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THE BIOLOGY OF LYGUS RUGULIPENNIS POPP. (HET., MIRIDAE) AND THE DAMAGE CAUSED BY THIS SPECIES TO SUGAR BEET

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VARIS, ANNA-LIISA 1972. The biology of *Lygus rugulipennis* Popp. (*Het., Miridae*) and the damage caused by this species to sugar beet. Ann. Agric. Fenn. 11: 1—56.

In southern Finland, *Lygus rugulipennis* Popp. hibernates at the adult stage mainly in forest litter and in branches of conifer trees close to the ground. The species migrates to cultivated fields in mid- or late May. The bugs appear on sugar beet soon after seedling emergence. Oviposition begins in late May. The adults emerge in late July or August. The species is univoltine in Finland. The lengths of the various developmental stages are given and behaviour of adult towards a choice of food and oviposition hosts is described.

The bug was found to feed on eggs of the mangold fly (*Pegomya betae* Curt.). The mymarid *Anaphes fuscipennis* Hal. was found to parasitize eggs of the bug. The proportion of parasitized eggs was 4 % in 1967 and 10 % in 1969.

In cultures reared in the insectary one adult bug injured an average of 24 sugar-beet seedlings at the cotyledon stage. The symptoms of injury are described. A positive correlation was found between the feeding time of the bugs on sugar beets at the cotyledon stage and the degree of injury to the plants.

Mechanical injury proved to be a very important factor in the appearance of symptoms. Its effect was accentuated by application of pectinase to the growing point and by suction of cell sap. These treatments produced plants with symptoms very similar to those caused by *L. rugulipennis.*

Bug injury promoted the development of multiple crowns. Injured plants weighed less than healthy ones. The earlier they were damaged, the lower was their weight. Differences in root weight were greater than differences in top weight. With the root weight of healthy plants as 100, the relative weight of the roots of plants injured at the cotyledon stage was 60, of those injured at 1- to 2-leaf stage 74, and of those injured at the 3- to 4-leaf stage 91.

The average sucrose content of roots was 0.57 percentage units lower in injured beets than in uninjured beets. The earlier the stage of development at which the plants were injured the lower it was. The ash content was somewhat higher in injured beets.

I INTRODUCTION

Bugs of the genus *Lygus* occur on a large number of plant species, which they damage by feeding on them. In Finland the commonest of these bugs is *Lygus rugulipennis* Popp. (LINNAVUORI 1951), which is widespread in cultivated crops in Finland (VARIS 1959) and elsewhere in Europe (e.g. KULLENBERG 1944, STICHEL 1956—1958, AFSCHARPOUR 1960). KULLENBERG (1944), BONESS (1963) and BECH (1969), among others, have described the biology of the species. SÖMERMAA (1961), in laboratory experiments, found that *L. rugulipennis* was responsible for retarded growth, leaf wilting and malformation in oats. The bug has also been observed to cause malformation of fruits in strawberry (TAKSDAL and SØRUM 1971). The effects of injury by *L. rugulipennis* on the yield and baking quality of wheat have been investigated in Finnish conditions. NUORTEVA and VEIJOLA (1954) did not observe any noticeable impairment of the baking quality of wheat. According to RAUTAPÄÄ (1969), injury by this bug, although not affecting the amount of yield, decreased the falling number of wheat.

The aim of the present study was to describe the main features of the biology of *L. rugulipennis* and the injuries caused by the species to sugar beet and the damage done to the crop. The present paper is the fourth of a series of studies dealing with the occurrence of this bug in sugar beet. The previous papers were concerned with the injury caused by *L. rugulipennis* and some other *Lygus* species (VARIS 1959), on the effectiveness at different temperatures of the insecticides used to control this bug (VARIS 1971), and on the rate of disappearance of insecticidal residues from young sugar beet seedlings (VARIS 1972).

II NOMENCLATURE

The genus *Lygus* Hahn 1833 contains a very large number of species. Many of these are highly variable both in morphological characteristics and in colouring.

The genus has been divided into subgenera in various ways (e.g. REUTER 1875, KNIGHT 1917, 1941, CHINA 1941, TAYLOR 1947, WAGNER 1949, 1952, SLATER 1950). LESTON (1952) reviewed the previous suggestions and presented his own.

As long ago as 1917, KNIGHT (1917) proposed a revision which, according to LESTON (1952), has been ignored by Europeans until recently. KNIGHT's suggestion was a group of species under the name of *Lygus pratensis*. WAGNER (1949) confirmed the *L. pratensis* complex of KNIGHT (1917) by separating a subgenus named *Exolygus*.

KELTON (1955) promoted the subgenus *Exolygus* Wagn. to generic status and within it he also placed *Liocoris* species, WAGNER (1949), too, regarded *Liocoris* species as very closely related to *Exolygus* species. By priority the genus should be called *Liocoris* Fieb. Accordingly, all species belonging to the *Lygus pratensis* group ought to be called *Liocoris* species. Since, however, the group includes many pests of economic importance, commonly known as »lygus bugs», CARVALHO et al. (1955) suggested that the name *Liocoris* should be again replaced by *Lygus* Hahn where these bugs are concerned. WAGNER (1957) and COBBEN (1958) considered it desirable not to group *Liocoris* and *Exolygus* together.

WAGNER (1957) accepted KELTON's (1955) suggestion of raising the subgenus *Exolygus* to generic status, providing the name *Exolygus* Wagn. was retained. STICHEL (1956—1958) placed the *Lygus pratensis* complex in the subgenus *Lygus* s. str. LINNAVUORI (1966) agreed with STICHEL (1956—1958). The present study follows the nomenclature of STICHEL (1956—1958) and LINNAVUORI (1966).

FALLÉN (1829) subdivided *L. pratensis* into two species, *Phytocoris pratensis* and *Ph. campestris*. REUTER (1875) regarded *L. pratensis* as one single species, which he divided into four varieties. REUTER's (1912) *L. pratensis pubescens* (he was not satisfied whether this was a variety, »Varietät», or a strain, »Rasse») is, according to KULLENBERG (1941), a synonym of *Phytocoris campestris* Fall., but since the name *campestris* was already assigned to another *Lygus* species, REUTER (1912) suggested that this variety should be named *pubescens*.

WAGNER (1940) and KULLENBERG (1941) raised *L. pratensis pubescens* to specific rank. According to LINNAVUORI (1951), *L. pubescens* Reut. is indentical with *L. rugulipennis*, described by POPPIUS (1911), and thus the name given by POPPIUS (1911) has priority.

According to WAGNER (1940) and KULLENBERG (1941), up to the 1940s authors included both *L. pratensis* and *L. rugulipennis* in the species *L. pratensis*. It has, as a matter of fact, comprised the entire *L. pratensis* species group.

At present, the previous *L. pratensis* complex includes seven European species. The status of *L. rugulipennis* is fully accepted, but there are dissenting views as to the validity of the other species in the *L. pratensis* complex (cf. KULLENBERG 1944, LESTON 1952, SLATER and DAVIS 1952).

As the English name of *L. rugulipennis* SOUTHWOOD (1956) proposed »the European tarnished plant bug».

III MATERIAL AND METHODS

This investigation was carried out in the years 1961—1971. Some of the rearing experiments to investigate the biology of *L. rugulipennis* were conducted in the insectary of the Department of Pest Investigation, Tikkurila, where the temperature and humidity are approximately the same as outdoors; others were conducted in the open. Similarly, damage by *L. rugulipennis* to sugar beet plants was studied both in the laboratory and in the field. The bugs used were collected with a sweep net from field crops, mainly from winter turnip rape, from which bugs were obtainable relatively early in the spring (late May). In addition to the main investigations at Tikkurila, some studies on overwintering were also made at Tuusula.

A. Biological studies

The number of eggs laid and the length of the oviposition period were studied by means of rearing corks (Fig. 1). One male and one female bug were introduced into each cork. The test plant was winter turnip rape planted in pots 15 cm in diameter. The eggs were counted every other day. At the same time the pair of bugs was transferred to another part of the plant and the eggs were covered with a new rearing cork, and later the duration of the egg stage and the various nymphal instars were observed and recorded. These cultures were examined daily. The duration of the egg stage was also studied in cultures in Petri dishes. A leaf of winter turnip rape with 0- to 1-day-old eggs was placed on a Petri dish with a disk of moist filter paper and inspected daily for the number of eggs hatched. These studies were made in the insectary in 1964—1965. Records of the length of the oviposition period and the numbers of eggs laid were also made in connection with rearings of egg parasites in the field in 1967 and 1969.

Red clover, potato, bush bean and winter turnip rape were tested for suitability as host plants. Red clover and potato were soon eliminated, because in these two species leaflets and leaves injured by bugs tended to die so quickly that there was no chance of survival for the eggs deposited in them. Bush bean could not be used because of its hairy lower leaf surfaces which impeded the movements and feeding of the tiny newly-hatched nymphs. Winter turnip rape was chosen for the rearing experiments as being naturally in a suitable growth stage to provide fresh food for the bugs and nymphs right from the beginning of the experiments in late May.

Fig. 1. Rearing corks used for rearing *L. rugulipennis*. Photo by A.-L. Varis.

The bugs also readily deposited eggs in this species, and the plants tolerated both feeding and oviposition very well without abscission of plant parts. A drawback to the use of winter turnip rape was its early maturing before all the eggs had hatched; the last nymphs thus emerged from relatively dry plants even though the rearing corks were attached to the youngest plant shoots at the time when these eggs were laid.

Selection of host plants and distribution of eggs on the plant were studied in 1965—1967. For these studies, 0.9-m^2 rearing cages were used in which both annual and biennial plants were provided at growth stages corresponding to those occurring in the open at the time.

Selection of food plants was studied in laboratory experiments in 1965 and in field experiments in 1965—1967. In the laboratory the test plants, sugar beet (var. Hilleshög), carrot (Nantes Markthalle) and swede (Mustiala) were grown in pots 15 cm in diameter, each species occupying a sector of 120°. During the experiment the pots were covered with PVC cylinders 9 cm in diameter and 29 cm high. The field experiment in randomized blocks was carried out on finesand soil.

The seasonal occurrence of *L. rugulipennis* in sugar beet was studied by sweep-net collections and visual counts. Sweep-net samples were taken once a week throughout the growing seasons of the years 1961—1970. Samples were also collected from winter rye, spring wheat, barley, oats, ley (red clover, timothy, meadow fescue), potatoes and winter turnip rape. The present paper is largely confined to the results from sugar beet, but the appearance of *L. rugulipennis* on cultivated fields every spring will be discussed in terms of the entire material. The sugar beet used for the investigation was a commercial crop grown in a field about 3.5 ha in size. It was treated with insecticide twice a year, with parathion or parathion + DDT at the time of seedling emergence, with trichlorfon or dimethoate in mid-June. Each sweep-net sample consisted of 2 × 30 sweeps with a net 34 cm in diameter at its mouth. The net handle was 75 cm long. The samples were taken in dry weather, when there was not much wind, between 13 and 15 hrs. Samples were not taken nearer than five metres from the edge of the crop.

In 1969 and 1970 visual counts of the abundance of lygus bugs in sugar beet were made 3—5 times a week from the emergence of the seedlings until early August. The amount of the crop inspected at one time was 336 row metres. The rows under observation were never treated with insecticide.

An attempt was made in 1969 to use yellow pan water traps (Moericke 1951) for collecting bugs. Yellow metal pans 39 × 57 × 6 cm were used. They were 1/2 to 2/3 full of water in which a surface-tension reducing substance »Fairy liquid» dish-washer was added. The bugs trapped in the water were collected at intervals of 2—4 days.

Overwintering was studied in outdoor overwintering experiments with *L. rugulipennis* adults as well as in samples taken from various places, assumed to be hibernation sites, late in winter or early in spring.

Overwintering experiments were conducted in 1967 and 1968. Pots 20 cm in diameter and rearing bags made of terylene organdy were used.

Overwintering samples were collected in 1970 and 1971 from several possible hibernation sites at Tikkurila and Tuusula. Tree bark samples were taken late in winter, other samples at the time of the snow-melt or shortly afterwards. Tree saplings were kept in rearing cages 60 cm high and 30 cm square, the other samples in 5-litre plastic containers under a canopy of terylene organdy. The insects that emerged from the different materials were collected daily for one week; then the entire sample was thoroughly scrutinized for any remaining bugs.

Sweep-net collections were made at both Tikkurila and Tuusula in early spring in order to follow the migration of *L. rugulipennis* adults from their hibernation sites in woods to their summer habitats in cultivated fields.

Studies on parasites of *L. rugulipennis* were made principally according to the methods of Clancy and Pierce (1966). The occurrence of parasites in the eggs was investigated in 1967 and 1969. One male and one female adult of *L. rugulipennis* were caged on field-grown winter turnip rape. After 48 hours the eggs were counted and their position indicated with coloured yarn. The eggs were then exposed to natural parasites. After 1—1 ½ weeks, the branches of plants carrying eggs were cut off and taken to the insectary, where they were placed in PVC rearing cylinders. The cut ends were inserted into water-filled glass bottles closed with a loose plug of cotton wool and with a piece of tubing to permit addition of water from outside without opening the cylinder. The cultures were examined about 3 weeks later. The numbers of bugs and emerged parasites were counted and the parasites saved for indentification.

The occurrence of parasites in nymphs and adults was investigated in 1968. Nymphs of the fourth and fifth instars and adults were swept from various cultivated crops and released into PVC rearing cylinders in the insectary. Bush bean pods tied on a string and suspended from the top of the cylinder, served as food. The base consisted of a glass jar containing a disk of moist filter paper; the jar and cylinder were separated from each other with 18-mesh wire gauze. The parasites were checked from the glass jar.

The feeding of certain insect predators was studied in Petri dish experiments in the laboratory.

B. Studies on injury

The feeding of *L. rugulipennis* and the injury it causes to young sugar beet seedlings were studied in greater detail in laboratory experiments and also in the field. Components of the injury, mainly the importance of mechanical damage, were also analysed. Sugar beets were sown either on »multipot» growing trays holding 51 5-cm pots, or on »paperpot» growing trays holding 700 3 × 13 cm pots. Single 15-cm pots were also used. The peat compost used for potting was analysed in the laboratory of Soil Testing Service (Viljavuuspalvelu Oy) and fertilized for sugar beet according to their recommendations.

Field trials were arranged on sandy clay soil to determine the effects of *L. rugulipennis* injury on the fresh weight of beet roots and tops, the number of leaves, the occurrence of multiple crowns, and chemical composition of roots. Two different methods in collecting the material were used. Caged *L. rugulipennis* adults were given free access to young seedlings in the field. PVC rearing cages 9 × 29 cm or lantern globe cages 7 × 24 cm with a screen collar between the globe and the soil were used. This method was applied in Material 1. Injured or uninjured seedlings were marked and their development followed in the field. This method was applied in Material 2 and in the multifactorial experiment.

More detailed information on the arrangements will be given in connection with the description of each experiment.

Analyses of beets were made in the laboratory of the Finnish Sugar Corporation (Suomen Sokeri Oy) except in 1971, when they were made in the laboratory of Salo Sugar Factory (Salon Sokeritehdas Oy). The yield from the two harvests of the multifactorial experiment were analysed simultaneously in late October. Over the period between harvest and analysis the beets were kept in polythene bags in temperature-controlled cold storage at + 3 ± 1 °C.

Sucrose (°S by polarisation) was determined with a sucrose polarimeter from a clarified 1: 7 water extract, and expressed as a percentage of root weight. Ash content (K + Na) was determined from a 1: 3 water extract by conductivity measurement and calculated from the empirical formula of Wiklund and Ewertz (Wiklund 1966); ash content is expressed in terms of milli-equivalents per 100 g of roots. Noxious nitrogen (amino nitrogen) was determined colorimetrically by the method of Stanek and Pavlas from a clarified 1: 7 water extract as a Cu complex (Wiklund 1966). The results are expressed in mg per 100 g of roots. Invert sugar was determined by Lane and Eynon's volumetric method from 1: 3 extract and is expressed as percentage of root weight (De Whalley 1964).

Recoverable sugar was calculated according to the method recommended by the laboratory of the Finnish Sugar Corporation. This is based on the assumption that equimolar amounts of sucrose and ash will remain in molasses (342 mg of sucrose per milli-equivalent of ash). The amount of sucrose thus bound by the ash was deducted from the total amount of sucrose.

Since there is a difference of opinion as to whether noxious nitrogen should be taken into consideration in calculating recoverable sugar (Lüdecke 1961), noxious nitrogen was as a rule disregarded in this study. Yet for the sake of comparison the amounts of recoverable sugar in healthy and injured beets were calculated in relation to both ash content and noxious nitrogen content. The loss of sucrose caused by noxious nitrogen was calculated according to Lüdecke (1961).

C. Statistical calculations

Significance of the results is expressed as follows:

* P = 5 %
** P = 1 %
*** P = 0.1 %

In calculating significant differences between the results obtained from the analyses of variance, the Student-Newman-Keuls multiple range test was applied (Sokal and Rohlf 1969). In many of the following tables means which do not differ significantly from each other are indicated by identical letters following the means. In the chi-square test the Yates correction was applied.

Both the annual and total results of the weighings and leaf countings in field experiment materials 1 and 2 were calculated by analysis of variance for experiments of unequal groups (Mudra 1958). Results of the beet quality analyses were subjected to analysis of variance.

Analysis of variance was also performed on the results of the multifactorial experiment. The variation within experiment was omitted.

D. Weather

The data on mean monthly temperature (Table 1), precipitation (Table 2) and mean monthly relative humidity (Table 3) were obtained from the Finnish Meteorological Institute.

The daily temperature and precipitation records are also available at the Finnish Meteorological Institute. Since 1966 they are to be found in the periodical surveys of the Institute (Anon. 1966—1967, 1968, 1969, 1970 a, 1971).

The most exceptional summer of the experimental period was that of 1962 which was very

Table 1. Mean monthly temperatures (°C) at Tikkurila in April-September 1961—1971.

Month	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	Mean 1931—1960
April	2.2	3.7	2.6	2.9	3.3	—0.1	3.4	4.2	3.2	1.5	2.2	2.9
May	9.9	8.6	13.0	9.5	6.8	9.4	9.9	7.7	8.7	9.5	10.5	9.3
June	16.8	11.8	14.5	14.8	15.1	16.9	13.7	16.6	15.6	16.6	14.1	14.3
July	15.9	14.7	16.7	16.4	14.4	17.6	16.7	15.2	16.5	16.4	17.0	17.0
August	14.0	12.9	16.5	14.5	14.1	14.4	16.0	16.2	16.1	15.4	15.5	15.4
September	9.8	9.5	12.7	10.0	12.5	8.8	12.6	10.7	9.9	9.7	8.8	10.4

Table 2. Precipitation (mm) at Tikkurila in April-September 1961—1971.

Month	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	Mean 1931—1960
April	28	69	10	30	17	59	33	47	43	81	15	42
May	39	48	25	32	22	14	53	85	41	25	9	40
June	56	61	36	16	43	23	19	37	18	13	21	48
July	91	73	34	48	103	64	39	68	63	120	25	73
August	96	106	111	60	82	54	107	52	28	31	90	75
September	26	144	67	40	85	72	75	47	95	78	62	69

Table 3. Mean monthly relative humidities (%) at Tikkurila in April-September 1961—1971.

Month	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
April	65	77	74	76	66	78	70	67	72	82	64
May	63	63	59	62	57	62	65	66	62	57	53
June	63	65	53	58	60	59	60	57	55	49	56
July	70	74	65	61	71	68	59	65	66	69	59
August	77	79	74	75	77	71	77	74	61	68	70
September	78	87	80	80	87	79	80	80	79	78	78

cool and rainy. The summer of 1963, on the other hand, was very warm and dry. In the years 1961, 1964, 1966 and 1970 the early part of the summer was warmer than normal, in 1964, 1965, 1966, 1970 and 1971 it was drier than normal.

IV THE BIOLOGY OF L. RUGULIPENNIS

L. rugulipennis occurs in various parts of Europe (Wagner 1940, Ossiannilsson 1943, Blattný et al. 1948, Balcells 1949, Leston 1951, Mancini 1953, Shapiro 1956, Southwood 1956, Skuhravý and Novák 1957, Bilewicz 1958, Cobben 1958, Afscharpour 1960, Bogush 1964, Clancy and Pierce 1966, Popova 1966, Josifov 1970). Outside Europe the species has been found in Algeria (Ossiannilsson 1943) and in Asia (Ossiannilsson 1943, Kulik 1965, Wagner 1967). Leston (1952) reported it from Alaska. According to Stichel (1956—1958) the bug is Palaearctic.

L. rugulipennis is common throughout Finland (Linnavuori 1951).

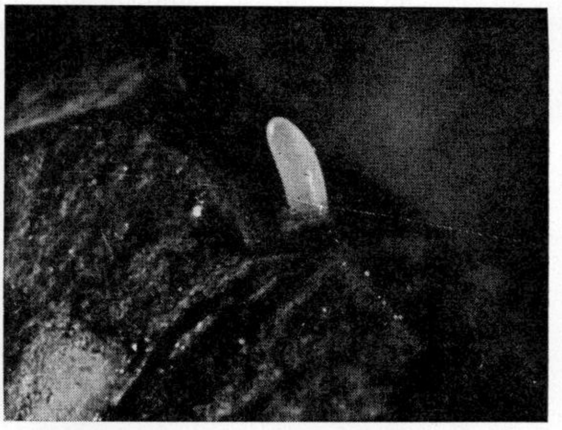


Fig. 2. One-week -old egg of *L. rugulipennis* protruding from a sugar beet leaf. Photo by O. Ulvinen.

A. Developmental stages

Egg

The egg of *L. rugulipennis* is yellowish, translucent, oblong in shape and slightly curved (Fig. 2). Kullenberg (1942) has described the egg in detail.

Both the length and breadth of the egg were found to increase with age (Figs. 3 and 4). Eggs deposited by different females were different in size. A positive correlation was found between the length of a female bug and the average length of its eggs (r = 0.89*).

Lengths of eggs ranged from 0.83 to 1.14 mm and breadths from 0.21 to 0.38 mm. A total of 436 eggs were measured.

Nymph

Boness (1963) published figures showing the five nymphal instars of *L. rugulipennis*. He also reported some measurements of third to fifth instar nymphs. There are few characters by

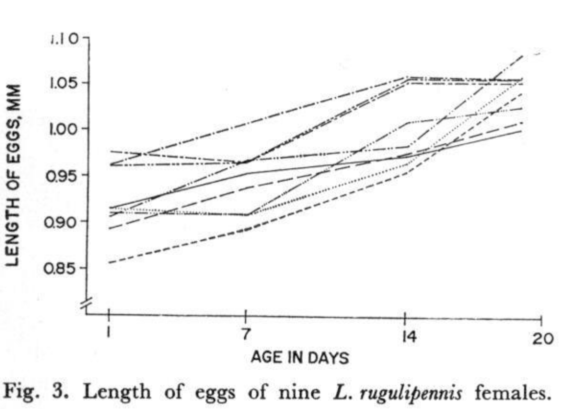


Fig. 3. Length of eggs of nine *L. rugulipennis* females.

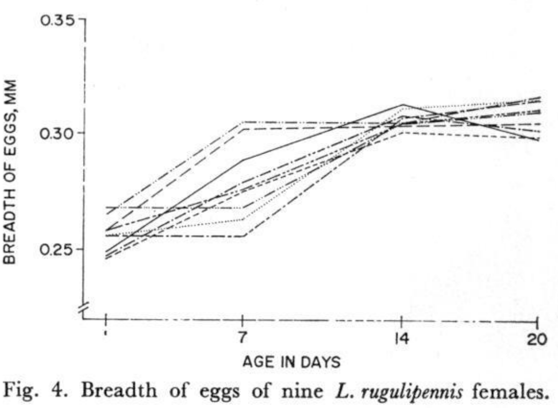


Fig. 4. Breadth of eggs of nine *L. rugulipennis* females.

which to distinguish the nymphs of *L. rugulipennis* from those of other closely related species (COBBEN 1958, BECH 1969).

Adult (*Figs. 5 and 6*)

In the adult most obvious feature by which to distinguish *L. rugulipennis* from other related species is the dense pubescence of the hemielytra, which gives the insect a matt appearance.

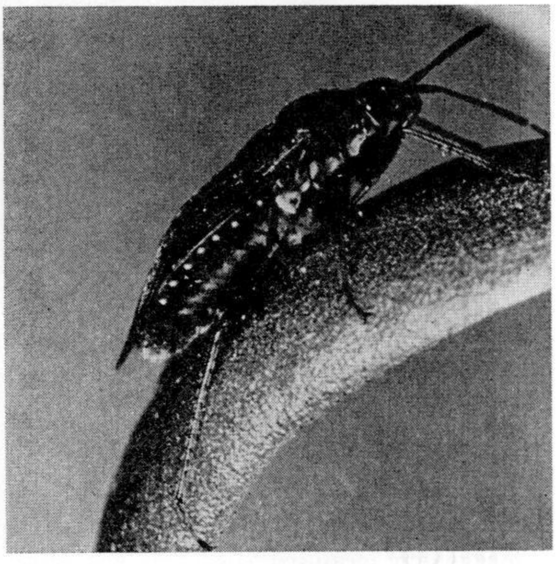


Fig. 5. Male of *L. rugulipennis*. Photo by L. Nordlund.

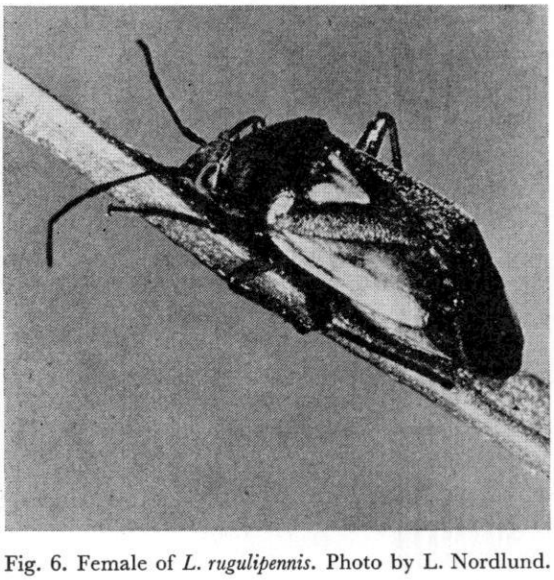


Fig. 6. Female of *L. rugulipennis*. Photo by L. Nordlund.

B. Life cycle

Egg stage

The oviposition period of *L. rugulipennis* begins in late May or early June. In the insectary cultures in both 1964 and 1965 the average duration of the egg stage was 21 ± 0.2 days.

The length of the egg period was greatly affected by temperature. In the present study the mean temperature for the egg period varied from +13.5 to +18.5 °C.

The minimum length of egg development was calculated from the formula $t(T - c) =$ constant, where t is the duration of the egg stage in days, T the average temperature during the egg period, and c a constant to be calculated, equal to the developmental zero. For *L. rugulipennis* the equation was found to take the form $t(T - 7.8) = 127.6$ (Fig. 7).

According to ROMANKOW (1960), in cultures of the first generation reared in an insectary in Poland the eggs took 11—17 days to hatch in 1956 and 25—35 days in 1957. For eggs of the second generation the respective figures were 15—22 and 17—24 days.

Air humidity does not appear to affect the rate of egg development unless very severe drought occurs, which in itself can prove destructive (BONESS 1963). Neither has day length been found to affect the embryonic or nymphal development of this species in any way (BONESS 1963).

Nymphal stage

The duration of the different nymphal instars are presented in Table 4. In addition, the following developmental periods from egg to adult were found for those individuals that attained the adult stage:

Year	Total development from egg to adult, days	
	Mean ± S.E.	Range
1964	56 ± 2.8	39 — 63
1965	58 ± 1.7	47 — 67

According to BONESS (1963), total development of the first generation in Germany in 1961

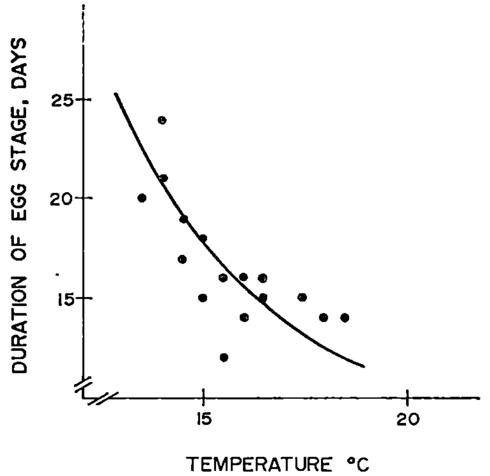


Fig. 7. Minimum developmental period of *L. rugulipennis* eggs at different temperatures.

took an average of 50 days. Nymphal development lasted 28 days on the average. First-instar nymphs took an average of 6 days, the second, third and fourth instars 4 days each, and the fifth instar 10 days. In Poland according to ROMANKOW (1960), the nymphal stage in 1956—1957 lasted 22—23 days in the first generation and 23 (1956) — 33 (1957) days in the second. In Finland development is slower, presumably owing to lower temperatures.

Nymphal mortality in the rearing experiments was very high (Table 5), especially in the first nymphal instar. BONESS (1963) gave the mortality of *L. rugulipennis* as 78—87 % at +20 °C temperature and 75—100 % relative humidity, and 85 % at +30 °C temperature

Table 4. *L. rugulipennis*, duration of nymphal instars.

Nymphal instar	Year	No. of specimens	Nymphal instar, days	
			Mean ± S.E.	Range
I	1964	50	8.6 ± 0.66	3—18
I	1965	126	9.0 ± 0.29	3—18
II	1964	30	6.3 ± 0.59	3—13
II	1965	79	7.8 ± 0.39	3—16
III	1964	23	6.5 ± 0.78	3—13
III	1965	64	8.8 ± 0.55	3—24
IV	1964	18	7.4 ± 0.99	3—17
IV	1965	58	5.3 ± 0.41	3—13
V	1964	17	8.4 ± 1.28	3—23
V	1965	44	9.5 ± 0.52	4—18
I—V	1964	17	37.8 ± 2.66	29—54
I—V	1965	44	39.8 ± 1.05	28—57

Table 5. Mortality of *L. rugulipennis* nymphs in insectary cultures. Mortality % from nymphal instar I to adult stage was 95 in 1964 and 87 in 1965.

Year		Nymphs of instars				
		I	II	III	IV	V
1964	Total started	366	50	30	23	18
	Died	316	20	7	5	1
	Per cent loss	86	40	23	22	6
1965	Total started	328	126	79	64	58
	Died	202	47	15	6	14
	Per cent loss	62	37	19	9	24
1964—1965	Per cent loss	75	38	20	13	20

and 100 % relative humidity, but if at the same temperature relative humidity was reduced to 75 %, the mortality of the species rose to 92 %. Thus in BONESS's experiments mortality was very high, too, and can be ascribed either to withering of detached plant parts or to eggs and nymphs becoming overgrown by fungi. In the present study no detached plant parts were used; the rearing corks were placed on the leaves of a live plant. Further, the amplexicaul leaves of winter turnip rape stayed very firmly attached to the plant. Nevertheless, drying of the plants as they matured may have contributed to the high rate of *Lygus* mortality. There was no trouble from fungi in these experiments, since the air humidity in the well-ventilated rearing corks remained reasonably low. Apparently, the high maximum temperatures in June (+29.2 °C in 1964, +26.6 °C in 1965) combined with the low relative humidity (mean for June 1964 58 %, June 1965 60 %) were harmful to the bugs in the early nymphal instars. Although attempts were made to carry out the rearing experiments under conditions as close to nature as possible, perfect simulation of natural conditions proved impossible. Thus, for instance, with potted host plants the protective effect of a dense plant population was practically lost. Bech (1969) suggests that at relative air humidities below 60 % death of the first instar nymphs may result because in such conditions they are unable to release themselves from the embryonic membranes. The studies of Strong et al. (1970) indicate that under the conditions prevailing in Arizona, the nymphal mortality of *Lygus hesperus* Knight would be about 92 %.

Adult stage

At Tikkurila the adults of *L. rugulipennis* begin to emerge in the first half of July. Large populations do not occur until late July or August. Migration to the hibernation sites begins at the end of August or in September (see Overwintering, p. 21). Kullenberg (1944) made observations on *L. rugulipennis* in Uppland, Sweden, in 1938 and 1939. He found that adults began their flight in early May and migrated to *Vaccinium myrtillus* in the middle of May. A week later, single specimens were found in open areas, and during the last few days of May almost the whole population had reached the summer biotopes.

Overwintering experiments showed that adult bugs emerge from forest litter in the warmest hours of the first sunny days as early as the end of March or beginning of April. They appear on field crops in mid- or late May. In weekly net collections the first *L. rugulipennis* from various crops were captured on the following dates:

1961 18. 5. winter rye, winter turnip rape
1962 17. 5. winter rye, ley (red clover, timothy, meadow fescue)
1963 29. 5. winter rye, winter turnip rape
1964 5. 6. winter rye, ley (red clover, timothy, meadow fescue)
1965 20. 5. winter rye
1966 26. 5. winter rye, ley (red clover, timothy, meadow fescue)
1967 11. 5. ley (red clover, timothy, meadow fescue)
1968 28. 5. winter rye
1969 14. 5. winter turnip rape
1970 13. 5. winter rye

At first the males caught appreciably outnumbered the females. Those adults that had overwintered died in late July.

The life cycle of *L. rugulipennis* is shown in Fig. 8.

In Finland *L. rugulipennis* is univoltine. In England, Czechoslovakia, Germany and Poland the species is bivoltine (Southwood 1956, Skuhravý and Novák 1957, Afscharpour 1960, Romankow 1960).

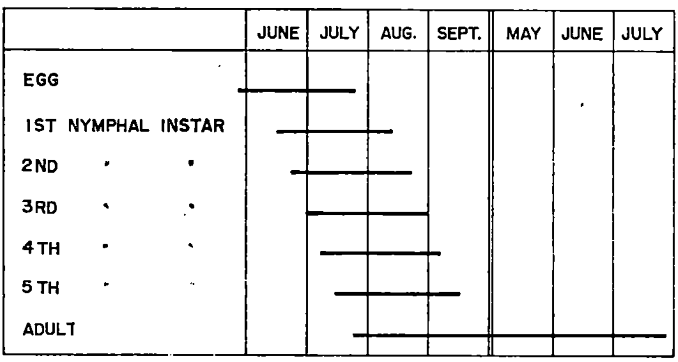


Fig. 8. Life cycle of *L. rugulipennis* in 1964—1966.

C. Reproduction

Oviposition and the oviposition period

Oviposition was studied in 63 *L. rugulipennis* females placed on winter turnip rape in rearing corks. In 1964 and 1965 these experiments were conducted in the insectary, in 1967 and 1969 in a field of winter turnip rape. The average duration of the oviposition period (Table 6) was 29 ± 1.7 days.

Table 6. *L. rugulipennis*, duration of oviposition period.

Year	No. of females	Oviposition period, days	
		Mean ± S.E.	Range
1964	10	30 ± 5.0	3 — 45
1965	15	35 ± 3.9	1 — 52
1967	19	28 ± 2.8	11 — 46
1969	19	24 ± 2.9	3 — 44

The numbers of eggs laid varied greatly from day to day (Fig. 9). Fluctuations in temperature

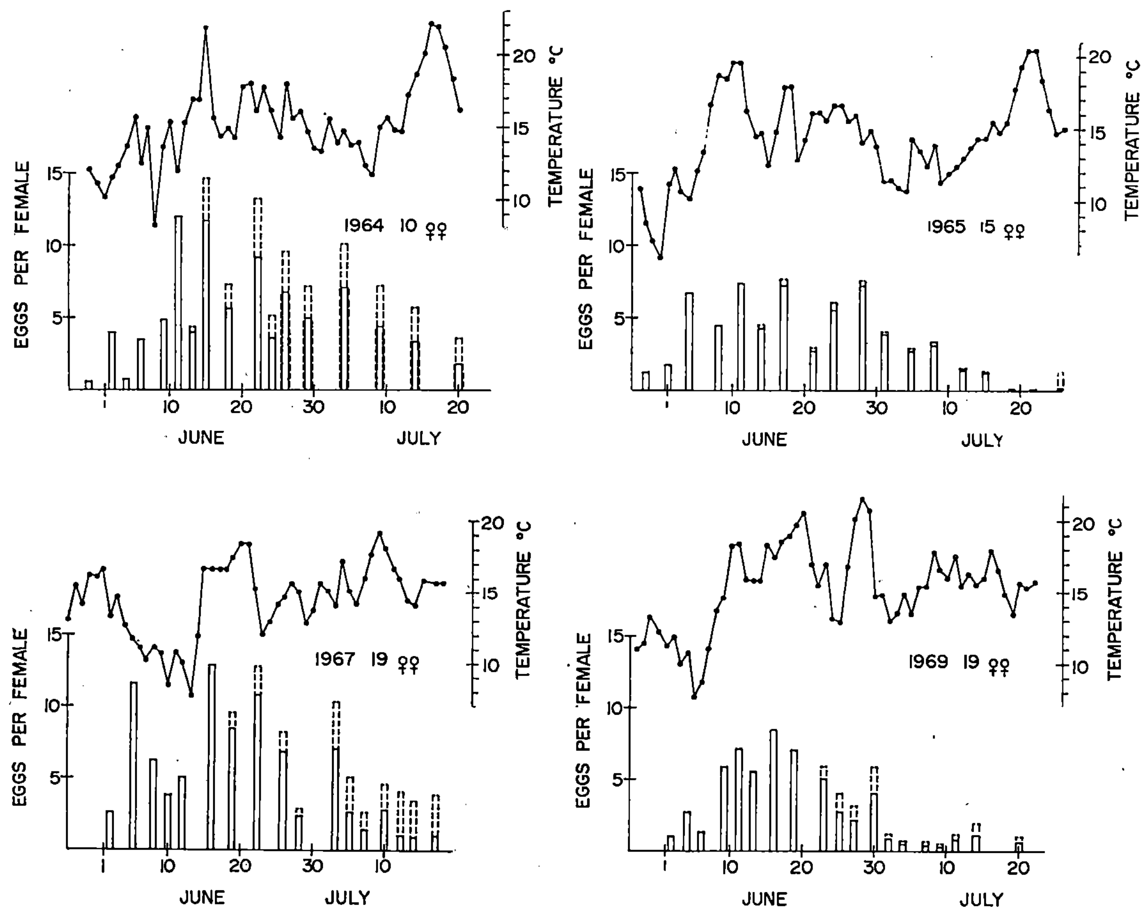


Fig. 9. Oviposition of *L. rugulipennis* females in the insectary in 1964 and 1965 and in the field in 1967 and 1969.

eggs per female eggs per surviving female daily mean temperature °C were found to be one of the causes of this variation. More eggs were deposited in warm than in cool weather.

The females survived for an average of 8.0 days after laying the last egg.

The average number of eggs per female was 72 ± 5.1. The yearly variation was as follows:

Year	No. of females	Eggs per female Mean ± S.E.	Range
1964	10	88 ± 14.5	6 — 141
1965	15	61 ± 7.0	2 — 102
1967	19	86 ± 9.7	39 — 192
1969	19	57 ± 8.1	10 — 145

Boness (1963) did not mention the average number of eggs in his experiments but states that the bugs in his laboratory cultures laid as many as 320 eggs in 74 days. He does not specify the host plant used, but as will be shown in the following, the species of host plays an important part in determining the length of the oviposition period and the number of eggs laid. Yet under natural conditions in Finland the overwintered adults of *L. rugulipennis* die at the end of July, and since oviposition begins in May or early June, it seems hardly possible in our conditions to exceed the maximum oviposition period found with winter turnip rape. Boness (1963) also stated that in the open oviposition began a couple of weeks later than in the laboratory cultures from which he derived his figures.

Oviposition hosts

Besides winter turnip rape, red clover was tested as host plant in 1964 and bush bean in 1965.

Year	Plant species	No. of females	Eggs per female Mean ± S.E.	Range
1964	Red clover	8	22 ± 2.1	13 — 29
1965	Bush bean	9	37 ± 7.3	5 — 84

Compared with winter turnip rape in the same year, the number of eggs per female was significantly lower in red clover ($t = 4.53^{***}$) and in bush bean ($t = 2.36^{*}$). There was no significant difference between the numbers of eggs in winter turnip rape in the two years ($t = 1.68$, $P > 0.05$); neither was there any significant difference between the numbers of eggs deposited in bush bean and red clover ($t = 2.07$, $P > 0.05$).

The oviposition period of *L. rugulipennis* was shorter on red clover than on winter turnip rape.

Year	Plant species	No. of females	Oviposition period, days Mean ± S.E.	Range
1964	Red clover	8	10 ± 2.5	4 — 27
1965	Bush bean	9	22 ± 3.7	1 — 34

On red clover the females died 3.0 days, on bush bean 3.1 days after completing oviposition.

Choice of host plant was studied with eleven different plant species which were placed in an outdoor rearing cage. The number of replicates was four, and each cage contained one plant of each species in randomized order except for spring wheat, of which groups of six young seedlings were used. In early June 30 pairs of *L. rugulipennis* adults were introduced into each cage, and the plants were inspected in the laboratory one month later. The eggs were counted and their distribution on the plants noted. The results obtained in the three years are shown in Table 7. Eggs were found in every species tested, even in pine, but their numbers

Table 7. Number of eggs of *L. rugulipennis* in different host plants in outdoor rearing cages in 1965—1967.

Plant species	No. of eggs per plant Mean [1]
Scentless mayweed (*Tripleurospermum inodorum*)	63 a
Potato	36 ab
Winter turnip rape	35 ab
Swede	26 b
Red clover	22 b
Sugar beet	17 b
Bush bean	15 b
Mugwort (*Artemisia vulgaris*)	11 bc
Spring wheat	3 bc
Carrot	2 bc
Pine	1 bc
F	9.92^{***}

[1] In this and many of the following tables numbers followed by the same letter(s) are not significantly different at the 5 % level.

varied greatly according to the plant species. Eggs were most numerous in *Tripleurospermum inodorum*. KULLENBERG (1944) also mentions this species as one of the favourite host plants. He also names *Trifolium medium*, *Chrysanthemum leucanthemum* and *Urtica dioica* as plants suitable for oviposition.

BONESS (1963) recorded oviposition in the laboratory in the following plants: red clover, rape, vetch, mayweed, *Chrysanthemum leucanthemum*, *Atriplex patula*, *Senecio vulgaris*, *S. viscosus*, and *Urtica dioica*.

BECH (1969) was successful in inducing *L. rugulipennis* to deposit eggs in the following species not mentioned previously: *Medicago sativa*, *Phaseolus vulgaris*, *Solanum tuberosum*, *Anethum graveolens*, *Apium graveolens*, *Beta vulgaris*, *Brassica napus*, *B. rapa*, *Triticum aestivum*, *Carum carvi*, *Stellaria media*, *Achillea millefolium*, *Anthemis tinctoria*, *Artemisia vulgaris*, *Matricaria maritima*, *Capsella bursa-pastoris* and *Thlaspi arvense*.

Distribution of the eggs

L. rugulipennis lays its eggs in all aerial parts of plants. The site where the eggs are laid in the host varies according to the plant species,

Table 8. The percentage distribution of *L. rugulipennis* eggs between various parts of plants in 1965—1967.

Plant species	Stems %	Leaves %	Inflorescences %	Fruits %	Total No.
Scentless mayweed (*Tripleurospermum inodorum*)	18	47	35	—	760
Potato	19	81	—	—	438
Winter turnip rape	48	12	17	23	422
Swede	—	100	—	—	314
Red clover	8	84	8	—	247
Sugar beet	—	100	—	—	200
Bush bean	18	81	1	—	177
Mugwort (*Artemisia vulgaris*)	30	62	8	—	128
Spring wheat	11	89	—	—	41
Carrot	—	100	—	—	30
Pine	all in young needles				11
Total number of eggs	—	—	—	—	2 768

[1] first-year plants, no other plant parts available

but most are found in the soft succulent parts (Table 8). The ovipositor is inserted into the plant tissue or right through it. Often only the anterior end of the egg can be seen at the level of the plant surface.

The eggs were laid either singly or in groups of varying size. Fig. 10 illustrates schematically their distribution in some plant species.

Fig. 10. Distribution of eggs of *L. rugulipennis* in scentless mayweed, potato and winter turnip rape.

D. Food plants

L. rugulipennis is a highly polyphagous species. About one hundred food plants are known, distributed among some thirty plant families (WAGNER 1940, KULLENBERG 1944, STICHEL 1956—1958, AFSCHARPOUR 1960, SÖMERMAA 1961, BECH 1969).

According to BONESS (1963), *L. rugulipennis* accepts animal food in addition to its normal vegetable diet. He succeeded in rearing *L. rugulipennis* in the laboratory from the first-instar nymph to the adult exclusively on animal food (bits of mealworm) and water. However, parallel cultures on vegetable diet were equally successful. *L. rugulipennis* has also been found to destroy eggs of *Leptinotarsa decemlineata* Say (BOGUSH 1964).

In the course of the present study *L. rugulipennis* bugs were observed to feed on eggs of the mangold fly (*Pegomya betae* Curt.).

It was also established that *L. rugulipennis* was able to survive for quite a considerable time entirely without food. Twenty-eight overwintered adult bugs collected from cultivated crops on 11 May 1971 survived outdoor temperatures in PVC cylinders for an average of 12 ± 1.0 days, with a maximum of 20 days. A plug of cotton wool, well moistened daily, was placed in each cylinder.

When, in connection with this study, *L. rugulipennis* was reared on different plant species, differences were found in the numbers of eggs laid as well as in the duration of oviposition and post-oviposition periods of the females (tables on p. 15 and 16).

Food plant selection

Food plant selection by *L. rugulipennis* was studied in the laboratory with three different plant species. The test plants were sown at such times that all were at the cotyledon stage when tested. Thus sugar beets were sown 8 days, carrots 11 days, and swedes 5 days before the experiment. When ready, each pot was covered with a rearing cylinder into which two male and three female bugs were released. The bugs had been captured with a sweep net from field crops the previous autumn and kept over the winter in rearing cages out in the open. After the bugs had been inserted, their movements and feeding on the plants were noted at 10-minute intervals. Observations were made on two successive days over a period of 3 hrs 40 min. Prior to the observation periods the bugs had been kept fasting for 18 hrs with nothing but water available. The number of replicates was six and the experiment was conducted six times in April—May. At each examination the total number of bugs on each species tested was noted and the results were treated by analysis of variance.

Table 9. Number of *L. rugulipennis* specimens observed on seedlings of sugar beet, swede and carrot, and number of bugs observed feeding in laboratory experiment 1965.

Plant species	Bugs on plants No.	Bugs on plants %	Bugs feeding No.	Bugs feeding %
Sugar beet	1 887 a	43.4	799 a	55.5
Swede	1 817 a	41.8	528 b	36.7
Carrot	644 b	14.8	113 c	7.8
Total	4 348	100.0	1 440	100.0
F	31.16***		27.42***	

The bugs clearly spent less time on the carrot plants than on the sugar beets and swedes; between the two latter there was no significant difference (Table 9). Feeding occupied an average of 33 % of the total time spent on a plant. The proportion was highest, 42 %, on sugar beet and lowest, 18 %, on carrot. On swede, feeding took up 29 % of the time spent on the plants. The bugs fed most frequently on sugar beet, significantly less on swede, and least of all on carrot.

Food plant selection was also studied in field tests in 3 years. Fifteen plant species were grown on trial plots 1 m² in size. The plots were spaced 40 cm apart and there were three replicates in a continuous line. The plots were examined twice a week in June, July and August for the numbers of *Lygus* adults and nymphs. The inspections were made between 10.30 and 13.30 hrs.

Adults were most numerous on *Artemisia vul-*

Table 10. Occurrence of *Lygus* spp. adults and nymphs on different test plants in June-August 1965—1967. Counts were made twice a week from 3 × 1 m² plots. Data from the different years were combined.

Plant species	No. of adults	No. of nymphs
Mugwort (*Artemisia vulgaris*) ..	930 a	798 a
Stinging nettle (*Urtica dioica*) ..	715 b	156 bc
Scentless mayweed (*Tripleurospermum inodorum*)	264 c	190 b
Winter turnip rape, 2nd year ..	168 cd	219 b
Potato	59 d	112 bcd
Red clover	42 d	61 cd
Bush bean	15 d	8 d
Winter turnip rape, 1st year ..	13 d	0 d
Carrot	8 d	1 d
Sugar beet	7 d	2 d
Spring wheat	7 d	1 d
Barley	4 d	0 d
Swede	4 d	0 d
Oats	2 d	0 d
Turnip	1 d	3 d
F	$41._{71}$***	$35._{54}$***

garis, Urtica dioica and *Tripleurospermum inodorum* (Table 10). The same species also carried large numbers of nymphs. Nymphs were also fairly abundant on winter turnip rape and potatoes, suggesting that these two were favourite oviposition hosts as well. This is also supported by the results of the experiment on selection of plants for oviposition (cf. Table 7). It was not possible during the observations to identify all individual lygus bugs by species, but the general trend was for *L. rugulipennis* to outnumber all other species on cultivated plants, whereas on weeds other *Lygus* species were numerous as well, e.g. *L. gemellatus* H.S. in mugwort.

Afscharpour (1960) reported that *L. rugulipennis* bugs were more numerous on certain weeds of field crops than on the crops themselves. Examples of such weeds were *Matricaria chamomilla* and *Chenopodium album.*

In interpreting the results it is necessary to bear in mind that, true to their specific characteristics, the different crops displayed very dissimilar stands as far as luxuriance of growth and abundance of plant mass are concerned. It was observed in general that the bugs preferred sheltered places and tall, dense plants to open spaces and small plants. Thus bugs were seldom encountered in the sugar beet plots, although numerous beet plants displayed signs of bug injury.

Occurrence in sugar beet

Afscharpour (1960), Novák (1966), Bilewicz-Pawińska (1967) and Štepanovičová (1969), among others, have studied the abundance of lygus bugs in sugar beet by means of sweep-net collections. Since the sweeping method is only practicable at relatively late stages of plant growth, when the stand already more or less completely covers the ground (cf. Heikinheimo and Raatikainen 1962), the sweep net results were supplemented by visual counts in sugar beet early in the summers of 1969 and 1970. These were performed by walking between two plant rows in a direction in which the observer's shadow did not fall on either of them before the count was taken. All lygus specimens observed in the two rows were counted. The method is subjective and depends largely on the alertness of the observer, but such counts are of great value in assessing occurrence of lygus bugs in the early stage of plant growth. Bilewicz-Pawińska (1965) also used the »captures by watching» method to check and supplement the results obtained by net sweeping in ecological analysis of *Heteroptera* communities in oats, rye and potato fields.

The number of specimens caught by yellow-pan trapping (Moericke 1951) was very small in comparison with the visual counts. Bech (1965) also found that the use of yellow pans gave very small numbers of lygus bugs.

The first lygus bugs appeared on sugar beet very shortly after the seedlings emerged (Fig. 11). They then occurred throughout the growing period until harvest (Fig. 12). Then the bugs migrated to their overwintering habitats. According to the sweep-net samples, 95 % of the specimens on sugar beet were *L. rugulipennis*. The proportion was still higher when the plants were small, for the other closely related species occurring in Finland appear slightly later in spring than *L. rugulipennis*. The numbers of individuals obtained by the methods used were rather small.

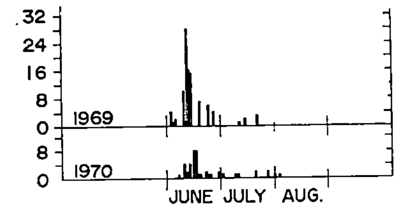


Fig. 11. Numbers of *Lygus* bugs on sugar beet in the years 1969 and 1970 according to visual counts.

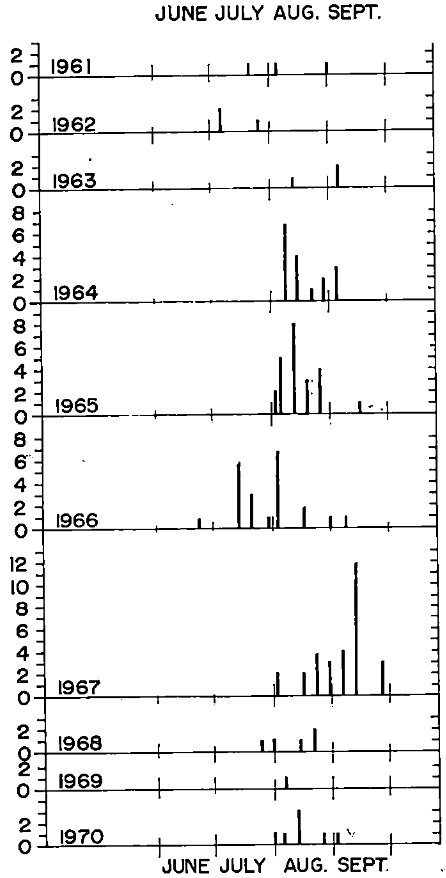


Fig. 12. Numbers of *Lygus* bugs on sugar beet in the years 1961—1970 according to sweep-net collections.

E. Overwintering

According to KULLENBERG (1944), *L. rugulipennis* hibernates in coniferous trees. BONESS (1963) found overwintering lygus bugs in an afforested area with spruce trees 1—3 metres high and in a beechwood. The overwintering sites investigated adjoined farmland or meadows, and in mid-winter only a few specimens of *L. rugulipennis* could be found. These were hidden under the topmost layer of fallen leaves or other forest litter. As soon as the temperature reached + 10 °C in early spring, the bugs emerged from the litter in fine weather and climbed onto the lowest branches of the spruce saplings.

In the studies of BECH (1969) most hibernating specimens of *L. rugulipennis* were encountered in the leaf litter of meadow forests (Auenwald — Bodenlaub), in shrubland weed populations (Hochstauden — Unkrautgesellschaften) and in *Chenopodiaceae*-populations (Meldengesellschaften).

Overwintering experiments

30- to 50-cm saplings of juniper, pine and spruce were planted in plastic pots 20 cm in diameter, one tree in each. The fourth treatment was forest litter, composed of conifer needles, broken conifer twigs and dry grass. A layer of sand was placed at the bottom of each pot. The pots were placed in randomized blocks in the field and sunk into the ground up to their rims. Three replicates were arranged.

Each tree sapling was enclosed in a loose bag of light fabric with the open end of the bag gathered and tied around the trunk. In the treatment with forest litter the open end was attached to the rim of the pot. *L. rugulipennis* adults were inserted in early October through an opening at the top, which was immediately closed.

The bugs used were caught by sweeping from cultivated crops and maintained in the insectary until the start of the experiment.

In the spring the bugs were seen moving on

Table 11. Overwintering of *L. rugulipennis*.

Year	No. of bugs per treat-ment	Overwintered bugs per treatment							
		Forest litter		Juniper		Spruce		Pine	
		No.	%	No.	%	No.	%	No.	%
1967—1968	276	40	14	9	3	0	0	0	0
1968—1969	165	48	29	0	0	12	7	0	0

Table 12. Overwintering of *L. rugulipennis* males and females.

Year	Sex	Total No.	Overwintered bugs		χ^2
			No.	%	
1967—1968	♂♂	564	13	2	—
	♀♀	540	36	7	12.37***
1968—1969	♂♂	300	22	7	—
	♀♀	360	38	11	2.06

warm days as early as the end of March — beginning of April. The experiment was terminated by May.

L. rugulipennis overwintered most successfully in the forest litter (Table 11) but even here only about 20 % of the individuals survived. The species was also found capable of overwintering in juniper and spruce. Hibernation succeeded better in 1968—1969 when the overwintering sites were completely covered with snow. The previous winter they had remained partly uncovered. When the treatments were examined in the spring, no bugs were found that could have been supposed to have died late in the spring. All dead specimens were quite far decayed. Females survived the winter better than males (Table 12). The difference was significant in 1967—1968.

In the studies of Bech (1969), drying-up was found to cause greater mortality among overwintering bugs than unfavourable temperature. Bech (1969) also studied the hibernation of *L. campestris* L. in refrigerators at temperatures of + 6 °C, 0 °C and — 6 °C. Relative humidity was 75—85 %. Survival was best at 0 °C. At this temperature bug mortality after 4 months was 66 %, while all those at — 6 °C had already died, and all those at + 6 °C died within 3 months. With longer hibernation the mortality rose comparatively rapidly at 0 °C as well: 93 % died in 5 months, 100 % in 6 months.

Overwintering samples

Of the sweep-net collections made in wooded areas in spring, the first that contained *L. rugulipennis* adults were obtained from a heather-grown pine moor where spruce was also present. In the spring of 1969 four different collections in this area and the adjoining cultivated field of winter rye yielded the following numbers of *L. rugulipennis:*

	19. 5.	22. 5.	28. 5.	10. 6.
Heather	3	8	0	0
Spruce	11	8	2	0
Pine	0	1	4	0
Winter rye	0	1	11	26

In the autumn of 1968 four collections from heather on the same pine moor gave 4 adults and 4 nymphs on 23 August and 26 adults on 2 September.

Among the other overwintering samples (Table 13) the largest numbers of hibernating *L. rugulipennis* adults were obtained from conifer needle litter and from the lowest branches of large spruce trees. Both sweep-net and other samples showed that in a forest no bugs were caught from the boundary area between the forest and the adjoining field, but some 100—150 metres away from it. Kullenberg (1944) had the same experience with species of the *L. pratensis* group. In his opinion this was due to

Table 13. Occurrence of *L. rugulipennis* in different overwintering environments in 1970 and 1971.

Nature of sample	Size of sample	No. of *L. rugulipennis*
Conifer forest		
spruce saplings	16 specimens	—
lowest branches of large spruces	200 l	5
spruce cones	46 l	—
pine saplings	21 specimens	—
pine bark	73 m²	—
junipers	26 specimens	—
needle litter	35 m²	11
grass vegetation	20 m²	1
heather	42 m²	1
moss	3 m²	—
Mixed forest		
junipers	20 specimens	—
needle litter	10 m²	—
leaf litter	40 m²	1
grass vegetation	30 m²	—
moss	20 m²	—
Edge of cultivated field		
grass vegetation	55 m²	—
umbellifers etc.	15 m²	—

the bugs' preference for sites protected from wind. He found most overwintering bugs in forest edges that were either sheltered from the prevailing winds or composed of large, richly branched conifers extending their lowest branches near the ground. It is probable that the hibernation sites described in the present work were expressly chosen by bugs for the shelter they offered from the wind.

F. Natural enemies

Clancy and Pierce (1966) compiled information on the natural enemies of some lygus bugs. According to their review, two species of *Mymaridae*, *Anaphes ovijentatus* Cr. & Leon. and *Polynema pratensiphagum* Wall. are known from eggs, several species of *Braconidae* mainly from nymphs, occasionally from adults, and several species of *Tachinidae* from adults. Loan (1969) described two new braconid parasites of *L. lineolaris* P. de B. One braconid, *Leiophron* (*Euphorus*) *pallipes* Curt., has been found parasitizing *L. rugulipennis* (Adlung 1964, Clancy and Pierce 1966) and one tachinid, *Alophorella obesa* F., parasitizing *L. rugulipennis* and *L. pratensis* (Clancy and Pierce 1966).

Many insects are known to prey on lygus bugs, e.g. *Nabis* and *Geocoris* spp. (Clancy and Pierce 1966). Kullenberg (1944) observed *Nabis ferus* L. and *N. rugosus* L. feeding on eggs of *L. rugulipennis*. As further predators of the species he mentioned two birds, the great tit (*Parus major* L.) and the goldcrest (*Regulus regulus* L.)

From eggs deposited by *L. rugulipennis* in winter turnip rape, 900 *Lygus* nymphs and 36 adult parasites emerged in 1967. Thus the proportion of parasitized eggs was 4 %. In 1969 the corresponding numbers were 333 bugs and 35 parasites, 10 % of the eggs being parasitized. The parasite was the mymarid *Anaphes fuscipennis* Hal.

In the rearing experiments to determine the occurrence of parasites in nymphs and adults 30 fourth- to fifth-instar nymphs or adults of *L. rugulipennis* were placed in rearing cylinders. With both nymphs and adults the number of replicates was seven. No parasites were found in these experiments. In connection with removal of the salivary glands of *L. rugulipennis* one larva, obviously a tachinid, was found in the abdomen of an adult female. The parasitized adult was paler than normal.

The ability of some insect species to prey on lygus bugs was tested in experiments in which single predators were placed in Petri dishes with 3—4 *Lygus* nymphs or one adult. Additional food was offered according to need. The number of replicates was six.

Larvae of *Coccinella septempunctata* L. and *C. quinquepunctata* L. fed on nymphs of *L. rugulipennis*, but if aphids were present, they clearly preferred these. The ladybird larvae soon pupated, but in five days one of the species *C. septempunctata* consumed seven fifth-instar *Lygus* nymphs and one adult female of *L. rugulipennis*. *C. septempunctata* adults fed on *L. rugulipennis* adults but did not appear to take them readily.

An adult of *Nabis* spp. took an average of 0.9 fifth-instar *Lygus* nymphs per day in a 10-day period if no other food was available. If nothing but *L. rugulipennis* adults was offered, *Nabis* adults consumed on an average 0.05 such adults per day in a period of 10 days. In this experiment some of the *Nabis* adults died. Further, a syrphid larva was observed in a rearing cage feeding on a *Lygus* nymph.

In the years of this investigation, natural enemies of *L. rugulipennis* were of minor importance. In the studies of Bilewicz-Pawińska (1964) in 1962, 12 % of the fourth- and fifth-instar nymphs of *L. rugulipennis* were parasitized by braconids. The numbers of parasites may vary considerably in different years. Thus, for example, in France 50—75 % of *L. rugulipennis* were parasitized by *Leiophron* (*Euphorus*) *pallipes* Curt. in 1962 but only 3 % in 1963 (Adlung 1964).

A. Sites and duration of feeding and amounts taken

Material and methods

Young sugar-beet seedlings grown on multipot trays were enclosed in PVC rearing cylinders. One *L. rugulipennis* adult was introduced into each cylinder. Its behaviour was watched continuously as long as the bug was kept in the cylinder. The experiments of 1966 and 1967 were mainly concerned with the behaviour of single bug specimens over several hours. Observation periods generally varied from 2 ½ to 5 ½ hours. When the bug had fed on a plant once or more it was transferred to another plant and kept under observation. These observations were made between 25 May and 13 July. The 1970 experiment was aimed at studying the differences in plant response following bug injury to different parts of the plant. In these experiments a bug was transferred to another plant as soon as one feed was completed, and if it failed to feed on plant, it was replaced by another individual. The effects of feeding were observed during the course of several weeks. When necessary, plants were transplanted from the multipots to larger single pots or (in 1970) to the field.

Amounts of food ingested were studied by allowing *L. rugulipennis* adults to feed on leaves of sugar beets and weighing them individually before and after feeding.

Results and discussion

Slightly more than one-tenth of the total time was spent by *L. rugulipennis* in feeding. The frequency of feeding was higher in females than in males. The females spent 15 % of their total time on the plants in feeding, while the males only spent 7 %. It was found that when the substratum was peat the bugs preferred to stay in it and only occasionally climbed up into the plants to feed. When a thin layer of sand was strewn on top of the peat soil, visits to the plants became more frequent. Before starting to feed, the bugs probed into the plant tissue with their stylets several times in quick succession. Such trial probing was not always followed by feeding. The younger the host plant, the higher was the number of trial punctures. In cotyledon-stage seedlings the number of trial punctures was 4.1-fold, in seedlings with 1—2 true leaves 1.3-fold, and in those with 3—4 true leaves 0.9-fold as compared to the number of stylet insertions resulting in actual feeding. Male and female bugs did not differ from each other in this respect. In cool weather the behaviour of the bugs was very passive; their activity and frequency of feeding increased remarkably with the rise in temperature. This was also clearly shown by another experiment by the present author (VARIS 1971), in which *L. rugulipennis* adults became increasingly active the higher the temperature in the range + 5 °C to + 20 °C.

In small seedlings the duration of a feed as well as the total feeding time were longer in growing point feeding than in stem or leaf feeding (Table 14).

The younger and smaller the plant, the shorter was a single feeding period; apparently in small plants the bugs were forced to change position more frequently to obtain adequate food.

Table 14. Site and duration of feeding by *L. rugulipennis* on sugar-beet seedlings in different growth stages.

Growth stage	No. of feeds	Total feeding time min.	Proportion of feeds and their average duration on different plant parts					
			Stem		Growing point		Leaf	
			%	min	%	min	%	min
Cotyledon stage	112	326	12	3.3	29	4.8	59	1.9
1-to 2-leaf stage	124	1 220	38	12.6	22	10.0	40	7.1
3-to 4-leaf stage	45	848	16	19.2	40	17.5	44	19.9

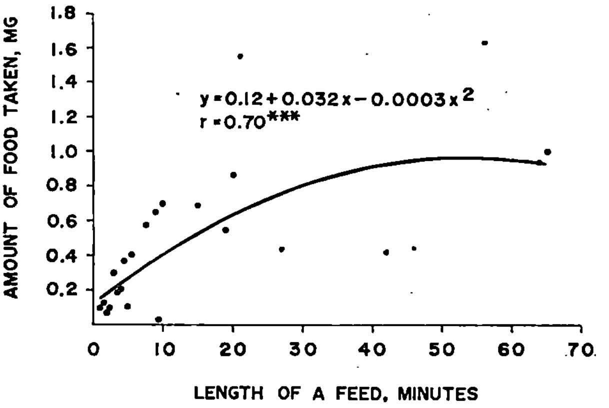


Fig. 13. Correlation between the length of a feed and the amount of food taken by *L. rugulipennis*.

Similarly, in tiny plants, bugs feeding on a leaf changed position more often than those feeding on the stem or growing point.

There was no significant difference between male and female bugs in the length of a feed ($t = 0.57$, $P > 0.05$ d.f. 392).

The correlation between the length of a feed and the amount of food ingested in *L. rugulipennis* is shown in Fig. 13. The amounts of food taken in a given time varied greatly, especially with the longer feeding times, and it was impossible to know whether the insects were actually feeding during the whole time that their proboscides were inserted into the host tissue.

In *L. hesperus* Knight, Strong and Landes (1965) studied the amount of food ingested by weighing the food source before and after feeding. Adult males were found to ingest an amount equal to 112 % of their body weight in 24 hours. Since the average weight of an adult in the present experiment was about 6 mg, it would be necessary for such an insect to feed e.g. for 18 × 10 min. in every 24 hrs to ingest the large amounts reported by Strong and Landes (1965) with *L. hesperus*. Observations during the present study revealed average feeding times that do not imply such large intakes of food, but it is also possible that the readiness of the bugs to feed varies with the time of day.

B. Nature of the injury

Injury to the plants in some cases became visible very soon. Thus a 19-minute feed on the growing point caused wilting of one of the cotyledons within 20 minutes, and a 7-minute feed on the growing point caused one of two true leaves to wilt in 25 minutes. The following day the apex itself was black.

In very small seedlings just emerged from the soil, a feeding period as short as 1—1 ½ min. made the cotyledons wilt within 1 hour. On one occassion, feeding on a tiny cotyledon caused its leaf margins to curl back immediately after 2 minutes of feeding.

The symptoms usually appeared at the very point where injury was inflicted. Feeding on a hypocotyl turned this black and often resulted in death of the entire plant. Even when no injury could be discerned at the feeding site, the growth of the young plant was sometimes retarded. Feeding on a leaf resulted in wilting of all or part of the leaf concerned. On many occasions only minute, light-coloured feeding punctures could be seen on the leaf. Feeding on the stem apex injured the growing point but could also cause a cotyledon or a leaf to droop. Moreover, new leaves that developed after the damage were sometimes malformed (Fig. 14). However, feeding did not always produce visible symptoms.

Plants in which the growing point was known to have been attacked by bugs when at the cotyledon stage, subsequently often showed symptoms of growing-point injury (Fig. 15); the growing point was killed and turned black, and often the tissue between the cotyledons was swollen. Some of the plants died.

In many cases the darkening of the growing point was only visible 5—10 days after the damage was inflicted.

The destruction of the growing point often resulted in enlargement and thickening of the cotyledons and development of lateral buds. In 1956, symptoms very similar to those described above, were noted in sugar beet seedlings in England (DUNNING 1957). It was thought likely that Mirid adults were responsible. This was also confirmed later and the bug was identified as *L. pratensis* L. (information by letter from R. A. Dunning).

It was further observed in the present study that insertion of the ovipositor and oviposition into the growing point was very likely to cause swelling of the tissue, and oviposition into the hypocotyl was sometimes found to kill a tiny plant.

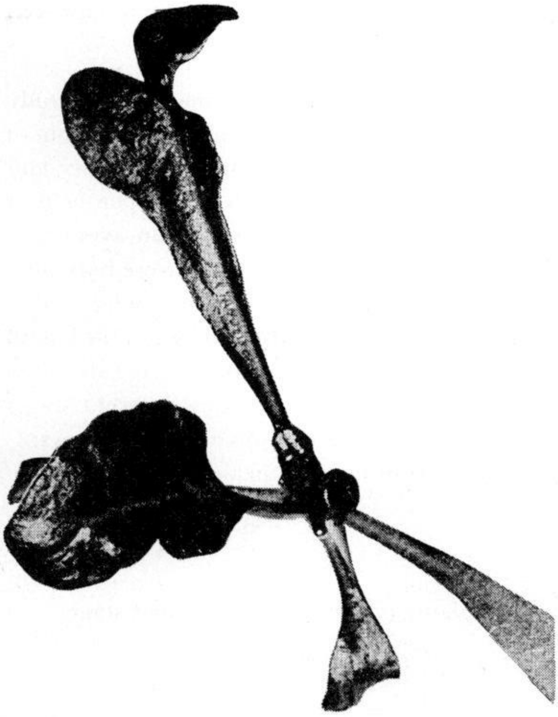


Fig. 14. Malformed sugar-beet leaves developed after injury to the growing point by *L. rugulipennis*. Photo by L. Nordlund.

C. Effect of feeding time

Effect of feeding frequency on plant injury

The experimental material used for these studies was partly the same as in the food plant selection experiment with sugar beets, carrots and swedes as test plants (cf. p. 18). Pots with seedlings at the cotyledon stage were covered with rearing cylinders into which adults of *L. rugulipennis* were inserted. Their feeding behaviour was examined at 10-minute intervals on 2 successive days. Before the first observation day and between the two observation periods the bugs were kept fasting for 18 hrs although they had access to water. Damage to the sugar beet plants was recorded after the termination of the experiment. The experiment consisted of six replicates and was repeated four times.

At each inspection the numbers of bugs feeding on the plants were totalled up by replicates. Correlations between the frequency of feeding and the degree of damage to the plants were calculated.

A positive correlation was found to exist between the feeding frequency of *L. rugulipennis* and the degree of injury to the sugar-beet plants ($r = 0.66^{**}$).

Since the frequency of feeding can be considered to represent feeding time as well, the conclusion can be drawn that the degree of injury is positively correlated with feeding time. This subject was investigated further in the following additional experiments.

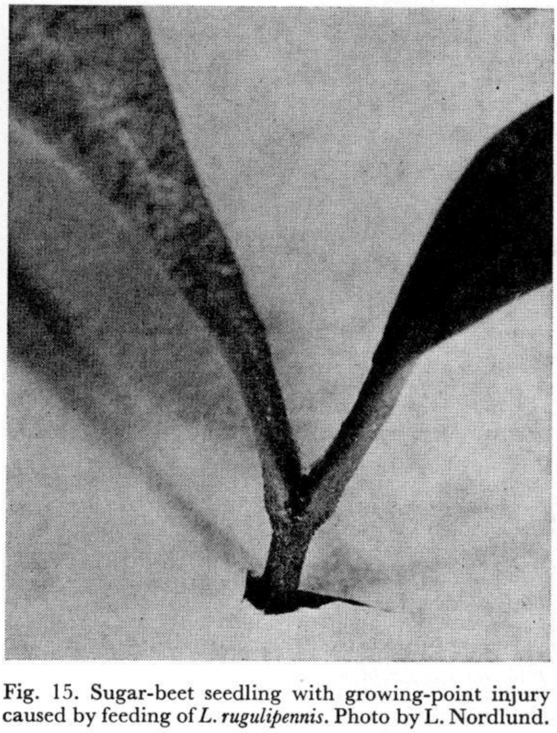


Fig. 15. Sugar-beet seedling with growing-point injury caused by feeding of *L. rugulipennis*. Photo by L. Nordlund.

Effect of feeding time on the weight of sugar-beet roots

Growing of the 1970 plant material for study of the length of feeding and the selection of feeding sites (p. 23) was continued further and the plants were transplanted to an open field at the end of June, when they had an average of 5—6 true leaves each. The beets were harvested in late September and weighed individually. From these data, correlations between the length of feeding and the weight of roots were calculated separately for plants injured at different stages of growth. The correlations were as follows:

For plants injured at the cotyledon stage

$$y = 733.55 - 0.811x$$
$$r = -0.44^{**}, \text{ d.f. } 44$$

For plants injured at 1- to 2- leaf stage

$$y = 695.82 - 0.184x$$
$$r = -0.24^{*}, \text{ d.f. } 68$$

For plants injured at 3- to 4- leaf stage

$$y = 594.83 - 0.006x$$
$$r = -0.02, \text{ d.f. } 35$$

where y is root weight in grams and x duration of feeding in seconds.

The effect of the length of the feeding time was apparent in small plants right up to the time of harvest but indiscernible in plants damaged at a later stage of development. Plants injured at different stages were not comparable with each other in this experiment, since the populations of plants injured later, although sown simultaneously with the others, were thinned in a later phase of growth.

FLEMION et al. (1952) did not find a direct relation between the amount of damage to various plant tissues and the length of feeding by *L. lineolaris* P. de B.

D. Capacity for injury

How many sugar-beet plants one individual *L. rugulipennis* adult is able to injure, was studied at Tikkurila in the years 1968—1969.

Sugar beets were sown in 15-cm pots in the insectary at the normal sowing time. At the cotyledon stage the plantings were thinned to 10 plants per pot. PVC rearing cylinders were placed over the plants and one adult *L. rugulipennis* was introduced into each cylinder. In the 1968 experiment the bug was transferred to new plants when damage was apparent on all plants in the cylinder. In the 1969 experiment the bugs were removed from the cotyledon-stage seedlings after 1—2 days, from those with two true leaves after 2—4 days, and from larger plants after 2—10 days, even though some of the plants still appeared undamaged. All the beets had been sown on the same day, and thus each time a transfer was made, development of the plants was farther advanged than at the start of the experiment. For this reason some further thinnings had to be made before the bugs were transferred. In both years ten individual males and ten females were observed to find the number of plants they would injure. The plants were subsequently transplanted to the field in 1968 and to a cold frame in 1969 and examined in the autumn for the number of multiple crowns. The results were subjected to the *t*-test.

Results (Table 15) showed that one adult specimen of *L. rugulipennis* injured an average of 24.2 sugar-beet plants. In 7.4 of these the injury was so serious that they later died. Female bugs did more damage than males; the numbers of both injured and totally destroyed plants were higher after feeding by females. The largest number of deaths occurred at the cotyledon stage. The over-all number of plants injured and killed by the bugs was smaller in 1968 than in 1969.

Of all the plants injured by one male bug, an average of 6.2 plants developed multiple crowns in 1968, while the corresponding figure for the plants injured by one female was 5.7. In the 1969 experiment the damage done by one male bug gave rise to an average of 12.9, that by one female 14.0 beets with multiple crowns.

Supposing that wide spacing were used, in sugar-beet sowing to obtain, for instance, eight seedlings per row metre, it appears that one

Table 15. Average number of sugar-beet seedlings injured and killed by one adult *L. rugulipennis*. Numbers of injured plants also include the dead plants.

Year	Treatment	Seedlings injured at different growth stages: 1st cotyl. stage [1]	2nd cotyl. stage [2]	2-leaf stage [3]	3- to 4-leaf stage [3]	Total	t
1968	Injured by						
	male	9.9	4.9	0.6	0.1	15.5	2.47*
	female	12.5	6.0	1.5	0.3	20.3	
	Killed by						
	male	2.8	0.7	0.0	0.0	3.5	3.93***
	female	7.8	0.5	0.0	0.0	8.3	
1969	Injured by						
	male	16.0	9.1	1.1	0.0	26.2	2.70*
	female	19.6	11.9	3.2	0.0	34.7	
	Killed by						
	male	3.7	1.0	0.2	0.0	4.9	2.56*
	female	10.1	2.4	0.3	0.0	12.8	
1968—1969	Injured by						
	male	13.0	7.0	0.8	0.0	20.8	2.45*
	female	16.0	9.0	2.4	0.1	27.5	
	Killed by						
	male	3.3	0.8	0.1	0.0	4.2	3.76***
	female	9.0	1.4	0.2	0.0	10.6	

[1] no true leaves visible
[2] true leaves beginning to show
[3] next true leaves beginning to show

bug per three row metres would be sufficient to cause damage to all the plants, providing no other food were available.

E. Injury by nymphs

Injury to sugar beet by *L. rugulipennis* nymphs was studied in the summer of 1968. Second-instar nymphs (two per plants), third-, fourth- and fifth-instar nymphs (one per plant) and adults (one male or female per plant) were released on young sugar-beet seedlings growing in multipots. The plants were examined at the same hour daily, and when injury was visible, the respective insect was transferred to another plant. All test plants were of the same age, i.e. in the early cotyledon stage at the start of the experiment. The number of replicates varied from four to ten. Observations were made on the development of the injured and control plants during one month, after which the plants were weighed individually.

In July 1968, injury by *Lygus* nymphs was studied in sugar beets sown in the field at the normal sowing time. First- to fifth-instar nymphs and adult males and females were inserted individually into rearing corks attached to the leaves. The control consisted of corks without insects. The experiment had four replicates and was observed for 21 days. The plants were examined in the same way as in the previous experiment. When injury to a leaf was observed, the rearing cork with the insect was transferred to another leaf. The first- and second-instar nymphs died after only two days in the corks; the third- to fifth-instar nymphs and adults survived over the whole experimental period.

When nymphs fed on the seedlings, the injury produced, whatever their instar, was similar to that caused by adult bugs: destruction of growing points that gave rise to lateral growing points; wilting and malformation of the leaves (cf. p. 24). Some of the injured plants died.

The plants damaged by nymphs weighed less than control plants ($F = 4.57^{*}$). There was no significant difference between the weights of plants damaged by nymphs and those damaged by adults:

	g
Undamaged plants	47.2
Plants damaged by nymphs	33.5
Plants damaged by adults	30.1

In the leaves of large plants comparatively little damage was found. Only one of the treatments with nymphs showed wilting of the leaf part enclosed in the rearing cork; this was due to injury by a third-instar nymph and occurred 7 days after the start of the experiment. Of the treatments with adults only two showed leaf wilting inside the rearing cork; in both cases the damage was due to injury by a female bug 5 days after the start of the experiment. When transferred to a fresh leaf, the same individuals failed to cause any more damage. The control leaves were perfectly healthy.

From these results it can be concluded that *L. rugulipennis* nymphs, when occurring in normal numbers, are incapable of causing any appreciable injury to large sugar-beet plants in mid- or late summer. Since the first nymphs from eggs deposited by overwintered females only hatch in the latter half of June, the damage they do to sugar-beet crops is of no practical significance.

F. Components of injury

As feeding sites, lygus bugs select the plants' meristematic tissue or developing reproductive organs. In young sugar-beet seedlings they feed on different parts of the plants (cf. p. 23), but since injury is restricted to the immediate surroundings of the feeding site, feeding on the growing point or stem is in general more harmful than feeding on the leaves.

In connection with observations on feeding sites and length of the feeding time, *L. rugulipennis* bugs were seen to probe the plant tissue several times with their stylets (cf. p. 23). Similarly, during the feeding process, the bugs partially withdrew and reinserted their stylets, while keeping the tip of the rostrum stationary. Similar probing with the stylets has been observed in *L. lineolaris* P. de B. (Flemion et al. 1954) and in *L. hesperus* Knight (Strong 1970). According to Flemion (1958), the stylets penetrate both inter- and intracellularly without following any particular path.

Various authors have supposed that the saliva of lygus bugs contains toxic substances which are the primary cause of the injury (Smith 1920, Baker et al. 1946, Carter 1952). Most investigations into this matter have dealt with hydrolytic enzymes. The saliva of an adult *L. pratensis* has been found to contain amylases and invertases but no proteases or lipases (Baptist 1941). Amylases have likewise been detected in the salivary glands of *L. rugulipennis* adults, but no proteases or lipases have been found. The salivary glands of the nymphs, on the other hand, contain amylases and proteases (Nuorteva 1954).

The suggestion has also been made that some of the injury done by bugs could be due to growth hormones present in the saliva (Miles 1968). Nuorteva (1956) could detect no auxins in the saliva of *L. rugulipennis*. Investigations have also shown that *L. hesperus* fails to synthesize indoleacetic acid either in its body or during salivation (Strong and Kruitwagen 1968), and there is no evidence to suggest that any hormones are first ingested by the bug and then re-injected into the plant (Strong 1970). The saliva of certain bugs has been found to contain auxin inhibitors or at any rate substances which inhibit plant growth (Nuorteva 1956). Fischer et al. (1946) prevented some economic loss due to *L. oblineatus* Knight (= *L. lineolaris* P. de B.) by dusting bean plants with auxins. This bug causes abscission of buds, flowers and young beans and distortion and dwarfing of small leaflets. However, such damage is not necessarily due to auxin inactivators (cf. Strong 1970).

Some workers (e.g. Taylor 1945) place

special emphasis on mechanical injury. Stephenson (ref. TAYLOR 1945) concluded that discolouring of plant tissues might be due to breakdown of the middle lamellae of the cell walls.

LAUREMA and NUORTEVA (1961) found pectin polygalacturonase (pectinase) in the salivary glands of lygus bugs. According to BROWN (1955), pectolytic enzymes cause the tissue to lose coherence along the line of the middle lamella. He carried out his investigations with the enzyme secreted by the tips of advancing mycelia and attempted to distinguish between the enzymic and toxic effects, but came to the conclusion that the enzyme and the toxin were the same substance. STRONG (1970) suggested that the injury caused by *L. hesperus* is due principally to enzymatic digestion of the plant tissue by polygalacturonase secreted during feeding, although a limited amount of mechanical injury may result as well. The type of damage thus depends on the size of the organ fed upon and the specific site of feeding.

Material and methods

Several experiments were conducted at Tikkurila to study the significance of mechanical injury and the effects of the saliva of *L. rugulipennis*. The experiments were carried out in the greenhouse with young sugar-beet seedlings grown on paperpot trays. The treatments were:

1. Control
2. Piercing of the growing point with an insect pin No. 0, diam. 0.28 mm at 1.5-mm distance from the tip.
3. Piercing of the growing point with a 1-ml hypodermic syringe needle, diam. 0.38 mm at 1.5-mm distance from the tip and withdrawal of fluid.
4. Salivary glands of *L. rugulipennis* applied to the growing point, one pair per plant.
5. Treatments 2 and 4 combined.
6. Pectinase, standardized purum, in 10 % aqueous solution applied to the growing point.
7. Treatments 2 and 6 combined.

The treatments were made at the early cotyledon stage. In Treatment 2 a sterilized insect pin was inserted approximately 1.5 mm into the tissue under a binocular microscope. A parallel experiment was made with a Size 00 pin, diam. 0.22 mm at 1.5-mm distance from the tip. According to STRONG (1970) the stylets of *L. hesperus* can penetrate to a maximum depth of 2 mm. In Treatment 3 the disposable syringe needle was weighed before and after suction. The amounts of fluid withdrawn were so minute that only a very small portion of the needle cavity was filled. In Treatment 4 freshly detached salivary glands were macerated with forceps and placed on the growing point with the help of an insect pin. A further experiment was carried out to investigate the effects of different numbers of salivary glands. One to ten pairs of glands were used in such a way that each different number was applied to two replicate plants. On some plants the glands were applied without scratching the plant surface; on others the surface was lightly scratched with the insect pin. Glands from males and females were investigated separately. For this experiment a total of 188 pairs of glands were needed.

Pectinase in aqueous solution was dripped onto the growing point with a small pipette. The average volume applied was 0.01 ml per plant. Every treatment consisted of ca. 150 plants. The plants were sown in paper pots at the usual sowing time, transplanted to the open field in late June, and harvested in early October.

Results (*Fig. 16, Table 16*)

E f f e c t o f p i e r c i n g. In many pierced plants the puncture was found to have turned black by the following day. In most cases such necrosis was very limited and could not be mistaken for the darkening of the growing point caused by bug damage. In some of the plants, however, the dark spots looked remarkably similar to those caused by bug injury and could not be distinguished from them. In some plants the cotyledons wilted. Later on, malformed leaves and lateral growing points were observed. A number of the injured plants died. The mortality among those pierced with the Size 0

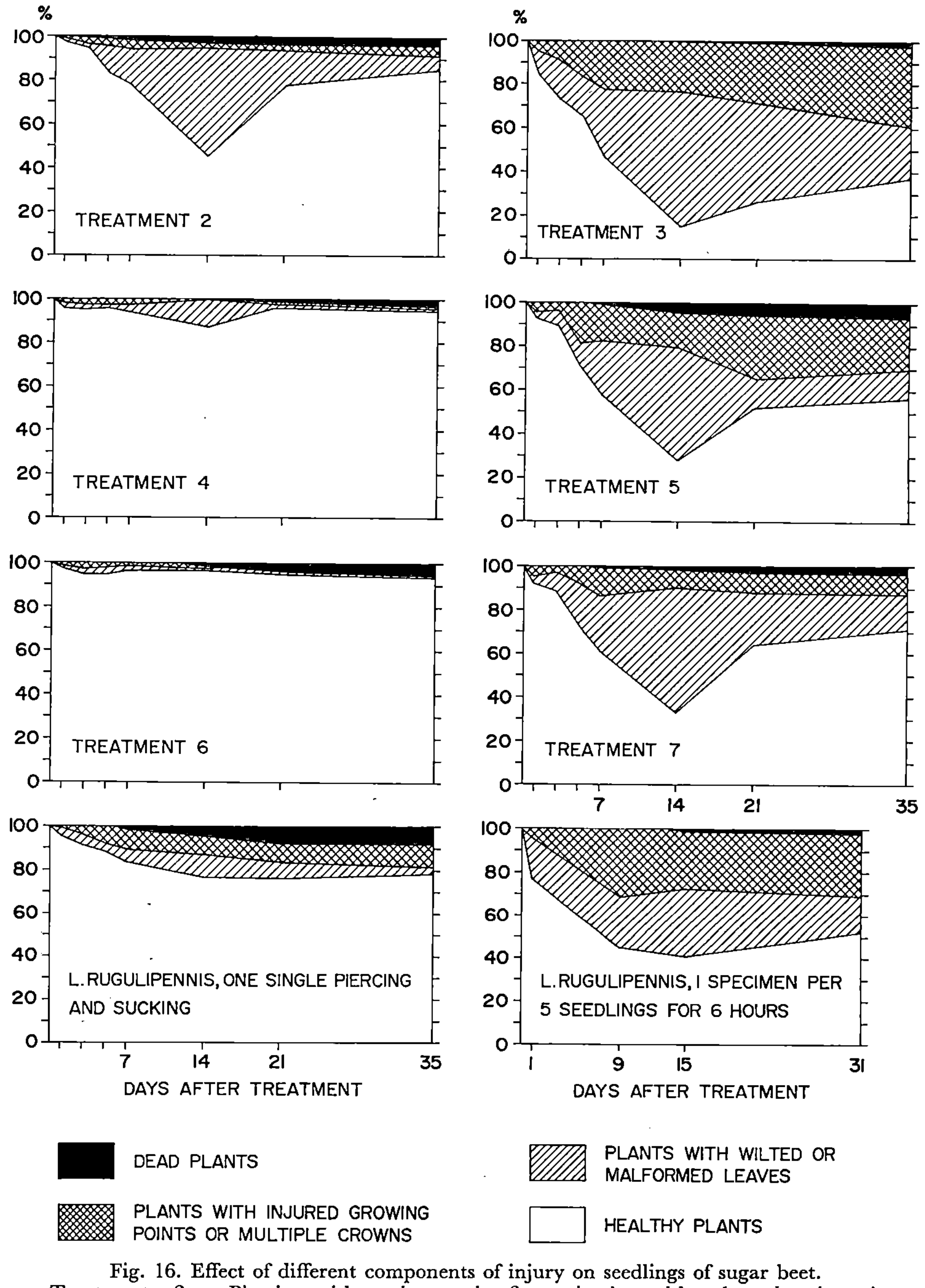


Fig. 16. Effect of different components of injury on seedlings of sugar beet. Treatments: 2 = Piercing with an insect pin, 3 = piercing with a hypodermic syringe needle and suction, 4 = salivary glands of *L. rugulipennis*, 5 = piercing with an insect pin + salivary glands of *L. rugulipennis*, 6 = pectinase, 7 = piercing with an insect pin + pectinase.

pin was slightly higher than among those treated with the Size 00 pin, but otherwise there were no noteworthy differences in the nature on the injury.

Piercing of the growing point with a fine pin thus produced symptoms (Fig. 17) closely resembling those caused by bug injury; this was true for both the early and the late symptoms.

Table 16. Effect of different components of injury on the late development and weight of sugar beets.

Treatment[1]	Multiple crowns %	No. of leaves per beet	Weight of roots		Weight of tops	
			g per beet	Rel.	g per beet	Rel.
1. Untreated	0 a	20.6 a	444.3	100	465.7	100
2. Piercing	19 c	22.2 a	434.3	98	429.5	92
3. Piercing and suction	40 d	24.2 b	425.0	96	439.2	94
4. Salivary glands	6 abc	20.5 a	445.0	100	441.9	95
5. Piercing and salivary glands	38 d	24.8 b	420.2	95	442.6	95
6. Pectinase	3 ab	20.6 a	432.0	97	439.3	94
7. Piercing and pectinase	16 bc	21.6 a	411.3	93	427.2	92
(One piercing per growing point by *L. rugulipennis*	17 bc	21.9 a	455.3	102	456.3	98)
F	15.01***	6.13***	1.03		0.56	
Treatments without piercing (4 and 6)	4.4 } t =	20.5 } t =	438.5 }	t = 99	440.6 } t =	95
Treatments including piercing	28.4 } 4.42***	23.2 } 4.50***	422.7 }	1.46 95	434.6 } 0.32	93

[1] Treatments described in detail on p. 29.

E f f e c t   o f   p i e r c i n g   a n d   s u c t i o n. One day after the piercing-suction treatment the injured plants showed more extensive leaf wilting and growing point damage than those damaged by piercing alone. Numerous plants with multiple growing points developed and the plants looked very similar to those damaged by bugs (Figs. 19 and 20). The leaves were malformed and quite a number of »bushy» plants appeared.

E f f e c t   o f   s a l i v a r y   g l a n d s. Application of the salivary glands on a plant's growing point resulted either in a small dark spot in the area affected or in desiccation of the glands on the plant surface or in darkening of the growing point as in plants damaged by bugs. Some plants, even among those with the largest number of glands, failed to show any symptoms of injury at all. In many, some of the leaves wilted, and some of the injured plants died.

Later some malformation of leaves was observed. A few beets developed lateral growing points. Puncturing with a pin considerably increased the number of plants with injury as well as the proportion of beets with multiple crowns. There were no appreciable differences between the effects of glands of male and female bugs, neither were there differences between the effects of different numbers of glands (Table 17).

E f f e c t   o f   p e c t i n a s e. Pectinase solution applied to the growing point caused occasional darkening of the growing point, leaf wilting and, later, malformation of leaves. Multiple crowns developed in 3 % of the injured plants. Piercing with a pin before the application of pectinase enhanced the injurious effect to a considerable degree (Fig. 16). After

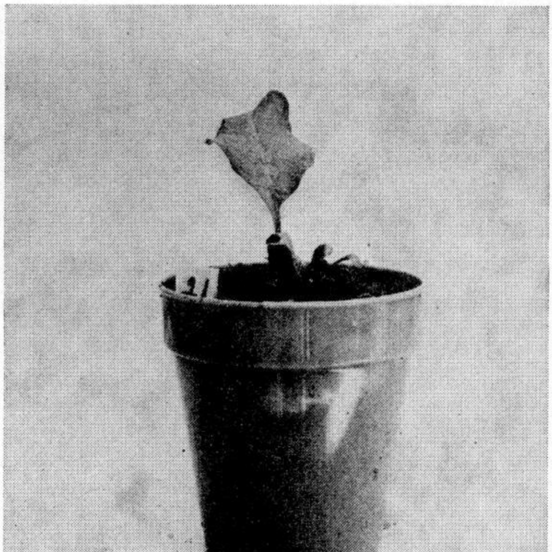
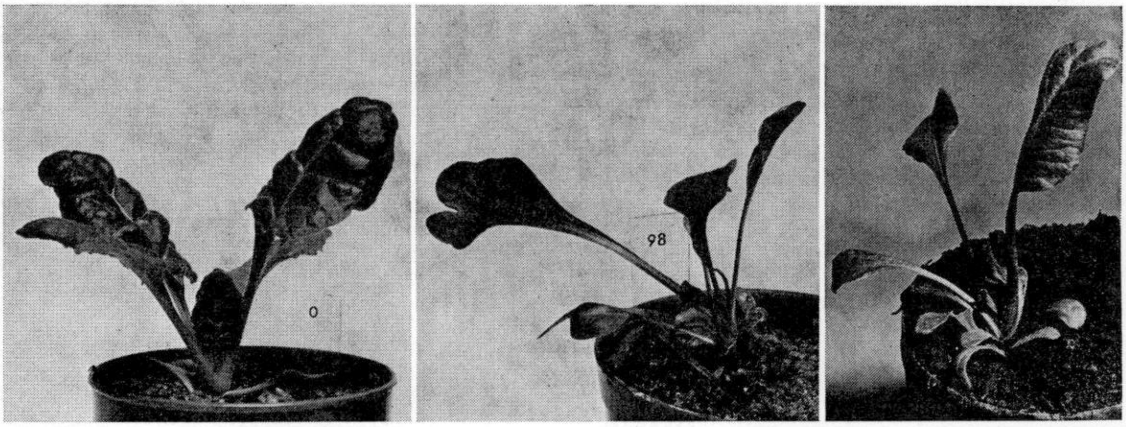


Fig. 17. Sugar beet seedling injured at the cotyledon stage by piercing the growing point with an insect pin. Photo by A. Varis.



Figs. 18, 19 and 20. Untreated sugar beet seedling (left), seedling injured at the cotyledon stage by piercing with a hypodermic syringe needle and suction (centre) and seedling injured by *L. rugulipennis* (right). Photos 18 and 19: Institute of Photography, University of Helsinki, Photo 20: L. Nordlund.

such treatment more plants showed symptoms of damage, the number of those with multiple crowns increased greatly, and some plants died.

Treatments that included mechanical damage seemed slightly to reduce the weight of the beets (Table 16). It was also found that the number of leaves increased as a result of piercing.

Discussion

Lygus injury simulated by inserting a fine pin into the growing point of small sugar-beet seedlings produced plants very similar in appearance to those injured by bugs. A pin prick is not, of course, a perfect imitation of the puncture made by the bug's stylets; a pin

Table 17. Effect of the saliva of *L. rugulipennis* on sugar beet seedlings. Freshly detached salivary glands were macerated with forceps and placed on the growing point with an insect pin.

Treatment	No. of plants	Symptoms of injury in the plants[1]: 1—3 days after treatment: Healthy	χ^2			Growing-point injury	3 weeks after treatment: Healthy	χ^2			Dead	Multiple growing points 7 weeks after treatment
			A	B				A	B			
A. Salivary glands of male	40	11	—	—		20	26	—	—		6	1
B. Salivary glands of female	40	9	0.07	—		19	19	1.83	—		9	2
C. Control	40	38	35.60***	40.44***		1	33	2.32	9.29**		0	2
			χ^2: 1	2	3			χ^2: 1	2	3		
1. Salivary glands, plant surface not scratched	40	16	—	—	—	13	28	—	—	—	3	0
2. Salivary glands, plant surface scratched	40	4	8.07**	—	—	26	17	5.08*	—	—	12	3
3. Control, plant surface not scratched	20	20	17.58***	—	—	0	20	5.74*	—	—	0	0
4. Control, plant surface scratched	20	18	—	33.38***	0.53	1	13	—	1.88	6.23*	0	2
								χ^2				
a. 1—5 pairs of salivary glands per seedling	40	10				23	21	—			7	2
b. 6—10 pairs of salivary glands per seedling	40	10				16	24	0.20			8	1

[1] Treatments also resulted in malformation of leaves. This occurred both in connection with growing-point injury and independently.

is much thicker than a bug's stylet bundle, and it is further obvious that the flexible movement of the stylets cannot be imitated. Yet a very similar kind of injury was obtained with pins of two different sizes. Furthermore, it should be noted that only one puncture was made with the pin, whereas a bug can insert its stylet many times in the course of one feeding. When withdrawal of cell sap was added to the mechanical injury, more widespread leaf wilting occurred and larger numbers of »bushy» plants developed. The resultant injury was very similar to that caused by the bugs. The amounts of fluid withdrawn with the syringe were minute, on the average 0.093 mg (cf. Fig. 13).

The present experiments showed that the saliva, or rather the macerated salivary glands of *L. rugulipennis*, had a mildly injurious effect very closely resembling that obtained by applying pectinase to the growing point. The effects of both salivary glands and pectinase were greatly enchanged when mechanical damage was added, and the injury thus induced was very similar to that caused by the bugs.

Mechanical damage alone produced symptoms of growing-point injury, beets with multiple crowns, and death of plants.

The results show the great importance of mechanical injury. This injury was aggravated by application of pectinase and by removal of cell sap by suction. The treatments seemed to reduce the weight of the beets, and mechanical injury augmented this effect. Mechanical injury combined with other treatments also led to an increase in the number of leaves (Table 16), although their size was smaller.

Feeding by *L. rugulipennis* on sugar-beet seedlings was not found to cause any specific symptoms which could not be produced artificially by mechanical damage to the plants combined with application of pectinase, or by mechanical damage combined with withdrawal of fluid.

VI EFFECT OF INJURY ON LATER DEVELOPMENT AND CHEMICAL COMPOSITION OF SUGAR BEET

A. Experimental arrangements

Material 1

Sugar beets were sown in the field at the normal time. Emerging seedlings were covered individually with rearing cages into which *L. rugulipennis* adults were released at the time when they appeared on the field crops. The first bugs were usually obtained from winter turnip rape or winter rye.

The treatments were:

1. One male *L. rugulipennis* per plant
2. One female *L. rugulipennis* per plant
3. Control plant without lygus bugs

The cultures were inspected daily at the same hour, and the bug was removed from the plant as soon as injury was observed. After this, the plants were inspected several times in the course of the growing season. When there were 5—6 rough leaves, the cage was removed. The beets were harvested in late September or early October. Fresh weights of roots and tops were determined individually and the numbers of beets with multiple crowns noted. Tests with isolated plants were made in 1961, 1963 and 1965—1968. The variety sown in the first 3 years was the diploid Hilleshög, in the other years the polyploid Polykuhn. At the time of harvest, Material 1 consisted of the following numbers of plants annually:

	Injured by males	Injured by females	Healthy	Total
1961	28	27	27	82
1963	24	14	39	77
1965	12	9	16	37
1966	13	13	26	52
1967	14	6	25	45
1968	19	19	25	63
Total	110	88	158	356

Bolting plants were omitted. In this material there was only one such plant.

Material 2

In a field of sugar beet sown at the normal time, young seedlings with signs of growing-point injury were marked with numbered plastic sticks stuck into the ground [1]. Healthy plants were marked as well. The plants were chosen at random but never closer to each other than the normal thinning distance. The stand was thinned in the normal way at the appropriate time. The plants were inspected several times during the growing season, first weekly, then at 3-week intervals in late summer. Plants which showed symptoms of bug injury at a later date were discarded. The beets were harvested in late September or early October. Individual fresh weights of roots and tops were determined and the numbers of individuals with multiple crowns recorded. Bolting plants were omitted. This experiment was conducted in 1966, 1967, 1968 and 1970.

The following additional studies were made: in 1967, 1968 and 1970 the data on bug injury were classified according to the different developmental stages of the plants, those injured at the cotyledon stage, at the 1- to 2-leaf stage and at the 3- to 4-leaf stage were treated separately. At harvest the number of leaves, sucrose, ash and noxious nitrogen were also determined. Invert sugar content was determined in the 1968 and 1970 experiments. In 1970 the experiment was carried out with both genetic monogerm seed (Monohill) and multigerm polyploid seed (Hilleshög Aa Be Ce Poly). In the other years only the polyploid Polykuhn was used.

At harvest, Material 2 consisted of a total of 1529 plants, distributed as follows:

	Injured by bugs	Healthy	Total
1966	184	100	284
1967	182	95	277
1968	171	95	266
1970	468	234	702
Total	1 005	524	1 529

Multifactorial experiment

The layout was as follows:

A. Seed type
1. Monogerm (Monohill)
2. Multigerm, polyploid (Hilleshög Aa Be Ce Poly)

B. Time of injury
1. Healthy
2. Injured at the cotyledon stage
3. Injured at 1- to 2-leaf stage
4. Injured at 3- to 4-leaf stage

C. Time of harvest
1. Late August — early September
2. Late September — early October

Each type of seed was sown on the field in a plot, 50 × 13 m. Individual seedlings injured at different growth stages as well as healthy seedlings were marked at random in the same way as in Material 2. Also other arrangements during the growing season were the same as used in connection with Material 2. The average number of beets per treatment was 90. This experiment was conducted in 1970 and 1971, in both years on the same field.

The experiment was harvested in five replicates. Individual fresh weights of roots and tops were determined and numbers of beets with multiple crowns were counted. Samples of ten beets were taken at random from each replicate of each treatment. The samples were analysed for the following characteristics: number of leaves, contents of sucrose, ash, noxious nitrogen and, in 1970, invert sugar in roots. The

[1] In this connection observations were made on other insects occurring in the sugar-beet field from the time of emergence the seedlings to the time when the plants were marked. In addition to *L. rugulipennis*, only *Bembidion* spp., *Chaetocnema* spp. and *Phyllotreta* spp. were found in notable numbers. Experiments were arranged to establish whether any of these species caused damage to sugar beets that might be mistaken for that of *L. rugulipennis*.

It was found that *Bembidion* and *Phyllotreta* spp. caused no damage of any kind. *Chaetocnema* adults perforated the leaves and killed the seedlings. When they attacked young leaves just emerging from the growing point, the injury was in general distinguishable.

The effect of low temperature was also studied. Temperatures of 0° to — 7 °C brought about drooping, spottiness and death of the plants. In a few cases the symptoms resembled those caused by bugs, but they were accompanied by other, very obvious and much more conspicuous symptoms of frost damage.

numbers of leaves and multiple-crowned beets were also recorded in late July or early August, and thus factor C in the experimental layout given above consists of three different observation times as far as these data are concerned. In the following tables the seed types are indicated as Mono and Poly and the times of inspection and harvest as early August, early September and early October.

B. Occurrence of multiple crowns

Plants with multiple crowns or tops are defined in this study as individuals with more than one leaf rosette. Thus even beets carrying one small lateral rosette in addition to a normal, well-developed top were placed in this group; this will explain the large numbers of multiple-crowned beets found in this study.

Decoux and Roland (1935) and Munerati (1949) ascribe the occurrence of multiple crowns to genetic factors. According to Lüdecke and Winner (1959) damage to the growing point by frost may induce growth of multiple leaf rosettes. Certain growth-regulating herbicides have been found to have a similar effect (Čača 1967). According to Schmidt (1937), the main reason for the appearance of multiple crowns is destruction of the growing point by insects.

Bug injury increased the numbers of multiple-crowned beets very significantly (Table 18). Of the 1 203 injured plants examined at harvest, 629 (52 %) had multiple crowns, while the figure for the 682 control plants was only 48 (7 %). Thus the number of multiple-crowned individuals among the injured plants was more than seven times that among the control plants. These proportions varied from year to year:

Beets with multiple crowns %

	Material 1		Material 2	
	Healthy	Injured by bugs	Healthy	Injured by bugs
1961	26	36		
1963	23	32		
1965	19	71		
1966	0	42	3	41
1967	4	20	4	43
1968	8	45	1	49
1970			6	63

In this table attention is drawn to the relatively high proportions of multiple-crowned beets among the healthy plants in 1961, 1963 and 1965. This may partly have been due to the beet variety grown in those years, Hilleshög, whereas in the later years the variety was Polykuhn. The tendency of the diploid Hilleshög beet to produce multiple crowns was also observed in laboratory tests.

Multiple crowns occurred regardless of whether the injury was inflicted by male or female bugs (Table 19). Their number increased very significantly as a result of feeding by either sex.

Plants injured at the cotyledon stage developed slightly smaller numbers of beets with

Table 18. Frequency of multiple crowns in healthy and injured sugar beets.

Treatment	No. of beets	Beets with multiple crowns No.	%	χ^2
Material 1				
Years 1961, 1963, 1965 (Hilleshög)				
Healthy	82	19	23	—
Injured	114	47	41	6.18*
Years 1966, 1967, 1968 (Polykuhn)				
Healthy	76	3	4	—
Injured	84	32	38	25.26***
Material 2				
Healthy	524	26	5	—
Injured	1 005	550	55	363.27***

Table 19. Frequency of multiple crowns in sugar beets injured by male and female bugs.

Treatment	No. of beets	Beets with multiple crowns No.	%	χ^2 Healthy	Injured by males
Healthy	158	22	14	—	—
Injured by males	110	42	38	19.68***	—
Injured by females	88	37	42	23.00***	0.16

Table 20. Frequency of multiple crowns in sugar beets injured at different growth stages.

Treatment	No. of beets	Beets with multiple crowns No.	%	χ^2 Healthy	Injured at cotyledon stage	Injured at 1- to 2-leaf stage
Healthy	424	22	5	—	—	—
Injured at cotyledon stage	215	114	53	195.84***	—	—
Injured at 1- to 2-leaf stage	393	219	56	250.46***	0.41	—
Injured at 3- to 4-leaf stage	213	139	65	271.87***	6.13*	5.19*

multiple crowns than those injured later (Tables 20 and 21).

The plants from different seed types did not differ significantly from each other in the frequency of multiple crowns (Table 21).

Table 21. Frequency of multiple crowns (%) in sugar beets from different seed types injured at different growth stages.

Treatment	Mono	Poly	Mean
Healthy	3	4	3 a
Injured at cotyledon stage	62	57	59 b
Injured at 1- to 2-leaf stage	75	79	77 c
Injured at 3- to 4-leaf stage	70	79	74 c
Mean	52	55	53

	F
Seed type	0.26
Time of injury	228.77***
Seed type × time of injury	1.69

Table 22. Frequency of multiple crowns (%) at different times of inspection in sugar beets injured at different growth stages.

Treatment	Early August	Early September	Early October
Healthy	3	4	3
Injured at cotyledon stage	65	59	54
Injured at 1- to 2-leaf stage	80	77	74
Injured at 3- to 4-leaf stage	76	75	73
Mean	56	53	51

	F
Time of inspection	1.45
Time of injury × time of inspection	0.42

Different times of inspection (Table 22) did not reveal significant differences in the frequency of multiple crowns.

The interaction seed type × time of inspection was not significant (F = 0.36), neither was the 3-factor interaction seed type × time of injury × time of inspection (F = 1.02). The results of the two years were similar.

C. Number of leaves

Injured plants had larger numbers of leaves than healthy plants (Table 23).

Injured plants with single crowns had very significantly fewer leaves than healthy plants or injured plants with multiple crowns (Table 24). Injured plants with multiple crowns had larger numbers of leaves than healthy plants.

On the other hand, the number of leaves in a single crown was higher in healthy (23.5 leaves per crown) than in injured single-crowned

Table 23. Number of leaves per beet in healthy and injured sugar beets.

Year	Healthy	Injured	Difference	F
1967	22.5	24.2	+1.7	1.84
1968	32.9	36.7	+3.8	3.30
1970	21.5	27.0	+5.5	57.07***
Weighted mean	25.1	28.8	+3.7	41.86***

Table 24. Number of leaves per beet in injured sugar beets with single and multiple crowns.

Treatment	1967	1968	1970	Weighted mean
Healthy	22.5 b	32.9 b	21.5 b	25.1 b
Injured single-crowned	18.2 a	27.1 a	18.4 a	20.7 a
Injured multiple-crowned	31.4 c	44.5 c	32.2 c	35.3 c
F	55.19***	31.69***	168.10***	167.73***

Table 25. Number of leaves per beet in sugar beets injured at different growth stages.

Treatment	1967	1968	1970	Weighted mean
Healthy	22.5 a	32.9 a	21.5 a	25.1 a
Injured at cotyledon stage	21.8 a	41.1 b	23.0 a	26.6 a
Injured at 1- to 2-leaf stage	23.6 a	35.0 ab	28.9 b	30.2 b
Injured at 3- to 4-leaf stage	31.2 b	32.8 ab	28.4 b	29.4 b
F	3.86**	3.45*	29.06***	17.76***

(20.7 leaves per crown) or in injured multiple-crowned (14.4 leaves per crown) beets.

Similar results were obtained every year but the actual numbers of leaves showed great variation from year to year.

More leaves developed on plants injured at a later stage than on those injured at the cotyledon stage or not at all (Tables 25 and 26).

The effect of the time of injury was the same, irrespective of type of seed. The number of leaves in plants grown from the two types of seed was almost the same.

Between the different times of inspection the numbers of leaves increased considerably both in healthy and injured beets (Table 27).

The interaction seed type × time of inspection was not significant (F = 0.07), neither was the 3-factor interaction seed type × time of injury × time of inspection (F = 0.06). The results of the two years were similar.

D. Weight of roots

In both Material 1 and Material 2 the root weight was very significantly lower in sugar beets injured by bugs than in uninjured beets (Table 28). With the weight of healthy roots as 100, the relative weight of the roots of injured plants was 66 in Material 1 and 76 in Material 2.

Table 26 Number of leaves per beet in sugar beets from different seed types injured at different growth stages.

Treatment	Mono	Poly	Mean
Healthy	19.2	20.0	19.6 a
Injured at cotyledon stage	21.1	22.0	21.6 a
Injured at 1- to 2-leaf stage	28.8	27.2	28.0 b
Injured at 3- to 4-leaf stage	30.3	31.2	30.8 b
Mean	24.9	25.1	25.0

	F
Seed type	0.16
Time of injury	17.81***
Seed type × time of injury	0.26

Table 27. Number of leaves per beet at different times of inspection in sugar beets injured at different growth stages.

Treatment	Early August	Early September	Early October
Healthy	16.4	20.1	22.4
Injured at cotyledon stage	19.5	21.5	23.8
Injured at 1- to 2-leaf stage	23.8	29.1	31.1
Injured at 3- to 4-leaf stage	26.1	32.5	33.7
Mean	21.4 a	25.8 b	27.7 b

	F
Time of inspection	8.96**
Time of injury × time of inspection	0.23

Similar differences were observed every year. In Material 1 the difference was significant in 4 years out of 6, in Material 2 it was very significant in all 4 years of the study.

Table 28. Root weight of healthy and injured sugar beets.

Year	Healthy g	Injured g	Injured Relative weight Healthy = 100	F
Material 1.				
1961	446.1	304.2	68	6.50*
1963	807.1	490.7	61	13.82***
1965	739.1	493.0	67	8.20**
1966	684.2	400.2	58	7.52**
1967	271.4	190.4	70	2.64
1968	430.9	407.9	95	0.11
Weighted mean	574.0	381.0	66	30.71***
Material 2.				
1966	400.3	334.6	84	8.90**
1967	486.1	372.1	76	12.44***
1968	488.7	365.1	75	14.15***
1970	603.7	447.8	74	166.36***
Weighted mean	522.7	399.3	76	202.72***

Table 29. Root weight of sugar beets injured by male and female bugs.

Treatment	g	Rel.
Healthy	574.0 b	100
Injured by males	407.6 a	71
Injured by females	347.8 a	61
F	16.20***	

Injury by both male and female bugs led to a highly significant reduction in root weight (Table 29). The average root weight was slightly less in plants injured by females than in those injured by males, but the difference was not significant.

Roots of both single- and multiple-crowned injured beets were smaller than those of healthy beets (Table 30). The difference was highly significant in both materials. Injured beets with multiple crowns were larger than those with single crowns; this difference was significant in Material 2.

Multiple crowns also occurred in some of the uninjured beets. In Material 1 the average weight of the root was greater in such plants than in healthy plants with single crowns; in Material 2 there was no significant difference. Results varied in the different years.

The earlier the growth stage at which the plant was injured, the lower was the root weight (Tables 31 and 32). This was observed in all experimental years.

Weights of roots from different seed types did not differ from each other significantly (Table 32). The effect of the time of injury was very clear in both varieties.

Root weights of both healthy and injured plants increased very markedly in the period between the two harvests, from early September to early October (Table 33). In Finnish conditions sugar beet attains its greatest weight

Table 30. Root weight of injured sugar beets with single and multiple crowns.

Treatment	1961 g	1961 Rel.	1963 g	1963 Rel.	1965 g	1965 Rel.	1966 g	1966 Rel.	1967 g	1967 Rel.	1968 g	1968 Rel.	Weighted mean g	Weighted mean Rel.
Material 1														
Healthy	446.1 b	100	807.1 b	100	739.1 b	100	684.2 b	100	271.4	100	430.9	100	574.0 b	100
Injured single-crowned	284.1 a	64	408.1 a	51	574.5 ab	78	351.5 a	51	194.6	72	461.6	107	353.6 a	62
Injured multiple-crowned	339.2 ab	76	669.8 ab	83	460.3 a	62	466.6 ab	68	173.5	64	341.6	79	422.3 a	74
F	3.58*		9.31***		4.50 *		4.03*		1.32		1.02		17.31***	
Material 2					1966		1967		1968		1970			
Healthy					400.3 b	100	486.1 b	100	488.7 b	100	603.7 b	100	522.7 c	100
Injured single-crowned					314.4 a	78	348.6 a	72	362.8 a	74	454.7 a	75	383.6 a	73
Injured multiple-crowned					362.0 ab	90	399.6 a	82	367.0 a	75	443.7 a	74	412.3 b	79
F					6.11**		7.14***		7.06***		55.54***		103.74***	

Table 31. Root weight of sugar beets injured at different growth stages.

Treatment	1967 g	1967 Rel.	1968 g	1968 Rel.	1970 g	1970 Rel.	Weighted mean g	Weighted mean Rel.
Healthy	486.1 b	100	488.7 b	100	603.7 d	100	551.6 d	100
Injured at cotyledon stage	324.4 a	67	348.3 a	71	328.8 a	54	331.5 a	60
Injured at 1- to 2-leaf stage ..	394.1 ab	81	369.9 a	76	436.8 b	72	410.7 b	74
Injured at 3- to 4-leaf stage ..	445.6 b	92	399.1 ab	82	519.7 c	86	502.6 c	91
F	6.37***		4.82**		80.60***		88.43***	

Table 32. Root weight, in g, of sugar beets from different seed types injured at different growth stages.

Treatment	Mono	Poly	Mean g	Mean Rel.
Healthy	488.7	565.2	527.0 d	100
Injured at cotyledon stage	208.7	268.3	238.5 a	45
Injured at 1- to 2-leaf stage	343.6	393.1	368.3 b	70
Injured at 3- to 4-leaf stage	442.0	483.6	462.8 c	88
Mean	370.8	427.5	399.2	

	F
Seed type	2.01
Time of injury	51.37***
Seed type × time of injury ..	0.18

Table 33. Root weight, in g, at different times of harvest of sugar beets injured at different growth stages.

Treatment	Early September	Early October	Difference
Healthy	411.4	642.5	+ 231.1
Injured at cotyledon stage	157.1	319.9	+ 162.8
Injured at 1- to 2-leaf stage	282.2	454.4	+ 172.2
Injured at 3- to 4-leaf stage	362.4	563.2	+ 200.8
Mean	303.3 a	495.0 b	+ 191.7

	F
Time of harvest	120.09***
Time of injury × time of harvest	0.78

by mid-October (MANTERE 1954) or in the latter half of October (KAIVOLA 1955).

The interaction seed type × time of injury × time of harvest was not significant (F = 0.00). The results of the two years were similar.

E. Weight of tops

In both Material 1 and Material 2 the weight of the tops was very significantly lower in the injured than in healthy plants (Table 34). The decrease in top weight following injury was smaller than the decrease in root weight. With healthy beets as 100, the relative weight of the tops of the injured beets was 80 in Material 1 and 85 in Material 2. Similar differences were observed in all experimental years. In Material 1 the difference was not significant in any year, but in Material 2 it was significant every year.

Injury by both male and female bugs reduced the weight of the tops (Table 35). Tops damaged by females weighed slightly less than those damaged by males, but the difference was not significant.

Table 34. Top weight of healthy and injured sugar beets.

Year	Healthy g	Injured g	Injured Relative weight Healthy = 100	F
Material 1				
1961..........	567.5	450.5	79	3.75
1963..........	901.1	707.7	78	2.78
1965..........	1 032.3	928.5	90	0.70
1966..........	664.2	492.8	74	2.88
1967..........	573.0	453.9	79	1.59
1968..........	528.1	498.3	94	0.16
Weighted mean	707.3	565.4	80	11.11***
Material 2				
1966..........	454.3	401.6	88	4.56*
1967..........	752.6	626.5	83	9.24**
1968..........	579.3	470.4	81	9.86**
1970..........	609.1	522.9	86	27.84***
Weighted mean	600.2	510.5	85	50.56***

Table 35. Top weight of sugar beets injured by male and female bugs.

Treatment	g	Rel.
Healthy	707.3 b	100
Injured by males	587.3 a	83
Injured by females	538.0 a	76
F	5.92**	

The tops of injured single-crowned beets weighed considerably less than those of healthy beets in both materials (Table 36). They also weighed less than the tops of injured multiple-crowned beets. In both materials the tops of injured multiple-crowned beets were lighter than those of healthy beets; this difference, although not significant in Material 1, was significant in Material 2. The reduction in the weight of the tops of injured multiple-crowned beets as compared with those of the healthy beets, was proportionally less marked than the reduction in root weight.

The earlier the stage at which the plants were injured the lower was the top weight (Tables 37 and 38). The tendency was the same in all years and in plants grown from both types of seed.

Between the two times of harvest there was very little increase in the weight of the tops. The average increment was not more than 8 % (Table 39). Root weight increased by 63 % during the same period (cf. Table 33). In Finland the weight of sugar-beet tops reaches its maximum by mid- or late September (Mantere 1954, Kaivola 1955). The proportional increase was larger in damaged than in healthy plants (F = 4.05*). The interaction seed type × time of injury × time of harvest was not significant (F = 0.08), neither was the effect of the years.

The single leaf weight (top weight per number of leaves) was appreciably lower in the injured beet plants than in the healthy ones (Table 40). No significant differences were found between plants injured at different developmental stages. The effect of injury showed the same tendency in plants grown from both seed types.

Table 36. Top weight of injured sugar beets with single and multiple crowns.

Treatment	1961		1963		1965		1966		1967		1968		Weighted mean	
	g	Rel.	g	Rel.	g	Rel.	g	Rel.	g	Rel.	g	Rel.	g	Rel.
Material 1														
Healthy	567.5	100	901.1 b	100	1 032.3	100	664.2	100	573.0	100	528.1	100	707.3 b	100
Injured single-crowned	419.0	74	573.3 a	64	994.0	96	419.9	63	450.9	79	516.6	98	503.3 a	71
Injured multiple-crowned	505.5	89	982.3 b	109	898.9	87	592.4	89	465.8	81	475.8	90	656.3 b	93
F	2.61		4.13**		0.47		2.08		0.78		0.18		9.28***	
Material 2					1966		1967		1968		1970			
Healthy					454.3 b	100	752.6 b	100	579.3 b	100	609.1 c	100	600.2 c	100
Injured single-crowned					379.5 a	84	595.6 a	79	425.0 a	73	489.6 a	80	475.9 a	79
Injured multiple-crowned					431.6 ab	95	662.6 ab	88	507.6 ab	88	542.6 b	89	539.2 b	90
F					3.85*		5.58*		6.98***		16.44***		32.53***	

Table 37. Top weight of sugar beets injured at different growth stages.

Treatment	1967		1968		1970		Weighted mean	
	g	Rel.	g	Rel.	g	Rel.	g	Rel.
Healthy	752.6 bc	100	579.3 b	100	609.1 c	100	634.6 d	100
Injured at cotyledon stage	534.7 a	71	454.7 a	78	440.3 a	72	480.5 a	76
Injured at 1- to 2-leaf stage	654.1 b	87	476.2 a	82	537.4 b	88	538.0 b	85
Injured at 3- to 4-leaf stage	793.2 c	105	483.9 ab	84	544.4 b	89	584.1 c	92
F	9.00***		3.34*		13.04***		18.52***	

There was no significant change in average leaf weight in the period between the two harvests, either in healthy or in injured plants (Table 41). The interaction seed type × time of injury × time of harvest was not significant (F = 0.21), neither was the effect of the years.

F. Top-root ratio

The top-root ratio was higher in injured sugar beets than in healthy beets (cf. Tables 28 and 34). In Material 1 the average top-root ratio was 1.2 in healthy beets and 1.5 in injured beets. The corresponding figures for Material 2 were 1.1 and 1.3.

The top-root ratio in the injured beets was higher in those with multiple crowns than in those with single crowns, but even in the latter higher than in healthy plants:

	Material 1	Material 2
Healthy plants	1.2	1.1
Injured plants with single crowns	1.4	1.2
Injured plants with multiple crowns	1.6	1.3

The earlier the growth stage at which the plant was injured the higher was the top-root ratio; in plants damaged at the 3- to 4-leaf stage it was almost the same as in the undamaged plants:

Healthy plants	1.1
Plants injured at the cotyledon stage	1.4
Plants injured at the 1- to 2-leaf stage	1.3
Plants injured at the 3- to 4-leaf stage	1.2

Table 42 shows that the same result was obtained from the multifactorial experiment.

The plants from different seed types did not differ significantly from each other in top-root ratio (Table 42). The interaction seed type × time of injury was not significant.

Between the two times of harvest the top-root ratio was found to decrease sharply (Table 43), in 1971 this ratio decreased less, from 1.2 to 0.8, between two harvests than in 1970, when it decreased from 2.0 to 1.1, respectively. The interaction seed type × time of harvest was not significant (F = 2.11), neither was the 3-factor interaction seed type × time of injury × time of harvest (F = 0.14).

Table 38. Top weight, in g, of sugar beets from different seed types injured at different growth stages.

Treatment	Mono	Poly	Mean g	Mean Rel.
Healthy	538.4	526.3	532.4 c	100
Injured at cotyledon stage	323.7	333.6	328.6 a	62
Injured at 1- to 2-leaf stage	458.8	434.9	446.8 b	84
Injured at 3- to 4-leaf stage	517.3	470.3	493.8 c	93
Mean	459.5	441.3	450.4	

	F
Seed type	0.09
Time of injury	40.18***
Seed type × time of injury	0.72

Table 39. Top weight, in g, at different times of harvest of sugar beets injured at different growth stages.

Treatment	Early September	Early October	Difference
Healthy	531.6	533.2	+ 1.6
Injured at cotyledon stage	298.9	358.3	+ 59.4
Injured at 1- to 2-leaf stage	434.8	458.9	+ 24.1
Injured at 3- to 4-leaf stage	471.3	516.2	+ 44.9
Mean	434.1 a	466.6 b	+ 32.5

	F
Time of harvest	5.43*
Time of injury × time of harvest	0.84

Table 40. Leaf weight, in g, of sugar beets from different seed types injured at different growth stages.

Treatment	Mono	Poly	Mean g	Mean Rel.
Healthy	26.2	24.8	25.5 b	100
Injured at cotyledon stage	15.0	14.8	14.9 a	58
Injured at 1- to 2-leaf stage	16.1	15.3	15.7 a	62
Injured at 3- to 4-leaf stage	17.2	15.1	16.1 a	63
Mean	18.6	17.5	18.0	

	F
Seed type	0.27
Time of injury	63.55***
Seed type × time of injury	0.38

Table 41. Leaf weight, in g, at different times of harvest of sugar beets injured at different growth stages.

Treatment	Early September	Early October	Difference
Healthy	26.6	24.5	— 2.1
Injured at cotyledon stage	14.4	15.4	+ 1.0
Injured at 1- to 2-leaf stage	15.6	15.7	+ 0.1
Injured at 3- to 4-leaf stage	16.0	16.3	+ 0.3
Mean	18.1	18.0	— 0.1

	F
Time of harvest	0.07
Time of injury × time of harvest	1.11

Table 42. Top-root ratio of sugar beets from different seed types injured at different growth stages.

Treatment	Mono	Poly	Mean
Healthy	1.2	1.0	1.1 a
Injured at cotyledon stage	1.7	1.4	1.5 b
Injured at 1- to 2-leaf stage	1.4	1.2	1.3 ab
Injured at 3- to 4-leaf stage	1.3	1.0	1.2 a
Mean	1.4	1.2	1.3

	F
Seed type	6.30
Time of injury	6.42**
Seed type × time of injury	0.16

Table 43. Top-root ratio at different times of harvest of sugar beets injured at different growth stages.

Treatment	Early September	Early October	Difference
Healthy	1.4	0.8	— 0.6
Injured at cotyledon stage	2.0	1.1	— 0.9
Injured at 1- to 2-leaf stage	1.6	1.0	— 0.6
Injured at 3- to 4-leaf stage	1.4	0.9	— 0.5
Mean	1.6 b	1.0 a	— 0.6

	F
Time of harvest	63.24***
Time of injury × time of harvest	1.21

G. Chemical composition of roots

The following aspects of the chemical composition of sugar beets are discussed here: sucrose content, ash content, noxious nitrogen content and invert sugar content.

In general, the sugar content of beets increases steadily throughout the growing period, but the rise is most marked in July—August (Kaivola 1955). The sugar content depends greatly on weather conditions. Of the sugars contained in beet, cane sugar or sucrose is the most important component.

Ash content represents the amount of soluble minerals, especially potassium and sodium salts, expressed in milli-equivalents. These salts are not removed from the solution by traditional factory processing. A high salt content causes a rise in the amount of sugar bound to the molasses and thus reduces the actual sugar yield. The ash content depends very much on the conditions during growth, especially on the availability of nutrients in the soil (Lüdecke 1961). In Finland the ash content of sugar beets is almost invariably high. This is due to the short growing period and the ample application of fertilizers. Added nitrogen and potassium tend to raise the ash content of the beets (Brummer 1959). The decrease in the ash content is rapid in summer, slow in autumn (Lüdecke 1961).

The term noxious nitrogen is used for certain nitrogen compounds (mainly amino acids) which are not eliminated in factory processing but remain in solution, decrease the proportion of crystallizable sugar and thus reduce the sugar yield. In Finland, owing to the short growing period and ample fertilizer application, noxious nitrogen is nearly always exceptionally high in sugar beets (Brummer 1959).

With heavy, unbalanced application of nitrogen fertilizers the content of noxious nitrogen increases. It also increases when protein synthesis is inhibited by weather factors (Lüdecke 1961). In late summer the content of noxious nitrogen often varies considerably according to the weather and resumed assimilation.

Invertase converts sucrose into reducing sugars, a mixture of glucose and fructose, also called invert sugar. Since invertase has been detected in the saliva of adults of the *L. pratensis* (Baptist 1941), determinations of the invert sugar content of beets damaged by *L. rugulipennis* and undamaged beets were considered appropriate in this study. Invert sugar does not crystallize and is normally destroyed in factory processing. In sugar beets the content of invert sugar is very low (Roemer 1927).

For beets injured by *L. rugulipennis* (Table 44), sucrose content was 0.57 percentage units lower and ash content 0.51 milli-equivalents higher on the average than for healthy beets. The noxious nitrogen content of the injured beets was lower than that of healthy beets. In invert sugar content there were no significant differences. In the experimental material of 1967 the ash content was higher and the noxious nitrogen content lower than in the following years.

Plants injured by male or female bugs did not differ from each other significantly in any of the characteristics investigated (Table 45).

In both materials the injured multiple-crowned beets had a slightly higher sucrose content and a lower ash content than the injured single-crowned beets (Table 46). However, the differences were not significant. In noxious nitrogen and invert sugar there was no clear tendency.

Plants injured at the cotyledon stage had the

Table 44. Chemical composition of roots of healthy and injured sugar beets.

Material and year	Sucrose %		Ash meq/100 g		Noxious nitrogen mg/100 g		Invert sugar %	
	Healthy	Injured	Healthy	Injured	Healthy	Injured	Healthy	Injured
1, 1967	14.90	14.82	8.30	8.82	52.0	47.6	—	—
1, 1968	14.60	13.74	7.27	8.27	79.0	76.0	0.075	0.065
2, 1967	14.80	14.62	9.42	9.34	51.5	50.9	—	—
2, 1968	15.01	14.34	7.46	7.27	81.8	77.0	0.088	0.047
2, 1970	14.50	13.85	6.56	7.36	70.2	60.2	0.088	0.080
Weighted mean	14.68 b	14.11 a	7.27 a	7.78 b	69.7 b	62.9 a	0.069	0.056
F	10.24**		8.69**		17.56***		3.77	

Table 45. Chemical composition of roots of sugar beets injured by male and female bugs.

Treatment	Sucrose %			Ash meq/100 g			Noxious nitrogen mg/100 g			Invert sugar %
	1967	1968	Mean	1967	1968	Mean	1967	1968	Mean	1968
Healthy	14.90	14.60	14.75 b	8.30	7.27	7.78	52.0	79.0	65.5	0.075
Injured by males	15.20	13.62	14.41 a	8.70	8.91	8.80	48.5	77.0	62.8	0.075
Injured by females	14.45	13.85	14.15 a	8.95	7.62	8.28	46.8	75.0	60.9	0.055
F			8.08*			4.81			1.15	1.13

Table 46. Chemical composition of roots of injured sugar beets with single and multiple crowns, 1968.

Treatment	Sucrose %			Ash meq/100 g			Noxious nitrogen mg/100 g			Invert sugar %		
	Mat. 1	Mat. 2	Mean	Mat. 1	Mat. 2	Mean	Mat. 1	Mat. 2	Mean	Mat. 1	Mat. 2	Mean
Healthy	14.60	15.01	14.80	7.27	7.46	7.36	79.0	81.8	80.4	0.075	0.088	0.082
Injured single crowned	13.65	14.24	13.94	8.48	7.33	7.90	74.0	78.2	76.1	0.055	0.063	0.059
Injured multiple crowned	13.82	14.42	14.12	8.05	7.24	7.64	78.0	75.8	76.9	0.075	0.032	0.054
F			5.49			0.75			1.00			1.46

Table 47. Chemical composition of roots of sugar beets injured at different growth stages.

Treatment	Sucrose %			Ash meq/100 g			Noxious nitrogen mg/100 g			Invert sugar %		
	1968	1970	Mean	1968	1970	Mean	1968	1970	Mean	1968	1970	Mean
Healthy	15.01	14.50	14.76 c	7.46	6.56	7.01	81.8	70.2	76.0 b	0.088	0.088	0.088
Injured at cotyledon stage	13.93	13.57	13.75 a	7.46	7.16	7.31	75.4	57.1	66.2 a	0.046	0.080	0.063
Injured later	14.56	13.98	14.27 b	7.12	7.46	7.29	81.5	61.7	71.6 b	0.059	0.080	0.070
F			10.64**			1.11			7.93**			1.67

Table 48. Chemical composition of roots of sugar beets from different seed types injured at different growth stages.

Treatment	Sucrose %			Ash meq/100 g			Noxious nitrogen mg/100 g			Invert sugar %		
	Mono	Poly	Mean	Mono	Poly	Mean	Mono	Poly	Mean	Mono	Poly	Mean
Healthy	14.01	13.95	13.98	7.61	7.69	7.65	54.5	60.3	57.4 b	0.099	0.093	0.096
Injured at cotyledon stage	13.67	13.40	13.54	7.45	8.05	7.75	47.9	50.7	49.3 a	0.094	0.104	0.099
Injured at 1- to 2-leaf stage	13.89	13.85	13.87	7.55	8.26	7.90	47.9	53.0	50.4 a	0.103	0.089	0.096
Injured at 3- to 4-leaf stage	14.00	14.01	14.01	7.99	8.20	8.09	49.9	56.9	53.4 ab	0.086	0.080	0.083
Mean	13.89	13.80	13.85	7.65	8.05	7.85	50.0	55.2	52.6	0.096	0.092	0.094
			F			F		F				F
Seed type			0.04			1.47		14.37				0.68
Time of injury			1.38			1.47		7.14**				2.45
Seed type × time of injury			0.11			0.90		0.42				1.22

Table 49. Chemical composition at different times of harvest of roots of sugar beets injured at different growth stages.

Treatment	Sucrose %			Ash meq/100 g			Noxious nitrogen mg/100 g			Invert sugar %		
	Early Sept.	Early Oct.	Difference	Early Sept.	Early Oct.	Difference	Early Sept.	Early Oct.	Difference	Early Sept.	Early Oct.	Difference
Healthy	13.11	14.85	+1.74	8.41	6.88	—1.53	59.0	55.7	—3.3	0.104	0.088	—0.016
Injured at cotyledon stage	12.62	14.45	+1.83	8.26	7.24	—1.02	50.1	48.4	—1.7	0.118	0.080	—0.038
Injured at 1- to 2-leaf stage	13.07	14.67	+1.60	8.49	7.31	—1.18	49.9	50.9	+1.0	0.115	0.077	—0.038
Injured at 3- to 4-leaf stage	13.43	14.58	+1.15	8.54	7.65	—0.89	54.4	52.5	—1.9	0.083	0.083	±0
Mean	13.06 a	14.64 b	+1.58	8.42 b	7.27 a	—1.15	53.4	51.9	—1.5	0.105 b	0.082 a	—0.023
		F			F			F			F	
Time of harvest ..		73.56***			52.36***			1.18			25.43***	
Time of injury × time of harvest ..		0.68			0.76			0.44			4.12*	

lowest sucrose content. A similar tendency was found for noxious nitrogen. In ash and invert sugar there were no significant differences (Table 47). The multifactorial experiment showed the same tendency (Table 48), but the differences were significant only in noxious nitrogen.

The plants from different seed types did not differ significantly from each other in any of the characteristics investigated (Table 48). The interaction seed type × time of injury was not significant.

From early September to early October the sucrose content rose markedly in all treatments, while ash and invert sugar decreased (Table 49). In noxious nitrogen no significant difference between the two harvests was found. In 1971 the noxious nitrogen content was considerably lower (41.6) than in 1970 (63.6).

The interactions seed type × time of harvest or seed type × time of injury × time of harvest were not significant in any of the characteristics investigated.

H. Sugar and recoverable sugar

In beets injured by *L. rugulipennis* bugs the amount of sugar, i.e. the total amount of sucrose was considerably lower than in healthy plants (Table 50). This was mostly owing to the smaller size of the injured beets, but their reduced sucrose content also contributed to the difference.

Table 50. Root weight and amounts of sugar and recoverable sugar, g per beet, in roots of healthy and injured sugar beets. Recoverable sugar: A ash content, B ash content and noxious nitrogen content taken into account.

Material and year	Root weight			Sugar			Recoverable sugar					
							A			B		
	Healthy g	Injured g	Rel. Healthy = 100	Healthy g	Injured g	Rel. Healthy = 100	Healthy g	Injured g	Rel. Healthy = 100	Healthy g	Injured g	Rel. Healthy = 100
1, 1967	271.4	190.4	70	40.44	28.20	70	32.72	22.47	69	29.20	20.20	69
1, 1968	430.9	407.9	95	62.92	56.05	89	52.20	44.50	85	43.65	36.76	84
2, 1967	486.1	372.1	76	71.95	54.40	76	56.30	42.53	76	50.02	37.81	76
2, 1968	488.7	365.1	75	73.36	52.36	71	60.90	43.26	71	50.92	36.25	71
2, 1970	603.7	447.8	74	87.54	62.02	71	74.02	50.74	69	63.39	44.02	69
Weighted mean	530.5	408.5	77	77.79	57.55	74	64.51	46.67	72	55.37	40.37	73

Table 51. Amounts of sugar and recoverable sugar, g per beet, in roots of sugar beets from different seed types injured at different growth stages.

Treatment	Sugar				Recoverable sugar			
	Mono	Poly	Mean g	Mean Rel.	Mono	Poly	Mean g	Mean Rel.
Healthy	69.65	79.52	74.58 d	100	57.24	64.89	61.06 d	100
Injured at cotyledon stage	29.88	36.59	33.24 a	45	24.65	29.26	26.95 a	44
Injured at 1- to 2-leaf stage	48.46	55.32	51.89 b	70	39.81	44.31	42.06 b	69
Injured at 3- to 4-leaf stage	62.88	68.16	65.52 c	88	51.14	54.62	52.88 c	87
Mean	52.72	59.90	56.31		43.21	48.27	45.74	
			F				F	
Seed type			3.09				3.95	
Time of injury			46.84***				44.43***	
Seed type × time of injury			0.14				0.17	

There was a still greater difference between healthy and injured beets in the amount of recoverable sugar. This was due to the higher ash content of the injured beets. The role of noxious nitrogen was negligible.

The earlier the time of injury, the smaller were the amounts of sugar and recoverable sugar. Differences in sugar were greater than differences in root weight:

	Rel. root weight	Rel. amount of sugar	Rel. amount of recoverable sugar
Healthy plants	100	100	100
Plants injured at cotyledon stage	51	48	47
Plants injured at 1- to 2-leaf stage	69	67	66
Plants injured at 3- to 4-leaf stage	89	87	84

The plants from different seed types did not differ significantly from each other in regard to sugar or recoverable sugar (Table 51). The effect of the injury was very clear in both varieties.

The amount of sugar increased very sharply from the first harvest (early September) to the second (early October) (Table 52). Owing to the rise in sugar content, the increase in sugar was comparatively larger than the increase in root weight.

In Finland the highest rate of synthesis of sugar in the leaves, as well as the highest rate of accumulation of sugar in the roots, occurs from mid-August to mid-September (Kaivola 1955).

As a result of the marked decrease in ash

Table 52. Amounts of sugar and recoverable sugar, g per beet, at different times of harvest in roots of sugar beets injured at different growth stages.

Treatment	Sugar			Recoverable sugar		
	Early September	Early October	Difference	Early September	Early October	Difference
Healthy	53.70	95.45	+41.75	41.39	80.24	+38.35
Injured at cotyledon stage	20.39	46.08	+25.69	15.81	38.10	+22.29
Injured at 1- to 2-leaf stage	36.94	66.84	+29.90	28.73	55.39	+26.66
Injured at 3- to 4-leaf stage	48.76	82.28	+33.52	38.30	67.46	+29.16
Mean	39.95 a	72.66 b	+32.71	31.18 a	60.29 b	+29.11
		F			F	
Time of harvest		154.80***			173 34***	
Time of injury × time of harvest		1.67			2.35	

content (cf. Table 49), the amount of recoverable sugar increased still more strikingly in the period between the two harvests (Table 52). The interaction time of injury × time of harvest was not significant.

The interaction seed type × time of injury × time of harvest was not significant neither in sugar (F = 0.02) nor in recoverable sugar (F = 0.06). The results of the two years were similar.

VII DISCUSSION

Lygus rugulipennis is a plant bug commonly occurring in field crops. It thrives on many plant species, preferring some to others. Besides its normal vegetable food *L. rugulipennis* also takes some animal food (Boness 1963, Bogush 1964). In the course of the present study it was found to feed on the eggs of the mangold fly (*Pegomya betae* Curt.). The species is also able to survive for considerable periods without food.

Boness (1963) successfully used several plant species as food and oviposition hosts for *L. rugulipennis* but did not study the effects of the various hosts on the bug specimens reared. When, during the present study, *L. rugulipennis* was reared on different host plants, differences were found in numbers of eggs and length of the oviposition period.

Natural enemies had no notable significance as regulators of *L. rugulipennis* populations. Boness (1963) came to the same conclusion. However, great fluctuations in the abundance of the enemies may occur in different years (Adlung 1964).

Abiotic factors had a more pronounced influence on the *L. rugulipennis* population. The early stages, especially the first-instar nymphs, proved highly susceptible to weather factors. This has been reported also by Boness (1963), Bech (1969) and Strong et al. (1970). Overwintering constituted another critical phase in the life cycle of the species. On the basis of overwintering experiments as well as sweep-net collections it was established that winter losses greatly reduced the numbers of the population. The high mortality of *L. rugulipennis* adults during the winter is also to be seen in the experiments arranged by Bech (1969).

Bilewicz-Pawińska (1967) made sweep-net studies on the abundance of *L. rugulipennis* in sugar beet in Poland. Specimens were not caught until early July. Similarly in the present study the first specimens of *L. rugulipennis* appeared in sweep-net collections from sugar beet in early July, but observations and visual counts in the field showed that the species was already present in sugar beet very soon after seedling emergence, generally from the beginning of June, even though the numbers of individuals then were small. Nevertheless, large numbers of plants were injured, as each individual bug is capable of damaging several small seedlings. The size of the seedlings at the time of injury largely determines the consequences of the bug attack. The smaller the seedlings, the greater the subsequent effect on beet weight. For large plants bug injury has no significance. Very large bug populations or prolonged feeding at the same point would be needed to produce obvious symptoms of injury in older plants (cf. HEINZE 1950, VARIS 1959). For this reason, nymphs of *L. rugulipennis* are of no significance as pests of sugar beet, because by the time the nymphs appear, the plants are large enough to be unaffected by the injury they do.

Lygus bugs are known to cause damage to a great number of plant species (OTTEN 1956). Factors causing injury have been widely discussed. In the opinion of many workers, the damage is due to toxicity of the bug's saliva (e.g. SMITH 1920, BAKER et al. 1946, CARTER 1952). The importance of mechanical injury, on the other hand, has also been emphasized (e.g. TAYLOR 1945, FLEMION 1958, SÖMERMAA 1961). STRONG (1970) suggested that damage by *L. hesperus* Knight is mainly due to the effect on plant cell tissue of polygalacturonase (pectinase) secreted during feeding, although a certain amount of mechanical injury may occur as well. The present study showed that mechanical injury played a very important role in producing symptoms in young sugar-beet seedlings, and the effect was further enhanced by pectinase. Withdrawal of cell sap by sucking had a marked effect when very tiny seedlings were attacked.

The effect of such treatments on the subsequent development and final weight of sugar beets was found to be parallel to the effect of injury by *L. rugulipennis*. The proportion of beets with multiple crowns and the number of leaves increased, and the weight of the beets tended to decrease. The reductions in weight were very small, however. This was at least partly due to the fact that the plants used for studies of the components of the injury had to be grown in paper pots in the insectary and watered daily. In those conditions recovery from bug injury was faster than in natural conditions in the field.

The growth of sugar beets damaged by *L. rugulipennis* is retarded in comparison with undamaged plants. The bugs frequently attack the growing point, which may be totally destroyed, and the plant will have to replace it by one or more lateral growing points. It is apparent that those injured plants that produce multiple crowns will have a larger leaf area for photosynthesis and so be able to catch up with growth quicker than injured plants that only develop a single leaf rosette. In this study the root weight of injured beets with multiple crowns was, on the average, a little higher than the weight of injured beets with single crowns.

When growing new leaves, injured and uninjured beets are in a somewhat different position in regard to external growth factors. In the main sugar-beet growing area of Finland, i.e. the southwestern and western parts of the country, spring drought is a recurrent phenomenon (PESSI 1963). Since there is often a dry spell of weather during the early development of sugar beets, injured plants are bound to be at a great disadvantage at the early seedling stage compared with uninjured plants.

In beets rapid early development of seedlings is considered essential for good subsequent growth and yield (e.g. KAMPE 1951, LÜDECKE 1955). KAIVOLA (1955) also stresses the importance of early seedling development. According to WATSON (1952), differences between varieties in the initial rates of leaf development may be reflected in their final yields.

BRUMMER (1961) has investigated the effects of sowing time on the yield of sugar beet in experiments carried out at various localities over

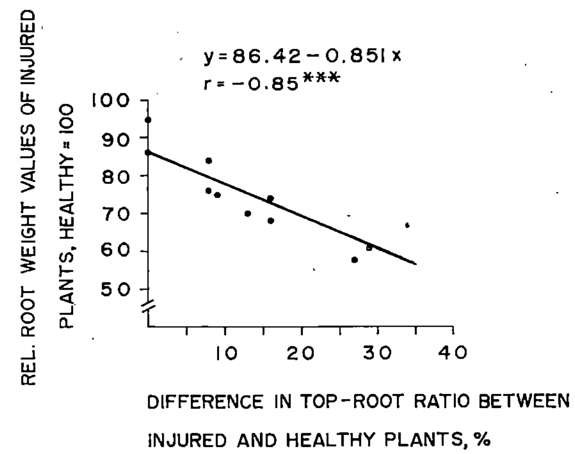


Fig. 21. Correlation between the percentage difference in top-root ratio between injured and healthy plants and the root weights of injured plants in relation to healthy plants.

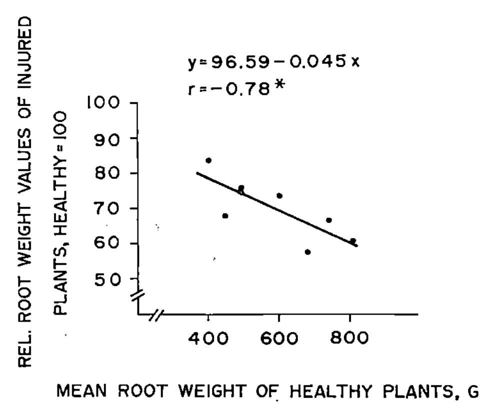


Fig. 22. Correlation between the mean root weight of healthy plants and the root weights of injured plants in relation to healthy plants.

a number of years. Late sowing has been found to reduce root yield significantly. If the yield from a normal sowing is taken as 100, sowing one week later gave a relative yield of 86, two weeks later 79, and three weeks later 73. In re-sowing trials arranged by the Research Centre for Sugar Beet Cultivation in 1970 (ANON. 1970 b), sowing one week later than normal led to a clear reduction in yield, and sowing three weeks later than normal gave 30 % less than successful sowing at the normal time. If the retardation in growth caused by bug injury is considered on the same basis, the average time corresponding to the relative root weight of 76 (injured beets in Material 2) is 2.5 weeks, and that corresponding to the relative root weight of 66 (injured beets in Material 1) is about 4 weeks. Actually, the relative values of injured beets are most likely between those of Material 1 and Material 2. In Material 1 caged bugs had access to only one plant and thus the damage was rather severe. This is also to be seen from the high rates of plant mortality. Material 2, on the other hand, consisted of plants with visible symptoms. Because feeding did not always produce visible symptoms, the differences between injured and healthy plants thus tend to be too small.

The top-root ratio can be taken as a criterion of the stage of beet maturity. In Germany this ratio is 0.5—1.3 at harvest time (LÜDECKE 1961). The ratio varies greatly and is at its most favourable at 0.8. In Finland, owing to the climatic conditions, sugar beets seldom have sufficient time to reach physiological maturity before harvesting. In the present study the top-root ratio was clearly higher for injured than for healthy beets. The greater the difference in top-root ratio between the injured and healthy beets in the different trials, the greater was the difference in root yield (Fig. 21).

It is also evident from the results that the larger the size of the beets at normal harvest time, the greater is the difference, both absolute and relative, between the weights of injured and healthy beets (Fig. 22, Table 28). KLEEMOLA and MANTERE (1966) arrived at the same conclusion when they determined the effects of bug injury solely on the basis of the occurrence of multiple crowns.

The quality of sugar beets is likewise linked with the relations between physiological development and harvest time: injured, retarded beets are poorer in quality, having a lower sucrose content and a higher ash content.

The content of noxious nitrogen was lower in damaged than in undamaged beets. In sowing time experiments arranged by BRUMMER (1961), late-sown beets had a slightly higher average noxious nitrogen content than beets sown at the normal time. The differences were very small, however, and were even reversed in many cases.

The lower content of noxious nitrogen of the injured beets in the present study may partly have been due to the change in plant habit due to bug injury. The injured beets included numerous individuals with multiple crowns (Table 18), they had larger numbers of leaves (Table 23), although these leaves were much smaller (measured by weight) than those of healthy plants (Table 40). According to SCHULZE (1953), the sharp decrease in noxious nitrogen content that occurs in the autumn in roots of beets infested with beet yellows is due to the fact that the nitrogen compounds needed for the production of fresh young leaves are mobilized from the roots, and this inevitably results in a decrease in both total and noxious nitrogen content of the roots. LÜDECKE (1961) also reports a wide variation in the noxious nitrogen content due to weather factors and resumed assimilation.

In the sugar beet crop, the proportion of plants injured by *L. rugulipennis* varies from field to field and from year to year. In the 5-year period 1967—1971 it averaged 26 % of the total number of plants in untreated plots of control trials at 4—5 different Experimental Farms of the Research Centre for Sugar Beet Cultivation. The state of the plants was inspected just before thinning when the most harmful injury had already been inflicted. The proportion of injured plants as well as the possibility of removing them in connection with thinning depends greatly on the seed spacing. At present the crop is mostly established by drilling monogerm seed at rather wide spacings. If the proportion of injured plants is assumed to be the same before and after thinning, the loss of root yield in this 5-year period, calculated from the weight loss results discussed above, would average about 7 % and the loss of sugar yield about 8 %. Especially in wide spacings the influence of injury on the final stand also has to be taken into account.

In this connection new problems arise: the occurrence of injury in successive plants, the effect of gaps, and of field size and surroundings, etc. Studies on these questions are in progress but will not be discussed here. The same applies to the prospects of preventing the losses caused by this pest.

VIII SUMMARY

The present study on the biology of *Lygus rugulipennis*, the injury it does to sugar beet, and the subsequent development of the beets was conducted in the years 1961—1971. The investigations were made in Southern Finland, near Helsinki, chiefly at the Department of Pest Investigation, Agricultural Research Centre, Tikkurila, but some overwintering studies were also made at Tuusula. The biology of the species was studied both in the insectary and outdoors in cultures and in the field. The effects of feeding were likewise studied in the insectary, in the laboratory, and in field experiments.

Biology

The oviposition period began in late May, and lasted for an average of 29 days. The average number of eggs deposited by one female was 72 ± 5.1. The size of the eggs increased with age. A positive correlation was found between the length of a female bug and the length of its eggs. The average duration of the egg stage was 21 ± 0.2 days. For specimens that reached the adult stage, development from egg to adult took an average of 57 days. The first adults of the new generation hatched in early

July but the bug did not appear in large numbers until the end of July or early August.

L. rugulipennis preferred winter turnip rape to red clover and bush bean as oviposition host. It accepted the following plant species for oviposition, in this order of preference: scentless mayweed (*Tripleurospermum inodorum*), potato, winter turnip rape, swede, red clover, sugar beet, bush bean, mugwort (*Artemisia vulgaris*), spring wheat, carrot, pine. The eggs were inserted either singly or in clusters into various succulent parts of the plants.

Sugar beet was more favoured as a food plant than either carrot or swede. The bug was found to feed on eggs of the mangold fly (*Pegomya betae* Curt.). In cultures in the insectary the adults survived for up to 20 days without food.

L. rugulipennis occurred in sugar-beet fields from the time of seedling emergence to the time of harvest. The populations were comparatively small. The adults left the fields in the late autumn.

Experiments showed that overwintering was most successful in forest litter but the adults were also able to survive in juniper and spruce. In the experiments overwintering succeeded best when the cultures were totally covered with snow. In their free habitats the largest numbers of overwintering adults were found in conifer needle litter and on the lowest branches of large spruce trees.

The mymarid *Anaphes fuscipennis* Hal. parasitized *L. rugulipennis* eggs. In 1967 4 %, and in 1969 10 % of the eggs were parasitized. Parasites of nymphs and adults were not found during this study.

In laboratory cultures, larvae of *Coccinella septempunctata* L. and *C. quinquepunctata* L. fed on *Lygus* nymphs but if aphids were available, they clearly preferred these. Likewise *C. septempunctata* adults were observed feeding on *L. rugulipennis* adults if no other food was available but did not appear to take them readily. A syrphid larva was seen feeding on a *Lygus* nymph. Adults of *Nabis* spp. also fed on the nymphs.

Injury

The smaller the plant, the shorter was the length of a feed of *L. rugulipennis*.

A positive correlation was found between the time of feeding by the bugs on sugar beet seedlings at the cotyledon stage and the degree of injury to the plants.

In insectary tests one adult injured an average of 24 sugar-beet seedlings.

Injury to sugar-beet seedlings by the nymphs was similar in appearance to that caused by the adults, but when the plants reached a more advanced stage of development, the nymphs were unable to damage them seriously. Normally by the time the nymphs appear the sugar beets have reached quite an advanced stage of growth. Similarly, adult bugs in their usual numbers failed to produce any noteworthy symptoms in sugar-beet plants at a later stage of development.

Components of the injury were studied. For this purpose, plants were treated as follows: detached salivary glands of *L. rugulipennis* were applied to the growing point; pectinase was applied to the growing point; each of these two treatments was combined with piercing the growing point with a pin; the growing point was pierced only; piercing was combined with withdrawal of cell sap by suction. Each of these treatments gave rise to plants clearly differing from the controls. The effect of mechanical injury (piercing) was very noticeable and was aggravated by application of pectinase and by withdrawal of sap by suction. These treatments produced plants with symptoms very similar to those caused by the bugs.

Effect of bug injury on subsequent development and chemical composition of sugar beet

Injury by *L. rugulipennis* caused the beets to develop multiple crowns. Injured beets with multiple crowns had larger numbers of leaves than healthy beets, and much larger numbers of leaves than injured beets with single crowns. But the leaves of injured plants were smaller in size (measured by weight) than those of uninjured plants.

The roots of the injured plants weighed less than those of the uninjured plants. The average weight reduction in a field crop was 24 %. The weight of the tops was affected less, the reduction being 15 %. The earlier the damage occurred, the less the injured plants weighed. With the respective weights for healthy plants as 100, plants damaged at the cotyledon stage had a relative root weight of 60 and a top weight of 76; plants damaged at the 1- to 2-leaf stage had a relative root weight of 74 and a top weight of 85; and those damaged at the 3- to 4-leaf stage had a relative root weight of 91 and a top weight of 92.

Of the damaged beets, those with multiple crowns had larger roots than those with single crowns, but they both had smaller roots than the healthy beets. Similarly, the tops of both multiple- and single-crowned injured beets weighed less than those of healthy beets.

The root weight increased remarkably from the first harvest (late August — early September) to the second (late September — early October) both in healthy plants and plants injured at different growth stages. The weight of the tops increased only slightly in the corresponding period.

The top-root ratio was higher in injured than in the uninjured beets. The earlier the plants were injured, the higher the ratio was. The top-root ratio decreased considerably in the period between the two harvests.

The average sucrose content was 0.57 percentage units lower for injured than for uninjured beets; the earlier the growth stage at which the plants were injured, the lower it was. Thus the relative amounts of sugar in the injured beets were smaller in comparison with the healthy beets than would have been expected from the difference in root weights.

The ash content was higher in the injured beets than in the healthy ones. When this was taken into account in calculations of the amounts of recoverable sugar, the difference between the quality of the healthy and injured beets was found to be still larger.

The noxious nitrogen (amino nitrogen) content was slightly lower in the injured than in the healthy beets; the earlier the growth stage at which the plants were injured, the lower it was.

In invert sugar content no significant differences were found between the healthy and injured beets.

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REFERENCES

Adlung, K. G. 1964. Beobachtungen über das Auftreten von Luzerneschädlingen und ihrer Parasiten. Gesunde Pfl. 16: 136—140.

Afscharpour, F. 1960. Ökologische Untersuchungen über Wanzen und Zikaden auf Kulturfeldern in Schleswig-Holstein. Z. Angew. Zool. 47: 257—301.

Anon. 1966—1967. Kuukausikatsaus Suomen ilmastoon 60—61. Ilmatieteellinen keskuslaitos.

— 1968, 1969, 1970 a. Kuukausikatsaus Suomen ilmastoon 62—64. Ilmatieteen laitos.

— 1970 b. Sokerijuurikkaanviljelyn tutkimuskeskus. Koetuloksia 1970. Rationalisointikokeet. 37 p. Salo.

— 1971. Kuukausikatsaus Suomen ilmastoon 65. Ilmatieteen laitos.

BAKER, K. F., SNYDER, W. C. & HOLLAND, A. H. 1946. *Lygus* bug injury to lima beans in California. Phytopath. 36: 493—503.

BALCELLS, R. E. 1949. Algunos insectos vectores de virus en cultivos de patata. Rev. Ilerda 12—13: 105—151. (Ref. Southwood, T. R. E. 1956).

BAPTIST, B. A. 1941. The morphology and physiology of the salivary glands of *Hemiptera-Heteroptera*. Quart. J. Microscop. Sci. 82: 91—139.

BECH, R. 1965. Licht- und Farbreaktionen der *Lygus*-Arten. Biol. Z.bl. 84: 635—640.

— 1969. Untersuchungen zur Systematik, Biologie und Ökologie wirtschaftlich wichtiger *Lygus*-Arten. Beitr. Ent. 19: 63—103.

BILEWICZ, T. 1958. Ilościowe wystepowanie *Lygus pubescens* (Reut.) i *Lygus pratensis* (L.) na kilku pospolicie uprawianych w Polsce roślinach. Summary: Numerical occurrence of *Lygus pubescens* (Reut.) and *Lygus pratensis* (L.) on some plants commonly cultivated in Poland. Ekologia Polska B 4: 299—303.

BILEWICZ-PAWIŃSKA, T. 1964. Udzial meczelkowatych (*Hym.*, *Braconidae*) w redukcji polnych pluskwiaków różnoskrzydlych (*Heteroptera*). Summary: The role of Braconids in the reduction of *Heteroptera*. Polskie Pismo Ent. B 3—4: 261—264.

— 1965. Ecological analysis of *Heteroptera* communities in cultivated fields. Ekologia Polska A 13: 593—639.

— 1967. From studies on the Heteropterofauna of the sugar beet. Ekologia Polska A 15: 373—384.

BLATTNÝ, C., KAC, A. & HOFFER, A. 1948. Pozorování a pokusy s pěstováním vojtěšky na semeno, zejména s ohledem na boj proti plodomorce vojteškové a j. škodliwým činitelům vojtěšky. Ochr. Rostl. 19—20: 40—46.

BOGUSH, P. P. 1964. Khishchnik Koloradskogo zhuka. Zashch. Rast. Vredit. Bolez. 1964, 8: 42.

BONESS, M. 1963. Biologisch-ökologische Untersuchungen an *Exolygus* Wagner (*Heteroptera, Miridae*). Z. Wiss. Zool. 168: 376—420.

BROWN, W. 1955. On the physiology of parasitism in plants. Ann. Appl. Biol. 43: 325—341.

BRUMMER, V. 1959. Lannoituksen vaikutuksesta sokerijuurikkaan satoon. Acta Agr. Fenn. 94: 201—239.

— 1961. Sokerijuurikkaan hehtaarisatojen ja säätekijöiden välisestä yhteydestä Suomessa. Summary: On the relations between sugar beet yields and certain climatic factors in Finland. Acta Agr. Fenn. 98: 1—180.

ČAČA, Z. 1967. Schäden an Zuckerrübenblättern durch wuchsstoffhaltige Herbizide. Nachr.bl. Deut. Pfl. schutzd. (Braunschweig) 19: 161—162.

CARTER, W. 1952. Injuries to plants caused by insect toxins II. Bot. Rev. 18: 680—721.

CARVALHO, J. C. M., KNIGHT, H. H. & USINGER, R. L. 1955. A proposal to use the plenary powers to fix the type species of the genus *Lygus* Hahn. 1833. Contrib. Ent. Div. Sci. Serv., Dept. Agric. Ottawa Canada 3344: 1—4. (Ref. Cobben, R. H. 1958.)

CHINA, W. E. 1941. A new subgeneric name for *Lygus* Reuter 1875, nec Hahn 1833 (*Hemipt. Heteropt.*). Proc. R. Ent. Soc. London B 10: 60.

CLANCY, D. W. & PIERCE, H. D. 1966. Natural enemies of some *Lygus* bugs. J. Econ. Ent. 59: 853—858.

COBBEN, R. H. 1958. Biotaxonomische Einzelheiten über niederländische Wanzen (*Hemiptera, Heteroptera*). Tijdschr. Ent. 101: 1—46.

DECOUX, L. & ROLAND, G. 1935. Betteraves anormales. Publ. Inst. Belge Amél. Betterave 3: 207.

DE WHALLEY, H. C. S. 1964. ICUMSA methods of sugar analysis. 153 p., 12 p. Amsterdam.

DUNNING, R. A. 1957. Mirid damage to seedling beet. Pl. Path. 6: 19—20.

FALLÉN, C. F. 1829. *Hemiptera* Sueciae. 188 p. Lund.

FISCHER, E. H., RIKER, A. J. & ALLEN, T. C. 1946. Bud, blossom, and pod drop of canning string beans reduced by plant hormones. Phytopath. 36: 504—523.

FLEMION, F. 1958. Penetration and destruction of plant tissues during feeding by *Lygus lineolaris* P. de B. Proc. Tenth Intern. Congr. Ent. Montreal 3 (1956): 475—478.

— LEDBETTER, M. C. & SCHAEFER KELLEY, E. 1954. Penetration and damage of plant tissues during feeding by the tarnished plant bug (*Lygus lineolaris*). Contr. Boyce Thompson Inst. 17: 347—357.

— MILLER, L. P. & WEED, R. M. 1952. An estimate of the quantity of oral secretion deposited by *Lygus* when feeding on bean tissue. Contr. Boyce Thompson Inst. 16: 429—433.

HEIKINHEIMO, O. & RAATIKAINEN, M. 1962. Comparison of suction and netting methods in population investigations concerning the fauna of grass leys and cereal fields, particularly in those concerning the leafhopper, *Calligypona pellucida* (F.). Publ. Finn. State Agric. Res. Board. 191: 1—31.

HEINZE, K. 1950. Saugschäden durch Weich- oder Blindwanzen (*Capsidae*) an Kartoffeln und Rüben. Nachr. bl. Deut. Pfl.schutzd. (Berlin) 2: 138—140.

JOSIFOV, M. 1970. Ergebnisse der Albanien-Expedition 1961 des Deutschen Entomologischen Institutes. 82. Beitrag, *Heteroptera*. Beitr. Ent. 20: 825—956.

KAIVOLA, A. 1955. Sokerijuurikkaan kasvukehitys vuosina 1950—1954 ja sadon arvioiminen kasvukaudella viikkonäytteiden perusteella. Referat: Über die Wachstumsentwicklung der Zuckerrübe in den Jahren 1950—1954 in Finnland sowie über Ertragsprognose im Laufe der Vegetationsperiode. J. Sci. Agric. Soc. Finl. 27: 85—103.

KAMPE, R. 1951. Klima, Witterung und Rübenertrag. Zucker 4: 69—72.

KELTON, L. A. 1955. Genera and subgenera of the *Lygus* complex (*Hemiptera: Miridae*). Can. Ent. 87: 277—301.

KLEEMOLA, S. & MANTERE, M. 1966. Niittylude sokerijuurikkaanviljelyn ongelmana viime kesänä. Juurikas 58: 8—14.

KNIGHT, H. H. 1917. A revision of the genus *Lygus* as it occurs in America north of Mexico, with biological data on the species from New York. Bull. Cor. Univ. Agric. Exp. Sta. 391: 555—645.

— 1941. The plant bugs, or *Miridae*, of Illinois. Bull. Ill. Nat.hist. Surv. 22: 1—234.

KULIK, S. A. 1965. Poluzhestkokrÿlÿe Vostochnoĭ Sibiri i Dal'nego Vostoka (*Heteroptera*-II. *Miridae*). Referat: Blindwanzen Ost Sibiriens und des Fernen Ostens (*Heteroptera-Miridae*). Acta Faun. Ent. Mus. Nat. Pragae 11: 39—70.

KULLENBERG, B. 1941. Über die Aufteilung von *Lygus pratensis* (L.). Ent. Tidskr. 62: 177—183.

— 1942. Die Eier der schwedischen Capsiden (*Rhynchota*). I. Ark. Zool. 33 A: 1—16.

— 1944. Studien über die Biologie der Capsiden. Zool. Bidr. Uppsala 23: 1—522, 25 tab.

LAUREMA, S. & NUORTEVA, P. 1961. On the occurrence of pectin polygalacturonase in the salivary glands of *Heteroptera* and *Homoptera Auchenorrhyncha*. Ann. Ent. Fenn. 27: 89—93.

LESTON, D. 1951. *Lygus pubescens* Reuter, a Mirid (*Hem.*) new to the British list. Ent. Month. Mag. 87: 244—246.

— 1952. On certain subgenera of *Lygus* Hahn 1833 (*Hem., Miridae*), with a review of the British species. Ent. Gaz. 3: 213—230.

LINNAVUORI, R. 1951. Hemipterological observations. Ann. Ent. Fenn. 17: 51—65.

— 1966. Nivelkärsäiset I. *Hemiptera* I. Anim. Fenn. 10: 1—205. Porvoo & Helsinki.

LOAN, C. C. 1969. Two new parasites of the tarnished plant bug in Ontario: *Leiophron pseudopallipes* and *Euphoriana lygivora* (*Hymenoptera: Braconidae, Euphorinae*). Proc. Ent. Soc. Ont. 100: 188—195.

LÜDECKE, H. 1955. Sicherung hoher Erträge im Zuckerrübenbau. Arch. Deut. Landw.-Ges. 16: 64—80.

— 1961. Zuckerrübenbau. 244 p. Berlin & Hamburg.

— & WINNER, C. 1959. Farbtafelatlas der Krankheiten und Schädigungen der Zuckerrübe. 86 p., 8 p. Frankfurt am Main.

MANCINI, C. 1953. Contributo alla conescenza degli Emitteri Eterotteri dell'Albania. Ann. Naturhist. Mus. Wien 59: 176—196.

MANTERE, M. 1954. Sokerijuurikaskantojen aikaisuuden vertailu. Referat: Vergleich über die Frühreife von Zuckerrübenstämmen. J. Sci. Agric. Soc. Finl. 26: 130—141.

MILES, P. W. 1968. Insect secretions in plants. Ann. Rev. Phytopath. 6: 137—164.

MOERICKE, V. 1951. Eine Farbfalle zur Kontrolle des Fluges von Blattläusen, insbesondere der Pfirsichblattlaus, *Myzodes persicae* (Sulz). Nachr.bl. Deut. Pfl. schutzd. (Braunschweig) 3: 23—24.

MUDRA, A. 1958. Statistische Methoden für landwirtschaftliche Versuche. 336 p. Berlin & Hamburg.

MUNERATI, O. 1949 Les anomalies chez la betterave. Publ. Inst. Belge Amél. Betterave 17: 31—37, 7 fig.

NOVÁK, I. 1966. Beitrag zur Methodik der Erforschung der Fauna auf den Zuckerrübenfeldern. Konferenz über Schädlinge der Hackfrüchte 2, Prag. p. 43—47.

NUORTEVA, P. 1954. Studies on the salivary enzymes of some bugs injuring wheat kernels. Ann. Ent. Fenn. 20: 102—124.

— 1956. Studies on the effect of the salivary secretions of some *Heteroptera* and *Homoptera* on plant growth. Ann. Ent. Fenn. 22: 108—117.

— & VEIJOLA, T. 1954. Studies on the effect of injury by *Lygus rugulipennis* Popp. (*Hem., Capsidae*) on the baking quality of wheat. Ann. Ent. Fenn. 20: 65—68.

OSSIANNILSSON, F. 1943. Studier över de svenska potatisfältens insektfauna och dess betydelse för spridning av virussjukdomar. I *Hemiptera*, förekomst och utbredning. Stat. Växtskyddsanst. Medd. 39: 1—72.

OTTEN, E. 1956. *Heteroptera*. Handb. Pfl.krankh. 5, 3: 1—149. (Begr. P. Sorauer, 5. Aufl.) Berlin & Hamburg.

PESSI, Y. 1963. Suomen ilmasto ja sääolot. Maanviljelijän tietokirja 1: 17—36. Porvoo & Helsinki.

POPOVA, V. 1966. Prouchvaniya v''rkhu *Heteroptera* v biotsenozata na lyutsernata v Plovdivsko. Summary: Studies on *Heteroptera* in lucerne biocenosis in Plovdiv area. Rast. Nauki 3: 49—57.

POPPIUS, B. 1911: Eine neue *Lygus*-Art aus Finnland. Medd. Soc. Fauna Flora Fenn. 37: 96—98.

RAUTAPÄÄ, J. 1969. Effect of *Lygus rugulipennis* Popp. (*Hem., Capsidae*) on the yield and quality of wheat. Ann. Ent. Fenn. 35: 168—175.

REUTER, O. M. 1875. *Hemiptera Gymnocerata* Scandinaviae et Fenniae. I *Cimicidae* (*Capsina*). Acta Soc. Fauna Flora Fenn. 1: 1—206, 1 tab.

— 1912. Hemipterologische Miscellen. Öfversikt Finska Vet.-Soc. Förh. 54 A: 1—76.

ROEMER, T. 1927. Handbuch des Zuckerrübenbaues. 366 p. Berlin.

ROMANKOW, W. 1960. The results of the studies on some fragments of the biology of *Lygus pubescens* Reut. (*Heteroptera, Miridae*) with references to seasonal activity of *Lygus* population of alfalfa fields. Prace Naukowe, Inst. Ochr. Rośl. II, 2: 215.

SCHMIDT, E. W. 1937: Über das Vorkommen vielköpfiger Rüben auf dem Felde. Deut. Zuckerind. 62: 1030—1031.

SCHULZE, E. 1953. Die Bedeutung der Vergilbekrankheit für Ertrag und Zuckergehalt der Zuckerrüben. Mitt. Deut. Landw.-Ges. 68: 75—77.

SHAPIRO, I. D. 1956. O povrezhdenii zernovýkh zdakov vreditelyami v Leningradski oblasti v 1952 g. Ent. Obozr. 35: 139—141.

SKUHRAVÝ, V. & NOVÁK, K. 1957. Entomofauna brambořište a její vývoj. Referat: Entomofauna des Kartoffelfeldes und ihre Entwicklung. Rozpravy Česk. Akad. Věd. 67: 1—50.

SLATER, J. A. 1950. An investigation of the female genitalia as taxonomic characters in the *Miridae* (*Hemiptera*). Ia. State Coll. J. Sci. 25: 1—81.

— & DAVIS, N. T. 1952. The scientific name of the tarnished plant bug (*Hemiptera, Miridae*). Proc. Ent. Soc. Wash. 54: 194—198.

SMITH, K. M. 1920. Investigation of the nature and cause of the damage to plant tissue resulting from the feeding of Capsid bugs. Ann. Appl. Biol. 7: 40—55.

SOKAL, R. R. & ROHLF, F. J. 1969. Biometry. The principles and practice of statistics in biological research. 776 p. San Francisco.

SÖMERMAA, K. 1961. Untersuchungen über die »Bollnäser Krankheit». III. Studien über die »Trübe Feldwanze» *Lygus rugulipennis*. Stat. Växtskyddsanst. Medd. 12, 86: 79—93.

SOUTHWOOD, T. R. E. 1956. The nomenclature and lifecycle of the European tarnished plant bug, *Lygus rugulipennis* Poppius (*Hem., Miridae*). Bull. Ent. Res. 46: 845—848.

ŠTEPANOVIČOVÁ, O. 1969. Saisondynamik der Heteropteren-Populationen in Agrobiozönosen. Ent. Problémy 7: 47—102.

STICHEL, W. 1956—1958. Illustrierte Bestimmungstabellen der Wanzen. II. Europa (*Hemiptera-Heteroptera* Europae) 2: 170—907. Berlin.

STRONG, F. E. 1970. Physiology of injury caused by *Lygus hesperus*. J. Econ. Ent. 63: 808—814.

— & KRUITWAGEN, E. C. 1968. Polygalacturonase in the salivary apparatus of *Lygus hesperus* (*Hemiptera*). J. Insect Physiol. 14: 1113—1119.

— & LANDES, D. A. 1965. Feeding and nutrition of *Lygus hesperus* (*Hemiptera: Miridae*). II. An estimation of normal feeding rates. Ann. Ent. Soc. Amer. 58: 309—314.

— SHELDAHL, J. A., HUGHES, P. R. & HUSSEIN, E. M. K. 1970. Reproductive biology of *Lygus hesperus* Knight. Hilgardia 40: 105—147.

TAKSDAL, G. & SØRUM, O. 1971. Capsids (*Heteroptera, Miridae*) in strawberries and their influence on fruit malformation. J. Hort. Sci. 46: 43—50.

TAYLOR, T. H. C. 1945. *Lygus Simonyi* Reut., as a cotton pest in Uganda. Bull. Ent. Res. 36: 121—148.

— 1947. Some East African species of *Lygus*, with notes of their host plants. Bull. Ent. Res. 38: 233—258.

VARIS, A.-L. 1959. Einige Wanzen der Gruppe *Lygus pratensis* L. (*Hem., Miridae*) als Schädlinge von Zuckerrübe. Publ. Finn. State Agric. Res. Board 178: 132—138.

— 1971. Effectiveness of dimethoate, formothion and methyl parathion against *Lygus rugulipennis* Popp. at different temperatures. Ann. Agric. Fenn. 10: 131—134.

— 1972. The loss of dimethoate, lindane and methyl parathion from sugar beet and the effect of plant growth on it. Ann. Agric. Fenn. (in print).

WAGNER, E. 1940. Zur Systematik von *Lygus pratensis* L. (*Hem. Heteropt. Miridae*). Verhandl. Ver. Naturwiss. Heimatforsch. Hamburg 28: 149—154.

— 1949. Zur Systematik der Gattung *Lygus* Hhn. (*Hem. Het. Miridae*). Verhandl. Ver. Naturwiss. Heimatforsch. Hamburg 30: 26—40.

— 1952. Blindwanzen oder Miriden. Die Tierwelt Deutschlands und der angrenzenden Meeresteile 41: 1—218. Jena.

— 1957. Das *Lygus-Liocoris*-Problem (*Hem. Het. Miridae*). Deut. Ent. Z. N. F. 4: 91—94.

— 1967. *Exolygus poluensis* nov. spec. (*Hem. Het. Miridae*). Deut. Ent. Z. N. F. 14: 123—124.

WATSON, D. J. 1952. The physiological basis of variation in yields. Adv. Agron. 4: 101—145.

WIKLUND, O. 1966. Handbok för sockerbolagets laboratorier. 318 p. Malmö.

SELOSTUS

Peltoluteen biologiasta ja vioituksesta sokerijuurikkaassa

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Maatalouden tutkimuskeskus, Tuhoeläintutkimuslaitos, Tikkurila

Lygus-suvun luteet esiintyvät hyvin monissa kasvilajeissa, joita ne vioittavat imennällään. Meillä yleisimpänä esiintyvä laji on peltolude, jota tavataan hyvin yleisesti myös viljelykasveissa. Kevätkesällä laji vioittaa usein sokerijuurikkaan taimia. Tässä tutkimuksessa selvitetään peltoluteen biologiaa, lajin aiheuttamaa vioitusta sekä sen vaikutuksia sokerijuurikkaassa. Tutkimukset tehtiin vuosina 1961—1971 pääasiassa Tikkurilassa. Lajin talvehtimista selvitettiin myös Tuusulassa.

Peltoluteen biologiaa selvittävät tutkimukset tehtiin osittain insektaariossa, osittain ulkona. Imennän aiheuttamaa vioitusta selvitettiin niin ikään sekä insektaario- ja laboratoriotutkimuksin että kenttäkokein.

Biologia

Laji talvehtii aikuisena etenkin karikkeissa ja havupuiden maanläheisissä oksissa. Se siirtyy viljelysmaille varhain keväällä, tavallisimmin toukokuun puolivälissä tai loppupuolella. Sokerijuurikaskasvustoihin luteet ilmestyvät usein varsin pian juurikkaiden taimelletulon jälkeen. Lajin muninta alkaa toukokuun lopussa. Kokonaiskehitys munasta aikuiseksi kestää lähes kahden kuukauden ajan. Uuden sukupolven aikuiset kuoriutuvat pääasiassa heinä—elokuun vaihteessa ja elokuussa ja siirtyvät talvehtimisympäristöön elokuun lopulta lähtien.

Munintakasveiksi kelpaavat hyvin monet kasvilajit, joskin niiden suosituimmuudessa on eroja. Peltoludenaaras muni keskimäärin 72 munaa kasvatuksissa, joissa isäntäkasvina oli syysrypsi. Munaloisena esiintyi mymaridi *Anaphes fuscipennis* Hal. Loisittujen munien osuus oli v. 1967 4 % ja v. 1969 10 %.

Ludeaikuisten todettiin imevän kuiviin juurikaskärpäsen munia.

Vioitus

Kun peltoludeaikuiset päästettiin insektaariokokeissa normaaliin aikaan kylvetyille sokerijuurikkaille näiden tultua pintaan, yksi ludeaikuinen vioitti keskimäärin 24 tainta.

Milloin luteen vioitus kohdistui taimen kasvupisteeseen, tämä usein tuhoutui. Monesti sirkkalehdet tällöin kehittyivät normaalia suuremmiksi ja paksummiksi. Myöhemmin kasvi kehitti uusia kasvupisteitä. Varteen kohdistuneesta imennästä saattoi olla seurauksena varren tummuminen ja veltostuminen. Imentä lehdestä voi aiheuttaa lehden kuihtumisen, mutta usein oli nähtävissä vain pieniä vaaleita laikkuja imentäkohdissa. — Osa vioitetuista kasveista kuoli. Aina ei imentä aiheuttanut lainkaan symptomeja.

Toukat aiheuttivat sokerijuurikkaan taimissa samanlaista vioitusta kuin aikuiset. Käytännössä ei toukilla kuitenkaan ole merkitystä sokerijuurikkaan vioittajina, sillä toukkien esiintymisaikaan taimet ovat jo varsin pitkälle kehittyneitä, ja tällaisissa kasveissa toukat eivät pysty saamaan aikaan mainittavaa vioitusta. Samoin eivät aikuiset meillä tavallisesti esiintyvin määrin pysty aikaansaamaan mainittavaa vioitusta varttuneissa sokerijuurikkaissa.

Vioitussymptomien ilmenemiseen oli mekaanisella vioituksella varsin huomattava osuus. Taimien kasvupisteeseen pantu pektinaasi ja imun aiheuttama nesteen poisto kasvupisteestä tehostivat vaikutusta. Näitä menetelmiä käytettäessä saatiin aikaan symptomeiltaan luteen vioittamien taimien kaltaisia taimia.

Vioituksen vaikutus sokerijuurikkaan myöhempään kehitykseen ja juuresten kemialliseen koostumukseen

Peltoluteen vioitus aiheutti moninaattisuutta sokerijuurikkaissa.

Luteiden vioittamien kasvien lehdet olivat kooltaan (painoltaan) pienempiä kuin terveiden kasvien lehdet.

Vioitetut kasvit painoivat huomattavasti vähemmän kuin terveet. Juuresten painossa ero oli suurempi kuin naattien painossa. Vioitetut kasvit painoivat sitä vähemmän, mitä aikaisemmalla kehitysasteella ne oli vioitettu. Kun terveiden kasvien juuresten painoa merkittiin 100:lla, sirkkalehtiasteella vioitettujen kasvien juuresten painon suhdeluku oli 60, 1—2 -kasvulehtiasteella vioitettujen 74 ja 3—4 -kasvulehtiasteella vioitettujen 91. Vastaavat naattien painon suhdeluvut olivat 76, 85 ja 92.

Vioitetuista juurikkaista moninaattiset olivat suurempia kuin yksinaattiset, mutta kummatkin olivat terveitä juurikkaita pienempiä.

Vioitettujen kasvien juuresten sokeripitoisuus oli keskimäärin 0.57 %-yksikköä alhaisempi kuin terveiden kasvien. Siten sokerin määrän erot terveiden ja vioitettujen juurikkaiden välillä olivat vielä suuremmat kuin vastaavat juuresten painon erot.

Sokeripitoisuus oli sitä alhaisempi, mitä aikaisemmalla kehitysasteella kasvit oli vioitettu.

Vioitettujen kasvien juuresten tuhkapitoisuus oli suurempi kuin terveiden. Kun tämä otettiin huomioon saatavissa olevan sokerin määrää laskettaessa, terveiden ja vioitettujen välinen ero suureni edelleen.

Haitallisen typen (aminotypen) pitoisuus oli vioitetuissa juurikkaissa hieman alhaisempi kuin terveissä ja sitä alhaisempi, mitä aikaisemmalla kehitysasteella kasvit oli vioitettu.

Ludevioituksen vaikutuksissa ei todettu eroja yksiituisen Monohill-lajikkeen ja polyploidin AaBeCe Poly -lajikkeen välillä.

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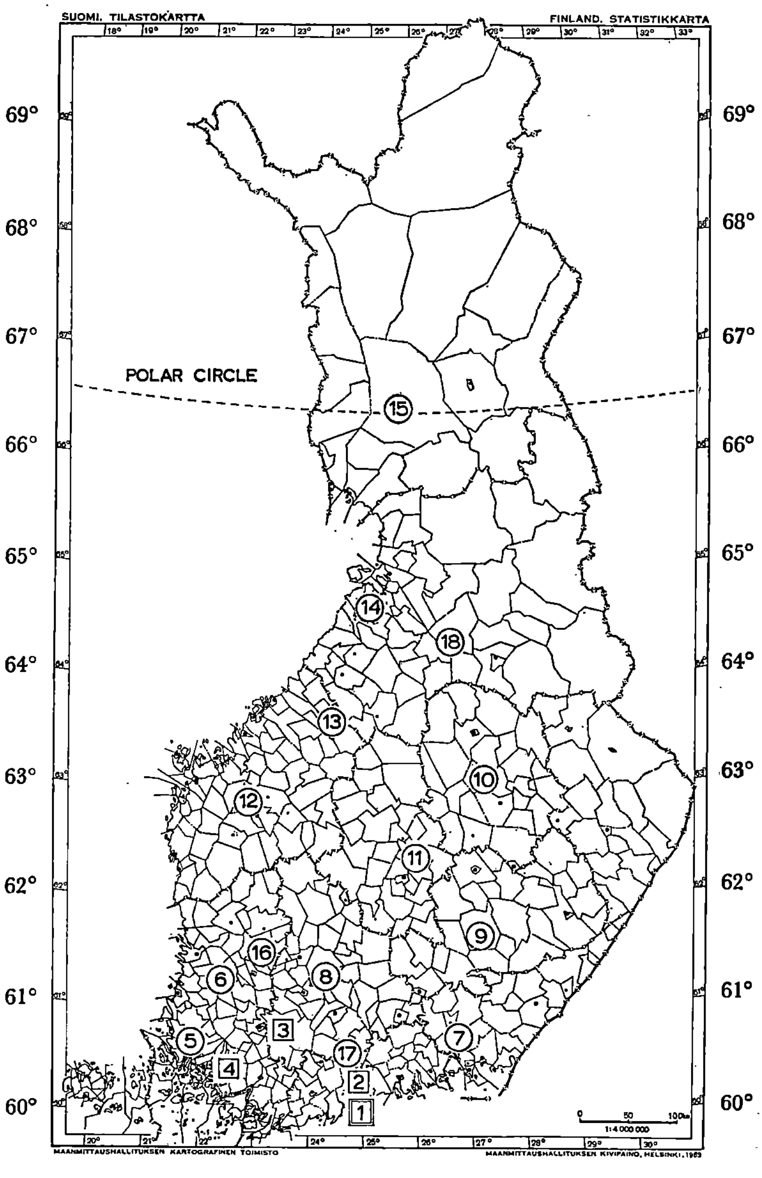

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