Causal Agents of Silver Top and Other Types of Damage to Grass Seed Crops

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Abstract *Can. Ent.* 99: 660–670 (1967)

Studies during 1962–64 showed that the mites *Siteroptes graminum* (Reut.) and *Aceria tulipae* Keifer, thrips, and the fungus, *Fusarium poae* (Pk.) Wr., were not causal agents of silver top in the Peace River region, and indicated leafhoppers were probably not involved. The fact that silver top is controlled with insecticides, but not with miticides, constituted strong evidence for insects as causal agents. In 1963, extensive examination of grasses with silver top revealed minute, inconspicuous punctures, 0.01 to 0.04 mm in diameter through leaf sheaths which were typical of those made by insects with piercing and sucking mouthparts such as plant bugs. In 1964, attempts to produce silver top by infesting grass plants with plant bugs, leafhoppers, and spittlebugs were unsuccessful for reasons inexplainable. Non-appearance of silver top in either infested or uninfested plants, however, indicated the causal agent was not present in the plants or attached soil when collected from fields in mid-May. Further studies in 1965 showed that grasses affected by silver top were infested with the plant bugs *Stenodema trispinosum* Reut., *S. vicinum* (Prov.), *Litomiris debilis* Uhl., *Capsus simulans* Stal., and *Trigonotylus ruficornis* (Geof.). Experimental infestation of plants with these bugs showed that they fed on stems by puncturing through leaf sheaths and so damaging stem tissue as to cause silver top. In 1966, examination of grasses with silver top from southern Alberta, Saskatchewan, and Oregon revealed punctures in leaf sheaths opposite areas of stem injury, indicating that plant bugs probably cause silver top in these regions.

Introduction

Silver top is a distinct type of damage affecting grasses at time of flowering in the form of silvery-white heads which appear mature but are without seed. Death of the inflorescence results from stem injury in the form of withered, dead tissue at one or more points above the terminal or penultimate node. Stem injury is caused by some agent withdrawing the sap from the stem thereby preventing further development of heads. The injury is done prior to or at the bloom stage, before pollination occurs. Stems break at the points of injury and the heads are easily pulled from the leaf sheaths. Other than the white, dead heads and stem injury, plants appear green, healthy, and uninjured.

Damage referred to as blasting or white heads had been observed for years in various cultivated and native grasses in the Peace River region but its true nature and probable cause were unknown. In 1959, the damage caused serious reductions in seed yield from Merion bluegrass in the Dawson Creek district of British Columbia and investigations were begun in 1960.

Review of Literature

The cause of silver top affecting grasses in North America has been a complex and puzzling problem for many years. Various organisms have been suspected or reported as causal agents but proof of possibilities has been inconclusive or negative. Early workers in eastern North America (Fletcher 1888; Comstock 1888) suspected insects such as certain species of Hemiptera, Meromyza, Chlorops, and Thripidae to be the cause of the stem injury. Comstock and Comstock (1917) refer to thrips, designated *Limothrips poaphagus*, "that damaged timothy and June-grass by working in the uppermost joints". Osborn (1891) believed that the stem injury might result from a number of different agents. His observations revealed that few stems of affected grasses were infested with thrips and even fewer with dipterous larvae or fungi and that most stems he examined had no insects of any kind within leaf sheaths. On the other hand he found that insect punctures were abundant around the injured parts of plants and in many cases the punctures were apparent in the stems. He attributed the punctures to species of Jassidae (Homoptera), insects generally common and abundant in grasses and which he considered the main cause of silver top. Hinds (1900), in Massachusetts, reported that thrips designated *Aptinothrips striata* (Obs.) caused silver top.

Later workers (Leach 1940) supposed silver top was a disease caused by a fungus, *Fusarium poae* (Pk.) Wr., in association with a mite *Siteroptes graminum* (Reut.). In Oregon, Hardison and Krantz (1956, 1957) and Hardison (1957) outlined the theory of Leach (1940) that silver top was a disease caused by the fungus *F. poae*, with mites as disseminators of the disease. Hardison, Krantz, and Dickason (1958) and Hardison (1959) found that grasses with silver top were infested beneath leaf sheaths with the fungus *F. poae*, the mite *S. graminum*, and two species of thrips, *Aptinothrips stylifer* Tybrom and *A. rufus* (Gmelin). They obtained satisfactory control of silver top by treating seed crops with the insecticides DDT, heptachlor, aldrin, or a mixture of DDT and parathion but found miticides ineffective. However, Hardison (1959) obtained evidence against the fungus and mite as causal agents, these organisms being found to be secondary invaders of the already damaged stem tissue.

In Oregon, Dickason (personal communication, 1963) tried to produce silver top experimentally with thrips but failed to establish them on host grasses. Results of work in Oregon were interpreted as evidence dictating a return to insects as the primary cause of silver top and, among insects involved, thrips were considered the most likely causal agents but their exact relationship to silver top was not determined.

In Germany, Wagner (1960) and Wagner and Ehrhardt (1961) found that treatment of grasses with endrin controlled white-ear (silver top) and the meadow plant bug, *Leptopterna dolabratus* (L.), and demonstrated that feeding of the bug by puncturing stems was the main cause of white-ear.

Holmes *et al.* (1961) found certain grasses in southern Alberta were infested beneath the leaf sheaths with the fungus *F. poae*, two species of thrips, *Limothrips cerealium* Hal. and *L. denticornis* Hal., the mite *S. graminum*, and another mite *Aceria tulipae* Keifer, a species not found in association with silver top in Oregon. They found the fungus in only a few affected stems and considered thrips of minor importance. They reported that microscopic examination of affected grasses showed no evidence of penetration through the leaf sheaths and considered the causal agent must have attacked the stem from inside the sheath. They reported that "the feeding of only one mite of either species appears to be sufficient to cause silver top." Although the mites *S. graminum* and *A. tulipae* were considered causal agents in Alberta the insecticides DDT and heptachlor, instead of miticides, were recommended for control of silver top (Report of Committee 1962).

Crawford and Harwood (1964) collected the mite *A. tulipae* in 1956 on Merion bluegrass near Pomeroy, Wash. They found the mite at leaf bases but considered it probably of no direct consequence to grasses.

Jewett and Spencer (1944) found in Kentucky that *Leptopterna* (*Miris*) *dolabratus* (L.) attacked blades, stems, and florets of grasses, and feeding by this species and *Amblytylus nasutus* Kirsch. on bluegrass seed heads can prevent seed development. In Kentucky, Starks and Thurston (1962) studied various agents as the possible cause of silver top as follows: virus infection, supposedly transmitted by a mite *Penthaleus major* Duges; genetic abnormality; mechanical injury; two plant bugs, *Leptopterna dolabratus* (L.) and *Amblytylus nasutus* Kirsch; thrips spp.; and grass flies (Chloropidae). They found that the plant bugs fed in the seed heads, and grass flies within the stems of grasses, without either organism producing the stem injury typical of silver top. Results of their studies on thrips, virus infection, genetic abnormality, and mechanical injury were either negative or inconclusive.

Nature of Damage

Preliminary surveys of Merion bluegrass in 1960 in the Dawson Creek district showed that seed loss resulted largely from two types of damage: (1) from cutworms, mainly *Crymodes devastator* Brace (Arnott and Arrand 1961*a*), a pest not previously known in the district, and (2) silver top, damage previously noted but not recognized as such (Arnott 1961*a*). The overwintering cutworms feed in spring on rhizomes and young grass shoots, destroying potential seed stalks and later cutting off developed seed stalks at the grass crown, the entire seed stalks becoming white and dead, which characteristic distinguishes cutworm damage from silver top. Subsequently, other native and cultivated grasses in the region were found to be affected by silver top and more or less damaged by cutworms.

Control of Damage

When studies were begun in 1960 it was assumed that the more common grass pests such as mites, cutworms, sod webworms, thrips, leafhoppers, or plant bugs were probably involved. Preliminary experiments on control of the damage were conducted during 1960 and 1961 in seed fields of Merion bluegrass. In 1960 DDT was tested for insect control, Rogor and Kelthane for mite control, and the effectiveness of these treatments in control of silver top. DDT reduced cutworm damage 68 to 76% and gave 78 to 80% control of thrips, leafhoppers, and plant bugs, reduced mites 33% and gave 87 to 95% control of silver top. Rogor was ineffective in control of cutworm damage, gave 73 to 83% control of thrips, leafhoppers, and plant bugs, more than doubled the mite populations, and gave only 50 to 53% reduction of silver top. Kelthane was ineffective against cutworms, gave only 22% control of thrips, leafhoppers, and plant bugs, reduced mites 43 to 53% and gave only 41% control of silver top. In 1961 DDT only was tested for control of silver top and cutworm damage. A single treatment at the rate of 1 lb toxicant per acre reduced cutworm damage 91% and a single treatment at the same rate 8 June reduced silver top 84.8%. Results of studies in 1960 and 1961 indicated that insects, rather than mites, were most probably a major cause of silver top. Studies were then made to learn whether or not thrips, mites, or the fungus *F. poae* were in any way responsible for silver top.

Studies of Thrips, Mites, and a Fungus

In 1960 Merion bluegrass affected by silver top was found to be infested with thrips and mites and some seed stalks were infested with the fungus *F. poae* (Arnott 1961*a;* Arnott and Arrand 1961*a*). When the experimental plots treated with DDT and miticides were swept with an insect net to determine the effect of treatments on insects and mites, several species of mites were found infesting the grass. Identity of the mites was not ascertained until January 1961,[1] when

[1]The authors are indebted to C. V. G. Morgan, Research Station, Summerland, B.C., for identification of the mites *Bryobia* sp. and *Aceria tulipae* and for identity of the other species to the following acarologists: D. A. Chant, formerly of the Research Station, London, Ont.; E. W. Baker, Entomology Research Division, U.S.D.A., Wash., D.C.; R. E. Beer, Department of Entomology, University of Kansas; F. M. Summers, Department of Entomology, University of California; T. A. Woolley, Department of Zoology, Colorado State University; G. W. Krantz, Department of Entomology, Oregon State University; and H. H. Keifer, State Department of Agriculture, California, who confirmed identity of *A. tulipae*.

the following species were recorded: *Eupodes* sp., *Tydeus* sp., *Tarsonemus setifer* Ewing, *T.* probably *waitei* Banks, *Typhlodromus* (A.) *marinus* (Willmann), *Cunaxoides biscutum* (Nesbitt), *Erythraeus* sp., *Byrobia* sp. of the *praetiosa* group, *Aceria tulipae* Keifer, *Tectocepheus velatus* Michael, and *Siteroptes graminum* (Reut.). So far as could be observed in the field, all these mites appeared to be present on the external parts of plants except *S. graminum* which occurred beneath leaf sheaths of some seed stalks with silver top.

Studies in 1961 revealed that seed stalks of Merion bluegrass with silver top were infested beneath the leaf sheaths with thrips and the two mites *A. tulipae* (Arnott 1961*b, c*) and *S. graminum.* However, the fungus and the mite *S. graminum* were not present in all affected stems of Merion bluegrass or in all stems of other affected grasses such as red fescue, bromegrass, crested wheatgrass, Pennlawn fescue, or timothy. Absence of these organisms in some grasses and irregular occurrence in Merion bluegrass indicated they were not likely the main cause of silver top but rather, as found in Oregon, secondary invaders of stem tissue having sustained prior injury.

In 1962, studies showed that Merion bluegrass was generally infested throughout the growing season with thrips and the mite *A. tulipae.* Observations throughout the period from mid-May to mid-July showed that thrips and *A. tulipae* fed on the inner surfaces of leaf sheaths and on stems without producing the typical stem injury of silver top. Although thrips fed beneath leaf sheaths for a considerable distance along stems below leaf bases, they were not found at or close to the uppermost nodes, at which location the typical stem injury of silver top most often occurs. It appeared that although thrips were small enough to penetrate beneath leaf sheaths they were not small enough to reach the nodes. The mites, being very small, about 0.05 mm in diameter were able to penetrate to the nodes but their feeding on stem tissue caused no injury resembling silver top. When the grass bloomed and approached the seed stage it was found that healthy, uninjured seed stalks and those with silver top were equally infested with thrips and the mite. The following grasses with silver top were examined for infestations of thrips and *A. tulipae*: bromegrass, red fescue, quackgrass, American sloughgrass, Kentucky bluegrass, tickle grass, crested wheatgrass, timothy, reedgrass, and slender wheat grass. Although most of these grasses were more or less infested with thrips, *A. tulipae* was found only in Kentucky bluegrass and red fescue (Arnott and Arrand 1962).

To demonstrate whether or not *A. tulipae* could cause silver top, an experiment was conducted in 1962 in which Merion bluegrass plants were grown in a greenhouse and infested with the mites collected from infested grass in laboratory plots. Infestation of plants was begun as soon as plant growth showed induction of seed heads. Over 1400 mites were used to infest 45 seed stalks from which 521 live mites and 287 mite eggs were later recovered. None of the infested stalks developed white, dead seed heads and none showed evidence of the stem injury typical of silver top.

In 1963, an experiment was carried out to demonstrate whether or not thrips, identified as *Anaphothrips obscurus* (Mull.),[2] which generally infested Merion bluegrass, could cause silver top. Plants were caged separately and grown in a greenhouse to the seed stage. Thrips were collected from infested seed fields and placed alive on the caged plants. Each of 32 plants was infested with from 50 to over 100 thrips per plant. When plants reached the bloom stage they were observed for occurrence of white, dead seed heads and, at the seed

[2]W. R. Richards, Entomology Research Institute, Canada Agriculture, Ottawa, who identified the thrips, noted that *A. obscurus* may prove to be a complex of two or three species and needs careful study.

stage, stalks were examined by dissection for stem injury. Live thrips were recovered from 29 plants ranging in numbers from 1 to 47 per plant. The plants produced 86 seed stalks, none of which had white, dead seed heads or evidence of the stem injury typical of silver top.

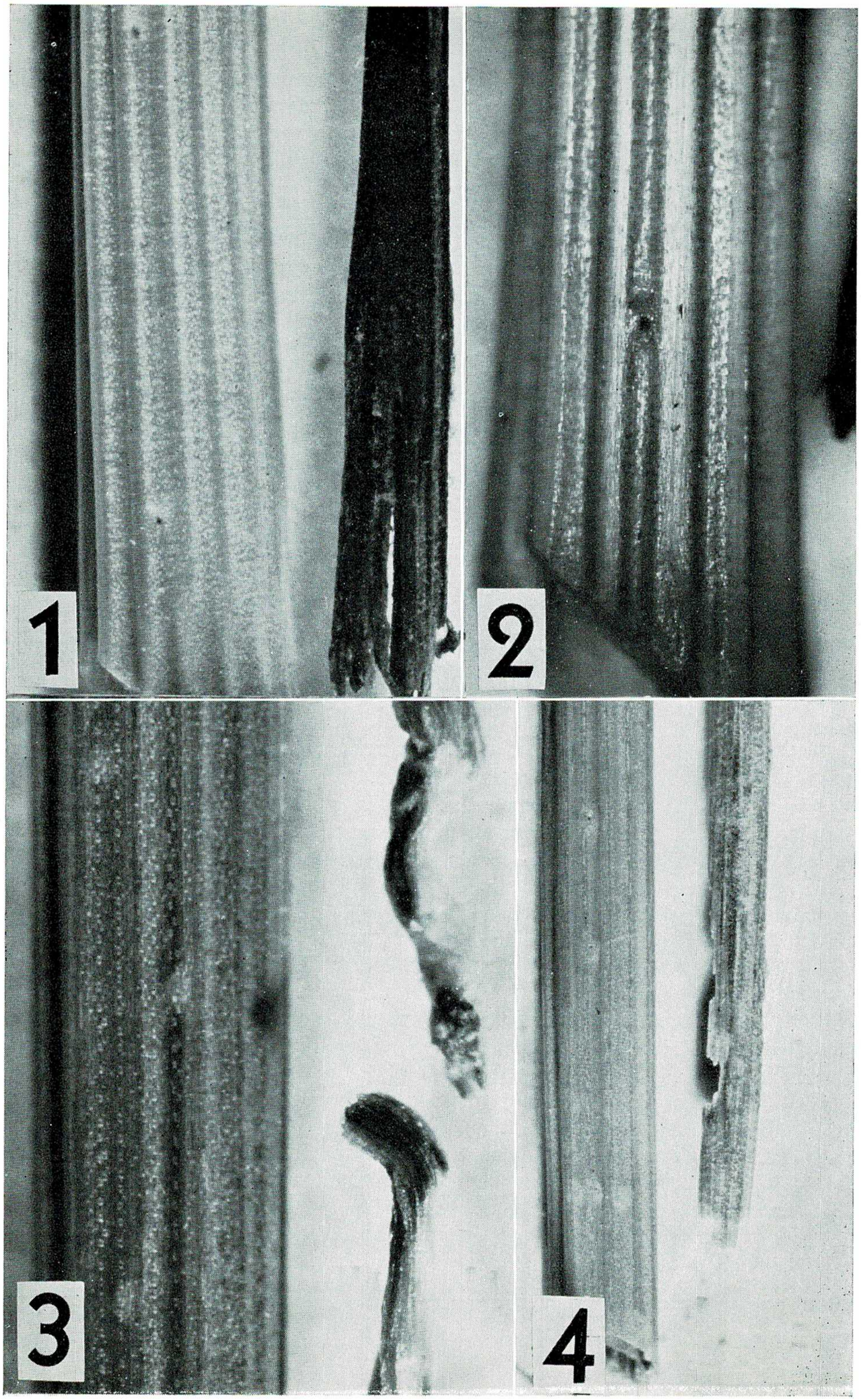
Exoneration of the fungus *F. poae* and the mite *S. graminum* in Oregon, along with evidence against these organisms, thrips, and the mite *A. tulipae* in the Peace River region, and the fact that silver top is controlled with the insecticides DDT, heptachlor, and aldrin but not with miticides, constituted rather convincing evidence for some insects other than thrips as a probable cause of silver top. In view of these facts, a thorough re-examination was made of several grasses to determine whether they showed any evidence of insect attack which might be directly responsible for the stem injury. The following grasses with silver top were collected during the summer of 1963 in the Peace River region and examined in the laboratory during the autumn and winter: Merion bluegrass, red fescue, Pennlawn fescue, bromegrass, tickle grass, and wheatgrass. Thorough examination revealed these grasses had punctures through the uppermost leaf sheaths opposite the areas of stem injury beneath. The punctures were typical of those made by insects with piercing and sucking mouthparts. The punctures were minute, 0.01 to 0.04 mm in diameter, and were very difficult to locate even under high magnification and were easily overlooked without great care and patience. Figures 1–9 show punctures in leaf sheaths of various grasses affected by silver top from the Dawson Creek district, B.C., southern Alberta, Saskatchewan, and Oregon. Among the insects with piercing and sucking mouthparts likely to attack grasses by puncturing through leaf sheaths, and feeding on stems beneath, are plant bugs. Since these insects are common in grasses and are readily controlled with DDT, which also controls silver top, their punctures offered at least one reasonable explanation for the cause of silver top.

Experiments with Plant Bugs, Leafhoppers, and Spittle Insects

In 1964, attempts to produce silver top in greenhouse experiments were unsuccessful. Reasons for this are not clear. Merion bluegrass plants were collected from seed fields in the Dawson Creek district of British Columbia and transported to a greenhouse at Kamloops. Plant bugs, including *Stenodema* spp., *Litomiris* spp., *Lygus* spp., leafhoppers, and spittle bugs were collected from the fields throughout the spring and early summer, shipped to Kamloops, and placed on the plants in the greenhouse. Failure of silver top to appear in either infested or uninfested plants at least suggested that the causal agents were not in either the plants or the attached soil when they were taken from the fields in mid-May.

In spite of the negative results in 1964, plant bugs were again given major attention in 1965, but all work was done in the Dawson Creek area instead of part at Kamloops. Knight (1941) recorded that *Stenodema trispinosum* and *S. vicinum* occurred on grasses, hibernating as adults, and that *Capsus simulans* fed on bromegrass. It was known from Kelton (1961) that *Stenodema* spp. collected from seed fields in 1964 were grass feeders, and along with Knight's records, that these bugs along with *C. simulans* should be suspected as causal agents. Experiments were thus conducted with the species of plant bugs found infesting seed fields of Merion bluegrass, red fescue, and other cultivated and native grasses

FIGS. 1–4. 1, Merion bluegrass, two punctures in sheath, Spring Coulee, Alta.; 2, Fig. 1 showing lower puncture enlarged 30×; 3, quackgrass, three punctures in sheath, Dawson Creek; 4, Canada wild ryegrass, seven punctures in sheath, Dawson Creek.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affected by silver top. Bugs were collected by sweeping grasses with an insect net.

During the experiment the bugs were not specifically identified, but were segregated only into those which appeared to be a single species or those belonging to *Stenodema–Litomiris* and *Lygus* spp. groups. Specimens of each kind collected and those recovered from infested plants were preserved and later identified. Identification revealed that from 7 June to early July, grasses affected by silver top were infested with the following species of Miridae: adults of *Stenodema vicinum* (Prov.), *S. trispinosum* Reut., and *Litomiris debilis* Uhl. were the most common and abundant species in most grasses throughout the period. Adults of *Capsus simulans* Stal. appeared in late June and were scarce in Merion bluegrass and red fescue but common and fairly abundant in stands of bromegrass and/or quackgrass. *Trigonotylus ruficornis* (Geof.) was scarce in grasses examined, only a few adults being taken on 3 June. *Lygus* spp. appeared scarce in pure stands of Merion bluegrass and red fescue but were common and abundant in weedy patches within and about edges of fields. No specimens of *Leptopterna dolabratus* or *Amblytylus nasutus* appeared in any collections during the period. A few plant bug nymphs appeared in Merion bluegrass 10 June and became abundant by 24 June.

When the infested and check plants reached the seed-set stage all seed stalks were removed from cages, labeled, and later examined in the laboratory for occurrence of silver top.

Greenhouse Experiments with Stenodema *spp. and* Litomiris debilis *Uhl.*

Seed plants of Merion bluegrass were obtained from fields that had been damaged annually by silver top and grown in 12-oz waxed-paper food containers in an improvised greenhouse constructed of wood frame and covered with clear plastic and plastic screen.

Bug collections were begun when the first adults appeared on 7 June and continued every 1 to 4 days, weather permitting, until early July, and the bugs placed on the potted plants. Small cages, ½ in. to 1½ in. in diameter and 4 to 6 in. long, made of glass tubing, clear plastic, or plastic screen, each end plugged with cotton, were used to enclose bugs on one or more seed stalks. Open mesh cotton cages $6 \times 6 \times 18$ in. and plywood cages $10 \times 10 \times 24$ in. with screen tops and sides, and glass fronts, were used to enclose whole plants. The small cages made it possible to study the feeding habits of the bugs under a binocular microscope.

The specimens looked very much alike when collected in the field and authoritative identifications were not made until later in the year. It was then learned that the plants had been infested with either one or other, or a mixture, of three species: *Stenodema vicinum* (Prov.), *S. trispinosum* Reut., and *Litomiris debilis* Uhl.

There was considerable bug mortality, especially in the glass and plastic tubes. Condensation drowned some of the bugs and high temperatures killed many. Mice invaded the greenhouse and stole many of the cotton plugs, allowing the bugs to escape. However, enough remained to permit observations and definite conclusions.

Under the microscope, the bugs were observed to pierce the leaf sheaths, usually the terminal ones, and feed on the stems a short distance above the terminal

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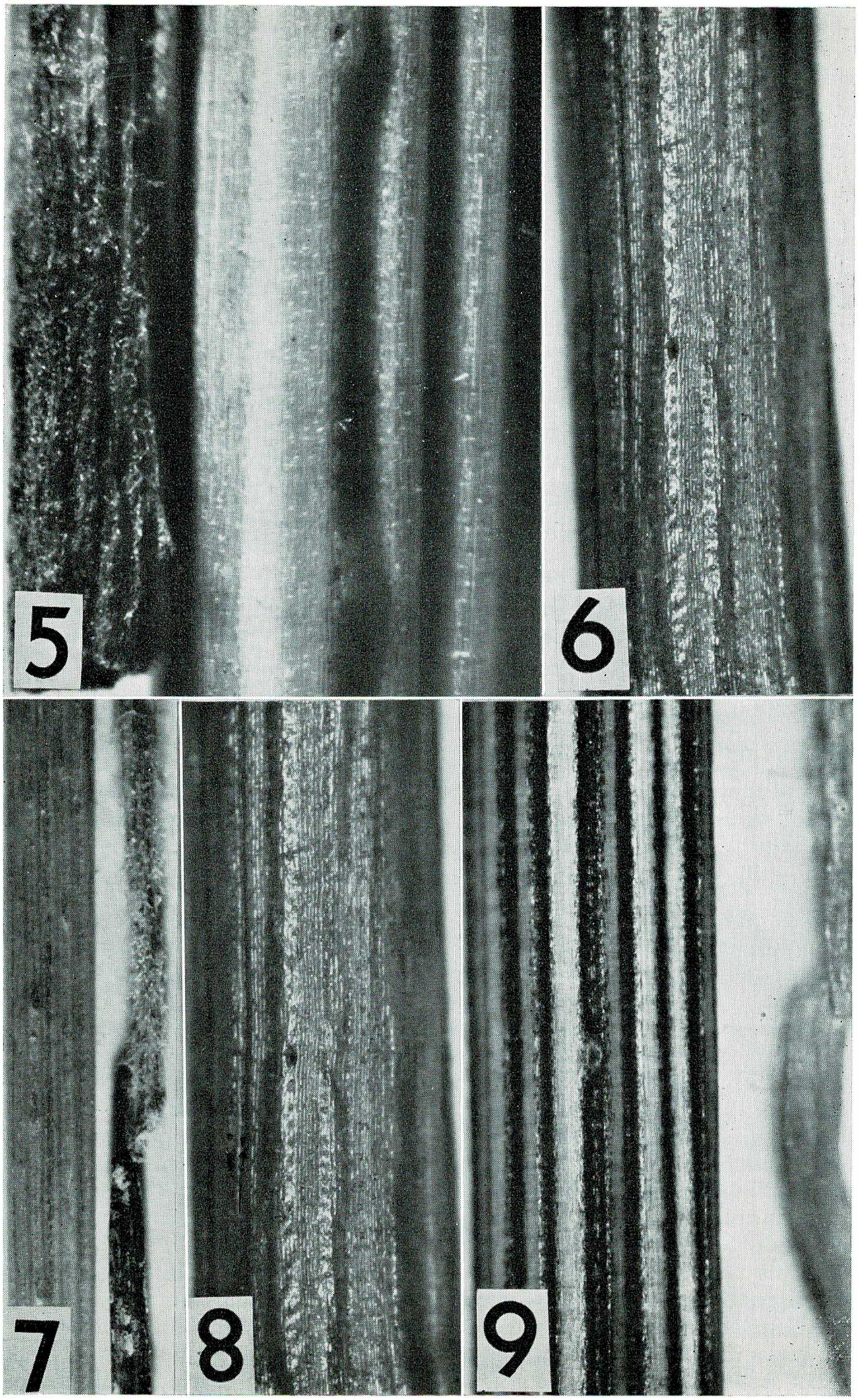
FIGS. 5–9. 5, speargrass with two punctures in sheath, Dawson Creek; 6, crested wheatgrass, one puncture, Saskatchewan; 7, bromegrass, six punctures in sheath, Bow Island, Alta.; 8, sheep fescue, one puncture in sheath, Oregon; bluegrass, one puncture in sheath, Oregon.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nodes, the site at which shriveled stems had previously been observed on plants showing the silver top type of damage.

The 45 plants surviving the experiment produced 182 seed stalks, 80 of which were infested manually and 102 left uninfested as checks. Silver top developed in 12 of the infested stems; there was none in the check stems.

Greenhouse Experiments with Capsus simulans *Stal.*

The greenhouse experiments with *C. simulans* were done in the same manner as those described for *Stenodema* spp. and *L. debilis*. However, the species was quite distinct in appearance, enabling completely separate experiments.

Adults appeared in grasses 30 June. Collections made then and on 1 July were used to infest 54 seed stalks on 11 plants. Of these, 33 developed the typical stem injury of silver top; 4 stalks left uninfested remained healthy.

There was no doubt that this species fed on stems by puncturing through leaf sheaths. The bugs were observed to move up and down stalks along the uppermost leaf sheaths and settle at one or more points where they probed through the sheath and proceeded to suck sap from the stem beneath. On examining the damaged stalks the leaf sheaths were found to have from 1 to as many as 10 punctures, which were opposite a similar number of injured spots on the stems beneath. Ten of the stalks had typical mirid eggs under the leaf sheaths ranging in numbers from 5 to as many as 62 per sheath.

Greenhouse Experiments with Trigonotylus ruficornis (*Geof.*)

This species was scarce in all grasses examined. The three adults collected 3 June were caged on a single grass seed stalk. By 10 June the seed head was grayish and wilted. On 11 June the stem was examined by dissection and found to have the typical stem injury of silver top at two points a short distance above the terminal node.

Greenhouse Experiments with Lygus *spp.*

Studies with *Lygus* spp. showed that although the bugs fed on epidermal tissue of stems and sheaths the feeding did not penetrate into the stems beneath or cause any damage resembling silver top.

Field Cage Experiments

Four cages measuring 6 ft × 6 ft × 40 in. were set up in a field during 28 May to 2 June over ground devoid of vegetation. Merion bluegrass was transplanted into each and 4 to 6 sq. ft of turf were taken from seed fields and also placed in each cage.

Observation of cages 2 to 16 June revealed that the only insects which appeared were a few Hymenoptera, Diptera, ground beetles, and leafhopper nymphs. These insects apparently emerged from the turf. During this period a few short seed stalks from the turf and the transplanted grass in some cages became wilted, arrested in growth, and finally became completely white and dead. Examination of these stalks showed that they were killed by a stem-boring insect. Of 431 seed stalks that developed in the four cages from the introduced turf, 68 were damaged by the borers. No silver top appeared in any of the cages prior to the introduction of bugs.

In the period 16 to 24 June, 92 adults of the *Stenodema–Litomiris* group were placed in cage 1. Of 345 seed stalks that developed from the bluegrass transplanted to this cage, 12 were damaged by borers and 16 by silver top. Cage 2 was infested with 350 bug nymphs on 25 June and 150 more on 26 June. Of 259 seed stalks, 35 were damaged by borers and 30 developed silver top.

Cage 3 was infested with at least 300 leafhoppers on 30 June; none of the 235 seed stalks was damaged. Cage 4 was left uninfested. Only 90 seed stalks grew in it; 13 were damaged by borers but none by silver top.

Study of Grasses with Silver Top from Alberta, Saskatchewan, and Oregon

Some workers have suggested that silver top is likely caused by several agents differing in different regions. To determine whether plant bugs might be involved as causal agents in a region other than the Peace River country a survey of grasses was made in southern Alberta 28 July – 1 August 1965. Seed stalks with silver top from seed fields and stands of cultivated and native grasses along highways and country roads were examined for punctures in leaf sheaths, and plant bugs were collected from the affected grasses. The following grasses all had punctures in the leaf sheaths and the stands were infested with adults of *Stenodema* spp. and/or *Litomiris debilis*: Kentucky bluegrass, Merion bluegrass, bromegrass, crested wheatgrass, timothy, tall wheatgrass, quackgrass, and reed grass.

In 1966 study was made of grasses affected by silver top from Saskatchewan and Oregon. Samples of Kentucky bluegrass, crested wheatgrass, bromegrass, and intermediate wheatgrass from Saskatchewan all showed punctures through leaf sheaths opposite the areas of stem injury. Samples of bluegrass and sheep fescue grass from Oregon also showed punctures through leaf sheaths.

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*Not seen by author.

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