diameter of the largest stem. The diameter of the stem was measured about one inch above the surface of the ground. The largest plants were in the no vine injury plots. The smallest plants both as to height and thickness of stem were produced from the seed of plants that were very heavily affected by psyllid yellows as shown in table 1. Many of the stems were weak and decumbent. There was also much irregularity in the size of the plants. Plots were harvested on the 25th of September and the tubers graded and weighed. Where vines were uninjured the plots gave the largest yield, and the production decreased significantly with increasing severity of injury to seed parents. These studies indicate that seed tubers produced from plants showing medium severe vine injury may produce good yields but that tubers produced from plants showing severe vine injury do not. One year's results, however, should not be taken as positive proof that medium heavy vine infection has little effect on vigor of seed. These tests cannot be repeated in 1940, because of the light infestation of psyllids in 1939 on the seed plots and throughout the Rocky Mountain region. Plans are being made to repeat these tests when psyllids appear on the plants in sufficient numbers to cause severe yellowing.

Elmer, O. H. 1939. Psyllid yellows not noted in Kansas. *Plant Disease Reporter*. 23(1):2.

There was no record of the presence of psyllid yellows in the State.

Essig, E. O. 1917. The tomato and laurel psyllids. *J. Econ. Entomol.* 10(4):433-444.

Some fifty species of psyllids occur in California, only two, the tomato Psyllid, *Paratrioza cockerelli* Sulc, and the laurel Psyllid, *Trioza alacris* Flor, being considered of economic importance. The former is widely distributed in the State, mainly infesting solanaceous food-plants, but also attacking others. Hibernation takes place in the adult stage on evergreen plants. Oviposition occurs from April until late in the year, so that all stages are found from May to November. When infestation becomes serious, which is seldom the case, care must be taken to use a spray that will not injure the delicate food-plants. Nicotine sulphate or Blacklear 40 may safely be used at the rate of 1:1,000 or 1,500. In Colorado, lime-sulphur proved the only successful control on tomatoes; used in the proportion 1:40 the Psyllids were killed without injury to the plants, though potatoes were seriously damaged by this spray.

Eyer, J. R. 1937. Physiology of psyllid yellows of potatoes. *J. Econ. Entomol.* 30(6):891-898.

A study in New Mexico of "Psyllid yellows" of potatoes caused by nymphs of *Paratrioza cockerelli* Sulc showed that, in addition to the mechanical rupturing of the cells and the withdrawal of carbohydrates, cell proteins are broken down, and such disintegration products as arginine, tyrosine and tryptophane were detected. Regardless of insecticides or fertilizers applied, diseased plants were markedly deficient in nitrates. The injury to the border parenchyma appears to be extended laterally, for sections through the midrib and petioles show necrosis of the phloem or principal carbohydrate-conducting tissues. The modification caused by injury in the distribution of carbohydrates in leaf, root, stem and tuber over a period of 24 hours are discussed in detail. In diseased plants, the chloroplasts are distorted and are smaller and more lightly pigmented than in healthy ones, and the percentage of chlorophyll and carotin is decreased.

Eyer, J. R. and Crawford, R. F. 1933. Observations on the feeding habits of the potato psyllid (*Paratrioza cockerelli* Sulc.) and the pathological history of the "psyllid yellows" which it produces. *J. Econ. Entomol.* 26(4):846-850.

Studies of histological sections of *Paratrioza cockerelli* in feeding position on potato foliage show the setal sheath penetrating the mesophyll into the border parenchyma immediately surrounding the vascular bundles. The majority of feeding seems to occur in this region. Further examinations of diseased leaves and stems reveal abnormally large deposits of chromoplastids, probably starch granules, in the chlorenchyma of the leaf and in the cortex and pith of the stem.

Eyer, J. R. and Miller, M. 1938. A study of the pathological anatomy of psyllid yellows with special reference to similar changes in sugar beets affected with curly top. *Phytopathology*. 28(9):669.

In a histological study of material from plants affected with psyllid yellows, 4 abnormalities were found. Phloem necrosis occurred in stems, stolons, roots, and lateral rootlets, being most severe in stems and stolons. Pseudocalluses in the sieve tubes, and an increase in number of sieve plugs also were observed. Nuclear changes were prominent in the companion cells, phloem parenchyma, pericycle, and cortex. These manifested themselves in the form of the flaky appearance of the nucleoplasm, beaded membrane and hypertrophy and contortion of the entire body. None of these abnormalities was observes in histological sections from healthy plants. Artschwager has reported very nearly the same malformations in his study of sugar beet seedlings affected with curly top.

Eyer, J. R. and Enzie, J. V. 1939. Dusting and spraying for the control of insect pests of the Irish potato. *N. Mex. Agr. Expt. Stn. Bull. 266*. 40 pp.

The most injurious insect pests of Irish potatoes in New Mexico are the potato psyllid, the western potato leaf hopper, and several species of flea beetles. The nymphs of the potato psyllid produce a disease known as psyllid yellows, which results in greatly decreased yields. It may be controlled through killing the psyllid nymphs with sprays of lime-sulphur or wettable sulfur, or with sulfur dusts. The timing of these applications is exceedingly important. In the case of the spring-planted crop, the first application should be made shortly after the first psyllid nymphs hatch. This usually takes place before blossoming, when the plants are about six inches high. The second application should be made from ten days to two weeks later, the shorter time interval being preferable if the psyllids are abundant. A third application is usually necessary ten days after the second is made. With late-planned potatoes this same timing schedule should be followed, although two sprays at two-week intervals are usually sufficient to protect the plants until maturity. Commercially prepared or homemade liquid lime-sulfur at the rate of 2 or 2 1/2 gallons to 100 gallons of water, or dry lime-sulfur at the rate of 5 pounds, or wettable sulfur at the rate of 6 pounds to 100 gallons of water, should be used. Bentonite clay or wettable sulfur added to the liquid or dry lime-sulfur spray at the rate of 1 to 2 pounds per 100 gallons forms an excellent spreader and sticker. A number of types of spray machinery are described. Only those developing sufficient nozzle pressure to coat thoroughly both upper and lower leaf surfaces are recommended. Sulfur dusts should be applied at the rate of not less than 25 pounds to the acre, using dusting machines which develop a forcible continuous stream of dust. Nitrogen and phosphate fertilizers for the purpose of encouraging vigorous growth are also mentioned as useful adjuncts to the timely use of insecticides.

Ferris, G. F. 1925. Observations on the Chermidae (Hemiptera; Homoptera). Part II. *Can. Entomol.* 57(2):46-50.

In this second installment of this work on Psyllidae descriptions are given of the nymphs of *Trioza urticae* L., and of *Paratrioza cockerelli* Sulc, these species being types of their respective genera, and of *Psylla* (*Psyllia*) *alni* L., which may or may not be the type of its genus, depending upon the view taken of a nomenclatorial difficulty.

Gardner, M. W. 1937. Diseases of plants in the U. S. in 1936. *Plant Disease Reporter, Supplement.* 103: 211.

Psyllid yellows (due to injury caused by the potato psyllid) was found at Colma, California, in October. This is the first report in California.

Gerhardt, P. D. 1966. Potato psyllid and green peach aphid control on Kennebec potatoes with Temik and other insecticides. *J. Econ. Entomol.* 59:9-11.

A 10% granular formulation of Temik (2-methyl-2-(methylthio)propionaldehyde O-(methylcarbamoyl)oxime) applied at 20 pounds per acre in the fertilizer band at planting time gave good season-long control of the potato psyllid, *Paratrioza cockerelli* (Sulc), and the green peach aphid, *Myzus persicae* (Sulzer), on Kennebec potatoes. Yields of marketable grades were substantially increased over the next best treatment and were more than twice that of the untreated check.

Gerhardt, P. D. and Turley, D. L. 1961. Control of certain potato insects in Arizona with soil applications of granulated phorate. *J. Econ. Entomol.* 54(6):1217-1221.

The principal insect pests of potato in Arizona requiring control are the potato psyllids, green peach aphids, leafhoppers and thrips. Of these the most serious pest is the potato psyllid, *Paratrioza cockerelli* (Sulc). A soil application of granules containing 10% phorate at the rate of 20 pounds per acre (2 pounds actual) made to Red Pontiac and Kennebec potatoes at time of planting gave good control of the potato psyllid and green peach aphid [*Myzus persicae* (Sulzer)]. Granules were applied approximately 2 inches below the seed piece and 4 to 5 inches to the side in the fertilizer band on one side only. The young plants did not readily pick up the phorate from the soil until after the first irrigation. Effective insect control was obtained for approximately 100 days after planting. A fertilizer-phorate mixture (0.2% phorate) applied to both sides of the seed piece also gave satisfactory control of psyllids and aphids. An aphid buildup may occur late in the growing season as the effectiveness of the phorate diminishes. Lack of psyllid control was found to reduce the potato yield by 50% or more.

Glick, P. A. 1939. The distribution of insects, spiders, and mites in the air. *USDA Tech. Bull. 673.* 151 pp.

Potato psyllid was the most abundant insect captured by airplane at all altitudes between 100 feet and 4000 feet in the Durango, Mexico area.

Goss, R. W. 1938. Psyllid yellows in central and eastern Nebraska. *Plant Disease Reporter.* 22(15):327-328.

The chief item of pathological interest in this state, since the wheat crop was harvested, is the very severe development of psyllid yellows. Psyllids are abundant on potatoes and tomatoes in central and eastern Nebraska for the first time. The damage on potatoes is very severe in small garden patches where the loss is at least 50 percent. In commercial fields of southcentral Nebraska the infestation is more spotted and chiefly on the margins of fields. In western Nebraska severe infestation occurred in the early planted fields and loss is severe enough so that some fields may not be harvested. Psyllids are also present in the late planted dry land fields of

northwestern Nebraska, where they have not commonly occurred in previous years. The amount of damage they will do in these fields is problematic, as there is no spray equipment available in any of this newly infested area. This is the typical psyllid yellows of potatoes and tomatoes and this particular infestation is interesting because of the invasion of additional territory. While no accurate surveys have previously been made in central and eastern Nebraska, we have never had any cause to suspect its presence. This year, however, the condition has been common on both potatoes and tomatoes. We have made careful surveys in the past throughout the western counties where certified potatoes are produced, and psyllid yellows - up to this year - has always been pretty much confined to Kimball, Banner, Scotts Bluff, and Morrill Counties. This year the infested area has extended north into Box Butte County and the infestation is severe enough so that we have had to purchase a sprayer for the experimental farm in that county. The spread of the trouble three or four hundred miles eastward this year raises the question whether there is any danger of its spreading into States east and north of us.

Harding, J. A. 1962. Tests with systemic insecticides for control of insects and certain diseases on potatoes. *J. Econ. Entomol.* 55(1):62-64.

Field tests with systemic insecticide treatments on Irish potatoes at planting in south Texas have shown that aphid, psyllid, and whitefly control was effective for 77 days and evident for 96 days after treatment. Flea beetle leaf injury was controlled. The incidence of obvious potato leafroll-psyllid yellows infected plants and potato crinkle plants was significantly reduced. Tuber yields were consistently increased. Phorate at 1.5 to 3, DiSyston (0,0-diethyl S-[2-(ethylthio)ethyl]phosphorodithioate) at 1.5 to 4, demeton at 1.5 to 3, and dimethoate at 3 pounds active ingredient per acre were most efficient.

Hartman, G. 1936. Potato psyllid control. *Wyo. Agr. Expt. Stn. Bull. 217.* 24 pp.

During the last few years the potato psyllid has caused very heavy losses in potato production in the state of Wyoming. A large number of tubers, only a few of which reach marketable size, are produced. The normal rest period of the tuber is disturbed, and the tubers sprout much earlier than is normal. Spraying with lime-sulphur solution was tested as a means of controlling the damage from potato psyllids. On the basis of net returns in money after deducting costs of spraying and extra costs of harvesting additional yields, two applications at the right time give larger net returns than one and as large or nearly as large as three. The best time of application appeared to be the early bloom stage for the first, and 15 to 17 days later for the second. On dry land the lowest net return from two applications was $4.95 per acre and the highest $24.75. On irrigated land the lowest was $16.91 and the highest $32.89. When potato psyllids are present in a potato field, the use of lime-sulphur as a spray is profitable. Two sprays applied at the right time seem to give the most profitable returns. The first spray should be applied at about the time the plants begin to bloom, followed two to three weeks later with the second application. The cost per acre for two applications, as determined in this study, is $3.25 per acre upon dry-land fields and $2.46 per acre upon irrigated fields. Potatoes appear to be bothered but little by potato psyllids until the plants have reached the budding or blooming stage of growth. Late planting appears to be a factor in controlling the damage done by the psyllids. During the season of 1935 late planted fields suffered less damage than the early planted ones. Lime-sulphur sprayed on the vines using a pressure of 300 pounds per square inch gave better control than lower pressures. To date, there is no indication that the symptoms produced upon potatoes by the action of the psyllids are in any way carried from one season to the next by seed tubers from infested fields. At present there is no known means of forecasting a serious infestation of psyllids or the extent of the damage which will be done in any season, even if it is known that the winter home of the psyllid is local.

——— 1937. A study of psyllid yellows in Wyoming. *Wyo. Agric. Expt. Stn. Bull. 220.* 40 pp.

The damage to the potato known generally as psyllid yellows is caused by the small potato or tomato psyllid, known scientifically as *Paratrioza cockerelli* Sulc. The losses in potato production caused by psyllids have been very severe in Wyoming during the past five or six years. It is now believed that the winter home of the potato psyllid is local. These insects probably increase to numbers sufficient to produce damaging infestations in potato fields by the latter part of June or the first part of July. The severity of the infestation appears to depend upon temperature conditions at this time. Potatoes in the field appear to be damaged but little, if any, by potato psyllids until they have reached the budding or early blooming stage of growth. Potato fields planted the first of June appear to be damaged to a lesser extent than fields planted before that time. Spraying potato vines before the first flower buds appear does not seem to benefit the potato plants and may result in injury. A few standard varieties appear to be partially resistant to the effects of the psyllid. These varieties may be used by the small grower for home consumption but are not to be recommended at the present time for the commercial potato grower in Wyoming.

Hill, R. E. 1947. An unusual weather sequence accompanying the severe potato psyllid outbreak of 1938 in Nebraska. *J. Kans. Entomol. Soc.* 20(3):88-92.

A study of the weather data for Scottsbluff, Nebraska, during the 26-year period, 1921-1946, shows that the summer of 1938 was peculiar, in that an extraordinarily wet July with very few hot days was followed by two months of exceptionally warm weather. It was in 1938 that Psyllid yellows was unusually severe and was responsible for an estimated loss of 25 percent of the commercial potato crop. From what is known of the seasonal life-history of the potato Psyllid (*Paratrioza cockerelli* Sulc), such a weather sequence provides conditions approaching the optimum for the development of a heavy population of this insect. The absence or infrequent occurrence of hot July days permits it to migrate to the late crop and there become established on the small plants at a time when the foliage offers little protection from the heat. Later, however, when the leaves are dense enough to shade the lower portions of the plants and the soil surface, relatively high temperatures become essential for the maintenance of optimum developmental conditions. In order for serious Psyllid injury to occur in late potato fields of western Nebraska, there appears to be needed a source of early infestation, cool, moist weather in late June and July and an unusually warm August and September. Sources of initial infestations are not fully understood, but the increasingly popular local practice of removing potential spring and early summer breeding places through the elimination of early potato plantings and volunteer growth on cull dumps should serve to curtail Psyllid populations considerably. Such practices greatly lessen chances of another serious Psyllid outbreak in this area.

Hill, R. E. and Tate, H. D. 1943. Increases in aphid populations on potato plants sprayed with zinc arsenite in western Nebraska. *J. Econ. Entomol.* 36(1):63-66.

The results are given of observations made in western Nebraska in 1941 on the increase of *Myzus persicae* Sulz., on experimental potato plantings that had been treated with a spray of zinc arsenite and lime-sulphur for the control of *Epitrix cucumeris* Harr., and *Paratrioza cockerelli* Sulc, and of additional investigations made in 1942 to determine more clearly the effect of different treatments on the Aphid populations. Zinc arsenite (40.3 per cent. As_2O_3) was applied in a spray, usually at a concentration of 2 lb. in 40 U.S. gals. spray with addition of 1 U.S. gal. liquid lime-sulphur, and Dutox (72 percent barium fluosilicate and 8 percent sodium fluoaluminate) as a dust in sulphur (usually 1:4) 1-4 times between 6th July and 23rd August. The results, which were estimated by sweeping the plants with an insect net and counting the Aphids on leaf samples, showed that although various species of Aphids were present, *M. persicae* was the only one that occurred in significant numbers, and that the population, in both treated and untreated plots, remained at a very low level until towards the end of August, after which there was a marked increase that continued until freezing temperatures occurred. The rate of increase was significantly higher on plants treated with zinc arsenite, particularly where two or more applications were made, than on untreated ones; some increase seemed to occur on plants treated with Dutox, but it was relatively slight. The lime-sulphur in the spray and the sulphur in the dust were shown to have no significant effect on the Aphid populations.

Hixson, E. 1938. *Paratrioza cockerelli* (Sulc) in Oklahoma. *J. Econ. Entomol.* 31(4):546.

An outbreak of the potato psyllid, *Paratrioza cockerelli* (Sulc.), occurred in the greenhouse planting of tomatoes at the Oklahoma Agricultural and mechanical College, Stillwater. The tomatoes were planted in the fall of 1937, but the infestation of psyllids was not noticed until March, 1938. The species was determined by C.F.W. Muesebeck of the U.S. Bureau of Entomology and Plant Quarantine. The psyllids were readily brought under control with lime sulfur, 1-45, as recommended by the Colorado Experiment Station. This spray left a residue on the tomato fruits that was most difficult to remove either by wiping with a dry or wet cloth.

Hodkinson, I. D. 1988. The Neartic Psylloidea (Insecta: Homoptera): An annotated check list. *J. Natural History.* 22:1179-1243.

The 302 species of jumping plant lice (Insecta: Homoptera: Psylloidea) recorded from the Neartic zoogeographical region are listed under their respective genera. Information is given on synonymy, host plants and distribution; and the taxonomic position of problematical species is discussed. A list of host-plants and their associated psyllids is also included.

Hungerford, C. W. 1929. Psyllid yellows. *Plant Disease Reporter, Supplement.* 68:29. (Ref.)

—— 1933. [Insect pests in New Mexico in 1931-32.] *Rep. New Mexico Agr. Exp. Stn.* 43:38-49.

The most abundant insect vector of disease in tomato fields was *Eutettix tenella* Baker. The adults appeared about 15th June, reaching a maximum late in the month, by which time symptoms of "western yellow blight" were becoming evident. *Paratrioza cockerelli* Sulc, was also present, but no "Psyllid yellows" was observed. When 5-25 adults of *E. tenella* were placed on tomato plants in cages, yellow blight developed in 10-21 days, the plants becoming dwarfed and fruitless. Young plants infested with more than 50 of the leafhoppers rapidly died. In potato fields *P. cockerelli* caused Psyllid yellows, and *Empoasca abrupta* DeLong, etiolation and hopperburn; the former, although more local was more important in lowering the crop yield. The overwintered adults of *E. abrupta* first appeared about 25th April and were abundant by 15th May. *P. cockerelli* became active a week later and was not abundant until early June. In cage observations this psyllid was found to have two complete generations in the season in one district. In the field, symptoms of psyllid yellows appeared 2-3 weeks after *P. cockerelli* had begun feeding, whereas plants protected by cages remained healthy. In the greenhouse, infested plants became etiolated and abnormal but never developed typical symptoms. The feeding of the adults on the spongy mesophyll and phloem interferes with the translocation of starch to the developing tubers. Some control of both species was obtained with Bordeaux-oil-nicotine sprays and Bordeaux dusts.

—— 1934. [Insect pests in New Mexico in 1932-33.] *Rep. New Mexico Agr. Exp. Stn.* 44:36-44. Sprays of Bordeaux mixture (5:5:50), alone or with 1 gal. Volck oil and 1 pint nicotine sulphate to 100 gals. or with 1 pint rotenone extract, applied against the potato Psyllid [*Paratrioza cockerelli* Sulc] noticeably increased the yield of potatoes.

—— 1935. [Insect pests in New Mexico in 1933-34.] *Rep. New Mexico Agr. Exp. Stn.* 45:36-42.

It appears that psyllid yellows of potatoes is a condition caused by the feeding of the potato Psyllid (*Paratrioza cockerelli* Sulc), which results in the degeneration of the chloroplast and the alteration of the carbohydrate metabolism. Sprays of lime-sulphur gave better control than combinations of oil and nicotine, but the use of nicotine is necessary against the western potato leafhopper (*Empoasca abrupta* DeLong).

—— 1939. [Insect pests in New Mexico in 1937-38.] *Rep. New Mexico Agr. Exp. Stn.* 49:43-57.

The effect on the yield of potatoes of dusts of sulphur and bentonite sulphur, both with 4 percent nicotine dust, and of sprays of 2 1/2 U.S. gals. liquid lime-sulphur or 5 lb. dry lime-sulphur, both with 2 lb. Kolofog [bentonite sulphur], in 100 U.S. gals. water, applied [against *Paratrioza cockerelli* Sulc] for the control of Psyllid yellows, was tested in New Mexico in 1937 and 1938. The dusts were used at the rate of 20 lb. per acre. The yields per acre from certified seed from Colorado varied from 15,053 t 18.872 lb., after the various treatments, with no significant difference between the yields after the use of the dusts and liquid lime-sulphur spray, which were superior to the spray of dry lime-sulphur, and those from seed from the same strain, but grown for one year in New Mexico, varied from 9,779 to 12,954 lb., with no significant difference between the four treatments. The control plots gave 9,708 and 6,851 lb. per acre, respectively.

—— 1941. [Insect pests in New Mexico in 1940-41.] *Rep. New Mexico Agr. Exp. Stn.* 1940-41. 52:48-62.

Work on the control of *Paratrioza cockerelli* Sulc, on potato was also continued. In comparative experiments with yellow dusting sulphur and liquid lime-sulphur, each applied alone or in combination with nicotine or an arsenical, the highest yields (33,070 and 32,686 lb. per acre) followed applications of a spray containing 2 gals. liquid lime-sulphur and 1 pint nicotine sulphate in 100 gals. water and yellow dusting sulphur alone, respectively; the highest percentage of first grade tubers was obtained from plants receiving the dust. Yellow dusting suylphur applied at intervals of 7, 10 or 14 days gave higher yields than weekly applications of lime-sulphur alone, and the yields increased with the frequency of the applications. When different types of sulphur dust, yellow dusting sulphur in combination with copper fungicides, pyrethrum or dry lime-sulphur, and a spray of wettable sulphur alone or in combination with a copper fungicide were compared, yellow dusting sulphur to which was added 6 per cent. of a proprietary brand of yellow cuprous oxide produced the highest yield (25,021 lb. per acre). All the dusts, except one containing 50 per cent. yellow sulphur dust, 25 per cent. monohydrated copper sulphate and 25 per cent. hydrated lime, were superior to wettable sulphur. The results of all experiments on the control of *P. cockerelli* were statistically significant.

Janes, M. J. 1937. *Paratrioza cockerelli* (Sulc) on tomatoes in southwest Texas. *J. Econ. Entomol.* 30(2): 379.

An infestation of the tomato psyllid, *Paratrioza cockerelli* (Sulc), was found for the first time in the Winter Garden area of Texas during the fall of 1936. The insect bred on tomatoes during October and November, causing noticeable damage in several localities. Nymphs and eggs were present in most places, sometimes in abundance. Adults were found in every tomato field examined. The species was widely distributed in Maverick, Dimmit, Zavala and Webb counties.

——— 1939. Observations on the potato psyllid in southwest Texas. *J. Econ. Entomol.* 32:468.

During the past two years of observations have been made on the seasonal activities and extent of damage caused by the potato psyllid, *Paratrioza cockerelli* (Sulc), in southwest Texas. The insects were found widely distributed on tomato plants in Maverick, Dimmit, Zavala and Webb counties in the fall of 1936 (Janes 1937) and since that time have occurred on tomatoes whenever this crop has been grown. Injury in general on tomatoes, however, has been comparatively light with only localized seedbeds or fields being severely infested. Injury to Irish potatoes on the hand has been severe. During the spring of 11938 every planting examined at Carrizo Springs was heavily infested with psyllids. "Psyllid yellows," the disease for which these insects are responsible, was very much in evidence and in some fields 100 per cent of the plants were severely affected. In the later cases the crops were a total loss. The insects were also found on eggplants and peppers, in low numbers. Dry lime sulfur spray and sulfur dust gave promising results in preliminary tests on control. Three important native host plants of *Paratrioza cockerelli* were observed during 1938. The plants are as follows: *Lycium carolinianum* Walt., var. *quadrifidum* (Moc. & Sesse ex Dunal) C. L. Hitchc., *Physalis mollis* Nutt. and *Solanum triquetrum* Cav. *P. mollis* is widespread and abundant, occurring in cultivated areas and on land still covered with native brush. Psyllids were found on these plants whenever examinations were made; they often occurred in abundance. These native host plants make possible a considerable survival of the psyllids from season to season.

Jensen, D. D. 1954. Notes on the potato psyllid, *Paratrioza cockerelli* (Sulc.). *Pan-Pacific Entomol.* 30: 161-165.

This paper discusses observations on the migration patterns of potato psyllid. Evidence is presented that migrations between summer sites in southern Idaho, Utah and Arizona and overwintering areas in southern California can be explained by local weather patterns in spring and fall. During these migrations large numbers could be found in mountainous areas on various non-solanaceous hosts including *Arctostaphylos pungens*, *Garrya flavescens*, *Lepidospartum squamatum*, and *Pinus monophyllum*; *Ephedra* sp. were heavily colonized in San Bernadino County during early April.

——— 1957. Parasites of the Psyllidae. *Hilgardia.* 27: 71-98.

Although most the species parasitic on psyllids develop within the body cavity of the nymph, this is not the case with *Tetrastichus triozae* Burks. Females of this species temporarily paralyze the nymphs of *Paratrioza cockerelli* (Sulc) and then laid eggs on the ventral surface of psyllid nymph's body. After hatching the parasite larva remained outside the body wall of the nymph during its feeding and development, but cut its emergence hole through the dorsal surface of the nymphal shell. In the present study, *Tetrastichus triozae* has been reared from at least nine additional species of psyllids.

Jensen, J. H. 1939. Psyllid yellows in Nebraska - 1938. *Plant Disease Reporter.* 23(2):35-36.

Psyllid yellows disease of potatoes caused widespread losses in Nebraska's 1938 potato crop. In the western section of the State, where most of the commercial crop is produced, losses in individual fields ranged from none to slight or complete. In the irrigated areas in the western section, this early crop was especially seriously affected. In many cases growers did not dig the crop at all, owing to the low yields of yellows-diseased fields. The late season crop was also damaged in the irrigated section, but many growers were able to cut their losses to a minimum by timely and adequate spraying with lime-sulphur for control of the insects. Reduction in yields in dry-land areas in the western section were, as a rule, not as serious as those in irrigated areas. Even in the dry-land areas, however, almost complete losses were suffered in some cases. In slightly affected areas the disease occurred in border rows or at one end of the field in many plantings. Losses ranged from slight to moderate in the early commercial potato crop section in central Nebraska, where most of the production is under irrigation. Throughout the remainder of the State, where almost all potatoes are grown in small gardens for home use, the damage varied widely. Some small patches suffered complete loss, some partial losses, usually restricted to border rows or at one end of the field, whereas still other patches apparently were not attacked.

Johnson, S. A. 1911. The tomato psyllid. *Col. Expt. Stn. News Notes*. (Ref.)

Johnson, T. E. 1971. The effectiveness of *Tetrastichus triozae* Burks (Hymenoptera: Eulophidae) as a biological control agent of *Paratrioza cockerelli* (Sulc.) (Homoptera: Psyllidae) in north central Colorado. *M.S. Thesis, Colo. State Univ.* 45 pp.

This study was undertaken to determine some of the factors affecting the value of the parasite, *Tetrastichus triozae* Burks, as a control agent of the potato psyllid, *Paratrioza cockerelli* (Sulc.), in the potato growing areas of Weld and Morgan counties. Field observations revealed that the parasite appeared after the spring psyllid infestation had declined and that the parasite population had declined by the time the fall psyllid infestation had built up again. Parasite pupal mortality ranged from 38-100% in the field populations. The time of appearance and high pupal mortality appeared to reduce the effectiveness of the parasite. In the laboratory, the parasite and psyllid cycles were synchronized in relation to time of development. Because the parasite attacked only fourth and fifth instar psyllid nymphs, the parasite could not prevent psyllid yellows from killing the potato plants. This makes mass releases economically unfeasible in commercial fields. However the parasite was efficient in the laboratory at controlling the psyllid populations indicating that the parasite might be of value as a biological control agent in the overwintering areas. Parasite dispersal was very rapid when the distance between host plants was 5 feet or less; distances of 7-30 feet greatly reduced dispersal. This may account for localization of the parasites. The cause of the high pupal mortality was not ascertained, but disease and predators may have been partially responsible.

Klyver, F. D. 1931. California psyllids of present and potential economic importance. *Dept. of Agr. Monthly Bull., State of California*. 20:691-697. (Ref.)

—— 1931. Chermidae from Utah, Nevada, and Arizona, including three new species (Homoptera). *Pan-Pacific Entomol*. 7(3):142-143.

A list of host plants and the psyllids distribution are included in this report with a general description of the species.

—— 1932. Biological notes and new records of North American Chermidae (Homoptera). *Entomol. News*. 43:34.

Given is a list of the areas of distribution in the states of Arizona, California, New Mexico, and Utah along with their host plants. The nymphs of this species are found on the ventral side of the leaves, on the calyx, and the fruit, the eggs being most common on the younger growth as far as available records show. The nymphs are oval in outline, and closely appressed to the leaf in shallow depressions. The younger nymphs are orange in color, the older nymphs have pale green bodies with the wing pads orange, and the eggs are yellow. This species is evidently of considerable, but imperfectly known, economic importance. There is evidence that it may be of some importance as a carrier of pathogenic organisms infesting economic plants.

Knowlton, G. F. 1933. Aphis lion predators of the potato psyllid. *J. Econ. Entomol.* 26:977.

Aphis lions have been observed to destroy psyllid nymphs under field conditions. A half-grown aphis lion (*Chrysopa* sp.) was placed in a 3-dram homeopathic vial with 14 adult potato psyllids, *Paratrioza cockerelli* (Sulc). The aphis lion immediately seized a psyllid and fed upon it for 13 minutes. Four minutes later a second psyllid was captured, the mandibles being first sunk ventrally into the body, one into the thorax and the other into the abdomen. The position of the mandibles was shifted several times during the course of feeding, the front tarsi sometimes being used to shift the prey. Feeding lasted for two minutes. Another psyllid was captured two minutes later and fed upon for nine minutes. The next psyllid was captured in less than one minute, its dead body being discarded at the end of four minutes of feeding. Two minutes later another psyllid was captured. During the nine minutes of feeding the aphis lion frequently changed the position of its mandibles, leaving the psyllid in a very much mangled condition. This predator killed and sucked the fluids from five *P. cockerelli* adults in 46 minutes. Another aphis lion was placed in a 3-dram vial with a number of *P. cockerelli* nymphs; within 35 minutes nine nymphs had been killed, the feeding interval upon each being 2, 2, 1, 2, 4, 1, 2, 1/2, and 1/2 minutes to each one, respectively.

---- 1933. Ladybird beetles as predators of the potato psyllid. Can. Entomol. 65(11):241-243.
Adults (and in most cases nymphs also) of *Paratrioza cockerelli* Sulc, were attacked in the laboratory in the spring of 1933 by the larvae and adults of *Hippodamia convergens* Guer., and the adults of *H. americana* Crotch, *H. lecontei* var. *uteana* Csy., *H. quinquesignata* Kby., and *H. tredecimpunctata* L. These coccinellids probably aid in the control of the Psyllid in Utah, as the larvae and adults are reasonably abundant wherever potatoes are grown.

---- 1933. Length of adult life of *Paratrioza cockerelli* (Sulc). J. Econ. Entomol. 26(3):730.

Data based on a limited number of cage tests are given on the longevity of adults of *Paratrioza cockerelli* Sulc, in Utah on 21 plant species upon which the nymphs have not been found to develop. The number of days of survival noted varies from 17 on honeysuckle to 96 on Douglas fir [*Pseudotsuga taxifolia*], and the adults probably survive much longer under favorable conditions. The ability to survive on these plants doubtless helps to keep the adults alive from the time that potatoes and other breeding plants mature or are killed by frost until the winter hibernation period, and again in spring until breeding plants become available. The majority of the breeding plants hitherto observed in Utah, most of which are Solanaceous, are not available in early spring or late autumn.

---- 1933. Notes on injurious Utah insects: Potato psyllid. *Proc. Utah Acad. Sci.* 10:153.

The relation of climate and weather to seasonal and periodic abundance of the potato psyllid is not as yet fully understood. Heat and drought appear to greatly retard normal reproductive activity, while the winter season, in most of Utah, is a season of hibernation and inactivity. Laboratory work has indicated that the seasonal change in reproductive activity noted in the field is not a definite physiological rhythm, as reproduction goes on rapidly in winter or summer with temperatures similar to those of fall or spring, but drops off rapidly if the temperature becomes noticeably hot or cold. Evidently, this is typically a temperature zone insect. During the short period of time that this insect has been under observation in Utah, considerable seasonal fluctuation in numbers has been noticed. The activity of predaceous insects may play some part in the case; (as ladybird beetles, the hemipterous bugs *Nabis ferus*, *Geocoris decoratus* and a minute pirate bug have been noted to attack it), but the seasonal differences in weather seem to be of greater importance. It is realized that it is difficult to accurately estimate the direct effect of the insect enemies. There does appear to be some correlation between potato psyllid abundance and summer temperatures. During the extremely hot, dry summer of 1931, *P. cockerelli* was extremely scarce; during the cooler summer of 1932, this insect was moderately abundant throughout the summer; causing varying amounts of damage to potatoes from June until the fall harvest. It does not seem beyond the range of probability, that with the accumulation of data on the effects of temperature on reproduction and winter survival, the effect and seasonal extent of control by natural enemies, and a knowledge of the sequence of host plants and their condition, that the forecasting of probable abundance and damage could be foretold in time to warn the farmers and allow them to be in readiness to apply control measures as soon as the need should arise. It seems important that spraying, to be most helpful, should be done before the potato or tomato plants receive too severe a setback from the attack of the nymphs of the potato psyllid. Potato plants upon the Davis County Experimental Farm, sprayed with pyrethrum or nicotine sprays or dusted with calcium cyanide during the spring of 1932, were not severely set back if treated before serious damage occurred; however, vines sprayed or dusted a week or more later, while showing partial or apparent recovery, did not ever catch up with or regain the healthy appearance shown by the adjoining early-sprayed rows. This difference in the appearance of the plants could be readily discerned from quite a distance.

---- 1934. A big-eyed bug predator of the potato psyllid. *Florida Entomol.* 18(3):40-43.

Observations are recorded on the feeding of *Geocoris decoratus* Uhler, on the adults and nymphs of *Paratrioza cockerelli* Sulc, in vials in the laboratory. This Lygaeid is common on potato throughout Utah and is known to be predacious on small insects in nature.

---- 1934. [Insect pests in Utah.] *Leafl. Utah Agr. Exp. Sta. no. 36.*

Of these leaflets, No. 36 deals with *Paratrioza cockerelli* Sulc. Potato plants should be sprayed or dusted before serious damage occurs, and early potatoes sometimes require treatment on or before 15th June. Among insecticides mentioned, sprays of 1 U.S. gal. summer miscible oil (preferable with the addition of 5-7 lb. fish-oil soap) in 100 U.S. gals. water or of 1 U.S. pint nicotine sulphate, 5 lb. fish-oil soap and 99 U.S. gals. water are effective against the nymphs.

---- 1934. Potato psyllid investigations. *Utah Acad. of Science, Arts and Letters, Proc.* 11:261-265. (Proc. Utah Acad. Sci.)

Further investigation in Utah on the potato Psyllid, *Paratrioza cockerelli* Sulc showed that there are five well defined nymphal instars. In experiments on its predacious enemies, adults of *Nabis ferus* L. confined with adults or nymphs of *P. cockerelli* killed several of them in about two hours. They also killed Aphids when these were confined with the Psyllid, and one of them fed for a time on the potato leaf. They appeared to find the active adult Psyllids more difficult to catch than they do the beet leaf-hopper, *Eutettix* (*Opsius*) *tenella* Baker. In another experiment, a Syrphid larva killed five adults of *P. cockerelli* in a few hours. The distribution of the Psyllid in Utah during 1932-33 is recorded.

---- 1937. Some potato insects of Utah. Proc. Utah Acad. of Sciences. 14:151-154.

The potato psyllid, *Paratrioza cockerelli* (Sulc), has at various times caused extensive and severe damage to the potato crop in many parts of Utah. Most frequent injury seems to occur in certain southern portions of the state. Equally severe injury occurs in northern Utah during outbreak years. The feeding of large numbers of scale like *P. cockerelli* nymphs upon potato foliage results in the production of a condition commonly called "psyllid yellows," described by Richards in 1928. For control thoroughly spray potato plants with commercial liquid lime sulphur, 1 gallon to 40 gallons of water (or equivalent amount of home-mixed or dry lime sulphur) as soon as nymphs become abundant. Much injury is avoided if control measures are applied before noticeable injury occurs.

---- 1937. Culture methods for the potato psyllid. in *Culture Methods of Invertebrate Animals*. Galtstoff, P.S., Lutz, F. E., Welch, P. S. and Needham, J. S., eds., pp 317-319.

The potato psyllid, *Paratrioza cockerelli* yields readily to domestication in the laboratory, when suitable cultural methods are used. For removal to the laboratory the adult psyllids may be placed in a temporary gauze cage, together with portions of a succulent plant, or inside of celluloid cages placed over young potato plants. In the laboratory, the adults may be transferred from the field cages to the rearing cages by means of a common aspirator. Several types of cages have been found to be suitable for the rearing and handling of potato psyllids. Large gauze cages, built to the width of laboratory windows, and about 20 inches deep, were found to be excellent for rearing potato psyllids. West windows were best in the winter and shaded east basement windows during the hot summer weather. Other cage designs are also discussed. Individual nymphs may be reared, when under constant observation, by placing but one to a leaf and only two or three upon a small plant. If disturbed the nymphs may move around. Nymphal mortality was somewhat higher in the small than in the larger cages. A high mortality often occurred at the first and second molts, where conditions were for any reason unfavorable. Optimum conditions for egg-laying and nymphal development seem to occur between 70° and 75° F., with slight temperature fluctuations. The eggs, which are at the extreme end of a short stipe, are laid principally upon the younger, apical potato leaves. Females have a rather long oviposition period, and nymphs and adults of all stages may be had by adding a new potted potato plant to the breeding cage about once or twice each week. Where caged in pairs, it may be necessary to replace males that die in order to maintain the fertility of the eggs. Adults reared in cages appear to live longer in captivity, and to be less excitable than do wild adults collected out of doors. The mortality of freshly captured wild adults is sometimes heavy, especially if they are placed in small cages during hot weather. When the nymphs become excessively abundant, it may be necessary to kill or to remove part of the insects to save the plants. As many as 2,000 to 3,000 nymphs, in addition to adults, have occasionally been found upon medium sized potato plants under both field and laboratory conditions.
Greenhouse rearings are usually successful during the fall, winter, and spring months, but the psyllids have difficulty surviving during the summer if temperatures become excessively high. Nymphs and adults have been observed to survive when the potato plants upon which they were feeding were destroyed by frost.

Knowlton, G. F. and Allen, M. 1936. Three hemipterous predators of the potato psyllid. *Proc. Utah*

Acad. Sci. 13:293-294.

Descriptions are given of the feeding habits in captivity of *Orius tristicolor* White and *Anthocoris melanocerus* Reut., which were predacious on the adults and nymphs of the potato psyllid, *Paratrioza cockerelli* Sulc, when confined with them, and of *Camptobrochis (Deraeocoris) brevis* Uhl., which attacked the adults. All three are common on the food-plants of *P. cockerelli* in Utah, where *O. tristicolor* has also been observed feeding on an aphid on birch.

Knowlton, G. F. and Janes, M. J. 1931. Studies on the biology of *Paratrioza cockerelli* (Sulc). *Entomol. Soc. Am., Ann.* 24(2):283-291.

The literature dealing with *Paratrioza cockerelli* Sulc (potato Psyllid) is reviewed. During the last three seasons a few areas in Utah have been affected by "yellows" disease but the potato crop in general has been far less seriously damaged than in 1927. Life-history studies showed that eggs are laid on both surfaces of the leaves, especially young apical ones, along the margins and occasionally on the petioles and stems, either in a row or scattered. In the laboratory 60 females deposited 19,833 eggs. The oviposition period averaged 21.45 days for 58 females, the egg and nymphal ones varied from 3 to 9 and 12 to 21 days respectively. Many infertile eggs are laid; of 9,615 about 73 percent hatched. Two or three days after reaching the adult stage and before oviposition begins the color darkens considerably. In the field, early potatoes began to show "yellows" early in June, and by 20th June the plants were in a serious condition; at this time adults were fairly abundant and examination revealed an average of 456 nymphs to a hill. The generations overlapped during the summer; adults reached their maximum numbers on 27th June and gradually decreased until very few were taken by sweeping with nets during August. The nymphs seek for preference the underside of the leaf, shade being apparently the factor determining their position.

Knowlton, G. F. and Thomas, W.L. 1934. Host plants of the potato psyllid. *J. Econ. Entomol.* 27:547.

Greenhouse and laboratory rearing tests, using a large number of plant species, showed that the potato psyllid, *Paratrioza cockerelli* (Sulc), will oviposit, complete its nymphal development, and emerge as a normal adult upon many plants, the majority of which are members of the family Solanaceae. The nymphs matured upon several varieties of tobacco, including Broadbent, Havana, White burley, Connecticut broadleaf, and Turkish. Adult potato psyllids fed upon many plants and laid eggs upon most of them, although the young failed to mature; however, on some plants, such as wanderberry, nymphs succeeded repeatedly in reaching the second to third instars. These tests show that *P. cockerelli* will breed upon a number of plants which occur in various sections of the United States.

Lehman, R. S. 1930. Some observations on the life-history of the tomato psyllid (*Paratrioza cockerelli* Sulc) (Homoptera). *J. N.Y. Entomol. Soc.* 38(3):307-312.

Paratrioza cockerelli Sulc, is only occasionally injurious in Colorado either to tomato or potato. The feeding of large numbers of nymphs caused wilting of the leaves of large tomato plants and the death of small ones. Observations in the laboratory showed that the length of the life-cycle varies with the temperature and at 16-27°C. [60.8-80.6°F.] occupies 25 days. A female lays an average of 75 eggs, usually near the edge on the upper surface of the leaf. The nymphs appear to be ready to feed immediately after hatching and seem to prefer the lower surface of the leaf.

Linford, M. B. 1927. Further observations on unknown potato disease in Utah. *Plant Disease Reporter*. 11(9):110-111.

The unknown potato disease previously described by Richards, Blood, and Linford continues to assume greater importance as the season progresses and is generally distributed throughout Utah. Losses include reduction in the number of tubers of marketable size and reduction in quality of the larger tubers through second growth or vegetative sprouting. Plants affected extremely early in their development sometimes fail entirely to set tubers. Sometimes, however, stolon development is profuse and great numbers of small tubers are formed, a condition that appears to be more common with the late varieties. While the correlation between earliness of planting and severity of injury continues to hold, generally, late-planted potatoes are failing almost totally in some localities. There appears to be two periods of abundant infection in some localities, one early and the other rather late. It seems clear that in the varieties which show least conspicuous leaf symptoms, late season infection after shoot growth is about complete may result in modification of the tubers without producing evident foliage symptoms. Although it was implied in the earlier report that this disease was new to Utah this year, it has since been learned that apparently this same disease caused the complete failure of potatoes at Green River, Utah last year and the year before and occurred sparingly the year before that. The relation of this disease to a species of psyllid, mentioned int he earlier account, is confirmed by additional observations.

---- 1928. Psyllid yellows (cause undetermined). *Plant Disease Reporter, Supplement.* 59:95-99. (Ref.)

List, G. M. 1917. A test of lime-sulphur and nicotine sulfate for the control of the tomato psyllid and effect of these materials upon plant growth. *Colo. State Entomol. Ann. Rep.* 9:40-41.

Sprays of lime-sulphur (1 to 40 or 45) proved effective in checking *Paratrioza cockerelli* Sulc, on tomatoes. Although the growth of the plant was temporarily checked, no vital injury was caused by this application and the insects were reduced to a negligible number. Nicotine sulphate, even at a strength of 1 to 200, proved useless against this psyllid.

---- 1918. A test of lime sulphur and nicotine sulfate for the control of the tomato psyllid and effect of these materials upon plant growth. *Ninth Ann. Rept. State Entomol. Colo. 1917. Cir.* 47:16. (Ref.)

---- 1925. The tomato psyllid, *Paratrioza cockerelli* Sulc. *Colo. State Ent. Circ.* 47:16.

No reports of injury by this "jumping plant louse" have been received during the year, but, in contrast with this, in 1923 such reports came from several localities. The greatest injury occurred in the early-tomato-growing sections about Denver and Littleton, some growers reporting as much as a 50 percent loss. The use of liquid lime-sulfur, one gallon to forty gallons of water, a treatment which had previously been tested and reported on in the Ninth Annual Report, pp. 40-41, was recommended. Good results were reported by County Agent A. H. Tedmon and growers. Mr. Harry M. Osborn, of Englewood, wrote as follows: "It has developed that the plants sprayed with the lime sulphur solution grew and developed well, while those not sprayed did not. "The frequent rains soon after I sprayed helped those not sprayed, but even with this help they are scrawny plants with few tomatoes of marketable size, almost none. "Before receiving your letter I tried fish-oil soap and Black Leaf 40 on a few plants and they dwindled to nothing."

---- 1932. Relation of the potato psyllid *Paratrioza cockerelli* (Sulc) to the potato disease known as

"psyllid yellows." *Forty-fifth Ann. Rept. of the State Entomologist, Colo. Agr. Expt. Stn. 1931.* 32:42-47. (Ref.)

A study of a number of potato fields with a view to determining the relation between *Paratrioza cockerelli* Sulc, and "Psyllid yellows" indicated that the condition was independent of irrigation and cultural methods. The most important wild food-plants of the psyllid were found to be *Quincula lobata, Solanum rostratum* and *Physalis lanceolata.*

---- 1933. The relation of the potato psyllid *Paratrioza cockerelli* to the potato disease known as "psyllid yellows." *Colo. Agr. Expt. Stn. Rept.* 46:14.

Loss to the potato crop from the work of the tomato psyllid, *Paratrioza cockerelli* Sulc was estimated at from 5 to 8 million bushels. A survey showed the pest to occur in all sections of the state. The early crop in Weld and Morgan counties was almost a complete failure, and the late crop not more than 25 percent of normal. In the San Luis Valley the yield was reduced from 40 to 60 percent in some fields. A bulletin on this subject giving control measures is being published.

---- 1934. Lime-sulfur for tomato psyllid control. *Colo. Agr. Expt. Stn. Bull. no. 411.* 14 pp.

The toxicity of lime-sulphur to *Paratrioza cockerelli* Sulc, was largely due to the power of calcium pentasulphide and calcium tetrasulphide to take up large amounts of oxygen and to give off sulphur in finely divided particles. Control was obtained by the lethal effect of direct contact with the adults at the time of application, by repelling ovipositing females, and by a residual effect on the scale-like nymphs that settle on the sprayed surfaces. The difference between the minimum strength that is toxic to Psyllids and the maximum strength that potatoes and particularly tomatoes can support is so small that the materials must be selected and made up with great care. Commercial liquid lime-sulphur is sufficiently standardized to be used at recommended strengths on tomatoes and potatoes. If the concentrate is prepared by the grower, the quicklime should be 95-98 percent pure, and should contain a minimum of magnesium oxide. The formula is 50 lb. quicklime, 100 lb. commercial ground sulphur, and water enough to make 50 U.S. gals. Directions for making it are given. Approximately 5 lb. dry lime-sulphur has the same sulphide sulphur content as 1 U.S. gal. proprietary liquid lime-sulphur, and should therefore be used at the rate of 1 lb. to 8 U.S. gals. water for potatoes and 1 lb. to 9 or 10 U.S. gals. for tomatoes.

---- 1935. Psyllid yellows of tomatoes and control of the psyllid, *Paratrioza cockerelli* (Sulc), by the use of sulfur. *J. Econ. Entomol.* 28(2):431-436.

The feeding of tomato psyllid nymphs on tomatoes produces a definite disease condition known as psyllid yellows. An upward rolling of the older leaves, puckering of the younger leaves, with a general loss of the natural green color with some purpling of veins and a general stunting of the plant are some of the symptoms. The fruits are reduced in size and quality. Lime sulphur spray and sulphur dusts have a distinct repelling effect upon tomato psyllid adults and a lethal effect upon the nymphs. Plants freed of the insect show a marked tendency to recover and give a marked increase in yield and quality of fruit.

---- 1938. Test of certain materials as controls for the tomato psyllid, *Paratrioza cockerelli* (Sulc), and psyllid yellows. *J. Econ. Entomol.* 31(4):491-497. Abs.

Paratrioza cockerelli Sulc, is a serious pest of tomato in Colorado, and lime-sulphur, though effective in its control, has not been extensively used on this crop, as it tends to injure the foliage. Sulphur dusts, however, exercise definite control without apparent injury to the plants. Reports are here given of two experiments carried out in 1936, one designed solely to test the lethal effect of sulphurs and lime-sulphurs upon the Psyllid nymphs and the other to determine the comparative protection afforded and injury caused on one variety of tomato by certain of these materials in definite control programmes. The materials used in the test of lethal effect were liquid lime-sulphur (33° Baume and 32.2 percent by volume sulphide sulphur) at a concentration of 1:49, a 300-mesh dusting sulphur and a 300-mesh gashouse dusting sulphur undiluted, and a 300-mesh wettable sulphur at the rate of 1 lb. to 10 U.S. gals. water. The applications were made on 10th September and counts taken 10 days later. The same materials were tested in the other experiment with the exception of the gashouse sulphur and the addition of dry lime-sulphur (70 percent calcium polysulphide) at the rate of 1 lb. in 10 U.S. gals. water. Applications were made on 26th June, 7th July and 11th August. There was no significant difference in the lethal effect of the substances in either experiment. All gave high kills. Three applications were significantly more effective in controlling *P. cockerelli* and psyllid yellows caused by it than two, and the difference in favor of two as compared with one approached significance. Both lime-sulphurs seriously retarded plant growth and setting of fruit, and gave reduced yields as compared with untreated controls, but dusting and wettable sulphurs gave increased yields based on total weight of crop. The control of even a light infestation resulted in larger fruits. There was no significant difference in this respect between one and two applications, but three produced larger fruits than either. A moderate infestation of psyllids stimulates flowering and fruiting. Significantly more fruits were produced on the control plots than on treated plots, and differences between treatments were highly significant, plots treated with lime-sulphur producing very few fruits, probably on account of plant injury.

—— 1939. The effect of temperature upon egg deposition, egg hatch, and nymphal development of *Paratrioza cockerelli* (Sulc.). *J. Econ. Entomol.* 32(1):30-36.

Laboratory tests with the tomato psyllid, *Paratrioza cockerelli* (Sulc), indicate that the species thrives best at about 80 degrees with less retardation at temperatures below 80 degrees than above that point. Oviposition, hatching and survival are definitely reduced under 90 degrees constant temperature, while a temperature of 95 degrees for only two and three hours per day permit little, if any, increase in numbers. One hundred degrees for one and two hours of the day are very definitely lethal to eggs and nymphs and practically stop all egg laying. These results support field observations made over a period of more than 20 years. High temperatures cause the insect to disappear almost completely in the Grand Valley and Arkansas Valley, Colorado, early each summer. In certain other regions, represented by Fort Collins, high temperatures appear to determine the summer population. In altitudes of 6,000 feet or more, the summer temperatures are seldom detrimental, in many cases the mean maximums are near the optimum for the species. Under these conditions increase is uninterrupted during the season, the seriousness of the infestation depending upon the degree of spring infestation. Some regions that experience lethal summer temperatures may have definite building up of the population after mid-season, to the extent that tomatoes and late potatoes are seriously affected. High temperatures make the adults very restless and may cause them to take flight and thus reach air currents that carry them great distances. Results of catches made in traps operated in the Grand Valley indicate that the spring infestation of this section comes, at least in part, from migrations. There is a need for a more detailed study of the relation of temperatures to the psyllid problem in a number of the important tomato and potato growing portions of the affected area. There is also a very definite need for a comprehensive study of the insect over its entire range to determine more in detail the relationship of the southern breeding areas to the spring infestation of the northern and the high altitude regions.

---- 1939. The potato and tomato psyllid and its control on tomatoes. *Colo. Agr. Expt. Stn. Bull. 454.* 33 pp.

The tomato psyllid, *Paratrioza cockerelli* (Sulc), is a native of the Rocky Mountain region and is western in distribution. It has been reported as a tomato pest in Colorado since 1989. The principal food plants in Colorado belong to the potato or nightshade family. The insect feeds by piercing and sucking. The feeding of the nymphs upon the tomato plant causes a condition known as psyllid yellows. This seriously affects plant growth and fruit production. The adult psyllid is somewhat similar in appearance to the winged plant lice but is more robust and active. The egg is very small, yellow, and is placed in a short stype or stem, usually on the edge of the leaves. The nymph is flat and scalelike in appearance, yellow to orange in color at first, but a light green when near maturity. Psyllids are reported to winter elsewhere on pines and cedars. There are believed to be five generations per year on tomatoes in the Fort Collins section, but this no doubt varies with temperature conditions. Laboratory studies indicate that the insect thrives under comparatively low temperatures. Eighty degrees appears to be near the optimum. Temperatures above this retard the insect's development and multiplication more than temperatures below this point. Ninety-degree temperature is definitely detrimental to the insects, 95 degrees temperature for any great length of time reduces numbers materially, while 100 degrees temperature for even a few hours per day soon almost eliminates the infestation. This temperature effect appears to accounts for the disappearance, before total crop losses result, of early infestations that occur in certain tomato growing areas almost each year. It also seems to explain the continued building up of the psyllid population throughout the growing season in certain cool, high-altitude regions. High temperatures cause the adults to become restless. This may be partly responsible for many of the insects getting into air currents and being carried into the Grand Valley as indicated by trapping records in 3 different years. The residue after spraying with lime sulfur and the deposit of sulfur after dusting with sulfur or spraying with wettable sulfur definitely repel adult psyllids. Two seasons' tests with dry and liquid lime sulfurs, wettable sulfur, 300-mesh dusting sulfur, and gashouse dusting sulfur, failed to show any differences in the effectiveness of these materials in killing psyllid nymphs. All killed a high percentage of the nymphs. Sulfur deposits from lime sulfur sprays, and sulfur sprays and dusts, kill nymphs that attempt to settle upon sprayed or dusted surfaces as many as 16 days after treatment. Liquid lime sulfur, 1 part to 50 parts of water, and dry lime sulfur, 1 pound to 10 gallons of water, seriously retarded plant growth as shown by plant measurements. This was reflected in yield of fruit. In field control experiments in 1934 under conditions of heavy infestation, plants treated with lime sulfur spray gave a large increase in yield over the untreated plants, even though some spray injury occurred. In 1936 under conditions of light to a medium infestation, liquid and dry lime sulfur sprays caused a reduction in yield as compared with the yield from untreated plants, while dusting sulfur and wettable sulfur treatments resulted in increased yields. Since population counts showed no differences in the effect of the materials in the control of the psyllids, this difference can be attributed only to the plant injury caused by the lime sulfurs. Temperature conditions in 1938 were favorable for psyllid development. An almost complete tomato crop failure resulted on untreated plantings. Sulfur dust thoroughly applied gave good protection.

---- 1939. *Colo. Agric. Expt. Stn., Fifty-second Ann. Rpt., 1938-39.* pp 23-29.

One section of this report (pp. 23-29) deals with work on insect pests in Colorado during the year ending 30th June 1939. The potato psyllid (*Paratrioza cockerelli* Sulc) caused severe damage to potatoes and tomatoes, and it was found that the sulphur dusts recommended for its control on tomatoes render the latter unfit for canning, as the sulphur cannot apparently be removed from the fruits and shortly after canning the cans swell and burst.

---- 1940. *Colo. Agric. Expt. Stn., Fifty-third Ann. Rpt., 1939-40.* pp 23-26.

One section of this report deals with work on insect pests in Colorado during the year ending 30th June 1940. In experiments, some strains of potato showed resistance to Psyllid yellows, caused by the feeding of the psyllid (*Paratrioza cockerelli* Sulc). The pentatomid, *Chlorochroa sayi* Stal, attacked potato severely in some localities; as many as 27 bugs were observed on single plants, and their feeding produced a condition very similar to psyllid yellows, for which the name "big bug blight" is suggested.

---- 1941. *Colo. Agric. Expt. Stn., Fifty-third Ann. Rpt., 1940-41.*

Several strains of potato showed resistance to psyllid yellows, caused by the feeding of the psyllid [*Paratrioza cockerelli* Sulc].

---- 1943. Psyllid control on potatoes and tomatoes in the Victory Garden. *Bull. Colo. Agr. Exp. Stn. no. 479.* 8 pp.

This bulletin comprises notes on the appearance and bionomics of the potato and tomato psyllid [*Paratrioza cockerelli* Sulc], which causes psyllid yellows of the two plants, in Colorado and an account of methods of controlling it in gardens. It is recommended that a well-agitated spray of 1 lb. wettable sulphur in 10 U.S. gals. water should be applied at the rate of about 1 U.S. gal. for 115 ft. of row, or 1 U.S. gal. for 75 ft. if the sprayer is small, or that dusting sulphur should be used a 1 lb. for 580 ft. of row or at 1 lb. per 300 to 400 ft. if the duster is small. In one test, potatoes with a medium to heavy infestation were effectively protected by dusting the sulphur through a double muslin cloth bag rather to the side of the plants when there was slight air movement to drive the dust through the foliage; this method took about 1 lb. sulphur for 250 ft. of row. When tomatoes are transplanted, the tops should be dipped into wettable sulphur (1 lb. per 10 U.S. gals. water) if the plants have not previously been sprayed or dusted; they should be allowed to dry before being set. The first spray or dust should be applied about 10 days later, followed by additional treatments every 7 to 10 days until the fruit is well formed; usually four are sufficient, even if infestation is heavy, but additional ones can be made if necessary without injuring the fruit. Potatoes should be treated when 4 to 6 ins. high, with three additional applications 7 to 10 days apart. Treatment should not be delayed until symptoms of psyllid yellows are seen, as it is then too late for complete protection.

---- 1943. The effects of sulfur residue on keeping qualities of canned tomato products. *J. Econ. Ent.* 36(5):694-700.

Control of *Paratrioza cockerelli* Sulc, is essential for successful tomato production in most parts of Colorado, and dusting sulphur, wettable sulphur and lime-sulphur are the most effective materials to use. Since, however, a residue of elemental sulphur on the fruit might hasten spoilage in canned products and it is sometimes advisable to spray or dust after the fruit is well formed, tests of the effect of sulphur residues were carried out. The plots were treated with dusting sulphur at the rate of 110 lb. per acre 13 days before the first picking (21 days after the first treatment) or with a spray of 5 U.S. quarts lime-sulphur and 5 lb. wettable sulphur per 100

US gals. water at 103 and 92 U.S. gals. per acre, respectively, on the same dates, and controls were taken for each treatment and date. At the factory, the fruit was washed and the juice was extracted and canned under commercial conditions; only this product was tested, as the fruit is not peeled in its preparation and would therefore be most likely to carry injurious amounts of sulphur. Dusting sulphur was added to some cans at the rate of 2, 4, 6 and 10 parts per million parts of can content just before they were sealed. The temperature of the juice at the time of sealing was approximately 180°F and the cans were stored at 72 and 98° F. and examined at intervals of three months over a period of two years. Much of the non-bacterial spoilage of canned fruit is caused by corrosion of the tin plate of the cans by fruit acids; hydrogen is produced and the vacuum is consequently lost. The presence of other materials may affect corrosion, but the observations showed that increasing the storage temperature from 72 to 98° F. was a much greater factor in vacuum loss than the addition of 2, 4, 6 or 10 ppm of sulphur, the effect of storage at 98° F being more than six times that at 72° in the case of cans carrying known amounts of sulphur and almost seven times that at 72° for the field-plot material. Increases in the amount of sulphur added resulted in an increase in the rate of vacuum loss at 72°F, but the loss was not serious for additions of up to 6 ppm. It is calculated that at 98°, a complete loss of vacuum can be expected after 2 3/4 years when 10 ppm of sulphur is added and after 3 3/4 years when 6 ppm is added. At both temperatures, the field treatments appeared to have a negligible effect and the data indicated that the use of two applications of sulphur dust or lime-sulphur with wettable sulphur, even after harvest has begun, does not involve any risk from sulphur residues if the usual care in washing the fruit is taken, so that the present general practices of Psyllid control on canning tomatoes may safely be continued.

List, G. M. and Daniels, L. B. 1934. A promising control for psyllid yellows of potatoes. *Science.* 79(2039):79.

The feeding of the psyllid, *Paratrioza cockerelli* Sulc, causes a very serious disease condition known as psyllid yellows. It is the most serious problem for the potato growers of many western sections, and tomatoes are often very seriously injured. It has been estimated that the condition reduced the 1932 potato crop in Colorado as much as 8 million bushels. Practically all sections of the state were infested, with some suffering a total crop loss. Production has become so uncertain in some important sections that the acreage has been very materially reduced. Reports indicated that the loss has been equally heavy in other western states. The condition is characterized by an upward rolling of the basal portion of the terminal leaves, which may be somewhat smaller than normal and stand more or less upright. They early take on a chlorotic appearance that may develop to a distinct yellow and in extreme cases an early dropping of the leaves. The nodes become enlarged and all buds are abnormally active. The effect upon the tubers is just as pronounced. If the set has taken place the growth is checked. When the tubers are not definitely formed, numerous stolons are thrown out with small tubers forming into a chain effect. Such tubers frequently give rise to sprouts. In advanced cases aerial tubers are characteristic. Considerable work has been done to determine the exact cause of this abnormal development, without evidence that it is of bacterial or virus origin. The best evidence supports the theory that it is of the nature of a toxin injected into the plant by the insect. This theory is strongly supported by the rather remarkable recovery shown by plants upon removal of the insect parasites. Numerous tests are under was with a large series of possible controls with outstanding early results being shown from lime-sulfur applied as a spray. It shows a very definite lethal effect upon the insects and apparently has a positive residual effect in preventing the location of the small scale-like nymphs. Plants showing distinct psyllid yellow symptoms have after spraying shown almost complete recovery, as evidenced by a normal top growth and good tuber production. In an early field of the Irish Cobbler variety the checks produced at the

rate of 51 bushels of marketable potatoes while a block receiving only one application of lime-sulfur, testing 33 degrees Baume, used at the rate of one gallon to 40 gallons of water, produced at the rate of 209 bushels of much better quality and size. In another field the check produced at the rate of 128.9 bushels and the sprayed portion 378.5. Extensive tests are being carried on in the late-producing areas and several hundred acres have been sprayed by commercial producers. The early indications of results are promising. A more complete report will be made after the harvest.

Metzger, C. H. 1934. Control of flea beetle and psyllid yellows in Colorado. Annual Rept. Nebr. State Board of Agr., 1934:606-610. (As part of the *Fifteenth Ann. Rept. Nebr. Potato Improvement Assn.*:606-610) (Ref.)

---- 1936. Some preliminary notes on the effect of psyllid yellows on seed stock from infected plants. *Am. Potato J.* 13(10):277-285.

Sufficient evidence has already been presented to show that damage to seed from psyllid infestation may occur under certain environmental conditions, and that it is dangerous to certify fields showing more than fifteen per cent of mild symptoms of psyllid yellows on second inspection. This tolerance was adopted in Colorado beginning with the season of 1934.

Mills, H. B. 1939. Montana insect pests for 1937 and 1938. The twenty-seventh report of the State Entomologist of Montana. *Bull. Mont. Agr. Exp. Sta. no. 366.* 32 pp. Abs.

Paratrioza cockerelli Sulc, was generally distributed in 1938 on tomatoes and potatoes, the injury to the latter being increased by the purple-top [Psyllid yellows] caused by it; the plants affected produced very small tubers, which in many cases did not justify the cost of digging. Experiments showed that young nymphs are killed by sulphur dusts or by a spray of lime-sulphur (33° Be, 1:40) applied with force to the lower surfaces of the leaves early in the season, before purple-top has been produced.

---- 1941. Montana Insect Pests 1939 and 1940. Twenty-eighth report of the State Entomologist. *Bull. Mont. Agr. Exp. Stn. no. 384.* 28 pp.

Damage to potato by *Paratrioza cockerelli* Sulc, was far less serious than in 1938.

---- 1942. Montana insect pests, 1941 and 1942. Twenty-ninth report of the State Entomologist. *Bull. Mont. Agr. Exp. Stn. no. 408.* 36 pp.

Incipient outbreaks of *Paratrioza cockerelli* Sulc, on potato were checked in 1941 and 1942 by high temperatures in July and reductions in yields were slight.

Mills, H. B., Callenbach, J. A. and Reinhardt, J. F. 1945. Montana insect pests, 1943 and 1944. Thirtieth report of the State Entomologist. *Bull. Mont. Agr. Exp. Sta. no. 425*, 30 pp.

The first recognized outbreak of *Paratrioza cockerelli* Sulc, in Montana was in 1938, when it reduced the potato crop by about 25 per cent. It occurred in smaller numbers until 1943, when it was not observed at all, but was present on potato, and possibly injurious, in some places in 1944.

Morris, H. E. 1939. Psyllid yellows in Montana in 1938. *Plant Disease Reporter.* 23(1):18-19.

A map which has been prepared through the cooperation of the Horticulture Department, the Entomology Department, and the Plant Pathology Department gives the distribution of psyllid yellows in Montana in 1938. Psyllid yellows, identified as such, occurred in real epidemic form in practically all of the State this season. It is our opinion, however, that we have probably had one or two outbreaks of psyllid yellows in the past which were not identified as this disease. It is estimated that psyllid yellows caused an actual loss of 25 percent of the potato crop in Montana in 1938. This loss greatly exceeded the combined loss from all other potato troubles during the season and it is hoped that it is only a temporary situation that will not recur. Spraying to control the insect was attempted but apparently most of the damage was done before any spraying was recommended, consequently the results of spraying were not satisfactory.

Orton, W. A. 1914. Potato wilt, leafroll, and related diseases. *USDA Bull. no. 64*. 48 pp.

Reference is made to outbreaks of a leafroll-type disease during 1911 and 1912 in eastern Colorado and western Nebraska that caused immense losses to the potato crop.

Pack, H. J. 1929. Tomato psyllid, *Paratrioza cockerelli* (Sulc.). *Utah Agr. Expt. Stn. Bull.* 209:55.

This insect is apparently responsible for transmission of the yellow blight of potatoes. Life history studies were begun in the greenhouse in the fall of 1927 and are being continued in the field at the present time. In recent experiments calcium cyanide so far has given almost complete control. These experiments will be continued on a larger scale during the summer.

---- 1930. Notes on miscellaneous insects of Utah. *Utah Agr. Expt. Stn. Bull. 216*. 30 pp.

Paratrioza cockerelli Sulc, is sometimes abundant on potatoes, and appears to be the cause of disease known as Psyllid yellows, which first appeared in Utah in 1927.

Papp, R. P. and Johnson, J. B. 1979. Origins of psyllid fallout in the central Sierra Nevada of California (Homoptera). *Pan-Pacific Entomol.* 55(2):95-98.

Lists are given of some 16 species of psyllids (some of economic interest) that were collected in the summers of 1972-1974 from the alpine snowfields of Mount Conness in the Sierra Nevada, California, after being blown there by the wind. The species include *P. pyricola* Forst. (which attacks pear) and *Paratrioza cockerelli* (Sulc) (which attacks potato, tomato and other solanaceous crops). Lists are also given of the food-plants of each species collected and of the distribution and habitat type of some of these food-plants, which did not necessarily include the collection area in the Sierra Nevada. It is concluded from the data that the psyllids collected from the central Sierra Nevada originated from the Central Valley and west slope, and also from the Owens Valley and east slope. They form a food source permitting the survival of useful predators and scavengers in the snowfields.

Pletsch, D. J. 1940. Potato psyllids and psyllid yellows in Montana, 1939. *Plant Disease Reporter.* 24:173.

An early season survey (June 19-27, 1939) revealed low populations of adult psyllids generally present east of the continental divide. The accompanying map includes points where negative, as well as positive, collections were made at this time. In spite of these findings in June, later reductions in yield from psyllid yellows were noted in only occasional fields in Yellowstone and Phillips Counties. A small garden plot was damaged in Gallatin County also. Thus, low yields of potatoes in Montana in 1939 were not generally traceable to psyllid infestations.

---- 1942. The effect of some insecticides on the immature stages of the potato and tomato psyllid, *Paratrioza cockerelli* (Sulc). *J. Econ. Entomol.* 35(1):58-60.

The results are given of tests on the susceptibility to insecticides of the several nymphal instars of *Paratrioza cockerelli* Sulc, carried out in August 1939 on heavily infested tomatoes in Montana. The sprays tested were 1 gal. liquid lime-sulphur (28° Be.) in 35 gals. water, 1 lb. dry lime-sulphur containing 70 per cent. calcium polysulphide or 1 lb. wettable sulphur in 10 U.S. gals. water, and 4 oz. nicotine sulphate with 20 oz. summer oil emulsion in 8 U.S. gals.water, and the dusts were dusting sulphur, a mixture of hydrated lime, dusting sulphur, household lye and nicotine sulphate (10:80:1:1) and one of pyrethrum dust (10 per cent. Dry Pyrocide), dusting sulphur and diatomaceous earth (2:11:7). The insecticides were applied to individual leaves in the laboratory or to the growing plants, and the mortality of each instar was determined on the following day. None of the treatments caused outstanding collapse or shrivelling of the eggs. Nymphs in the first instar showed little resistance to any of the insecticides used, mortality of those in the second instar remained uniformly high except on foliage treated with the spray of oil and nicotine, and that in the third instar showed little change, remaining above 80 percent for all but the oil-nicotine treatment. Fourth-instar nymphs showed increasing resistance to the oil-nicotine and the wettable sulphur spray, the remainder of the treatments giving more than 80 percent kill, but there was a great range in mortalities from the various treatments in the fifth instar. The most effective material against this instar was the dust containing nicotine sulphate and sulphur, which, however, had to be used soon after mixing for maximum effectiveness and tended to clog the duster; the liquid lime-sulphur spray, which is already recommended against the Psyllid as a standard measure of control, gave between 60 and 80 percent mortality, sulphur dust alone between 40 and 60 percent, and the other treatments less than 40 percent. It is concluded that insecticides will be most effective if applied when the younger nymphal instars predominate.

---- 1947. The potato psyllid *Paratrioza cockerelli* (Sulc), its biology and control. *Montana Agr. Expt. Stn. Bull. 446.* 95 pp.

A detailed study has been made of the potato psyllid, *Paratrioza cockerelli* (Sulc), including its biology and distribution, its host and climatic relationships, and the factors influencing its control. Field work was centered in the Yellowstone Valley, Montana, supplemented with greenhouse and laboratory studies at Bozeman. The relationship of the potato psyllid to the "Psyllid yellows" disease has been reviewed. Studies have been made, using radioactive "tracers," of the feeding relationship of *Paratrioza cockerelli* and its plant host. Psyllid nymphs and adults fed on "phosphorus loaded" tomato plants have in turn become "loaded" with radioactive phosphorus. They have subsequently given off radioactive phosphorus in excrement and in cast skins, but no proof has been obtained of injection of the material into normal tomato plants. Attempts have been made to transmit leafroll of potatoes, using potato psyllid nymphs and adults. Results have been negative. Recognized outbreaks of the psyllid yellows disease (induced by the potato psyllid) occurred in Montana during 1927-1928 and in 1938-1939. Evidence was presented in support of a similar Montana outbreak in 1911-1912. The detailed distribution of *Paratrioza cockerelli* (Sulc) was compiled from the literature and extensive correspondence with state and Federal entomologists. Confirmed records were obtained for Minnesota, North and South Dakota, Nebraska, Kansas, Oklahoma, Texas, and all states west of these except Oregon and Washington. Records from Canada included Alberta and Saskatchewan, while Mexican collections had been made as far south as Mexico City and Rio Frio, Puebla. In

Montana this insect pest has only been found east of the Continental Divide. In studies of the stages of the potato psyllid's life history, the uniform occurrence of five nymphal instars has been established by numerous measurements. Properties of the sugar-like nymphal excrement, which has attracted attention on heavily infested foliage, have been considered. Analyses indicate that the material is essentially carbohydrate, possessing some characteristics not recognized from known sugars. The excrement was found to fluoresce strongly under ultraviolet light with a wave-length peak of 3660 Angstrom units. The use of such a light source for detection of psyllid infestations was tested, and it proved feasible in the greenhouse but impractical under field conditions. A list has been compiled of plant species on which the potato psyllid has been found. The series showed a preponderance of Solanaceae, with ten other families represented. The manner in which the psyllid winters has not been definitely established by these investigations. Less than one dozen specimens were collected from cedars in late autumn and early spring. Large numbers of adults caged in November on sheltered cedars failed to survive until spring. Many adult psyllids were found in bushy asparagus plantings late in October, 1940, but adults could not be recovered from the suspected hibernacula in midwinter. Bindweed was suspected when nymphs of *Paratrioza maculipennis* (Crawford), a close relative of the potato psyllid, were found clustered on the roots late in November, but specimens of *Paratrioza cockerelli* (Sulc) have not been found in the same situation. Methods used for sampling psyllid populations during the growing season included net sweeps for the adults and careful examinations of weighed leaf samples for nymphs and eggs. In sampling for adults the number of specimens captured in each 100 sweeps was used as a "psyllid index" of population density. Spring surveys have been made in late June or early July during eight consecutive seasons (1939-1946, inclusive). Early season populations of psyllid adults in eastern Montana have varied considerably from year to year; none were found in the spring of 1943, while threatening numbers were present in 1939, 1941, and 1946. Prediction value of the spring surveys was indicated because high spring psyllid indices showed considerable correlation with subsequent psyllid yellows damage. Highest spring survey indices have consistently occurred in Yellowstone, Big Horn, and Carbon counties of south-central Montana. Unless the spring survey in these counties shows an index of 2-3, the remainder of the State need have little concern about psyllid yellows, and surveys would not be necessary in other localities. The annual Montana surveys have indicated a simultaneous appearance of adult psyllids in widely scattered areas, strongly suggesting air-borne introduction about the time early potato plantings are 4"-10" high. Extensive early season examinations of solanaceous hosts, both cultivated and uncultivated, have been made. There have been no indications of any psyllid development on other plant species before the appearance of early potatoes above ground. However, following potato maturity or harvest in August, increased psyllid populations were found on tomato, pepper, eggplant, common nightshade, and bindweed where these hosts adjoined the potato plantings. Where tomatoes, peppers, and eggplant were equally available to psyllids forced from potatoes by maturity of vines or by harvest, the severity of infection has been much greater on tomatoes than on eggplant and peppers. Psyllid development has been noted late in the fall on wild ground cherries which were miles from cultivated areas. Psyllid populations in Yellowstone Valley potato plantings were sampled periodically during 1939, 1940, and 1941. In 1940 a low adult population level was maintained until the first week in August, when rapid increases occurred. In 1939 and 1941 the upward population trend began near mid-July. Subsequent samplings showed a progressive population increase in 1939, but in 1941 this trend was not shown until early August. The psyllid index showed a close correlation with the extent of psyllid yellows symptoms observed in the plantings. The development of successive generations of psyllids during the season was studied at Juntley and at Bozeman. Field investigations and large-cage rearings showed that in south-central Montana three to four complete generations could develop on potatoes, and an additional generation could be completed on tomatoes which adjoined potato plantings. At Bozeman a maximum of three generations might develop. Experiments in the greenhouse and temperature cabinets have been carried out investigating the comparative reactions of *Paratrioza cockerelli* to potato, tomato, eggplant, and pepper. When adults were offered a choice of these four host plants, adult recoveries were highest from potato and tomato, lowest from pepper, and intermediate numbers were found on eggplant. When females were offered the same fur hosts for egg deposition, eggs were most numerous on potato. The numbers on tomato, eggplant, and pepper decreased in the order listed. When newly-emerged females were confined on potato, tomato, eggplant, and pepper plants to obtain oviposition records, the highest average number of eggs per female (259) was obtained on potato. Average longevity was greatest on eggplant, with potato, tomato, and pepper less favorable for survival. Psyllid development, starting with newly-laid eggs, was studied in temperature cabinets on the same four hosts. At 28° ($\pm 2°$)C the nymphal development was completed only on potato and tomato. The period of adult emergence of potato extended from 16 to 34 days after egg deposition. The corresponding period on tomato extended from 18 to 30 days after egg deposition. Complete observations on the adult life of an unmated female yielded the following data: pre-oviposition period, 6 days; oviposition period, 55 days during which 595 eggs were deposited; postoviposition period, 55 days. None of the unfertilized eggs hatched. In greenhouse rearings on various hosts the first adults emerged at the following intervals after egg deposition: on pepper, 20 days from egg deposition to adult emergence; spiny buffalobur and cultivated ground cherry, 22 days; matrimony vine and tomato, 23 days; common nightshade, 26 days; and bindweed, 37 days. The locations of eggs and nymphs on the foliage have been recorded for a number of solanaceous hosts. Under greenhouse conditions most of the eggs were deposited on the leaf margins: in the field the majority were laid on the lower leaf surface, under both field and greenhouse conditions. The proportionate numbers of males and females have been determined from field and greenhouse material. Of 1,383 adults examined from field collections on ten different plant species, 48 per cent were females. Of 509 adults emerging in the greenhouse on nine host species, 49 per cent were females. From these figures it was evident that males and females were developing in equal numbers. In an analysis of temperature effects on *Paratrioza cockerelli* it has been shown that in the Yellowstone Valley damage is greatest in seasons when June and July have few days with temperatures above 90°F. The Montana data indicated dual temperature requirements for maximum psyllid development and survival: first, the occurrence of mean temperatures high enough to support and hasten psyllid development; secondly, the lack of excessive temperature maxima (90°F and above) which might prove fatal to psyllids if occurring before protective vine growth was available. Suggestions from the literature that psyllid damage is worst in dry years have not held true in Montana. Five years' precipitation records (1937-1941) showed that the year with the greatest precipitation from May through August (1938) was also the year of most severe psyllid damage. Experiments on longevity of fasting psyllid adults at 20, 50, 80, 90, and 100 per cent relative humidities have been conducted at 4°C. and 11°C. Psyllid survival at each temperature increased with the relative humidity (conversely, decreased with the saturation deficit). Greatest longevity (92 days) was noted at 4°C and 100 percent relative humidity. Importance of this finding on possible overwintering was discussed. Insecticidal tests have been conducted in 1940 and 1941, using five sprays and two dusts. Samplings of adult psyllids in treated plots showed that in 1940 the insecticides produced significant differences in numbers of adult psyllids. This was not true in 1941. Yields from treated plots in 1940 and 1941 indicated highly significant increases in yields only from the use of liquid lime-sulfur, in 1940. The tests demonstrated that at low or moderate levels of psyllid infestation, insecticides could reduce the psyllid populations without proportionately increasing the yields. Tests at Billings (1946) indicated the effectiveness of 5 per cent DDT dust against potato insects. Its use for one or two applications against Colorado potato beetles and flea beetles would hold potato psyllids at a noneconomic level in all but outbreak years. Whenever psyllid indices have reached alarming levels (5-10) before the middle of July, two to three additional applications should be made at 10-day intervals. In greenhouse experiments, dusting sulfur and lime-sulfur spray only partially prevented oviposition on treated plants, but the residual effects of the insecticides produced significant mortality among the nymphs hatching on these treated plants. The detailed history of a parasite of psyllid nymphs (*Tetrastichus triozae* Burks) has been worked out in the laboratory. The parasites were common in the field in only one locality late in the 1939 season. During 1940 and 1941 they were rare, and offered little promise as a factor in natural control. Observations on predators of the potato psyllid have been limited to the big-eyed bugs (*Geocoris*), the coccinellids and chrysopids. Of these only the chrysopids warranted detailed investigation. Adults were taken frequently in the field samplings, while eggs and larvae were commonly found in leaf samples. In laboratory studies the larvae readily attacked psyllid eggs and nymphs. One individual disposed of 553 eggs and 67 nymphs during its larval life. The seasonal trends and importance of these forms were discussed briefly. Two species of parasitic wasps have been reared from chrysopids during the studies. One species was reared from the egg stage, the other from the pupal stage, of *Chrysopa*.

Richards, B. L. 1928. A new and destructive disease of the potato in Utah and its relation to potato psylla. (Abstract) *Phytopathology*. 18(1):140-141.

The name "yellows" is suggested for a new and very destructive disease of potato observed in Utah, Montana and Wyoming, with which *Paratrioza cockerelli* Sulc, is found to be associated. The early crop is most seriously affected. Experiments showed the disease to be induced in some way by the nymphs of this Psyllid. Confined in gauze bags to single leaf, they produced the early symptoms of the disease in 9 days.

—— 1928. Potato psyllid yellows in Utah. *Plant Disease Reporter*. 12(4):43.

In a recent survey, June 12 to 16, the new potato disease psyllid yellows (cause unknown but induced by *Paratrioza cockerelli*) was found generally distributed in the early potato sections including the counties of Utah, Salt Lake, Davis, Weber, and Boxelder. The disease was located in every field visited varying in plants affected from 2 to 60 per cent. The most severe form of the trouble was found in Utah and Boxelder counties. In no case were the insects found in numbers equal to last year and it is quite evident that the loss will be correspondingly less. It is evident that considerable damage to the state's crop will result although it is impossible at present to predict the outcome in certain regions. Letters indicate a possible total failure of crop in Fruita district in Colorado.

—— 1929. Psyllid yellows (Cause undetermined). *Plant Disease Reporter Supplement*. 68:28.

Psyllid yellows appears to be largely confined to Utah and adjacent states, although in 1928 it was also reported from California. Losses in 1928 were greatly reduced compared ot the previous year, the total loss in the state probably not exceeding 7 percent. The potato psylla, associated with the disease, overwintered throughout its entire 1927 range and in the extreme soutwest part of the state (Washington County) were first noted in serious numbers by May 10. In the extreme north end of the state, around Logan, psyllids in the nymph stage were collected from matriimony vine on May 14. Reports have been received of serious crop loss due to psyllid yellows in 1926 in southern California and western Colorado.

—— 1931. Further studies with psyllid yellows of the potato. (Abs.) *Phytopathology*. 21(1):103.

In repeated tests, adults of *Paratrioza cockerelli* Sulc, used in numbers of up to 1,000 individuals to a plant, failed to produce psyllid yellows on potato. Nymphs produced by adults used in such tests, as well as those from all other sources employed, when used in sufficient numbers, produced the disease uniformly. All attempts to separate nymphs from the infective principle by rearing young nymphs on healthy plants from eggs hatched on healthy leaves in Petri dishes have failed. The type of symptoms and the degree of the injury to the potato appear to be definitely correlated with the number of nymphs feeding, length of feeding period, and the intensity and duration of light exposure. Under greenhouse conditions the disease is not induced uniformly with fewer than 15 nymphs. With larger numbers, symptoms appear in from 4 to 6 days. The progress of the disease is interrupted, and the plant apparently may assume a normal character, if the feeding nymphs are removed from the infested plant in 5 to 10 days after the appearance of the first symptoms. Growth, which is stimulated by insect feeding, but which occurs after their removal, is to all appearances normal. In Utah, normal plants were obtained from tubers grown from infested plants.

---- 1929. Project 92--Psyllid yellows of potatoes. Biennial Rpt. of Director, July 1, 1926-June 30, 1928. *Utah Agr. Expt. Stn. Bull.* 209:50-51.

This project has for its prime purpose the study of a new disease of the potato which appeared suddenly in 1927 and which purports to become the outstanding disease problem in the intermountain states. In its rate of spread and in its degree of destruction it would seem that nothing has been more startling in American agriculture. In the one year, 1927, the disease spread throughout Utah, the western slope of Colorado, reached well into southern Idaho, and established itself in Montana and Wyoming. It was observed in 23 of the 29 counties in Utah and in every field visited in 16 counties. The trouble was most severe on the early crop, and in Washington, Davis, Weber, Utah, and Boxelder Counties practically the entire early plantings were destroyed. The loss for the state is estimated between $500,000 to $800,000. Many fields in the various counties did not return the seed planted; others were left unharvested; Washington County reported total failure. An idea of the loss is seen in the estimates from Weber County. Based on average yield and acreage planted, the county would have shipped 740 cars; but 110 cars were actually shipped, and with a return upwards of $30,000 below cost of seed planted. Grand Valley, Colorado, estimated a shipment of 600 cars; two cars were actually shipped out of the entire region. The later potato areas were much less affected. The studies conducted during the season have resulted in a clear recognition of the disease symptoms and have related the disease in its etiology to the sucking process of a small insect, the jumping plant louse or psyllid (*Paratrioza cockerelli* Sulc). The correlation of the occurrence of the insect with the disease in the field is complete, and numerous greenhouse experiments have confirmed its etiological connection. Just how the insect causes the disease remains as a problem for the future. A scientific paper on the occurrence, economic importance, symptomology, cause and nature of the disease, together with a discussion of the insect responsible for its spread, is now in preparation. This paper will include the results of field and greenhouse studies during the period from June 20, 1927 to May 1928. Survey conducted during May and June, 1928, show the trouble distributed throughout the state seriously damaging the 1928 crop in Washington, Utah, Salt Lake, Davis, Weber, and Boxelder Counties. It is difficult to predict the outcome of the disease in 1928; however, if failure comparable with 1927 results, potato-growing in certain areas will be indefinitely suspended.

Richards, B. L. and Blood, H. L. 1933. Psyllid yellows of the potato. *J. Agr. Res.* 46(3):189-216.

Psyllid yellows as a disease of the potato first came to the attention of plant pathologists in 1927, although there is evidence that the trouble has existed in certain isolated areas in Utah for a number of years prior to this date. The disease may develop suddenly over a vast area in any one season and is capable of extensive and frequently complete destruction in both the early and the late potato crop. Studies since 1927 have shown the dangerous nature of psyllid yellows and indicate that in certain districts it is a perennial menace even to the extent of eliminating the potato as a crop. This condition exists particularly in Washington County in southern Utah, and also in the early potato-growing areas of Davis and Weber Counties in the northern part of the State. A similar condition is reported also for the Fruita section in the Grand Junction district of Colorado (western slope). In survey studies the tomato psyllid (*Paratrioza cockerelli* Sulc) has been found constantly associated with psyllid yellows of the potato, and experiments have shown that the disease is in some way induced during the feeding processes of the nymphs of this insect. Under conditions especially favorable for symptom expression as few as three to five nymphs might occasionally produce psyllid yellows, although uniformity of appearance and full expression of symptoms seldom result with fewer than 15 to 30 actively feeding nymphs. The adult form of *Paratrioza cockerelli* in numbers up to 1000 per potato plant appear incapable of producing psyllid yellows symptoms on the plant in the field or in the greenhouse. The symptomatology of psyllid yellows varies greatly with the number of insects feeding, the length of feeding period, and the intensity and duration of light exposure during the time of feeding. Psyllid-yellows symptoms under conditions of unmodified sunlight consist of yellowing, basal leaf rolling and purpling of the younger leaves, yellowing and rolling of older leaves, nodal enlargement, increased axillary angle, aerial tubers and shoots, frequent rosetting, various apical growths, and distortion, excess tuberization, and inhibition of rest period. Under conditions of decreased exposure and intensity of light, basal, marginal, and interveinal yellowing becomes a constant feature of the disease. Progress in symptomatological expression is stopped abruptly when insects are removed at intervals of 12, 16, and 26 days after feeding has commenced, indicating that the full expression of symptoms of psyllid yellows results only when nymphs of *Paratrioza cockerelli* are allowed to feed continuously on the tissues of the infested plant. A tendency toward recovery results when time of feeding in the greenhouse is less than 16 days. Recovery in the field has also been observed. So far as is known, *P. cockerelli* is the only factor capable of producing psyllid yellows in the potato and in related plants. Attempts to transmit psyllid yellows from diseased to healthy plants have failed. Under Utah conditions the disease does not appear to be transmitted from diseased plants to the following generation through the tuber. The size, motility, prolific fecundity, longevity, and long oviposition period of the female are important factors in the rate of dissemination of the insect. The factors, when considered in connection with the apparent general distribution of the insect, provide, in part, at least, an explanation of the sudden widespread epidemic of psyllid yellows in 1927. In preliminary tests nymphs of *Paratrioza cockerelli* were not separated from the infective principle by hatching eggs on healthy potato leaves in Petri dishes. In fact, nymphs so hatched produce a more vigorous symptom response on healthy Irish Cobblers than psyllid nymphs of the same age grown on infected potato plants. The true nature of the infective principle injected into potato plants by *Paratrioza cockerelli* at present remains unknown. Available facts, however, question somewhat the virus theory of the disease and suggest the possible existence of some toxic substance which is produced in some way during the feeding process of the psyllid nymph. Additional facts will be necessary before final conclusions can be drawn as to the true etiology of psyllid yellows.

Richards, B. L., Blood, H. L. and Linford, M. B. 1927. Destructive outbreak of unknown potato disease in Utah. *Plant Disease Reporter.* 11(8):93-94. (Ref.)

Richards, B. L., and Stephens, F. E. 1932. Psyllid Yellows in Utah. *Proc. 10-13 Annual*

conferences Western Plant Quarantine Bd. Cal. Dept. Agr. Sp. Bull. 115. (Ref.)

Riedl, W. A. 1941. Sulfur dusting for the control of psyllid yellows of potatoes. *Wyo. Agr. Exp. Stn. Bull. 245*, 15 pp.

In order to find a more satisfactory method than spraying for the control of *Paratrioza cockerelli* Sulc, which causes the condition known as psyllid yellows on potato and is responsible for considerable losses of crop in Wyoming, the effectiveness of sulphur dusts and sprays were compared in small-scale tests in 1939 and 1940. In 1939, all the treatments, which were applied on 17th and 29th July and 16th August, gave significant or nearly significant increases in yield over untreated plots. Sulphur dust (98 percent of which passed a 325-mesh screen) applied at the rate of 70 lb. per acre, resulted in yields significantly and almost significantly higher, respectively, than those from applications of 2 U.S. gals. lime-sulphur and of 5 lb. wettable sulphur and 1 U.S. gal. lime-sulphur in 80 U.S. gals. water per acre; the difference between the two sprays was not significant. In 1940, the concentration of lime-sulphur and wettable sulphur (without lime-sulphur) were increased to 2 1/2 U.S. gals. and 8 lb. per 80 U.S. gals. water, respectively, the rate of application of the dust was halved and the treatments were made on 25th July and 13th and 26th August. Sulphur dust gave the best control of the adults and eggs, but the lime-sulphur gave better control of the nymphs, probably because the dust was applied too lightly or too late. All treatments gave significant increases in yield over the untreated plots; lime-sulphur gave significantly and insignificantly higher yields than wettable sulphur and sulphur dust, respectively. In field trials, in which a power duster was used, sulphur dust gave insignificantly higher yields than lime-sulphur, wettable sulphur or no treatment when the Psyllid population was small and significantly higher yields when it was larger. It is pointed out than dusting is quicker than spraying and required less labor and motive power, that the necessary equipment is cheaper, lighter and more convenient to use, that more chemicals can be mixed in dust form and that dusts are less caustic than sprays. The materials are more expensive, however, and cannot be applied in windy weather unless a hood is used. It is concluded that sulphur dust applied at the right time at the rate of 40-50 lb. per acre should give satisfactory control of *P. cockerelli*, but that further large-scale tests are necessary to determine whether dusting with sulphur is more economical than spraying with lime-sulphur in large fields.

---- 1943. Dusting for potato psyllid control. *Wyo. Agr. Exp. Stn. Bull. 260.* 20 pp.

Investigations on the control of *Paratrioza cockerelli* Sulc, on potato in Wyoming were continued in 1941 and 1942. In 1941, the treatments and rates per acre per application were 2 U.S. gals. lime-sulphur or 1 U.S. gal. lime-sulphur and 4 lb. wettable sulphur in 80 U.S. gals. water, and 30 lb. of dusting sulphur (98 or 93 per cent. 325 mesh), tribasic copper sulphate or a mixture of sulphur and red copper oxide (94:6). They were applied on 21st July and 12th and 27th August. The two dusting sulphurs contained an inert conditioning agent to prevent lumping, and the dusts were applied from a machine equipped with a hood to confine them round the plants. Counts made at weekly intervals during the growing season showed that all the treatments reduced the populations of adults, eggs and nymphs. Sulphur dust, with or without red copper oxide, gave as good control as the sprays or better; tribasic copper sulphate was least effective. All treatments except tribasic copper sulphate gave significant or nearly significant increases in yield; these were greatest for the two dusting sulphurs and progressively less for the spray of wettable sulphur and lime-sulphur, sulphur dust with red copper oxide and the lime-sulphur spray. On both yield and population figures the coarser dusting sulphur was slightly superior to the finer one. The treatments and rates per acre in 1932 were: 2 U.S. gals. lime-sulphur in 80 U.S. gals. water; 37 lb. conditioned dusting sulphur (98 per cent. 325 mesh); 30 lb. conditioned dusting sulphurs (microfine and 93 per cent. 325 mesh); 20 lb. unconditioned dusting sulphur (93 per cent. 325 mesh); 27 and 28 lb., respectively, of mixtures of sulphur with calcium arsenate and cryolite (2:1); and 37 lb. of a mixture of sulphur and basic copper sulphate (9:1). They were applied on 9th and 30th July and 12th and 25th August, and the numbers of adults on treated and untreated plants were compared weekly from 21st July to 9th September. The average reductions in their numbers were 59-76 percent for the dusts and 48 percent for the spray; the unconditioned dusting sulphur gave the best control, but is difficult to handle. All the treatments gave significant increases in yield, with no significant difference between them except that the yield for the sulphur dust containing copper sulphate was higher than that for the unconditioned dusting sulphur alone. Fungus disease was not a factor, but it is possible that the copper had a stimulating effect on the plants. The microfine sulphur gave good yields of potatoes of a high quality, but is expensive and should be tested further to determine whether lower rates of application will afford satisfactory control. The effectiveness of the mixtures containing calcium arsenate and cryolite against leaf-chewing insects could not be determined as these were not numerous. In a subsidiary test, the same dusting sulphur applied at the rates of 20 and 30 lb. per acre on the same dates gave slightly higher yields at the higher rate, but the differences were not significant. The comparative costs of spraying and dusting are discussed, and it is concluded that dusting is cheaper, quicker and easier, and results in less damage to the plants and the fields. General recommendations for dusting are appended.

Riedl, W. A., and Harrison, L. R. 1945. The control of psyllids and flea beetles on potatoes. *Wyo. Agr. Exp. Stn. Bull. 271.* 27 pp.

Two of the most important insect pests of potato in Wyoming are *Epitrix tuberis*, Gentner, which injures potatoes grown under irrigation in the North Platte Valley, and *Paratrioza cockerelli* Sulc. The adults of *E. tuberis* feed on the leaves, but are less injurious than the larvae, which tunnel along the surface of the developing tubers or into them to a depth of 1/4 inch or more. *P. cockerelli* causes the condition known as psyllid yellows. In a field in which the Psyllid population was low and *E. tuberis* did not occur, a 90 percent microfine sulphur dust and two 325-mesh sulphur dusts containing 7 percent of different conditioning agents, applied on 14th and 26th July and 11th August, gave approximately equal yields. Applications of 10, 20 and 30 lb. per acre usually gave significant increases yield over no treatment, and there were no significant differences between them. The sulphur dust used in all the experiments in 1944 was 325-mesh with 7 percent conditioning agent. Potatoes infested heavily by the flea-beetle and lightly by the Psyllid were treated on 12th July, when they were about eight inches high, and on 21st and 29th July and 4th and 22nd August. Dusts of sulphur alone or with Dutox (4:1) and a spray of lime-sulphur (1:40) containing 5 lb. zinc arsenite per 100 U.S. gals. did not. Sulphur alone or with Kryocide or cryolite (3:1) gave the best control of nymphs and adults of *P. cockerelli*, and sulphur with Kryocide or with cryolite (3:1 or 4:1) gave significantly higher yields of tubers free from flea-beetle injury and better control of the adult flea-beetles than the other materials. Where the Psyllid population was high, but *E. tuberis* was absent, and applications of 10, 20 and 30 lb. sulphur dust per acre were made on 9th and 27th July and 14th and 24th August, the yields increased with the rate of application and all differences were significant. Where the dust was applied at 20 lb. per acre and the psyllid population was high, the yield was significantly improved by covering the boom with a canvas hood when applications were made from each side of the row but not when they were made from above, and treatment from each side with a hood was slightly, though not significantly, better than treatment from above with or without a hood. No significant differences in yield resulted from any of the four methods of application when the Psyllid population was low, the flea-beetle population high and a dust of sulphur and cryolite (4:1) was applied at 30 lb. per acre. In preliminary tests with new materials, none prevented injury to the tubers by larvae of the flea-beetle, but 3 per cent. DDT in sulphur and 0.5 per cent. rotenone in sulphur gave excellent control of the adults. The second dust and a spray of lime-sulphur (1:40) containing 5 lb. zinc arsenite and 3 lb. Dithane [disodium ethylene bisdithiocarbamate] per 100 U.S. gals. gave the best control of nymphs and adults of the Psyllid, and the rotenone dust was the only treatment that gave a significantly higher total yield than no treatment; there were no significant differences in yield between the various treatments. As a result of these experiments, a sulphur dust of at least 325-mesh fineness containing not more than 10 per cent. conditioning agent is recommended when only *P. cockerelli* is present. It should be applied in the early morning or at night when there is little or no wind. Treatment is required when the number of adults per 100 sweeps of the net averages 2-3, and the first application is usually necessary when the plants are 4-6 ins. high. At least two applications should be made to potatoes grown under dry-land conditions and 3-4 to those grown under irrigation, at intervals of 2-3 weeks or less; frequent light applications give better control than less frequent heavy ones. The rate of application should be about 20 lb. per acre when the plants are small, and it should be increased to 30 lb. as they grow. The dust should be applied from each side of the row with a hood over the boom or from above the row if a hood is not used. If a spray is to be employed, lime-sulphur (1:40) should be applied with at least three nozzles per row and a pressure of 300-500 lb. per sq. in. When both insects are present, dusts of sulphur with cryolite (2:1, 3:1 or 4:1) or Dutox (4:1) should be applied at the rate of 30-40 lb. per acre 5-6 times at intervals of 7-10 days from the time when the plants are 4-6 inches high. For a spray, lime-sulphur (1:40) with the addition of 5 lb. zinc arsenite per 100 U.S. gals. should be used.

Romney, V. E. 1939. Breeding areas of the tomato psyllid, *Paratrioza cockerelli* (Sulc). *J. Econ. Entomol.* 32:150-151.

Observations pertaining to spring breeding sources of the tomato psyllid, *Paratrioza cockerelli* (Sulc), have been made in conjunction with studies to determine the breeding areas of the beet leafhopper, *Eutettix tenellus* (Bak.), in southern Arizona, New Mexico and Texas. *Paratrioza cockerelli* normally breeds abundantly on *Lycium andersonii* A. Gray and to some extent on *Lycium macrodon* A. Gray, which occur along washes in the semidesert areas of southern Arizona at altitudes below 3,000 feet. The distribution of *L. macrodon* is rather limited, but *L. andersonii* occurs commonly along washes throughout most of southern Arizona. Breeding normally occurs on these plants from January to May. The peak in numbers usually occurs late in April or early in May, after several generations have been produced. The adults move completely from the breeding source by the middle of June, and thereafter it is not possible to find the psyllid in its winter and spring breeding areas until an influx occurs late in October or early in November from an unknown source. Probably the more important factor causing a cessation in breeding by May is the fact that normally the host plants shed most of their leaves owing to lack of moisture. A hymenopterous parasite, *Tetrastichus* sp., attacks the nymphs in some locations, and numerous predators (coccinellids and chrysopids) reduce the numbers of eggs and nymphs to a varying degree from year to year. Data collected by means of insect traps (Fulton & Chamberlin 1931) located in the Grand Valley of western Colorado indicate a possibility that this district receives its psyllid infestation from southern Arizona, since movements of this insect have occurred coincidentally with movements of the beet leafhopper. Southern Arizona is known to be the principal source of beet leafhoppers which infect the Grand Valley district at least four-fifths of the years. East of the Continental Divide, *Paratrioza cockerelli* and a closely related species, *P. mexicana* F. D. K., occur together in varying proportions, but the latter species apparently does not occur west of the Divide. This would indicate that the source of the psyllid west of the Divide is different from that east of the Divide. Limited observations indicate that the tomato psyllid and its closely related species *P. mexicana*

breed on *Lycium* along the Rio Grande drainage above Laredo, Tex., for several hundred miles. There is a possibility that this is the main source of spring infestations that occur east of the Divide as far north as Colorado.

Rowe, J. A. and Knowlton, G. F. 1935. Studies upon the morphology of *Paratrioza cockerelli* (Sulc). *Utah Acad. Sci. Proc.* 12:233-239.

This paper describes the morphology of the egg, the nymph and the adult stages of the potato/tomato psyllid, *Paratrioza cockerelli* (Sulc).

Sanford, G. B. 1934. A malady of the potato in Alberta similar to psyllid yellows. *Sci. Agr.* 15(1):46-48.

A disease-like condition of potatoes that has been reported in several places in Alberta closely resembles "Psyllid yellows," which is associated in the United States with feeding of the nymphs of *Paratrioza cockerelli* Sulc. Like Psyllid yellows, it was not inherited by the progeny of infected plants. Psyllid nymphs have occasionally been found on potato in Alberta, but *P. cockerelli* has not been recorded with certainty from the province.

----- 1952. Phloem necrosis of potato tubers associated with infestation of vines by *Paratrioza cockerelli* Sulc. *Sci. Agr.* 32:433-439.

According to observational and experimental evidence, the intense tuber phloem necrosis and associated vine symptoms here described, developed in about 10 days as a result of nymphs and adults of *Paratrioza cockerelli* feeding on apparently healthy potato vines in open field culture during July and August. Present evidence indicates that the causal agent is a toxic substance injected into the plant by the insect while feeding, and that it soon becomes systemic. Apparently it is not a virus, because plants from affected tubers are merely weak in the first season and normal in the next tuber generation. It is suggested that the sudden appearance of tuber phloem necrosis in Alberta in 1938 was due to a genetic mutation in the local psyllid population. Further positive evidence that the causal agent can be transferred to healthy plants by grafting technique is required.

Schaal, L. A. 1938. Some factors affecting the symptoms of the psyllid yellows disease of potatoes. *Am. Potato J.* 15(7):193-212.

Experiments conducted in Colorado from 1928 to 1934, attempted to determine some causes of the expression of psyllid yellows caused by the tomato psyllid (*Paratrioza cockerelli* Sulc). The losses in production from 1929 to 1934 were heavy in the early crop districts of Colorado. The appearance of the disease was coincident with the appearance of the tomato psyllid. Certain varieties appeared to be more resistant to psyllid yellows than others. Greatest damage occurred during seasons of high temperatures and low humidity. The expression of symptoms was accentuated when the plants grew in sunlight and high air temperatures. Direct sunlight was necessary for the expression of the typical color symptoms of psyllid yellows. When an extract of psyllid nymphs was introduced into healthy potato plants in certain concentrations, symptoms similar to those found in the field were produced. Psyllid yellows was not found to be tuber-transmitted but there was a general weakening of the plants grown from infected tubers. Typical symptoms of psyllid yellows were produced when 25 or more nymphs were placed on single stem potato plants. The severity of the symptoms increased with numbers up to 100 to the plant. Potato plants growing in a highly alkaline soil, those infected with fungous diseases, and plants

with injured stems and root systems developed psyllid yellows symptoms with relatively fewer insects than plants growing under more favorable conditions. Spraying potato plants with cold water under pressure twice daily for a period of 14 days gave practically complete control. Workers at the Colorado Agricultural Experiment Station found that lime sulfur, 1 to 40, applied under 300 to 400 pounds pressure gave good control.

Scott, C. M. 1939. Psyllid yellows of potato in California. *Plant Disease Reporter*. 23(1):4.

Since the first report in 1928 (Shapovalov, Phytopath. 19:1140), psyllid yellows has been rarely reported in california. Our files contain one record for Colma, San Mateo County, made by Dr. M. W. Gardner in 1936. Specimens of potatoes sent in May, 1938 by Roy W. Southwick, Assistant County Agent of Ventura County, showed psyllid yellows symptoms and psyllids were present. The letter accompanying the specimens stated "Potatoes are not an important crop in this county, but I have had several calls to small patches where this same difficulty seems to be present".

Shapovalov, M. 1929. Tuber transmission of psyllid yellows in California. (Abs.) *Phytopathology*. 19(12):1140.

Tomato psylla (*Paratrioza cockerelli*) has been long known to exist in California but psyllid yellows was not discovered until the fall of 1928. At that time, there were some severely diseased fields and several young tubers were collected and planted out-of-doors at Riverside. One mixed lot produced plants in part affected with yellows; some also showed mosaic symptoms, and part were free from this disease. Another lot showed different stages of the disease in plants grown from tubers of different hills. In the spring of 1928, fields that were planted with potatoes grown in the psyllid infested area showed a considerable amount of the disease in the absence of psyllids. The symptoms were much more pronounced in dry and hot interior sections than on the Coast or when artificially shaded. These data indicate: (1) At least in some localities psyllid yellows may be transmitted with the tubers; (2) the progeny may show various stages of the disease; and (3) psyllid yellows and mosaic have distinct and specific effects when present in the same plant.

---- 1929. Psyllid Yellows. *Plant Disease Reporter Supplement*. 68:28-30. (Ref.)

Snyder, W. C., Thomas, H. E., and Fairchild, S. J. 1946. A type of internal necrosis of the potato tuber caused by psyllids. *Phytopathology*. 36(6):480-481.

Manson and Sanford are reported to have found in Canada an internal necrosis of the potato tuber caused by the tomato psyllid. In a recent study of spindling sprout in the White Rose potato an opportunity was afforded to examine for internal symptoms several dozen tubers from plants artificially infested with psyllids. The tubers had been stored at room temperature for about 6 months and either had produced spindling sprouts or failed to sprout at all. On cutting, all these tubers had a characteristic discoloration in the vicinity of the smaller vascular elements. A similar number of control tubers from noninfested plants were free from internal necrosis. The discoloration extended throughout the length of the tuber but was somewhat more prominent at the stem end. On closer examination the discoloration was found to be due to discontinuous dark flecks rather uniformly distributed in cross section from the main vascular ring to near the center of the tuber. In early stages under magnification an irregular black and white pattern was evident within the flecks. With still higher magnification the cells were seen to contain dark bodies irregular in size, and amorphous to smooth and spherical in appearance. In later stages, the flecks became more readily discernible macroscopically because of the brownish cast due to cell necrosis, but they lost the characteristic discrete, dark, intracellular bodies. It is hoped that the distribution of the flecks and their distinctive microscopic appearance will prove to be of diagnostic value for psyllid yellows where this type of internal necrosis of the tuber occurs. In other experiments in which spindling sprout was induced by infesting the mother plant with psyllids, internal necrosis was not observed. However, in these instances either the amount of toxin taken up by the tubers may have been less or the tubers may not have been held in storage for a sufficiently long time. Our evidence does indicate that the kind of internal necrosis may occur, like spindling sprout, as a symptom of psyllid yellows when tubers produced on heavily infested plants are held in storage.

---- 1946. Spindling or hair sprout of potato. *Phytopathology.* 36(11):897-904.

Artificial infestations of potato plants with psyllids under controlled conditions have shown that typical spindling sprout or hair sprout may be a symptom of psyllid yellows, when psyllids are present on plants approaching maturity. The form of spindling sprout studied is not tuber transmitted, nor is there any evidence of the involvement of a virus. There is no tendency for sprouts to grow out of the spindling sprout condition as long as all sprout growth is sustained by the tuber. Spindling sprouts that have struck roots into soil begin to grow normally. The yield from spindling-sprout tubers was approximately one-half that from normal sprouting seed. The second generation from spindling-sprout tubers fully recovered from all spindling-sprout symptoms and yielded normally. Severely affected tubers may fail to sprout. Internal necrosis in tubers affected with spindling sprout was observed in one experiment in which the tubers were stored for several months. The relation between spindling sprout and psyllid yellows makes double important the application of control practices against psyllids, especially in areas where seed potatoes are produced.

Staples, R. 1968. Cross protection between a plant virus and potato psyllid yellows. *J. Econ. Entomol.* 61(1):1378-1380.

When nymphs of *Paratrioza cockerelli* (Sulc) fed upon potato plants infected with Nebraska haywire virus (= tomato big bud virus), they were unable to induce psyllid yellows in healthy potato plants grown at 10-17°C. Under the same conditions potato plants infested with nymphs from stock culture exhibited typical symptoms of psyllid yellows. The weight of the evidence indicates that psyllid yellows is a plant toxemia caused by toxicogenic insect. The potato psyllid was not a vector of Nebraska haywire virus.

Starr, G. H. 1939. Psyllid yellows unusually severe in Wyoming. *Plant Disease Reporter.* 23(1):2-3.

The past year was one of the worst years on record for psyllid yellows losses. It is estimated that for early planted potatoes (before June 1) the loss was approximately 75 percent, and for late planted (after June 1) it was approximately 35 percent. The psyllid infestation began earlier and with a larger population than usual. Moreover, the insects continued to do damage until frosts killed the plants. Even though the moisture supply was abundant and the growing season unusually long, the tubers failed to make normal growth. In some fields that were not sprayed at all or in fact in a few that were sprayed once or twice the crop was not worth digging. However, lime-sulfur spray (1:40) did give good results in most cases. In the seed area in eastern Wyoming the majority of fields were sprayed, although a few farmers, who either did not have sprayers available or questioned the value of spraying, did not spray. It was demonstrated clearly, in a year of severe psyllid infestation, that spraying must be done properly to obtain its benefits. Some growers sprayed too late after a certain amount of damage was done; others did not continue the application late enough and late season damage resulted; still others made mistakes in the application of the spray, i.e., pulled the sprayed too fast, had the nozzles out of adjustment, too little pressure or some similar reason. However, the lack of timeliness in the spray application was responsible for most of the loss. The psyllids were generally distributed over the entire State even in very isolated spots, although occasionally a field could be found where the damage was slight and a good yield resulted. Psyllid yellows dealt out its toll to all varieties of potatoes and to tomatoes grown largely in the family garden. The chief varieties of potatoes grown in the State are the Bliss Triumph, 85 to 90 percent; Cobbler, 5 to 10 percent and the remainder composed of several varieties, i.e., Early Ohios, Red McClure, Burbank, Katahdin, Chippewa, Golden, and Warba. Although all of these varieties are susceptible, the Bliss Triumph is probably most susceptible of all. As a result of plot tests with many commercial varieties, no variety has shown enough resistance to be of any commercial importance.

Stephens, F. E. 1932. Psyllid yellows in Utah. *Proc. of the 10th, 11th, 12th, and 13th Annual Conferences. Western Plant Quarantine Board. Calif. Dept. Agr. Spec. Publ.* 115:35-38. (Ref.)

Strickland, E. H. 1938. The Chermidae (Homoptera) of Alberta. *Can. Entomol.* 70(10):200-206.

A list is given of 27 species of Psyllids collected in the neighborhood of Edmonton in 1937, showing the plants on which they were found. Two undescribed species were also taken. The collection was made as a result of the discovery of Psyllid yellows in potatoes, accompanied by a local infestation of *Paratrioza cockerelli* Sulc, in a city garden in Edmonton in 1936. *P. cockerelli* is thought to have been present on greenhouse tomatoes in Alberta in 1928, but it was not definitely identified there until 1934, when Psyllid yellows became prevalent in potato in a number of places in the south. It was probably introduced with infested greenhouse plants and escapes into the field each year, being unable to overwinter in the open.

---- 1939. Further notes on psyllidae taken in Alberta (Homoptera). *Can. Entomol.* 71:212-215.

In August reports were received to the effect that several adjacent gardens in Edmonton were showing signs of potato yellows. A careful examination of the supposedly affect plants failed to reveal any psyllids with the exception of a few *Psyllia negundinis* adults which had evidently scattered from some nearby Manitoba maples. Two greenhouses in the vicinity, in which tomatoes were growing, showed no signs of infestation. Although the range of this insect is increasing in southern Alberta, the infestation resulting from an importation into Edmonton in 1936 appears to have died out completely.

Sulc, K. 1909. *Trioza cockerelli* n.sp., a novelty from North America, being also of economic importance. *Acta Soc. Entomol. Bohemiae* 6:102-108.

This is the first documentation of the species referred as the potato/tomato psyllid later to be named *Paratrioza cockerelli*. A description of the morphology is given. Nothing is known of the biology and phenology at this time. Oecology: larvae and imagines were found on *Capsicum annuum* L. in rather large numbers and we may infer that the insect can become very destructive. Larvae form no galls living freely on the underside of the leaves. Geographical distribution: Boulder, Colorado, U.S.A., the garden of Prof. Cockerell only; the Capsicum, having been introduced in seeds from S. America, cannot be the original feeding plant of the insect, which remains unknown.

Swenk, M. H. and Tate, H. D. 1940. The potato flea beetle and the potato psyllid in Nebraska. *Bull. Nebr. Agr. Exp. Stn. 327.* 19 pp.

Potatoes are severely injured in western Nebraska by the nymphs of *Paratrioza cockerelli*, Sulc, which cause Psyllid yellows and *Eptrix cucumeris*, Harr. All stages of these pests are described, and an account is given of their bionomics, based partly on the literature and partly on observations carried out in Nebraska between 1928 and 1937. The Psyllid completes its life-cycle in about 3 weeks and has several generations a year. Effective control on potatoes can be obtained by spraying with 1 U.S. gal. liquid lime-sulphur (32^0 Be) or 4-5 lb. dry lime-sulphur in 40 U.S. gals. water, before the symptoms of Psyllid yellows appear. A protective spray each year when the plants are 6-8 ins. high is recommended. Control of both pests is obtained by adding zinc arsenite to the lime-sulphur spray. Reference is made to List's recommendation for the control of the Psyllid on tomato.

Tate, H. D. and Hill, R. E. 1944. Residual toxicity of sulphur to the potato psyllid in greenhouses. *J. Econ. Entomol.* 37(4):557-558.

Although *Paratrioza cockerelli* Sulc, does not occur in destructive numbers every year in Nebraska, sulphur sprays and dusts are fairly regularly applied to potato against it as a protective measure, and experiments were therefore carried out in the greenhouse during the winter of 1941-42 on residual toxicity of sulphur to this Psyllid. The test insects were released in cages covering individual leaves of plants that were untreated or had been sprayed with liquid lime-sulphur (33^0 Be) in water (1:40) or 1 lb. wettable sulphur per 9 U.S. gals. water at a rate equivalent to 100 U.S. gals. per acre or dusted with sulphur (325 mesh) at 30-40 lb. per acre at various intervals previously. Records were obtained for eggs and for nymphs in the third, fourth and fifth instars. Adults were confined on potato foliage for a given period, and any eggs deposited were kept under observation until they had hatched or proved to be non-viable; nymphs were kept on the plant until they died or transformed to adults. Relatively few eggs were laid by females confined on foliage during the first 4-5 days after treatment; increasing numbers of eggs were laid after this, but no normal individuals hatched from them until the time between treatment and caging exceeded 12 days. When the interval was 14 days, comparatively large numbers of eggs were deposited, but only a small proportion hatched normally; approximately normal deposition and hatching occurred in two series in which 19 and 25 days elapsed between treatment and caging. In all cases development on untreated leaves appeared to be normal. In 11 tests on the residual toxicity of liquid lime-sulphur to nymphs, only four normal adults emerged when the intervals between treatment and caging were 6-39 days; in 12 with wettable sulphur, none emerged after intervals of 1 to 36 days; and in nine with dusting sulphur only 10 emerged after intervals of 6 to 39 days. The rate of lethal action and mortality decreased as the interval increased. In four tests in which plants were sprayed with lime-sulphur and exposed to about 1/2 inch artificial rain 1 to 12 days later, immediately before nymphs were confined on them, and in two similar tests with dusting sulphur in which the intervals were 5 and 12 days, only 8 of 120 nymphs transformed to normal adults; and in five similar tests with wettable sulphur, with intervals of 5 to 21 days, only 13 of 100 nymphs gave rise to adults. When all the leaves but one on a plant were sprayed with lime-sulphur and 20 nymphs were confined on the untreated leaf ten days later, all developed normally, giving rise to adults that laid viable eggs, whereas none caged on treated foliage developed normally; when nymphs were caged on foliage that developed after treatment, development was again normal. It seems unlikely, however, that the protective value of the treatments is much affected by this fact, since the Psyllids feed largely

on the more mature leaves. Nymphs caged on the untreated surface of leaflets thoroughly covered with liquid lime-sulphur on one side also developed normally, indicating that thorough coverage is essential.

Tuthill, L. D. 1943. The psyllids of America north of Mexico, (Psyllidae: Homoptera). *Iowa State College J. of Sci.* 17(4):443-660. (Ref.)

---- 1945. Contributions to the knowledge of the Psyllidae of Mexico (part II). *J. Kansas Entomol. Soc.* 18(1):1-29.

A description is given to the morphology, the distribution and the host plant species of *Paratrioza cockerelli* (Sulc).

Wallis, R. L. 1940. The potato and tomato psyllid. *Nebr. Pot. Imp. Assoc. Ann. Rep.* 21:5-9. (Ref.)

---- 1941. The potato and tomato psyllid. *USDA Bur. Entomol. and Plant Quar., E Series, No. 532.* 6 pp. (Ref.)

---- 1946. Seasonal occurrence of the potato psyllid in the North Platte Valley. *J. Econ. Entomol.* 39(6):689-694.

Surveys of the potato psyllid, *Paratrioza cockerelli* (Sulc), on cultivated crops and noneconomic hosts in the North Platte Valley of Wyoming and Nebraska from 1940 to 1944 indicate that the psyllid does not overwinter in this area and that initial spring populations come from some unknown source outside the valley. In the fall of 1943 a very low population of psyllids occurred on all host plants, but during the spring of 1944 the population was high. This could not have been the result of an increase in the local area during the winter months. Potatoes growing in cull piles and the matrimony-vine, *Lycium halimifolium* Mill., are by far the most important noneconomic host plants of the potato psyllid in the North Platte Valley. These hosts collect the greater part of the initial population of adult psyllids in the spring, and serve as a source of infestation for other hosts, mainly early potatoes, in July. Wild buffalo-bur and groundcherry are not important host plants of the potato psyllid. The early potato crop serves to carry the psyllids over the hot July weather until later plantings of potatoes and tomatoes are large enough to support psyllid infestations. There is no apparent relation between spring infestations of psyllids and temperature or precipitation during the preceding winter. The spring movement of psyllids to the host plants under study began the first weeks in May and June. The population of adult psyllids increased very rapidly during the latter half of June, and reached a peak about July 1. The size of this spring population was affected by the temperature during May and June, the optimum temperatures for spring movement and development being between 60° and 70°F. The principal factors affecting psyllid populations after July 1 are the size of the spring infestations, size of plants, and maximum temperatures for July. Above-normal temperatures at this time will reduce numbers to the extent that the subsequent build-up is very slow except on early potatoes, which are large enough to protect the psyllids from the hot sun's rays. A fall peak of infestations is reached about September 15.

---- 1948. Time of planting potatoes as a factor in prevention of potato psyllid attack. *J. Econ. Entomol.* 41(1):4-5.

A survey of adult potato psyllid populations on early, medium and late plantings of potatoes from 1939 to 1946 in the North Platte Valley of Wyoming and Nebraska showed that potatoes planted

in April are more subject to attack by this insect than potatoes planted after June 1. Only 37 per cent as many psyllids were found on the medium crop as on the early crop, and 28 per cent as many on the late crop as on the early crop. The higher populations on the early planting is apparently due to its growth during late June, when an influx of psyllids from overwintering sources occurs, and to the fact that the plants reach their maximum growth in July, when critically high temperatures occur. These high temperatures retard the development of psyllid populations on the small plants of later plantings.

---- 1951. Potato psyllid selection of host plants. *J. Econ. Entomol.* 44(5):815-817.

Tests were carried out in 1941-45 to determine the preferences of ovipositing adults of *Paratrioza cockerelli* (Sulc) among the common wild and cultivated solanaceous plants of Colorado, Wyoming and Nebraska. The plants, which included tomato and potato, were grown in small plots at one locality in Nebraska, and leaf samples of an area approximately equal to 50 potato or tomato leaflets were taken at weekly intervals, from about 15th July until the plants were killed by frost, and examined for eggs. Statistical analysis showed that significantly more eggs were laid on *Physalis francheti* and *Solanum carolinense* than on cultivated and wild groundcherry (*P. ixocarpa* and *P. lanceolata*), and more on these than on any other plants. *P. francheti* and *P. ixocarpa* are annuals cultivated to only a limited extent and therefore of little importance as sources of Psyllids that may migrate to potato and tomato, but *S. carolinense* and *P. lanceolata* are widespread wild perennials and therefore important. Some plants were tested for 1-3 years only, because of the difficulty of propagating them, and of these, *P. pruinosa*, *Nicandra physaloides* and *Nierembergia hippomanica*, which are grown to limited extent, and *Datura stramonium*, a wild plant that does not grow abundantly in the area, were preferred to many of the more commonly occurring plants.

---- 1955. Ecological studies on the potato psyllid as a pest of potatoes. *USDA Tech. Bull. 1107.* 25 pp.

An ecological study of the potato psyllid [*Paratrioza cockerelli* (Sulc)], which causes psyllid yellows of potato and tomato plants, was made during the period 1939-52 to determine the cause of psyllid outbreaks. The potato psyllid occurs in North and South Dakota, Nebraska, Kansas, Oklahoma, and Texas, and all States west of them except Washington and Oregon. High humidity apparently prevents it from moving east of these States. Psyllid yellows appears first on plants at the edge of the field and progresses toward the center. The first symptoms in potato plants are an upward curling of the basal portions of leaflets near the top of the plants and a purpling of the curled portions. As the disease advances, the tops of the plants become dwarfed and the affected leaves become thick and leathery and eventually turn yellow or purplish. Underground there is a heavy set of small tubers close to the main stem. These tubers mature early, sprout, and produce secondary stolons, which may set additional tubers. The tubers are usually unmarketable. The host plants are confined almost entirely to the family Solanaceae. The only other plants on which it is known to breed are field bindweed, morning-glory, and sweetpotato. The potato psyllid overwinters in Texas and southern New Mexico, feeding mostly on wild *Lycium*. Development nearly stops during January because of low temperatures, but is resumed in February. In the spring the adults spread to the north or northwest with the prevailing winds. The psyllids move from the spring breeding areas in Texas and New Mexico into the potato-growing areas of Colorado, Wyoming, and Nebraska. This movement occurs during May and June, when temperatures in the potato-growing areas are between 60 and 70° F. The greatest movement is in June, reaching a peak near July 1. Psyllid populations in the plains areas decrease rapidly in July, when temperatures average above 70°. There is a corresponding increase in the mountainous areas, where temperatures are lower. Summer populations of psyllids in the potato-growing areas are also affected by the size of the host plants when maximum temperatures occur. Large plants, such as early potatoes, protect psyllids from high temperatures in July. In potato-growing areas the ornamental plant matrimony-vine and piles of sprouting cull potatoes are important sources of psyllid infestations to cultivated crops. Much benefit can be obtained by destroying these host plants. Matrimony-vine may be easily killed by spraying with 2,4-D. Sprouts in cull piles may be prevented by scattering the cull tubers when dumped, so that they are not more than one layer in depth. Groundcherries and buffalo-bur, which are abundant in the potato-growing areas, are not important sources of infestation since they do not begin growth until potato plants are available. A preseason survey each year of adult psyllid populations on non-economic host plants will indicate the expected population on potatoes for the growing season. Such a survey will save up to 10 million bushels of potatoes in the psyllid-infested area in outbreak years and will spare the farmer the expense of treating with insecticides when light attacks are indicated.

Werner, J. O. 1939. Occurrence of high temperatures in western Nebraska and their possible relationship to occurrence of psyllids. *Better Potatoes in Nebr.* 2(6 and 7):7-12. (Ref.)