Annales Agriculturae Fenniae

Maatalouden tutkimuskeskuksen aikakauskirja

Vol. 6, 4

Journal of the Agricultural Research Centre

Helsinki 1967

ANNALES AGRICULTURAE FENNIAE

Maatalouden tutkimuskeskuksen aikakauskirja
Journal of the Agricultural Research Centre

Ilmestyy 4—6 numeroa vuodessa; ajoittain lisänidoksia
Issued as 4—6 numbers yearly and occasional supplements

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ANNALES AGRICULTURAE FENNIAE, VOL. 6: 127—144 (1967)

Seria ANIMALIA NOCENTIA N. 28 — Sarja TUHOELÄIMET n:o 28

THE BIONOMICS OF THE RASPBERRY APHIDS APHIS IDAEI V.D. GOOT AND AMPHOROPHORA RUBI (KALT.) (HOM., APHIDIDAE)

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Received March 28, 1967

The first information about the life-habits of *Aphis idaei* v.d. Goot was presented by v.d. Goot (1912) as a reference to the dense colonies of aphids on raspberries. For almost thirty years subsequently, only short reports were published regarding new places where the species had been found, or mention of the species was made in the lists of aphids living on plants of the genus *Rubus* (Winter 1929, Dicker 1939). Dicker (1940) gave the first description of the general biology of *A. idaei*. Hille Ris Lambers (1950) supplemented the information regarding hatching, the time of appearance of sexuals and oviposition. De Fluiter and v.d. Meer (1952) and Nybom (1960) presented brief summaries of the life-habits of the species. The importance of *A. idaei* as a virus vector has been known for about 15 years (see Cadman 1961), but detailed data on the resistance of raspberries to *A. idaei* has been presented only by Baumeister (1961).

Kaltenbach (1843) and Buckton (1875) gave a quite accurate description of the morphology of *Amphorophora rubi* (Kalt.) and a general description of its life-habits. Later, Hille Ris Lambers (1949) provided supplementary and more accurate information regarding the morphology of the species. The most important general descriptions of the life-habits of *A. rubi* are those published by Winter (1929), Dicker (1940) and Hille Ris Lambers (1949, 1950), but the bionomics was not examined in detail.

The significance of *A. rubi* as a vector of raspberry viruses has been proved in many studies (see e.g. Cadman 1961) and a large amount of information has been presented about the resistance of raspberries to *A. rubi* (reviewed by Knight et al. 1959 and Baumeister 1961). The host plant relationships of biological strains of *A. rubi* have been clarified in many studies (see e.g. Briggs 1959, 1965), and Hille Ris Lambers (1949) has studied the morphological differences between the strains.

A few short reports and observations on raspberry aphids have been published in Finland. *A. idaei* was mentioned in the archives of the Dept. of Pest Investigation for the first time in 1934. Linnaniemi (1935) mentioned that *A. rubi* was observed in the Iisalmi region in 1921. According to Heikinheimo (1959), the significance of the two species as vectors of raspberry viruses in Finland is probably great (see also Tapio 1961). Thuneberg (1962) and Vappula (1965) presented data on the distribution of the species in this country.

The purpose of this study was to obtain more accurate data on the bionomics of *A. idaei* and *A. rubi*. At the same time the host plant relationships of both species was studied (RAUTAPÄÄ 1968). A short description of the results has already been published (RAUTAPÄÄ 1964), as has a report on the parasitic *Hymenoptera* species collected during the study (MARKKULA and RAUTAPÄÄ 1963).

Material and methods

In order to study the distribution of species in Finland, samples of living and parasitized aphids were gathered during trips made in different parts of the country. The aphid mummies were reared in the laboratory.

The majority of rearings of both species were carried out in the insectary of the Dept. of Pest Investigation, Tikkurila. According to measurements made during previous experiments in the insectary (e.g. MARKKULA 1953) and during the present study, the mean daily temperatures recorded at the insectary and at the meteorological station of the Agricultural Research Centre were almost identical. The minimum diurnal temperature was higher, however, and the maximum lower in the insectary than outdoors. All the mean temperatures given below have been figured from the temperatures recorded at the meteorological station.

Host plants were planted in pots (diam. 20 cm), and once a week artificial fertilizer »Kasvu» was added to the water.

According to observations made prior to the investigation, during the early summer the numbers of both species was greatest in inflorescences and in the tops of first-year canes. For this reason the first four generations of both species were reared in inflorescences and the other agamic generations in the uppermost open leaf and near the growing point of the first-year canes. The sexuals were confined to the lower leaves of the first-year canes. Each aphid was protected by a cylindrical rearing cage of transparent plastic and terylene-voile gauze (diam. 10 cm, length 15 cm). Rearings were checked as often as possible, at least every fifth day. To each male and female rearing some specimens of the opposite sex were added.

A. idaei. 17 fundatrices that hatched on April 28, 1961, in the vicinity of the insectary were isolated at the age of three days onto recently sprouted buds of raspberry variety Malling Promise. The rearing method was largely the same as the first-born line method used by MARKKULA (1953). After the reproduction of fundatrices had begun, the oldest larva of each of 12 fundatrices was transferred to a new rearing cage, where its life course and reproduction were kept under observations. Rearings were continued generation by generation, the oldest apterous larva of each female being transferred to a separate rearing. The number of first-born lines decreased after the death before onset of reproduction of one female in the third generation and two in the fourth generation. The life periods and reproduction of ten alate viviparous females were studied in 1962. The larvae born on June 27 were isolated at the age of three days onto flower buds of Preussen variety grown in the insectary.

A. rubi. A number of eggs were gathered into the insectary on April 30, 1962. The majority of the hatched fundatrices were parasitized, however, and only three reached maturity. The rearings were started from these fundatrices, and the host plant was raspberry variety Preussen. The number of aphids was increased by transferring the three oldest larvae of each of two fundatrices, and the oldest larva of one fundatrix, to rearings. The number of aphids varied in the different generations because some of the larvae died before reaching maturity. With the change to the subsequent generation the number of aphids was increased by transfer of several of the larvae of one female to the rearings. Therefore, the method was not the first-born line method used when the biology of *A. idaei* was studied. Six of the aphids in the fourth generation were alate, all others in every generation were apterous. In 1963, a comparison was made of the larval period of the alate and apterous females by rearings made on the variety Pressen, which was growing in the field in the vicinity of the insectary. A number of apterous females were placed on the tops of first-year canes inside rearing cages on July 25. All the aphids were descendants of the same fundatrix. The adults were removed from the cages after about 17 hours. After three days only the largest larva was left inside each cage. The rearings were checked daily.

Results and conclusions

Distribution in Finland

A. idaei, which is known to be quite common throughout Europe, is distributed in Finland at least as far as Kuusamo (lat. 66° N, Fig. 1). The northernmost occurrences in Sweden have been found, according to OSSIANNILSSON (1959), in the provinces of Gästrikland and Dalarna (lat. 61—62° N). *A. rubi*, like *A. idaei*, is very common in southern and central Finland (Fig. 1).

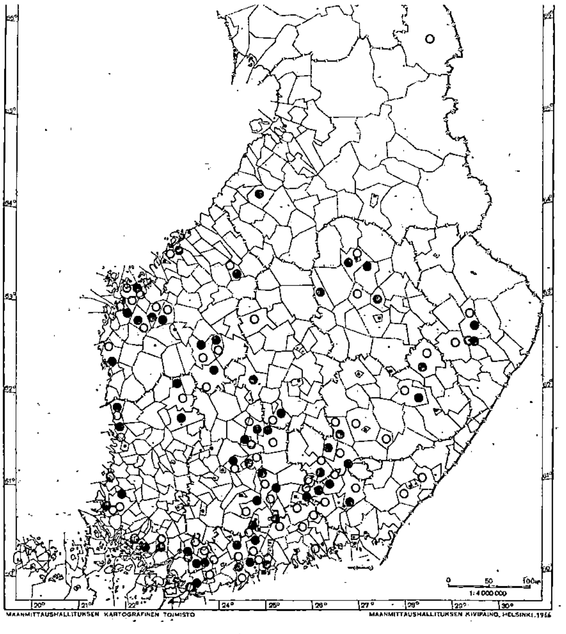

Fig. 1. Communes where *A. idaei* (open circles) and *A. rubi* (dots) have been found.

Kuva 1. Kunnat, joissa A. idaei (ympyrät) ja A. rubi (pisteet) on tavattu.

Number of generations

The greatest number of generations of *A. idaei* was nine per year (Fig. 2). One of the females in the seventh generation produced agamic sexuparae, the oldest of which formed the eight generation. The offspring of the latter were sexuals and formed the ninth generation. The specimens of the seventh generation of all other firstborn lines were either sexuparae or sexuales, and

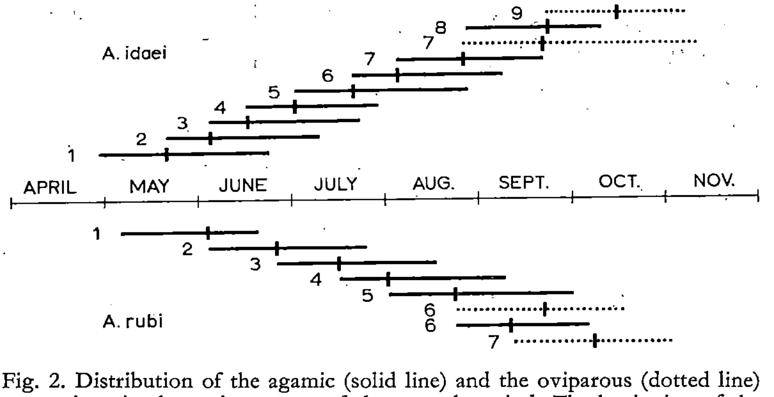

Fig. 2. Distribution of the agamic (solid line) and the oviparous (dotted line) generations in the various parts of the growth period. The beginning of the reproductive period is indicated by an intersecting line.

Kuva 2. Agamisten (yhtenäinen viiva) ja oviparisten (pisteviiva) sukupolvien ajoittuminen kasvukauden eri osiin. Lisääntymiskauden alku on osoitettu poikkiviivalla.

consequently only eight generations were produced in these lines. The greatest number of generations of *A. rubi* was seven (Fig. 2).

According to HEIKINHEIMO (1952), *Aphis grossulariae* Kalt. had twelve generations in Finland in 1951. The greatest number of generations of *Brevicoryne brassicae* L. was seven in 1949 and nine in 1950 (MARKKULA 1953) and that of *Acyrthosiphon pisum* (Harris) ten in 1959 and 1960 (MARKKULA 1963).

Hatching of fundatrices

In 1961, the first fundatrices of *A. idaei* hatched on April 26—27, and during the following year on May 5—7, while in 1963 hatching took place on April 27—29. Thus in three consecutive years hatching began around the turn of April—May. In England, the young larvae were observed in the first half of March in 1937 and 1938 (DICKER 1940).

On May 2, 1961, eggs of *A. rubi* were moved into a greenhouse (+ 24 ± 4°C), and into the insectary. In the greenhouse the first larvae hatched on May 8, and in the insectary on May 9. In 1962, the first just-hatched fundatrices were found on May 7 on raspberries that had overwintered in the vicinity of the insectary. In England (DICKER 1940) and in Holland (HILLE RIS LAMBERS 1950) it was found that the earliest fundatrices hatched at almost the same time, in the beginning of March.

To establish the number of eggs destroyed during the winter of 1960—1961, the hatching percentage of *A. idaei* was counted on June 5, 1961, from four Preussen raspberries that had overwintered in the vicinity of the insectary. Altogether, 2344 eggs were examined, of which 23.0 % were found to have been destroyed. The causes of destruction were not clarified. By the day on which the count was made the majority of fundatrices had hatched: only 24 unhatched, but apparently undestroyed eggs were found. According to ZIRNITZ (1932), about 20 % of the eggs of *A. idaei* were destroyed in Latvia during the severe winter of 1928—29.

Length of life periods: fundatrices and virginoparae

Larval period

The difference between the mean larval period of species (*A. idaei* 16.3 days and *A. rubi* 17.8 days) was not significant ($P > 0.05$) (Table 1). In both species the average larval period of the third generation was the shortest (*A. idaei* 9.2 days and *A. rubi* 15.8 days) and that of the fundatrices the longest (*A. idaei* 22.9 days and *A. rubi* 26.6 days), if a single specimen of the eighth generation of *A. idaei* is not taken into account.

Table 1. The larval period, in days, of the agamic females, and the average temperatures during the larval period. r = the correlation coefficient of the larval period and the temperature. ** $P < 0.01$

*Taulukko 1. Agamisten neitsyiden toukkakausi vuorokausina ja toukka-ajan keskilämpötila. r = toukka-ajan ja lämpötilan korrelaation kerroin. ** P < 0.01*

Generation *Sukupolvi*	Number of females *Yksilö-luku*	$\bar{x}$	$S_{\bar{x}}$	Range *Ääri-arvot*	°C
A. idaei					
I	17	22.9	± 0.3	21 — 26	7.5
II	12	12.8	± 1.9	10 — 16	15.3
III	11	9.2	± 0.6	9 — 14	19.2
IV	9	15.2	± 1.3	11 — 24	14.8
V	9	14.5	± 1.0	11 — 21	15.8
VI	9	15.3	± 0.8	12 — 19	15.8
VII	9	18.4	± 1.4	12 — 26	14.3
VIII	1	23.0			9.8
S	77	$\bar{x}$ 16.3	± 1.6	r = —0.952**	14.0
A. rubi					
I	3	26.6	± 1.5	24 — 29	9.6
II	7	19.0	± 1.5	15 — 26	12.3
III	13	15.8	± 0.5	13 — 20	14.5
IV	17	16.9	± 0.9	13 — 27	14.6
V	13	17.3	± 1.2	11 — 24	13.0
VI	4	21.5	± 1.3	18 — 24	12.1
S	57	$\bar{x}$ 17.8	± 1.1	r = —0.955 **	13.1

The negative correlation between the average larval periods of the different generations and temperature was highly significant ($P < 0.01$).

The larval period of alate females of *A. idaei* in 1962 was on average 10.5 ± 0.2 days, and the average temperature during the developmental period was 14.4°C. The developmental period was 4.7 days shorter than the larval period of the apterous females of the fourth generation (15.2 days) during the previous year, at nearly the same average temperature (14.8°C).

The mean larval period of 11 apterous females that belonged to the fourth generation of *A. rubi* was 17.6 ± 1.1 days and the mean temperature during that time was 14.7°C. The developmental period of 6 alate females of the same generation averaged 15.5 ± 0.4 days at a temperature of +14.4°C. The 2.1 day difference was not significant ($P > 0.05$) and the larval period for the fourth generation, given in Table 1, is consequently the average of both apterae and alatae. The average larval period for the 21 *A. rubi* that developed into apterous specimens in 1963 was 14.5 ± 0.4 days, and that of the 10 aphids that developed into alate specimens was 12.7 ± 0.5 days ($P < 0.05$).

The larval periods of the apterae and alatae of various species have been compared in many studies, and the apterae have usually had a shorter development period than the alatae (e.g. Markkula 1953, MacGillivray and Anderson 1958, Markkula and Myllymäki 1963, Adams and Drew 1964). When studying *Rhopalosiphum maidis* Fitch Adams and Drew (1964) found that alatae had a shorter larval period than apterae on *Avena* species, but a longer one on other host plants.

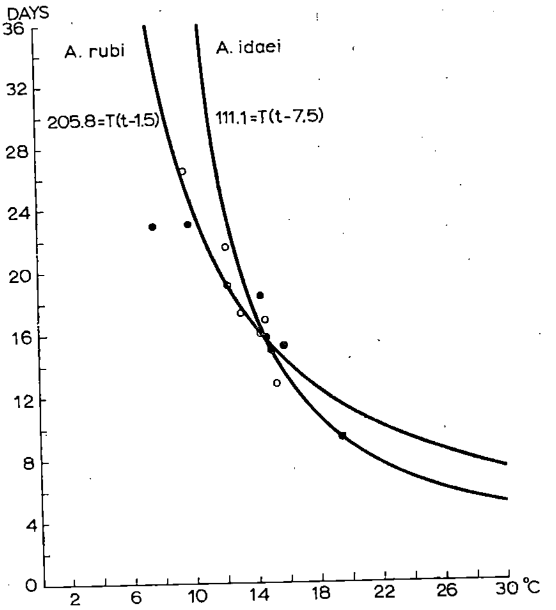

Fig. 3. The theoretical larval period of the agamic females at different temperatures. The dots indicate the larval periods of the generations of *A. idaei*, and the open circles those of *A. rubi*, at the prevailing temperature.

Kuva 3. Agamisten neitsyiden teoreettinen toukka-aika eri lämpötiloissa. Pisteet osoittavat A. idaein, ympyrät A. rubin sukupolvien toukka-ajan vallinneessa lämpötilassa.

The theoretical larval period of the two species at different temperatures, expressed as hyperbolas in Fig. 3, has been figured by means of the equation $K = T\ (t - a)$ (see e.g. Schwerdtfeger 1963, p. 141). The thermal constant K and the development threshold a were figured by emloying the average larval periods and the average temperatures for the third and fourth generations of *A. idaei* and the second and third generations of *A. rubi*. These generations were selected firstly because the average temperature of their larval periods differed greatly, and secondly because all the specimens were living in the middle of the growing season (see Fig. 2) and on the same parts of the host plants. The thermal constant of the development of *A. idaei* was 111.2° and the threshold of development +7.5°C. The corresponding values for *A. rubi* were 205.8° and +1.5°C.

On the basis of insectary rearing, Markkula (1953) reckoned the threshold of development of *B. brassicae* to be +1.7°C and the thermal constant to be 187°. Tanaka (1957) reported the development threshold of *Rhopalosiphum padi* L to be +6.1°C. According to Kawada (1964), the threshold of development of *Rhopalosiphum pseudobrassicae* Davis was +7.6°C and the thermal constant 123.6°, while in the study by Barlow (1962) the corresponding values for *Macrosiphum euphorbiae* (Thomas) were —0.03°C and 221.24°. The comparison of the results is made difficult by the fact that some of the studies were carried out in naturally varying temperatures (Markkula 1953, and the present study), while others (Tanaka 1957, Barlow 1962, Kawada 1964) were carried out at an almost constant temperature. The effects of constant and of changing temperatures upon larval periods of aphids has been compared in only a few studies. According to Barlow (1962), the larval period of *M. euphorbiae* at a constant temperature was the same length as MacGillivray and Anderson (1958) had previously reported it to be in a temperature equally high but varying. Messenger (1964), on the other hand, found that *Therioaphis maculata* Buckton reached maturity sooner in a varying than in a constant temperature.

Reproductive period

The fundatrices of *A. idaei* produced the first larvae on an average 1.5 $\pm$ 0.2 (range 0 and 2) days after the final moult. The reproduction of the third generation of *A. rubi* began on average 1.1 $\pm$ 0.3 (range 1 and 2) days after the final moult. Sufficiently accurate observations were not made on the beginning of the reproduction of other females, and therefore the reproductive period of all generations of both species has in Table 2 been counted as having started from the final moult. The period from the final moult to the beginning of reproduction has varied in different species from six hours (Banks and Macaulay 1964, *A. fabae*) to two days (Markkula and Myllymäki 1963, *Macrosiphum avenae* (F.)).

The average reproductive period of apterous females of *A. idaei* was 21.5 days (range 3 and 43) and that of *A. rubi* was 24.7 days (range 1 and 58) (Table 2). The 3.2 day difference is not significant ($P > 0.05$). The internal variation was great within lines descending from different fundatrices of *A. idaei*, and no line had a reproduction period repeatedly shorter or longer than that of other lines.

The correlation between the reproductive period and the temperature was not significant for either species (Table 2).

The reproductive period of alate females of *A. idaei* averaged 9.7 $\pm$ 2.4 (range 3 and 24) days in 1962. The average temperature of the reproductive period of the alatae was of almost the same length as the reproductive period of the fourth generation in 1961 (10.2 days, Table 2). The 0.3 day difference between the reproductive period of alatae and apterae in the fourth generation of *A. rubi* was not significant ($P > 0.05$).

Post-reproductive period

A. idaei lived on average 4.7 days (range 0 and 33) after completion of reproduction and *A. rubi* 5.8 days (0 and 48). The correlation between the length of the post-reproductive period and the temperature was negative but not significant ($P > 0.05$) (Table 3).

Table 2. The reproductive period in days of the agamic females, and the average temperatures during the reproductive period. r = the correlation coefficient of the reproductive period and the temperature

Taulukko 2. Agamisten neitsyiden lisääntymiskausi vuorokausina ja lisääntymiskauden keskilämpötila. r = lisääntymisajan ja lämpötilan korrelaation kerroin

Generation *Sukupolvi*	Number of females *Yksilö-luku*	$\bar{x}$	$S_{\bar{x}}$	Range *Ääri-arvot*	°C
A. idaei					
I	17	22.1	$\pm$ 1.9	5 — 34	15.9
II	12	24.8	$\pm$ 2.6	15 — 36	17.7
III	11	27.4	$\pm$ 2.4	18 — 41	15.6
IV	9	10.2	$\pm$ 2.4	5 — 23	15.6
V	9	30.3	$\pm$ 3.5	9 — 43	15.1
VI	9	17.7	$\pm$ 3.5	3 — 30	13.6
VII	9	12.8	$\pm$ 2.8	3 — 25	11.6
VIII	1	15.0			8.0
S	77 $\bar{x}$	21.5	$\pm$ 2.9	r = +0.517	15.1
A. rubi					
I	3	10.3	$\pm$ 4.9	1 — 18	10.1
II	7	24.9	$\pm$ 4.2	3 — 33	13.4
III	13	25.2	$\pm$ 2.7	2 — 40	14.6
IV	17	22.9	$\pm$ 3.0	4 — 42	13.0
V	13	29.2	$\pm$ 4.1	7 — 58	11.1
VI	4	22.2	$\pm$ 6.6	7 — 38	8.7
S	57 $\bar{x}$	24.7	$\pm$ 3.9	r = —0.402	12.5

Table 3. The life span in days of the agamic females after termination of reproduction, and the average temperatures during this period. r = the correlation coefficient of the post-reproductive period and the temperature

Taulukko 3. Agamisten neitsyiden elinaika vuorokausina lisääntymisen päätyttyä ja keskilämpötila tänä aikana. r = lisääntymisen jälkeisen ajan ja lämpötilan korrelaation kerroin

Generation *Sukupolvi*	Number of females *Yksilö-luku*	$\bar{x}$	$S_{\bar{x}}$	Range *Ääri-arvot*	°C
A. rubi					
I	17	0.7	$\pm$ 0.1	0 — 4	14.0
II	12	3.9	$\pm$ 1.9	0 — 24	16.9
III	11	5.4	$\pm$ 1.3	0 — 11	15.8
IV	9	6.0	$\pm$ 1.2	0 — 13	15.5
V	9	5.3	$\pm$ 5.0	0 — 15	12.2
VI	9	8.7	$\pm$ 8.7	0 — 19	12.8
VII	9	6.8	$\pm$ 3.6	0 — 33	10.5
VIII	1	0			
S	77 $\bar{x}$	4.7	$\pm$ 2.2	r = —0.357	14.0
A. idaei					
I	3	3.0	$\pm$ 3.0	0 — 9	9.3
II	7	2.9	$\pm$ 1.1	0 — 9	14.3
III	13	3.3	$\pm$ 1.4	0 — 1	13.0
IV	17	7.1	$\pm$ 2.4	0 — 25	10.6
V	13	9.8	$\pm$ 3.4	0 — 48	9.8
VI	4	3.0	$\pm$ 0.7	1 — 4	8.8
S	57 $\bar{x}$	5.8	$\pm$ 2.1	r = —0.283	11.2

The alate females of *A. idaei* lived in 1962 on average 15.6 ± 4.2 days (0 and 35) after completion of reproduction, which is about 3.3 times as long as the average for apterous females in 1961. During this period the average temperature was 13.4°C. The post-reproductive periods of the 11 alatae (7.5 ± 3.5 days) and the 6 apterae (6.8 ± 1.9 days) of the fourth generation of *A. rubi* were of nearly the same lengths ($P > 0.05$).

Total life span

The larval period, the reproductive period and the post-reproductive period of the agamic generations have been brought together in Fig. 4. On average all the life periods of *A. idaei* were a little shorter than those of *A. rubi* (see Tables 1, 2 and 3), and consequently the average life span of *A. idaei* (42.5 days) was 5.8 days shorter than the life span of *A. rubi* (48.3 days). The difference is not significant ($P > 0.05$).

The total life span of the fourth generation of *A. idaei* was 11.8 days shorter than that of the third generation and 18.7 days shorter than that of the fifth generation (Fig. 4). From Table 2 and Fig. 4 it can be seen that the exceptionally

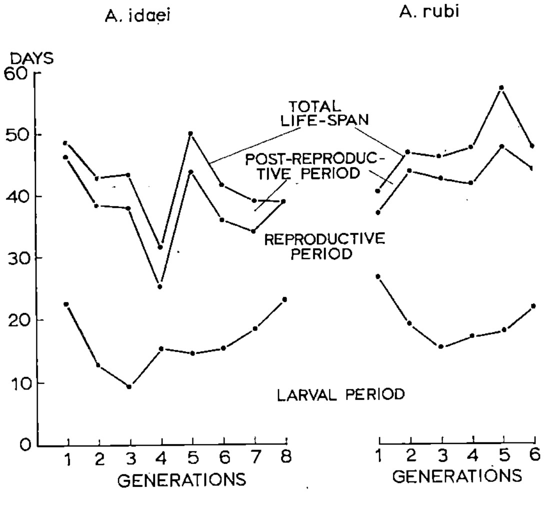

Fig. 4. The average lengths of the life periods of the agamic generations.
Kuva 4. Agamisten sukupolvien elämänvaiheiden keskipituudet.

Table 4. The relative length of the life periods of agamic females as percentages of life span
Taulukko 4. Agamisten neitsyiden elämänvaiheiden suhteelliset pituudet prosentteina elinajasta

	A. idaei		A. rubi
	Apterae *Siivettömät*	Alatae *Siivelliset*	Apterae *Siivettömät*
Larval period—*Toukka-aika*	38.4	28.1	36.9
Reproductive period—*Lisääntymiskausi*	50.6	30.1	51.1
Post-reproductive period — *Lisääntymisen jälkeinen elinaika*	11.1	41.8	12.0
Number of females — *Yksilöluku*	77	10	57

short total life span of the fourth generation was caused by a very short reproductive period. It has been established in many studies that the reproduction of the various aphid species is smaller in the middle of summer than it is in the beginning or end of the growing season, and the same can also be seen from the results of the present study (see later p. 137).

The proportion of the larval period in the life span of apterous females of the two species was nearly 40 %, that of the reproductive period was 50 %, and that of the post-reproductive period slightly more than 10 % (Table 4). The larval period and reproductive period of alate females of *A. idaei* were relatively shorter than were the same periods of the apterae. In contrast, the post-reproductive period was approximately 40 % of the total life span (Table 4).

The relative lengths of the three life periods of apterous *A. idaei* and *A. rubi* differs somewhat from that of other aphid species that have been studied in Finland. It is possible on the basis of the study by MARKKULA (1953) to calculate that the relative lengths of each of the three life periods of *B. brassicae* is about one-third of the total life span. On the other hand, the length of the larval period of *A. pisum* was app. 20 %, the reproductive period app. 50 %, and the post-reproductive period app. 30 % of the total life span (MARKKULA 1963).

Length of life periods: sexuals

Males

The first-born males of *A. idaei* belonged to the seventh generation, and were born on August 2—4. In order to establish the frequency and time of occurrence of the males their number was counted on the raspberries in three mass-rearing cages in the insectary. On September 20, 1961, their number was 31 and on October 12 there were 7 of them. On October 28, one hundred leaves of the variety Preussen were examined in the field in the vicinity of the insectary. The number of *A. idaei* females per leaf averaged 9.4 but only 5 males were found. According to DICKER (1940), the males of *A. idaei* in England appeared from the beginning of October to the middle of December.

The first males of *A. rubi* were born on August 19—21 in 1962. In August, larvae, probably of second degree, were found in the mass-rearing cages in the insectary, and these were later ascertained to be males. In mass-rearings and on field raspberries males were not found after the end of October. Males have been found in USA in early October (WINTER 1929). In England, the first males were born towards the end of September, and males were found on raspberries in mid-November (DICKER 1940).

The males of *A. idaei* in line rearings were progeny of sexuparae of the sixth and seventh generations. Some further males which were isolated in rearings were the progeny of sexuparae obtained from mass rearings in the insectary, and were born on August 19—20. No observations were made of the larval period of *A. idaei* males, and Table 5 consequently only shows the total life span. The males of *A. rubi* that were studied in individual rearings were the progeny of the fifth generation.

The life span of *A. idaei* males (33.9 days) was 8.6 days shorter, and that of *A. rubi* males (38.5 days) 9.8 days shorter, than the average life span of the agamic generations (42.5 and 48.3 days). The males of *A. rubi* spent 3/4 of their total life as larvae, which is relatively twice as long as the agamic females. The larval period of the males (29.5 days) in the prevailing temperature (10.1°C) was not significantly ($P > 0.05$) longer than the larval period of the females (27.2 days) at almost the same temperature (10.6°) (see Table 6).

Females

The females of the ninth generation of *A. idaei* died from lack of food after the leaves had fallen during early November. Table 6 shows only the average larval period of this generation.

The time between the final moult and the beginning of oviposition was established from six specimens of the seventh *A. idaei* generation and

Table 5. The length of the life periods of the males in days
Taulukko 5. Koiraiden elämänvaiheiden pituudet vuorokausina

Generation *Sukupolvi*	Number of females *Yksilöluku*	Range of birth dates *Syntymäaika*	Larval period *Toukka-aika*	Temperature during larval period *Toukka-ajan keskilämpötila* °C	Adult period *Aikuiskausi*	Total life-span *Elinaika*
A. idaei						
VII	10	8.—16.VIII 1961	—	—	—	32.0 ± 2.1
VIII	6	2.—10.IX	—	—	—	28.6 ± 1.9
From mass-rearing — *Massakasvatuksesta*	10	19.—20.VIII	—	—	—	39.1 ± 1.8
A. rubi						
VI	9	2.—12.IX 1962	29.5 ± 0.7	10.1	9.0 ± 1.6	38.5 ± 1.0
%			76.6		23.4	

Table 6. The length of the life periods of the females in days

Taulukko 6. Naaraiden elämänvaiheiden pituudet vuorokausina

Generation *Sukupolvi*	VI		VII		VIII		IX		
	$\bar{x}$ $S\bar{x}$	Range *Ääriarvot*	$\bar{x}$ $S\bar{x}$	Range *Ääriarvot*	$\bar{x}$ $S\bar{x}$	Range *Ääriarvot*	$\bar{x}$ $S\bar{x}$	Range *Ääriarvot*	$\bar{x}$ $S\bar{x}$
A. idaei									
Larval period — *Toukka-aika*			32.0 ± 1.4	26 — 35	23.0 ± 1.6	20 — 27	26.0 ± 2.1	19 — 41	28.5 ± 1.4
Reproductive period — *Munintakausi*			5.8 ± 1.5	2 — 8	4.8 ± 1.3	1 — 7	?		5.5 ± 1.1
Post-reproductive period — *Muninnan jälkeinen kausi*			13.4 ± 2.1	9 — 29	30.0 ± 2.5	27 — 36	?		17.9 ± 2.2
Total life-span — *Elinaika*			51.2 ± 2.5	26 — 62	57.8 ± 2.7	50 — 62	?		53.0 ± 2.1
Number of females — *Yksilöluku*			19		7		10		
Range of birth dates — *Syntymäaika*			16.—26.VIII		4.—10.IX		25.IX.—3.X		
Temperature during larval period °C — *Toukka-ajan keskilämpötila °C*			11.7		10.9		7.1		
A. rubi									
Larval period — *Toukka-aika*	27.2 ± 1.6	18 — 33	29.4 ± 3.3	20 — 41					28.2 ± 2.4
Reproductive period — *Munintakausi*	18.5 ± 2.3	6 — 31	13.3 ± 4.6	1 — 31					16.3 ± 2.4
Post-reproductive period — *Muninnan jälkeinen kausi*	4.2 ± 2.9	0 — 31	5.3 ± 2.8	0 — 21					4.6 ± 2.8
Total life-span — *Elinaika*	49.9 ± 1.5	30 — 67	48.0 ± 5.1	29 — 61					49.2 ± 3.8
Number of females — *Yksilöluku*	9		16						
Range of birth dates — *Syntymäaika*	25.—30.VIII		14.—18.IX						
Temperature during larval period °C — *Toukka-ajan keskilämpötila °C*	10.6		7.9						

five specimens of the seventh *A. rubi* generation. The oviposition of *A. idaei* began 1.5 ± 0.3 days (range 1 and 2), and that of *A. rubi* 1.9 ± 0.5 days (1 and 3) after the final moult. In Table 6, however, the oviposition period of all generations has been reckoned as beginning from maturity.

The larval period of the eighth generation of *A. idaei* (23.0 days) was 9.0 days shorter ($P < 0.01$), and that of the ninth generation (26.0 days) 6.0 days shorter ($P < 0.05$), than the larval period of the females of the seventh generation (32.0 days). Nevertheless the average temperature during the larval period of the seventh generation was 11.7°C, during the eighth generation 10.9°C, and during the ninth 7.1°C. These results suggest that among the causes of the relative shortness of the larval periods of the eighth and ninth generations of *A. idaei* may have been the acclimatization of the females to lower temperatures.

The developmental period of the sixth generation of *A. rubi* (27.2 days) was on average 2.2 days shorter ($P > 0.05$) than that of the seventh generation (29.4 days) (Table 6). The average temperature during the larval period of the seventh generation was 2.7°C lower than during the sixth, and the results do not suggest an acclimatization to the lower temperatures.

The females of the seventh generation of *A. idaei* lived as larvae approximately 23 percentage units longer than the females of the eighth generation (Table 7). The oviposition periods were of equal relative length — about 10 % of the total life span — but the post-reproductive period of the seventh generation occupied one-fourth and that of the eighth generation half of the total life span.

Table 7. The relative length of the life periods of the females as percentages of life span

Taulukko 7. Naaraiden elämänvaiheiden suhteelliset pituudet prosentteina elinajasta

Generations *Sukupolvet*	*A. idaei* VII	*A. idaei* VIII	*A. rubi* VI	*A. rubi* VII
Larval period—*Toukka-aika*	62.5	39.8	57.3	61.3
Reproductive period *Munintakausi*	11.3	8.3	34.3	27.7
Post-reproductive period — *Muninnan jälkeinen kausi*	26.2	51.9	9.6	11.0

Compared with the agamic females, the oviparous females of *A. idaei* lived as larvae relatively longer, and reproduced and survived after completion of reproduction a shorter period. The larval period of oviparous females of *A. rubi* was longer, the reproductive period shorter than, and the post-reproductive period almost the same length as that of the agamic females.

Reproduction of fundatrices and viviparae

Number of progeny

The average number of larvae of *A. idaei* was 30.4 (range 2 and 108) and of *A. rubi* 31.7 (1 and 65) (Table 8). On average, *A. idaei* produced 1.6 larvae per day, and *A. rubi* 1.5. The fundatrices of *A. idaei* produced most larvae, 64.4, and the seventh generation fewest, 9.3. Correspondingly, the females of the fifth generation of *A. rubi* produced most larvae, 39.4, and the fundatrices and the females of the second generation fewest, 16.3.

The alate females of *A. idaei* produced on average of 13.2 ± 2.1 larvae (range 5 and 24) in 1962. The mean was 17.2 larvae fewer ($P < 0.05$) than that of all the apterous females in line rearings, but only 3.8 fewer ($P > 0.05$) than that of the fourth generation that had been living during almost the same time and in the same parts of the raspberries. The difference between the larvae produced by apterous and alate females of the fourth generation of *A. rubi* (31.0 ± 3.6 and 42.0 ± 5.7) was 11.0 larvae ($P < 0.05$). In studies made on other species, the total number of progeny of apterae has been found to be greater than that of alatae (Heikinheimo 1952, Markkula 1953, 1963, Markkula and Myllymäki 1963).

The females of the fourth generation of *A. idaei* produced 11.5 larvae fewer than the females of the third generation, and 24.2 larvae fewer than the females of the fifth generation (Table 8). It

Table 8. The number of larvae produced by the agamic females, and the average temperature during the reproductive period. r = the correlation coefficient of number of larvae and the temperature

Taulukko 8. Agamisten neitsyiden toukkaluku ja lisääntymiskauden keskilämpötila. r = toukkamäärän ja lämpötilan korrelaation kerroin

Generation *Sukupolvi*	Number of females *Yksilöluku*	$\bar{x}$ $S_{\bar{x}}$	Range *Ääriarvot*	Larvae per day *Toukkia/vrk.*	°C
A. idaei					
I	17	64.4 ± 2.1	11 — 108	2.7	15.9
II	12	35.3 ± 5.2	29 — 56	1.4	17.7
III	11	38.5 ± 5.4	9 — 64	1.4	15.6
IV	9	17.0 ± 5.3	3 — 49	1.7	15.6
V	9	41.2 ± 6.2	20 — 74	1.4	15.1
VI	9	22.2 ± 4.6	5 — 40	1.3	13.6
VII	9	9.3 ± 2.6	2 — 27	0.7	11.6
VIII	1	15.0		1.0	8.0
S	77	$\bar{x}$ 30.4 ± 6.9	r = +0.602	1.6	14.2
A. rubi					
I	3	16.3 ± 10.3	1 — 36	1.5	10.1
II	7	16.3 ± 5.6	4 — 45	1.3	13.4
III	13	31.6 ± 4.4	4 — 59	1.6	14.6
IV	17	34.9 ± 5.2	7 — 61	1.5	13.0
V	13	39.4 ± 5.9	18 — 65	1.4	11.1
VI	4	19.5 ± 2.2	14 — 24	0.9	8.7
S	57	$\bar{x}$ 31.7 ± 5.5	r = +0.128	1.5	12.5

appears from Table 2 that the reproductive period of the fourth generation was shorter than the reproductive periods of the third and fifth generations. The females of the fourth generation, however, lived 6.0 days after completion of reproduction, while the females of the third and the fifth generations lived 5.4 and 5.3 days respectively (Table 3). Evidently the small number of larvae of the fourth generation females was caused by a decrease in the reproduction potential and not by the untimely death of the aphids. It has previously been shown in many studies that the reproduction of various aphid species decreased in mid-summer and changes taking place in the food plant during the period of growth have been suggested to be the cause of this (see e.g. KENNEDY and STROYAN 1959).

The effect of temperature upon the total number of aphid progeny has been clarified in several studies (e.g. TANAKA 1957, TAKAOKA 1960, BARLOW 1962, KAWADA 1964, MESSENGER 1964, MARKKULA and PULLIAINEN 1965). The lower and upper limits of the temperature range most advantageous for reproduction varied between +15°C (MESSENGER 1964) and +25°C (TANAKA 1957). A change in temperature to below or above these figures decreased the total number of progeny. The minimum average temperature during the reproductive periods of the different generations of *A. idaei* was 8.0° and the maximum average was 17.7°C (Table 8). Correspondingly, the temperature limits during the reproductive periods of *A. rubi* were 8.7° and 14.6°. The correlations between the temperatures and the average number of larvae of the generations were for both species positive but not significant (P > 0.05) (Table 8).

From the results it is possible to draw some conclusions regarding the effect of temperature on the daily number of larvae of the fundatrices and alate females of *A. idaei*. The fundatrices began to reproduce on May 24—27, and the last larva was produced on June 17. Subsequent to the beginning of reproduction the cultures were not examined daily, and the daily number of progeny has therefore been reckoned from averages of 1—3 day periods (Fig. 5). The daily number of progeny was greatest in the middle of the reproductive period, when the temperatures were highest. During the first six periods

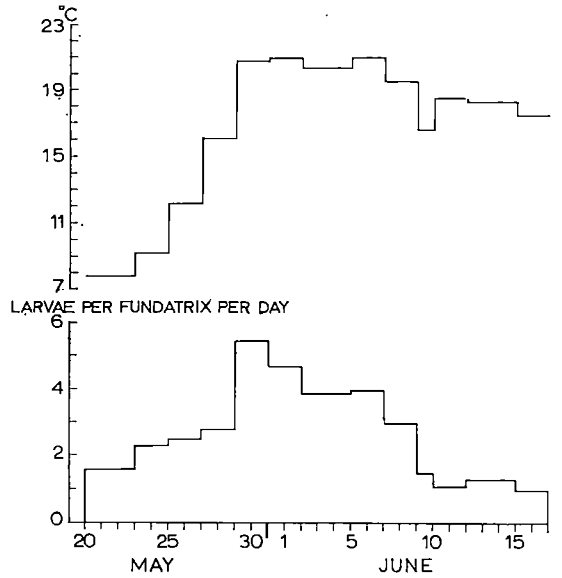

Fig. 5. The daily number of larvae of the *A. idaei* fundatrices, and the average temperature during the parts of the reproductive period varying in length.

Kuva 5. A. idaein kantaemojen vuorokautinen toukkaluku ja keskilämpötila lisääntymiskauden eri pituisten osien aikana.

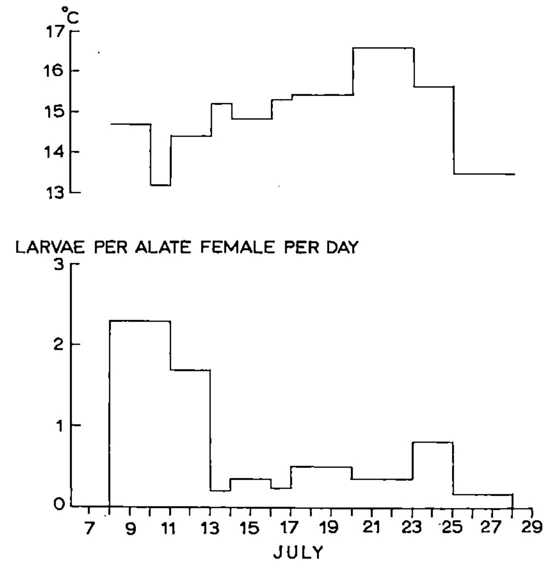

Fig. 6. The daily number of larvae of the alate viviparous females of *A. idaei*, and the average temperature during the parts of the reproductive period varying in length.

Kuva 6. A. idaein siivellisten neitsyiden vuorokautinen toukkaluku ja keskilämpötila lisääntymiskauden eri pituisten osien aikana.

of inspection, the correlation coefficient between the daily temperature and the daily number of larvae was $r = +0.935$ ($P < 0.01$) and the correlation equation $y = -0.396 + 0.250\ x$. Correspondingly, during the last seven periods of inspection the correlation coefficient was $r = -0.880$ ($P < 0.05$) and the correlation equation $y = 2.257 + 0.757\ x$. Thus, a one-unit change in the temperature caused a smaller change in the number of larvae in the beginning of the reproductive period (1° = 0.250 larvae) than it did towards the end of the period (1° = 0.757 larvae).

The daily number of larvae of alate *A. idaei* was greatest in the beginning of the reproductive period, and decreased during the reproductive period (Fig. 6). The negative correlation between the temperature and the daily number of progeny was not significant ($r = -0.405$, $P > 0.05$).

Morph composition of progeny

The proportion of alatae among the total progeny was 10.6 % in *A. idaei* and 4.5 % in *A. rubi* (Table 9). 92.5 % of the offspring of *A. idaei* were viviparous females, 4.8 % were sexuals and 2.7 % died before determination. Correspondingly, *A. rubi* produced 76.6 % viviparous females and 22.2 % sexuals. 1.2 % of larvae died before determination. The number of males in the progeny of *A. idaei* was 32 (24.1 %) and that of oviparous females 101 (75.9 %). The ratio was consequently 1 : 3.7. On the other hand, 34 males (8.3 %) and 409 oviparous females (92.3 %) were produced by *A. rubi*, giving a ratio of 1 : 12.0.

The sexuparae of both species produced males as well as females, and most of them also agamic females (Fig. 7). The nine *A. rubi* sexuparae of the fifth generation produced their offspring in the following order: agamic females were produced in the beginning of the reproductive period, the males in the middle of the period, and the oviparous females towards the end of it. The other four females in the same generation produced only agamic or oviparous females.

Table 9. The relative number in percentages of agamic females as well as males and females in the offspring of the different generations

Taulukko 9. Agamisten neitsyiden sekä koiraiden ja naaraiden suhteelliset määrät prosentteina eri sukupolvien jälkeisössä

Generation *Sukupolvi*	Total number of larvae *Toukkien määrä*	Agamic females *Agamiset neitsyet*		Males *Koiraita*	Females *Naaraita*	Dead as unknown *Kuolleet määrittämättöminä*
		Apterae *Siivettömiä*	Alatae *Siivellisiä*			
A. idaei						
I	1 095	82.4	17.6	0	0	0
II	420	91.7	7.9	0	0	0.4
III	423	88.3	9.4	0	0	2.3
IV	163	93.0	6.8	0	0.3	0.2
V	371	81.8	14.5	5.5	14.9	3.4
VI	201	71.6	7.0	18.1	59.5	1.0
VII	94	1.1	0	33.3	66.6	21.3
VIII	15	0	0	0	0	0
S	2 782	$\bar{x}$ 81.9	10.6	1.2	3.6	2.7
A. rubi						
I	49	89.6	10.4	0	0	0
II	221	87.8	12.2	0	0	0
III	546	90.0	10.0	0	0	0
IV	593	95.8	4.2	0	0	0
V	512	25.3	0	5.9	66.0	2.8
VI	78	0	0	3.8	87.1	9.1
S	1 999	$\bar{x}$ 72.1	4.5	1.7	20.5	1.2

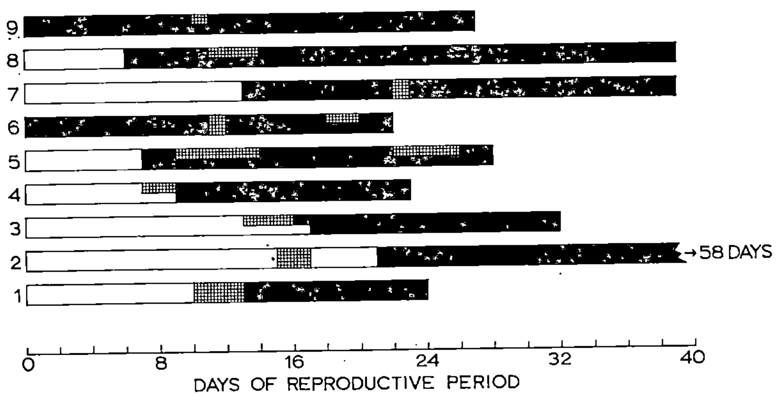

Fig. 7. Order of production of the offspring of the nine agamic females belonging to the fifth generation of *A. rubi*. Unshaded surface = agamic females, shaded surface = males, black surface = females.

Kuva 7. A. rubin viidenteen sukupolveen kuuluneiden yhdeksän neitsyen jälkeläisten syntymäjärjestys. Viivoittamaton alue = agamisia neitsyitä, viivoitettu alue = koiraita, musta alue = naaraita.

Oviposition

The oviposition of *A. idaei* began in the insectary on August 27—28, 1961 and September 3—4, 1962. In the line rearings the females laid their last eggs on November 2—8, 1961. Because of defoliation of the food plants the rearings of the ninth generation had to be discontinued. Yellowish eggs, resembling recently laid ones, were found on field rapberries as late as November 19.

The first eggs of *A. rubi* were found in the daily-examined mass-rearing cages in the insectary on September 12, and in the line rearings on September 15, 1962. In the insectary the females laid their last eggs on November 7—10, but yellow eggs resembling recentlylaid ones were found on November 19 on raspberries growing in the field.

N u m b e r o f e g g s. On average, the oviparous females of *A. idaei* laid 2.2 eggs, and those of *A. rubi* 7.8 eggs (Table 10). The largest number of eggs among *A. idaei* was 5, and among *A. rubi* 19. The 12 females that were transferred as larvae from mass rearings to cages, and that had not been fertilized by males, did not lay any eggs.

Table 10. Number of eggs produced by the females
Taulukko 10. Naaraiden munamäärä

Generation *Sukupolvi*	Number of females *Yksilö-luku*	$\bar{x}$ $S_{\bar{x}}$	Range *Ääri-arvot*	Eggs per day *Munia/vrk*
A. idaei				
VII	19	1.9 ± 0.2	0 — 3	0.3
VIII	7	3.8 ± 0.3	1 — 5	0.8
S	26	$\bar{x}$ 2.2 ± 0.4		
A. rubi				
VI	9	10.8 ± 1.5	5 — 19	0.6
VII	16	4.1 ± 0.9	1 — 8	0.3
S	25	$\bar{x}$ 7.8 ± 1.0		

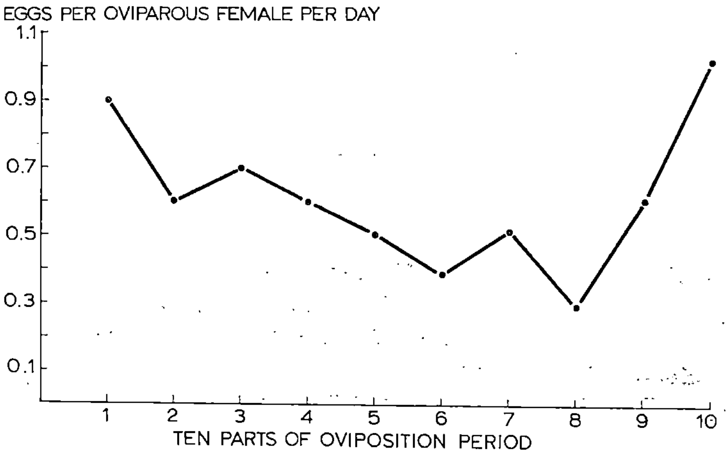

Fig. 8. The average number of eggs of nine oviparous females belonging to the sixth generation of *A. rubi* during the different parts of the reproductive period.
Kuva 8. A. rubin kuudenteen sukupolveen kuuluneiden yhdeksän oviparisen naaraan keskimääräinen munaluku eri osissa munintakautta.

Table 11. The location of eggs in the different parts of seven first-year canes of Preussen variety, expressed as percentages. The numbers were counted on October 11th 1962. The *A. idaei* eggs totalled 810, the *A. rubi* eggs 107
Taulukko 11. Munien sijainti Preussen-lajikkeen seitsemän ensimmäisen vuoden verson eri osissa prosenttiluvuin ilmaistuna. Lukumäärät laskettiin 11. 10. 1962. A. idaein munia yhteensä 810, A. rubin munia 107

		Eggs in leaf blades *Munia lehdissä*	Eggs in axils *Munia lehtihangoissa*	Eggs on canes *Munia varrella*	S
Upper part of cane —	*A. idaei*	0.2	18.9	0	19.1
Verson yläosa	*A. rubi*	16.8	0	0	16.8
Midd part of cane —	*A. idaei*	0.4	27.2	0	27.5
Verson keskiosa	*A. rubi*	13.1	6.5	0	19.6
Lower part of cane —	*A. idaei*	No leaves	42.1	11.2	53.3
Verson alaosa	*A. rubi*	*Ei lehtiä*	20.6	43.0	63.6
S	*A. idaei*	0.6	88.1	1.2	
	A. rubi	29.9	27.1	3.0	

The number of eggs deposited by *A. idaei* has previously been reported to be about 4 (Börner and Heinze 1957). Of three *A. rubi* females reared by Winter (1929), one laid 1 egg and two laid 6. Hille Ris Lambers (1950) stated that the number of eggs was 3—10.

Fig. 8 shows the frequency of oviposition in the sixth *A. rubi* generation. The frequency was counted by dividing the oviposition period of each female into 10 phases of equal length, and the average daily number of eggs was calculated for each phase. The frequency decreased during the oviposition period and reached its minimum when about 80 % of the period had elapsed.

L o c a t i o n o f e g g s. In the beginning of August 1962, a group of agamic females of both species were transferred to three raspberries, var. Preussen which had been planted in separate cages. Two of the plants had 2 first-year canes and one had 3. When the eggs were counted on October 11, the canes were divided into three equal lengths of 20—30 cm each. There were altogether 810 eggs of *A. idaei* and 107 of *A. rubi* (Table 11). Most of the *A. idaei* eggs (88.1 %) were located in the axils. In the lower part of the cane the frequency (53.3 %) was greater than in the midpart (27.5 %) or the upper part (19.1 %). Most of the *A. rubi* eggs (43.0 %) were located on the stalk of the lower part of the cane or on the spines (cf. Winter 1929). The numbers were nearly the same on the leaves (29.4 %) as in the axils (27.1 %).

Notes on the parasites of raspberry aphids

There is little information available regarding the *Hymenoptera* species parasitizing *A. idaei* and *A. rubi*. Dicker (1940) mentioned that an unidentified species of the *Aphidius* genus destroyed about 80 % of *A. rubi* of a rearing. *Praon volucre* Hal. has been known to parasitize *A. rubi* (e.g. Mackauer 1959). No previous information regarding the parasites of *A. idaei* could be found in the literature.

In addition to the three species mentioned formerly by Markkula and Rautapää (1963), *Trioxys acalephae* Marsh. also parasitized *A. idaei*. The few specimens were found at Tikkurila in 1964. The species is new to this country. In the same year *Aphidius rubi* Stary, a parasite of *A. rubi*, was also found at Tikkurila and at Piikkiö (lat. 60° 30′ N, long. 22° 30′ E). This species, too, has not previously been recorded in Finland. All the parasites were kindly determined in Czechoslovakia by Dr. Petr Starý.

Summary

The biology of *Aphis idaei* v.d. Goot and *Amphorophora rubi* (Kalt.) was studied mainly by insectary rearings during 1961—1963 at the Department of Pest Investigation, Tikkurila, Finland.

The fundatrices of both species hatched at the end of April or beginning of May. The greatest number of generations of *A. idaei* was nine, and that of *A. rubi* was seven. The first sexuals were produced in the middle of August.

The larval period of the apterous agamic females of *A. idaei* averaged 16 days, and that of *A. rubi* 18 days. The reproductive periods averaged 22 and 25 days, and the post-reproductive periods were 5 and 6 days respectively. The total life span of *A. idaei* was in average 43 days and that of *A. rubi* 48 days; *A. idaei* spent 38 % and *A. rubi* 37 % as larvae. The relative lengths of the reproductive periods were 51 % and 51 %, and that of the post-reproductive periods 11 % and 12 %. No essential differences could be found between the life periods of the species.

The alate females of *A. idaei* had a relatively longer (42 %) post-reproductive period than had the apterous females (11 %). The larval period (13 days) of the alate *A. rubi* was significantly ($P < 0.05$) shorter than that of the apterous females (15 days).

The negative correlation between temperature and the length of the developmental period was significant in the case of both species. In contrast, the temperature did not significantly affect the

length of the reproductive period nor that of the the post-reproductive period.

The thermal constant of the development of *A. idaei* was calculated to be 111.2°C, and the threshold of development +7.5°C. The corresponding values for *A. rubi* were 205.8°C and +1.5°C.

The larval period of males of *A. idaei* was not clarified. *A. rubi* males lived on average 30 days as larvae and 9 days as adults. The total life span of *A. idaei* males averaged 34 days, and that of *A. rubi* males 39 days.

The larval period of oviparous females averaged 29 days (*A. idaei*) and 28 days (*A. rubi*). The oviposition period lasted 6 days and 16 days, and after the termination of oviposition the females lived 18 days and 5 days, respectively. The total life span of *A. idaei* females thus averaged 53 days and that of *A. rubi* 49 days. Compared with agamic females, the oviparous females of the two species lived longer as larvae but their reproductive periods were shorter. After termination of reproduction the oviparous females of *A. idaei* lived relatively longer than and the oviparous females of *A. rubi* about as long as the agamic females.

The *A. idaei* females produced on average 30 larvae, and the *A. rubi* females 31 larvae. The daily numbers of larvae were 1.6 and 1.5 respectively.

Independently of the temperature, the alate females of *A. idaei* produced more larvae in the beginning of the reproductive period than in the middle and towards the end of it. The number of larvae produced by the fundatrices was greatest in the middle of the reproductive period, when the temperatures were highest.

The sexuparae of the two species produced both males and females, and most of them also produced agamic females. The agamic females were produced in the beginning of the reproductive period of *A. rubi* sexuparae, the males during the middle of it, and the females towards the end of it.

The number of *A. idaei* eggs averaged 2.2 and that of *A. rubi* 7.8. Most of the *A. idaei* eggs (88 %) were located in the leaf axils of raspberry canes. The frequency was greater (53 %) on the lower parts of the canes than in the middle parts (28 %) or on the upper parts (19 %). Most of the *A. rubi* eggs (43 %) were located on the stalk. 64 % of eggs were on the lower part of the canes, 20 % on the middle part, and 17 % on the upper part.

During the study parasitized aphids were collected. Four *Hymenoptera* species were found to be primary parasites of *A. idaei,* and two species to be primary parasites of *A. rubi. Trioxys angelicae* Hal. and *T. acalephae* Marsh., both of which parasitized *A. idaei,* as well as *Aphidius rubi* Stary, which parasitized *A. rubi,* proved to be new species in Finland.

Acknowledgements. My sincerest thanks are due to Professor Veikko Kanervo, Dr. Agr. and For., Head of the Department of Pest Investigation, and to Martti Markkula, Dr. Ph., for many valuable discussions and criticism during the study.

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SELOSTUS

Vadelman kirvojen biologiaa

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Vadelmissa elävät pieni vattukirva (*Aphis idaei* v.d. Goot) ja iso vattukirva (*Amphorophora rubi* (Kalt.)) ovat maassamme erittäin yleiset. Erityisesti *A. idaei* saattaa runsaana esiintyessään vaikuttaa imennällään epäedullisesti vadelmiin, mutta imentävioitusta haitallisempia ovat kirvojen levittämät virustaudit. Lukuisista maassamme tavatuista vadelmien virustaudeista leviää tiettävästi yksi *A. idaei*n ja muut *A. rubi*n välityksellä. Virusvektorien menestyksellinen torjunta edellyttää niiden biologian perusteellista tuntemista ja siksi on ollut syytä tutkia yksityiskohtaisesti lajien elämänkulkua ja lisääntymistä. Vaikka molemmat lajit ovat erittäin yleiset Euroopassa ja *A. rubi* myös Pohjois-Amerikassa, on niiden elämänvaiheista aikaisemmin esitetty vain summittaisia tietoja.

Tutkimus tehtiin vuosina 1961—1963 Tuhoeläintutkimuslaitoksen insektaariossa Tikkurilassa. Kummankin lajin kantaemot, joiksi ensimmäisen sukupolven yksilöitä nimitetään, kuoriutuivat talvimunista huhti-toukokuun vaihteessa. *A. idaei*n sukupolvien enimmäisluku oli yhdeksän ja *A. rubi*n seitsemän. Ensimmäiset avioliiset (= koiraat ja naaraat) syntyivät elokuun puolivälissä.

Kirvojen elinaika jakautui kolmeen osaan: toukka-aikaan, lisääntymiskauteen ja lisääntymisen jälkeiseen elinaikaan. Eri elämänvaiheiden pituuksissa ei todettu mitään oleellisia lajieroja. Partenogeneettisesti lisääntyvät kesäsukupolvien siivettömät yksilöt elivät toukkina keskim. 1/3 elinajastaan (*A. idaei* 16 vrk, *A. rubi* 18 vrk), lisääntymiskauden osuus elinajasta oli noin puolet (22 vrk ja 25 vrk) ja elinaika lisääntymisen päätyttyä oli noin 1/10 (5 ja 6 vrk) koko eliniästä. *A. idaei*n koko elinaika oli siten keskim. 43 vrk ja *A. rubi*n 48 vrk.

Kummankin lajin toukka-ajan ja vallinneen lämpötilan korrelaatio oli negatiivinen ja merkitsevä. Lämpötila ei sitävastoin vaikuttanut lisääntymiskauden eikä lisääntymisen jälkeisen elinajan pituuteen.

*A. idaei*n koiraiden toukkakauden pituutta ei selvitetty, mutta koko elinaika oli keskim. 34 vrk. *A. rubi*n koiraat kehittyivät aikuisiksi keskim. 30 päivässä ja elivät aikuisina 9 vrk. Elinaika oli siten keskim. 39 vrk.

Naaraiden kehitys syntymästä aikuiseksi kesti keskim. 29 vrk (*A. idaei*) ja 28 vrk (*A. rubi*). Munintakauden pituudet olivat vastaavasti 6 vrk ja 16 vrk, ja muninnan päätyttyä elivät naaraat 18 vrk ja 5 vrk. *A. idaei*n naaraiden elinikä oli siten keskim. 53 vrk ja *A. rubi*n 49 vrk. Partenogeneettisesti lisääntyviin keskikesän sukupolvien kirvoihin verrattuina elivät naaraat kauemmin toukka-asteella, mutta lisääntymiskausi oli lyhyempi. Lisääntymisen päätyttyä elivät *A. idaei*n naaraat suhteellisesti kauemmin mutta *A. rubi*n naaraat lähes saman ajan kuin partenogeneettisesti lisääntyvät kirvat.

Partenogeneettisten yksilöiden jälkeläismäärät olivat miltei samat (*A. idaei* 30, *A. rubi* 31). Vuorokaudessa syntyi vastaavasti 1.6 ja 1.5 toukkaa.

Lämpötilasta riippumatta synnyttivät siivelliset *A. idaei*t eniten toukkia lisääntymiskauden alussa. Siivettömien kantaemojen vuorokautinen toukkaluku sitävastoin oli suurin lisääntymiskauden keskellä, jolloin lämpötila oli korkein.

*A. idaei*n naaraat munivat vähemmän talvimunia (2.2/naaras) kuin *A. rubi*n (7.8/naaras). Valtaosa *A. idaei*n talvimunista (88 %) sijaitsi vadelman verson lehtihangoissa. Verson alimmassa kolmanneksessa oli runsaus suurempi (53 %) kuin keskimmäisessä (28 %) tai ylimmässä (19 %). *A. rubi*n talvimunista enemmistö (43 %) sijaitsi verson varrella ja muut lehtihangoissa ja lehdissä. Verson alimmassa kolmanneksessa sijaitsi munista 63 %, keskimmäisessä 20 % ja ylimmässä 17 %.

ANNALES AGRICULTURAE FENNIAE, VOL. 6: 145—158 (1967)

Seria ANIMALIA NOCENTIA N. 29 — Sarja TUHOELÄIMET n:o 29

CONTARINIA KANERVOI BARNES (DIPT., ITONIDIDAE), BIONOMICS, DAMAGE AND CONTROL

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Received May 18, 1967

Larvae of an unknown species of gall midge (*Itonididae*) were found damaging timothy inflorescences in Finland more than seventy years ago (REUTER 1900, p. 105, and 1901, pp. 28—30). In England, too, the occurrence of a gall midge on timothy inflorescences was recorded (BAGNALL and HARRISON 1918). However, the species was not identified until 1958, when BARNES (1958) described *Contarinia kanervoi* on the basis of material sent from Finland.

Little has been reported on the bionomics and control of *C. kanervoi*. The publication by BARNES (1958) contains what are so far the most extensive data on the bionomics of the species, the information being obtained from cultures reared in England. RAATIKAINEN (1966) has published a brief note on its bionomics and distribution. TINNILÄ (1959), KANERVO (1962, p. 411) and KANERVO and VAPPULA (1962, 1965) have published preliminary information on the control of the species. VAPPULA (1965) has gathered information on its occurrence as a pest in Finland up to 1961, and RAATIKAINEN and TINNILÄ (1967) have studied its occurrence in Sweden.

Towards the end of the 1950s, *C. kanervoi* became an economically very important pest in Finland, and this prompted research to ascertain the main outlines of its bionomics and control. The present work was done in the years 1957—1961, and the part published here was carried out at Nivala (64° N, 25° E), Laihia (63° N, 22° E), Vaasa (63° N, 22° E) and Tikkurila (60° N, 25° E). In addition, data on distribution have been gathered from various parts of Finland. At Nivala and Laihia two of the present authors, Raatikainen and Tinnilä, investigated the bionomics and control of *C. kanervoi*. The other author, Savas, did his research chiefly at Laihia and Vaasa. He also clarified the diagnostic character of the damage. Together we have studied the life cycle of the gall midge, its distribution and the crop losses due to its activities.

Bionomics

Emergence of adults

The emergence of *C. kanervoi* was studied on peat soil at Nivala. A cloth funnel mounted on a square wooden frame, 43 cm high and having a base area of 0.5 m², was used for collecting adults (Fig. 1). The cloth was double, the outer layer being grey and the inner layer black. At the peak of the funnel there was a wooden frame with two glass tubes. The funnels were placed

Figure 1. Cloth funnel used to trap midges emerged from the soil.

Kuva 1. Kangaspyramidi, jolla pyydystettiin maasta kuoriutuvia sääskiä.

out in the open field, with their edges were sunk to a depth of about 5 cm. The temperature inside the cloth funnels was higher than outside.

D a i l y e m e r g e n c e r h y t h m. The timothy midges rose into the glass tubes of the funnels chiefly in the morning. 93 % of the 242 males and 72 % of the 411 females obtained in funnels at Nivala on June 26—27, 1959, were obtained before 11 a.m. The males appeared in the glass tubes earlier than the females, $\chi^2 =$ 43.26***. According to BARNES (1958, p. 63), 79 % of the males and 76 % of the females of *C. kanervoi* sent from Nivala to England emerged in the morning before 12 noon, this material, too, showing a similar difference between the sexes. In the vicinity of Vaasa emergence occurred in the early hours, between 5 and 8 a.m. *C. kanervoi* appears to emerge at an earlier hour in Finland than in England, and this may be due to the earlier rise of the sun and the temperature. According to FRÖHLICH (1960, p. 22), all other phytopathologically important gall midges, too, hatch in the night or morning, or at noon. Some species, however, such as *C. tritici*, emerge chiefly in the evening (BARNES 1956, p. 40).

E m e r g e n c e p e r i o d. When the emergence period was being investigated, the funnels were on timothy leys at Nivala for the periods June 14—July 17, 1959, June 11—July 20, 1960, and June 2—July 15, 1961. The funnels were

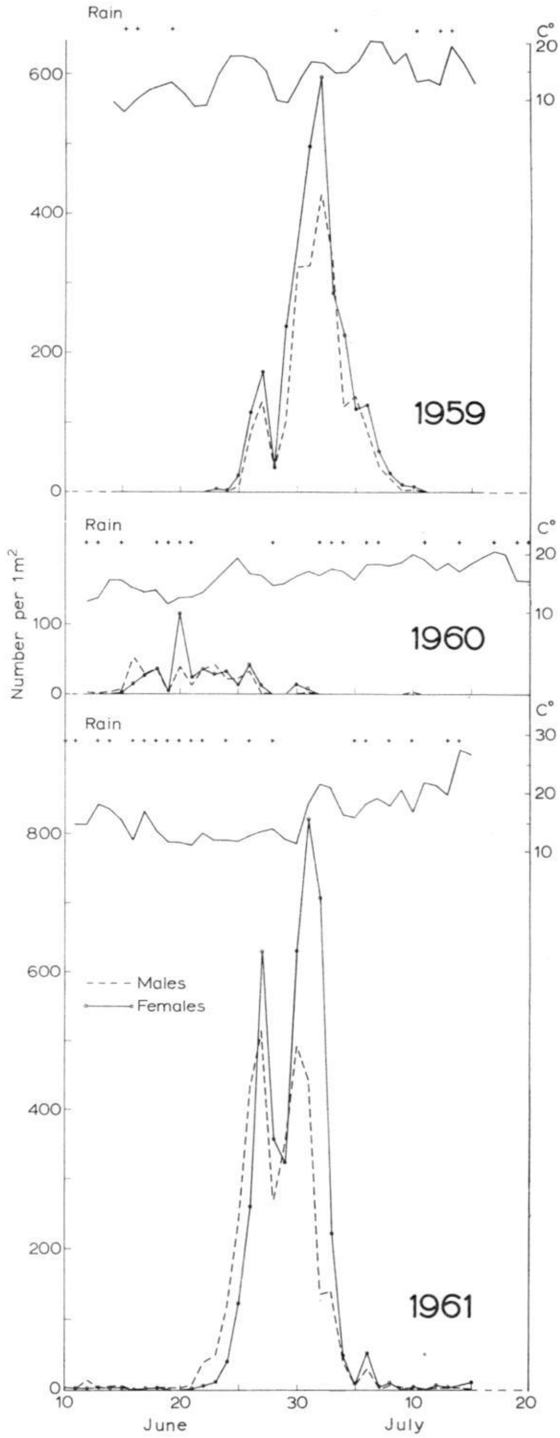

Figure 2. Emergence of *C. kanervoi* adults in the field at Nivala, 1959—1961.

Kuva 2. Timoteisääskien aikuistuminen päivittäin kesä—heinäkuussa 1 m²:n alalta v. 1959—1961 Nivalassa.

inspected daily between 6 p.m. and 8 p.m. The rainfall was measured at the research locality and temperature observations made at Reisjärvi Meteorological Station, about 25 kilometres from the research locality.

The emergence of *C. kanervoi* is shown in Fig. 2. Some emergence occurred at Nivala throughout almost the whole observation period each year, and it had obviously begun before the period of observation and continued subsequent to it. The majority of the population emerged within a short time, however, which varied between 14 and 16 days over the different years. At Laihia in 1958—1959, the values were 13 and 18 days. During the different years the main emergence began at Nivala around the period June 15—25. The emergence maxima occurred on June 20, 1960, July 1, 1961 and July 2, 1959. The day-to-day emergence of both males and females seemed to be rather sensitively dependent on the air temperature and the rainfall. Short periods of lower temperature and rain during the emergence period caused a considerable decrease in the number of midges emerging daily.

In order to compare the emergence times of males with those of females the data for each year were divided into three consecutive groups of about equal size (Table 1). It appears that in 1960 and 1961 in the first third of the emergence periods there were more males than there were in the second and last thirds. The year 1959 was exceptional. When the data of the different years are combined, it can be seen that the proportion of males was greatest in the first third of the emergence periods. The differences between the first third and the second ($\chi^2 = 68.58$***) and between the first and the last third ($\chi^2 = 91.78$***) are highly significant, but no real difference can be said to exist between the second and the last third ($\chi^2 = 2.02$).

The parasitic hymenoptera of *C. kanervoi* (cf. Barnes 1958) emerged both in the field at Nivala and in the laboratory at Vaasa towards the end of the emergence period of the midge.

E m e r g e n c e i n d i f f e r e n t t y p e s o f t i m o t h y f i e l d s. Timothy is grown for fodder, in which case it is cut at the beginning of July, and for seed, in which case it is cut at the beginning of August. Generally speaking, the purpose that the timothy ley is to serve is not finally decided until the haymaking season. The decision is primarily influenced by the success of the timothy crop and by the prices of fodder and seed. In 1959—1961, some of the funnels at Nivala were on leys from which timothy seed had been taken the previous year. Some of them were on timothy leys that had been cut for fodder the previous year but prior to that had been seed timothy. On the timothy leys that had been cut for fodder the midges that emerged the following year did not show a definite peak of emergence, unlike those that emerged in leys following seed timothy (Fig. 3). Very few midges emerged on leys from which timothy had been cut for fodder during the previous year, and those that did so emerged over a long period of time. The reason was presumably that in this type of ley there were no *C. kanervoi* larvae that

Table 1. The sex ratio of *C. kanervoi* in each of the three thirds of the emergence period at Nivala in 1959—1961
Taulukko 1. Timoteisääskikoiraiden osuudet kuoriutumisajan eri kolmasosissa Nivalassa vuosina 1959—1961

Year *Vuosi*	The three thirds of the emergence period — *Kuoriutumiskauden kolmasosat*								
	1.			2.			3.		
	Total *Yhteensä*	Males — *Koiraat* Number *kpl*	%	Total *Yhteensä*	Males — *Koiraat* Number *kpl*	%	Total *Yhteensä*	Males — *Koiraat* Number *kpl*	%
1959	4 815	2 105	43.7	5 532	2 257	40.8	4 830	2 259	46.8
1960	225	134	59.6	261	91	34.9	297	143	48.1
1961	2 557	1 463	57.2	2 424	1 117	46.1	2 729	824	30.2
1959—1961	7 579	3 702	48.7	8 217	3 465	42.2	7 856	3 226	41.1

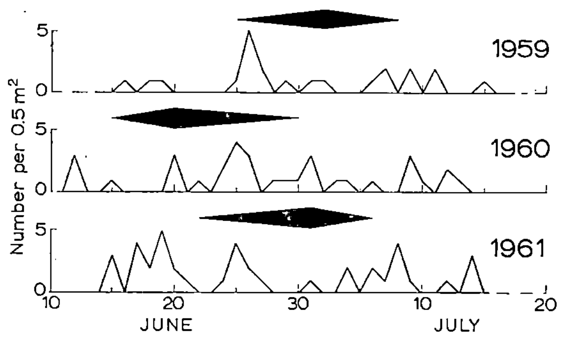

Figure 3. The emergence of *C. kanervoi* specimens that had probably been more than a year in diapause, in the field at Nivala, 1959—1961. The major emergence periods of specimens that had evidently been less than a year in diapause are marked out with rhombuses.

Kuva 3. Timoteisääsken todennäköisesti yli vuoden diapaussissa olleiden yksilöiden aikuistuminen 0.5 m²:n alalta kesä—heinäkuussa v. 1959—1961 Nivalassa. Vinoneliöillä merkitty ilmeisesti alle vuoden diapaussissa olleiden yksilöiden pääkuoriutumiskaudet.

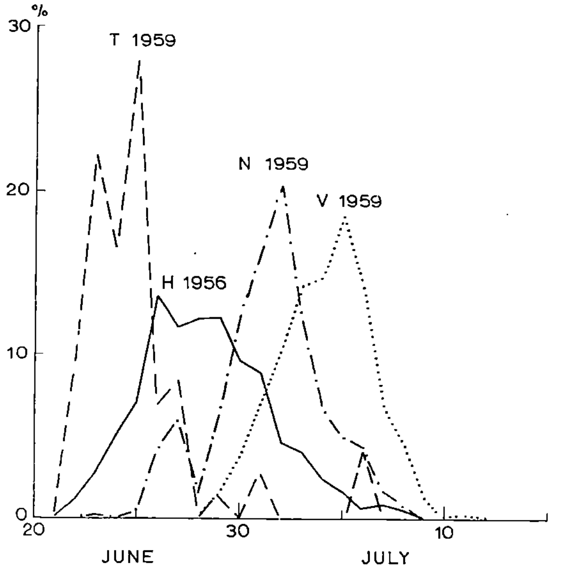

Figure 4. The emergence period of *C. kanervoi* in the insectary at Harpenden (H) 1956 (Barnes 1958, p. 63, altered), outdoors at Tikkurila (T) 1959, in the field at Nivala (N) 1959 and in the insectary at Vaasa (V) 1959. 1957 emerged at Harpenden, 72 at Tikkurila, 15177 at Nivala and 539 at Vaasa.

*Kuva 4. Timoteisääsken kuoriutumiskausi kesä—heinäkuussa Englannissa (H) insektaariossa 1956 (*Barnes *1958, s. 63, muutettu), Tikkurilassa (T) ulkona 1959, Nivalassa (N) kentällä 1959, ja Vaasassa (V) insektaariossa v. 1959. Englannissa kuoriutui 1957, Tikkurilassa 72, Nivalassa 15 177 ja Vaasassa 539 aikuista.*

had begun their diapause during the previous year, but only specimens that had been in diapause for more than a year and that had a long emergence period. From the fields used for seed timothy for at least the two preceding years some specimens (app. 2 %) of *C. kanervoi* emerged before and after the main emergence period, while from the fields that had been seed timothy for only one preceding year all the midges emerged during the main emergence period. These data likewise indicate that diapause may last more than one year and that there was an exceptionally long emergence period for that part of the population which had thus been in diapause for an unusually long time.

Emergence in different districts. The emergence period of *C. kanervoi* at different latitudes was clarified by transferring larvae in the year prior to emergence, from Nivala to south Finland (Tikkurila) and to the British Isles (Harpenden). The peat clods brought to Tikkurila were grown out-of-doors. The spot was covered with a funnel in the early summer, before the emergence period. The treatment of the material transferred to the British Isles is described in the paper by Barnes (1958). In addition to this, *C. kanervoi* material was taken at Laihia in the summer preceding emergence and transferred to Vaasa. In these experiments (Fig. 4) *C. kanervoi* emerged in south Finland about a week earlier than at Nivala. The midges belonging to the material kept in an insectary in the British Isles (Barnes 1958) emerged in 1956 about 4 days earlier than at Nivala in 1959, and in 1957 about 17—18 days earlier. The midges from the material near the seashore at Vaasa emerged about 3 days later than those at Nivala. The differences in emergence time are probably due to differences in temperature.

Sex ratio and copulation

Among the adult *C. kanervoi* that had been taken from Laihia as larvae and raised in an insectary at Vaasa there was a slight preponderance of females. A similar ratio was obtained with the material obtained from the funnels at

Table 2. The sex ratio of *C. kanervoi* adults from leys that had been grown for timothy seed the preceding year. In calculating χ^2, the expected sex ratio was 1 : 1

Taulukko 2. Edellisenä vuonna siementimoteina olleista nurmista kuoriutuneiden timoteisääskikoiraiden osuudet. Odotettu suhde 1 : 1

Year *Vuosi*	Place *Paikka*	Females — *Naaraat* Number — *kpl*	Males — *Koiraat* Number — *kpl*	%	χ^2
1958	Laihia	641	484	43	21.91***
1959	Laihia	273	266	49	0.09
1959	Nivala	8 541	6 610	44	246.11***
1960	Nivala	394	356	47	1.93
1961	Nivala	4 288	3 382	45	107.02***

Nivala (Table 2). More females than males have also been found in many other *Contarinia* species (BARNES 1958, p. 62). The sex ratio of the *C. kanervoi* specimens obtained from timothy at Nivala which had been cut for fodder the previous year and for timothy seed the year before that, may also have been female-dominated. It is true that only 45 males and 54 females were obtained from these leys. The sex ratio of the midges that had spent more than a year in diapause thus appears to be much the same as the sex ratio of those which had a diapause of less than a year.

According to observations made by Savas, copulation takes place almost immediately after emergence, usually on the lower leaves of the timothy, on the culm or on the ground.

Migration

After emergence, *C. kanervoi* specimens did not usually move over long distances but rose to the timothy in the vicinity where they emerged. The temperature, wind and air humidity all had a great influence on the activities of this species, as is the case with many other gall midges (e.g. FRÖHLICH 1960, p. 22). In windy weather *C. kanervoi* kept to the lower part of the vegetation, and there were often more midge eggs and larvae in the lower ears of the stand than in the upper ones. But if there was no timothy in the immediate vicinity of the site of emergence the imago would fly to timothy. In the evening in very calm weather Savas found *C. kanervoi* forming swarms in the same fashion as *Contarinia tritici* (Kirby) (WALLENGREN 1935, p. 20). The migrating midges were moving to timothy leys a few hundred metres distant. In leys of this type the number of midges was often greatest at the edges of the field.

The occurrence of adult and immature stages

The period of occurrence of adults was investigated at Laihia and Nivala by netting samples (60 sweeps each) taken from timothy at 3-day intervals. Judging from this material (Fig. 5)

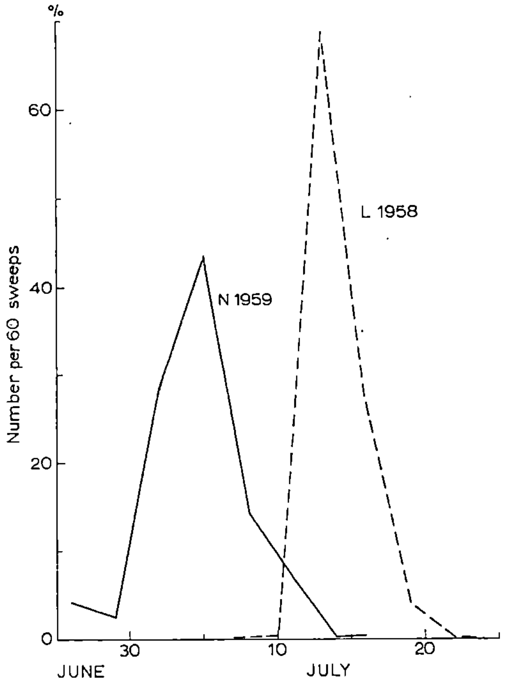

Figure 5. The number of *C. kanervoi* adults according to net samples at Laihia (L) 1958 and at Nivala (N) 1959. There were 18 900 imagos in the samples taken at Laihia, and 1 261 in those taken at Nivala.

Kuva 5. Timoteisääsken määrä kesä—heinäkuussa haavinvetoa kohden Laihialla (L) 1958 ja Nivalassa (N) 1959. Laihialta otetuissa näytteissä oli 18 900 ja Nivalasta otetuissa 1 261 aikuista.

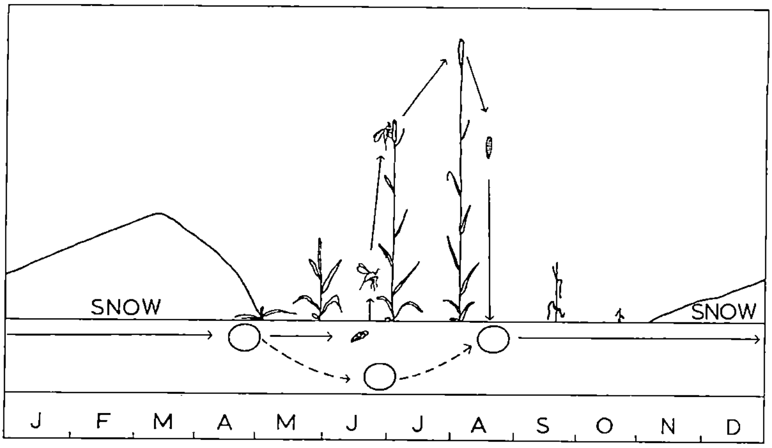

Figure 6. Diagrammatic presentation of the life cycle of *C. kanervoi*.
Kuva 6. Kaavamainen esitys timoteisääsken elämänkulusta.

C. kanervoi reached its maximum density immediately after the main emergence period (see Fig. 2). The life-span of the adults was very short, often only a couple of days, and they were not found taking in nutrition.

Oviposition usually took place in warm weather between 9 a.m. and 9 p.m. The female laid several dozen eggs at least and usually placed the eggs singly inside the glumes. The eggs were white and shiny, about 0.5 mm in length and 0.1 mm in breadth. The egg stage lasted about 4—5 days.

A single flower might carry from one to five larvae. Usually, however, there were only one or two larvae per flower. The larva may reach its full size, 1.4—1.5 mm in length and 0.5 mm in breadth, in about 3 weeks. In dry weather in 1959, however, there were larvae of small size as much as two months after oviposition.

The larvae leave the flowers rear end first, and fall to the ground. According to observations made at Laihia in 1957—1959, most of the larvae evidently left the panicles in the first half of August in moist weather. Having reached the soil the larva did not move away but dug into the surface layer of the soil where it fell, spun a cocoon around itself and spent the winter within it as a larva. According to observations made by Savas, pupation did not take place until the spring. *C. kanervoi* is univoltine (Fig. 6).

Distribution and abundance

Distribution

So far, *C. kanervoi* is definitely known only in Finland and Sweden (Barnes 1958, Vappula 1965, Raatikainen and Tinnilä 1967). There is also information from England regarding the occurrence of gall midges in timothy inflorescences (see Barnes 1958, p. 59). However, it has not been possible to identify the species. The distribution of *C. kanervoi* is presumably much wider than present information suggests.

In 1958, the Department of Pest Investigation requested that Agricultural Societies should send in timothy ear samples. It was requested that a sample of about 200 timothy ears should be taken and sent in between August 1—10, 1958. 205 samples were obtained from 115 communes. These samples revealed that *C. kanervoi* occurred in large numbers in 14 communes (Fig. 7). The species was found in altogether 34 communes. When Fig. 7 is compared with Fig. 8 it can be seen that *C. kanervoi* is most abundant in those areas where seed is chiefly grown.

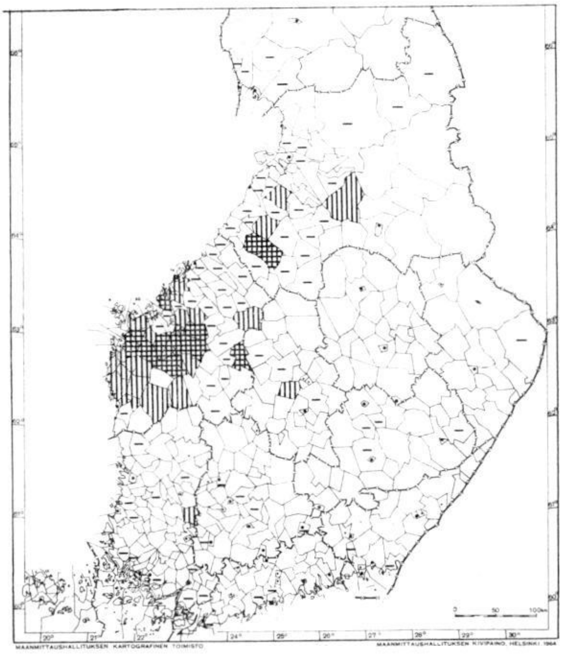

Figure 7. The abundance of *C. kanervoi* in 1958. Crosslines = more than 100 larvae per sample (200 ears), vertical lines = 1—100 larvae per sample, — = no larvae per sample.

Kuva 7. Timoteisääsken runsaus v. 1958. Ristiviivoitus = toukkia yli 100 kpl/näyte, pystyviivoitus = toukkia enintään 100 kpl/näyte, — = näytteessä tai näytteissä ei toukkia.

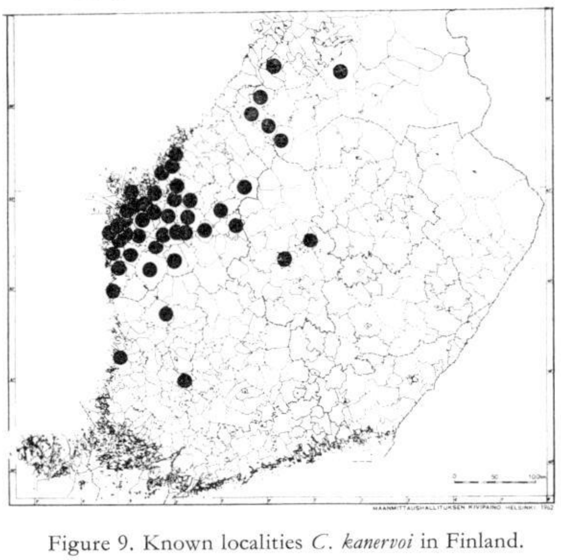

Figure 9. Known localities *C. kanervoi* in Finland.

Kuva 9. Timoteisääsken tunnettu levinneisyys Suomessa.

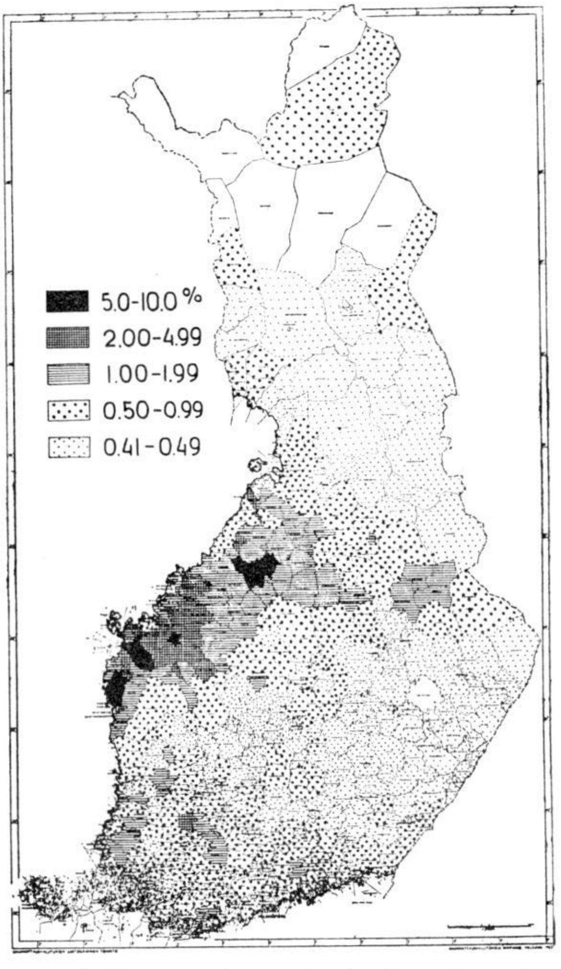

Figure 8. The area under crop for timothy seed according to VALLE (1962, p. 260). The acreage of seed leys expressed as percentages of arable land.

Kuva 8. Timotein siemenviljelyalueet VALLEn *(1962, s. 260) mukaan. Siemennurmien ala ilmaistu prosentteina peltoalasta.*

In 1959, a similar survey was made. On this occasion, however, the study was only concerned with west and central Finland, and it was requested that the samples should be sent earlier (July 17—25) than the previous year, because it was considered that the samples from 1958 had been taken too late. 200 samples were obtained from 98 communes. This survey, like the previous one, indicated a concentration of *C. kanervoi* in timothy seed-growing areas. In 1959, however, there were many fewer midges than during the previous year, and samples with a large number of *C. kanervoi* were obtained only from the communes of Ylistaro and Seinäjoki.

Fig. 9 shows the present known distribution of *C. kanervoi* by communes. The species has so far been encountered in the biogeographical provinces St, EP, PH, KP, Kn, in 46 communes altogether.

Abundance

Apparently the earliest report of an outbreak of *C. kanervoi* larvae came from Ylistaro in 1892 (REUTER 1901, p. 30). In 1899, *C. kanervoi* was abundant in at least 9 communes (REUTER 1900, p. 105, and 1901, pp. 28—30). The next record of the occurrence of the midge is from 1939, when it was found in at least 2 communes (VAPPULA 1965). In 1948, a report of *C. kanervoi* was received from one commune, and in 1955—1959 it was abundant in some of the communes of south and central Ostrobothnia (VAPPULA 1965). All the above records of *C. kanervoi* centre around the same region on the west coast of Finland, where the species was also abundant in 1958 (see Fig. 7).

The variation in abundance between different areas during one year, and within one area during different years, was very great. The most important reason for the spatial variation in abundance is probably the ratio of the area under crop for timothy seed to the total timothy area. Where timothy is grown for fodder it is cut at the end of the midge's oviposition period, and the small larvae in the panicles are destroyed, whereas where timothy is grown for seed it is not cut until August. At that time great numbers of *C. kanervoi* larvae have already had time to fall to the ground. Timothy is grown in south and central Ostrobothnia, usually for 3 or 4 years consecutively, and sometimes for 7 or 8 years, in the same field without tilling. In these conditions the larvae have an excellent opportunity to survive until the following year.

There is very little information regarding the causes of the variation in abundance from year to year. In the summer of 1959, it was found that the prolonged drought was very destructive to the larvae of the species. At the Vaasa meteorological station, for example, the rain in June was only 32 % and in July 52 % of the averages for the corresponding months (1921—1950), these averages being 53 and 56 mm respectively. The average temperatures were, respectively, 1.7° and 0.2°C higher than the average temperatures of these months in 1921—1950. Thus the relative humidity was 61 in June, 64 in July and 74 as late as August. Evidently, the *C. kanervoi* larvae remained small as a result of the drought and were largely destroyed in the ears. The drought was probably the primary factor that decreased the abundance of *C. kanervoi*, until by 1960 it was very scanty. In 1960, the humidity in June, July and August was fairly normal, and the midges increased and survived well. The following year they occurred again in relatively large numbers. This can also be seen from the material collected at Nivala (Fig. 2). 5050 *C. kanervoi* specimens per m² were obtained there in 1959 from funnels on timothy leys used for seed growing for at least one preceding year; there were 750 per m² in 1960 and 7670 in 1961.

Enemies also affect the numbers of *C. kanervoi*. In 1958, for instance, 250 midges and 177 hymenoptera emerged from a larval sample taken at Kauhava. The percentage of parasites was consequently 40. To what extent enemies are able to affect the variations in abundance of *C. kanervoi* is not known, however.

Diagnostic character and damage

Diagnostic character

In timothy flowers that are damaged by *C. kanervoi* larvae the ovary and often the whole gynoecium wrinkles and withers. The stamens, however, often appear to be undamaged. It is very difficult to spot the damaged flowers while the ear is young. After flowering, the difference is already noticeable. The damaged flowers do not shed their stamens, and they remain puckered, not opening as do the healthy spikelets which will produce seed. When the seeds mature, the ears become variegated. At this stage the orange-coloured larvae of *C. kanervoi* are usually visible enough to be spotted from outside (Fig. 10). Parasitic hymenoptera also very often occur on the ears damaged by *C. kanervoi*.

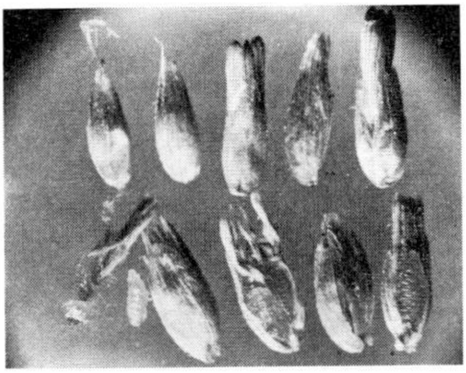

Figure 10. *C. kanervoi* larvae in timothy spikelets. At top right 2 healthy spikelets. Photo by O. Heikinheimo.

Kuva 10. Timoteisääsken toukkia timotein tähkylöissä. Oikealla ylhäällä kaksi tervettä tähkylää. Valok. O. Heikinheimo.

Damage

The loss caused to the timothy seed crop by *C. kanervoi* is sometimes considerable, but at other times the losses are apparently negligible. REUTER (1900, p. 30), for instance, mentions that in 1899 the crop loss on several farms was 85 %. In 1957—1959, there were several crop losses of more than 50 % in the Vaasa region. In 1957, one farmer living in Mustasaari obtained only about 20 % of the seed crop of the previous year. In his timothy seed fields the damage caused by the midge amounted to over one million old Finnish marks (well over $ 3 000), the price being reckoned at 130 marks per kilogram. Similar losses were caused by *C. kanervoi* in the commune of Nivala in Central Ostrobothnia during the same years.

To the private farmer the crop losses caused by *C. kanervoi* are on occasion economically a great blow. During the seasons of crop loss the damage occurs over a large area, and the losses consequently affect the purchases of seed buyers, and may even be felt on a nation-wide scale. Beginning with the postwar period the sales of timothy seed increased fairly steadily. But from 1955 to 1958, a steady decline could be perceived (see NUORTEVA 1959, p. 29), evidently in part due to the crop losses caused by *C. kanervoi*. This decline is seen even more clearly in the amount of timothy seed purchased from the farmers by the co-operative Nivalan osuuskauppa, which is located in an area where damage has been severe. This firm is the chief purchaser of timothy seed in the commune. From 1955 on, when *C. kanervoi* occurred in great numbers in the district, the amount of seed purchased was small for several years. In 1959 and 1960, the crop losses caused by the midge were slight. The land cultivated, the crops per hectare and the amounts of seed purchased increased in the following manner:

Year	Amount of timothy seed bought by the Nivala co-operative firm, kg
1954	109 591
1955	175 503
1956	24 412
1957	20 322
1958	54 200
1959	97 880
1960	85 568

Control

Control by cultivation technique

Delayed earing of timothy. The peak of abundance of *C. kanervoi* imagos lasts a very short time each year (Figs. 2 and 5). In theory, it would seem possible to delay the earing of a ley intended for seed timothy so much that most of the timothy reached the earing stage only when the peak of *C. kanervoi* had been passed. In 1959, experiments on cutting time were carried out at Nivala on ley that had been seed timothy the previous year. The effects of the cutting times upon earing time were studied. One of the trial plots was cut on June 2 to 10 cm stubble with a mowing machine, and the second trial plot on June 9 to the same height of stubble. When earing of the timothy began on June 26, however, there were no notable differences between the trial plots. The same must be said regarding the occurrence of *C. kanervoi* larvae. A 200-ear

Table 3. The number of *C. kanervoi* specimens that emerged in different types of timothy leys at Nivala. ST = seed timothy, FT = fodder timothy, T = timothy for unknown use, and C = cereal

Taulukko 3. Nivalassa erilaisista timoteinurmista kuoriutuneiden timoteisääskiaikuisten määrät. ST = siementimotei, FT = rehutimotei, T = timotei, jonka käytöstä ei tietoa ja C = vilja

Year *Vuosi*	Cloth funnels *Kangas-pyramideja*	Previous crop on field *Lohkon esikasvit*				Total *Yhteensä*		*C. kanervoi* per 0.5 m² *Timoteisääskiä 0.5 m²*
		1957	1958	1959	1960	Males *Koiraat*	Females *Naaraat*	
1959	4	ST	ST			5 360	6 672	3 008
»	1	C	ST			162	187	389
»	2	ST	FT			11	15	13
1960	2	C	ST	ST		356	394	375
»	1	ST	ST	FT		12	21	33
1961	2		C	ST	ST	3 382	4 288	3 835
»	1			ST	FT	22	18	40

sample from the first trial plot contained 87 larvae, a similar sample from the second trial plot contained 75 larvae, and the one from the control plot had 77 larvae.

D e c r e a s i n g t h e n u m b e r o f t i m o t h y s e e d c r o p f i e l d s. The abundance of *C. kanervoi* (Figs. 7 and 9) and the observations made at Nivala and in the vicinity of Vaasa indicated that this pest reached an economically harmful level when a considerable proportion of the timothy fields were continuously harvested for seed (Fig. 8).

The cutting of timothy for fodder has a decisive effect upon the numbers of *C. kanervoi*. Some of the cloth funnels were placed on fields that had been established at the same time but had been grown for seed for varying lengths of time. The results (Table 3) indicated that the number of midges emerging in the old timothy ley which had been cut for fodder the previous year was only 1 % (0.4 — 8.8 %) of the number in the old timothy ley that had been left for a seed crop the previous year. The same material (1959) also seems to indicate that a timothy ley which has been a seed crop for only one year will have a smaller number of midges than a ley which has been a seed crop for two or more years in succession.

Chemical control

To develop a method for the chemical control of *C. kanervoi* three different field experiments were carried out at Nivala in 1958. Each of the trial plots was a strip (6—16 ares), and the leys were 1—4 years old. The control treatments were carried out on July 11—14, when there were many *C. kanervoi* on the trial plots. The timothy was threshed on September 10—29 and the crop weighed. The results of the experiments are shown in Tables 4—6.

In 1959, the trials were carried out on timothy ley grown for seed for the second year in succession. The treatment was carried out with a

Table 4. *C. kanervoi* control trial in first-year timothy at Nivala 1958. Size of plots 9 × 67 metres. Treatment applied July 11, amount of liquid 200 litres per hectare or amount of dust 10 kg per hectare

Taulukko 4. Timoteisääsken torjuntakoe ensimmäisen vuoden timoteissa Nivalassa 1958. Ruutujen koko 9 × 67 m. Käsittely suoritettiin 11. 7., nestemäärä 200 l/ha ja pölytemäärä 10 kg/ha

Treatment (Product) *Koejäsen*	No. of trial plots *Koeruutuja*	Seed crop — *Siemensato* kg/ha	Relative values *Suhdeluku*
Parathion spray 35 % (Bladan E 605), 0.25 litre a.i. per ha *Parationiruiskute 35 %, 0.25 l tehoainetta/ha*	3	389	135
Parathion dust 2.5 % (Wofatox) 0.25 kg a.i. per ha *Parationipölyte 25 % 0.25 kg tehoainetta/ha*	1	355	123
Untreated — *Käsittelemätön*	3	289	100

Table 5. *C. kanervoi* control trial in third-year timothy at Nivala 1958. Size of plots 8 × 176 m. Treatment given on July 12, amount of liquid 200 litres per hectare

Taulukko 5. Timoteisääsken torjuntakoe kolmannen vuoden timoteissa Nivalassa 1958. Ruutujen koko 8 × 176 m. Käsittely suoritettiin 12. 7., nestemäärä 200 l/ha

Treatment (Product) *Koejäsen*	No. of trial plots *Koe-ruutuja*	No of *C. kanervoi* per 60 sweeps, July 13 *Sääskiä 13. 7. 60 haavinvedon näytteessä*	Seed crop — *Siemensato* kg/ha	Relative value *Suhdeluku*
Methyldemethone spray 50 % (Metasystox), 0.5 litre a.i. per ha — *Metyldemetoniruiskute 50 %, 0.5 l tehoainetta/ha*	1	112	638	123
Malathion spray 50 % (Bernerin Malation), 1 kg a.i. per ha — *Malationiruiskute 50 %, 1 kg tehoainetta/ha*	1	28	628	121
DDT dust 5 % (Täystuho H), 0.5 kg a.i. per ha *DDT-pölyte 5 %, 0.5 kg tehoainetta/ha*	1	213	542	104
Trichlorphone spray 50% (Dipterex), 0.5 litre a.i. per ha *Triklorfoniruiskute 50 %, 0.5 l tehoainetta/ha*	1	1 243	512	99
Malathion dust 4% (Liro-Malation), 0.6 kg a.i. per ha *Malationipölyte 4 %, 0.6 kg tehoainetta/ha*	1	40	506	98
Untreated — *Käsittelemätön*	2	1 990	519	100

Table 6. *C. kanervoi* control trial in fourth-year timothy at Nivala 1958. Size of plots 10 × 166 m. Treatment given July 14, amount of liquid 200 litres per hectare

Taulukko 6. Timoteisääsken torjuntakoe neljännen vuoden timoteissa Nivalassa 1958. Ruutujen koko 10 × 166 m. Käsittely suoritettiin 14. 7., nestemäärä 200 l/ha

Treatment (Product) *Koejäsen*	No. of trial plots *Koeruutuja*	Seed crop — *Siemensato* kg/ha	Relative values *Suhdeluku*
Malathion dust 4 % (Liro-Malation), 0.4 kg a.i. per ha *Malationipölyte 4 %, 0.4 kg tehoainetta/ha*	1	565	111
Malathion dust 4 % (Liro-Malation), 0.8 kg a.i. per ha *Malationipölyte 4 %, 0.8 kg tehoainetta/ha*	1	557	109
Untreated — *Käsittelemätön*	2	511	100

50 % malathion spray (1 litre of active ingredient per hectare) and a 4 % malathion powder (1 kg of active ingredient per hectare). The treatments were given between June 25 and July 3, before the peak of abundance of the *C. kanervoi* (see Fig. 2). The timothy began to ear about June 26. Larvae of *C. kanervoi* were present in very small numbers, and there were no distinct differences between the crops of the different trial plots.

Discussion

Because the damage caused by *C. kanervoi* is severest in those places where a large part of the timothy leys are left for seed crop, control by cultivation technique is possible. If, in areas where *C. kanervoi* is a scourge the ley is cut for hay one year, the number of midges will decline to about one hundredth of what it would be if seed were taken from all the leys. Subsurface drainage and the cutting of the timothy at the edges of the fields would also reduce the number of midges. There may be cause to make experiments with deferred earing as a control method, in spite of the fact that no positive results were obtained here.

The control trials revealed that *C. kanervoi* adults can be destroyed with malathion, parathion and methyldemethone sprays. Malathion and parathion dusts also had a satisfactory effect. In contrast, the effect of DDT and trichlorphon preparations was rather weak. The young larvae of *C. kanervoi* are well sheltered inside the timothy flower, and at this stage control is consequently difficult. There can be no question of destruction of larvae in the soil. The chemical protection of the seed crop must be carried out when the adults start oviposition. The most advantageous result is evidently obtained with a single treatment performed just before the peak of abundance is reached. If there are two treatments, the first should be carried out about one or two days after the timothy has eared and the second approximately 5—7 days later (see TINNILÄ 1959). Control of the midge cannot be combined with that of the timothy flies (*Amaurosoma flavipes* Fall. and *A. armillatum* Zett.), because timothy flies must be destroyed about three weeks earlier than *C. kanervoi* (see BORG 1959, RAATIKAINEN 1963).

Summary

Contarinia kanervoi Barnes (*Dipt.*, *Itonididae*), known as a pest on timothy seed, has so far been definitely found only in Finland and Sweden. The investigations presented here on the bionomics, damage and control of the species were carried out in Finland from 1957 to 1961.

At a latitude of 64 degrees the *C. kanervoi* imagos emerged early in the morning, 93 % of the males and 72 % of the females emerging before 11 a.m. Emergence took place over a period of at least 37 days, but the major emergence period lasted only two weeks. In the years 1959—1961 the major emergence period began on June 15—25, and maximum emergence occurred between June 20 and July 2. At a latitude of 60 degrees midges of the same population emerged in trial conditions approximately one week earlier. In the British Isles in 1956 and 1957 they emerged about 4—18 days earlier than they did at a latitude of 64 degrees. On leys that had been seed timothy the preceding year 750—7670 specimens of *C. kanervoi* per m^2 emerged in the different years. More females emerged than males, and in the largest sample, for example, the percentage of males was 44.

The midges migrated to nearby fields of timothy where, inside the glumes, they laid dozens of eggs at least. The eggs hatched in 4 or 5 days. The larvae reached full size in about 3 weeks. They fell to the ground in the first half of August, hibernated in the soil, and pupated the following spring.

Specimens of *C. kanervoi* were found in 46 communes in Finland. Their abundance was influenced by the prevalence of timothy seed cultivation and by weather conditions, and also by natural enemies to some extent. When it occurred in great numbers, the species caused considerable crop losses in timothy seed fields.

Preliminary experiments on the control of *C. kanervoi* reveal that an effective control method is to refrain from growing timothy to the seed stage in the same clearing in consecutive years. Suitable plant protection chemicals are malathion, parathion and methyldemethone, used as sprays. The treatment must be carried out just before the peak of abundance of *C. kanervoi*.

Acknowledgements. — In carrying out this investigation we have received valuable advice from Professor Veikko Kanervo and Dr. Martti Markkula. Farmers Matti Korri of Nivala and Onni Berg of Laihia have assisted in the gathering of the samples and Mrs. Kaisa-Liisa Mäkinen, hortonomist, and Miss Liisa Humala in examining this material. We wish to express our deepest gratitude to all the above persons.

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SELOSTUS

Timoteisääsken bionomiasta, vioituksesta ja torjunnasta

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Timoteisääski (*Contarinia kanervoi*) aiheutti timotein siemenviljelyalueillamme pahoja tuhoja 1890- ja 1950-luvun lopussa. Laji on löydetty vain Suomesta ja Ruotsista. Sääsken bionomian ja torjunnan pääpiirteet selvitettiin v. 1957—1961 Nivalassa, Laihialla ja Vaasassa.

Kuvassa 1 esitettyjä suppiloita käyttäen selvitettiin aikuisten kuoriutumiskausi Nivalassa v. 1959—1961. Pääkuoriutumiskausi alkoi 15.—25. 6. ja sitä kesti kaksi viikkoa (kuva 2). Koiraat kuoriutuivat aikaisemmin kuin naaraat, ja niitä oli yleensä vähemmän kuin naaraita (kuva 2 ja taul. 1—2). Pääosa sääskistä oli diapausissa alle vuoden, mutta muutamien diapausi kesti ilmeisesti yli vuoden (kuva 3). Tikkurilassa sääsket kuoriutuivat noin viikkoa aikaisemmin ja viileähkön rannikon läheisyydessä Vaasassa noin 3 vrk. myöhemmin kuin Nivalassa (kuva 4). Aikuisten elinaika oli lyhyt, ja niitä oli timoteissa vain noin parin viikon aikana (kuva 5).

Aikuistuttuaan sääsket hakeutuivat timoteihin ja munivat päivisin timotein kukkiin. Toukkien vioittamien kukkien sikiäin ja usein koko emiö surkastui eikä muodostanut siementä. Toukat kasvoivat kolmessa viikossa noin 1.5 mm:n pituisiksi ja pudottautuivat maahan elokuun alkupuoliskolla. Ne kaivautuivat putoamispaikalla maan pintakerrokseen ja kutoivat ympärilleen kehdon, jossa viettivät talven. Koteloituminen tapahtui vasta keväällä (kuva 6).

Timoteisääskeä oli runsaimmin alueilla, joilla timotein siemenviljelyksiä oli eniten (vrt. kuvat 7 ja 8). Laji on löydetty 46 pitäjästä (kuva 9). Kun timotei niitetään rehuksi kukissa olevat toukat kuolevat. Mitä suurempi osa timoteista jää siemeneksi sitä suurempi osa sääskistä jää eloon. Sääskiä kuoriutui v. 1959 5 050 kpl/m^2, mutta näiden toukat jäivät ilmeisesti kuivuuden takia pieniksi ja suuri osa niistä kuoli tähkissä. Seuraavana vuonna aikuisia kuoriutui vain 750 kpl/m^2 (taul. 3). Loispistiäiset vaikuttivat myös lajin runsauteen.

Sääski aiheutti 1950-luvun lopulla useissa siemennurmissa yli 50 %:n sadon alennuksia, ja kauppojen saamat timotein siemenmäärät jäivät tuhokausina pieniksi.

Tehokas torjuntakeino on luopuminen timotein siemenen otosta perättäisinä vuosina samalla viljelyaukealla. Rehuksi niitetyiltä lohkoilta aikuistui sääskiä seuraavana vuonna vain 1 % siemeneksi jätettyjen nurmien sääskimääristä (taul. 3). Malationi-, parationi- ja metyylidemetoniruiskutukset ovat myös käyttökelpoisia torjuntatapoja (taul. 4—6). Käsittely on suoritettava kesäkuun lopulla juuri ennen sääsken kuoriutumiskauden huippua (kuva 2).

ANNALES AGRICULTURAE FENNIAE, VOL. 6: 159—173 (1967)
Seria AGRICULTURA N. 27 — Sarja KASVINVILJELY n:o 27

SVENNO-KEVÄTVEHNÄ SUOMEN OLOSUHTEISSA

Summary: **Svenno spring wheat under Finnish conditions**

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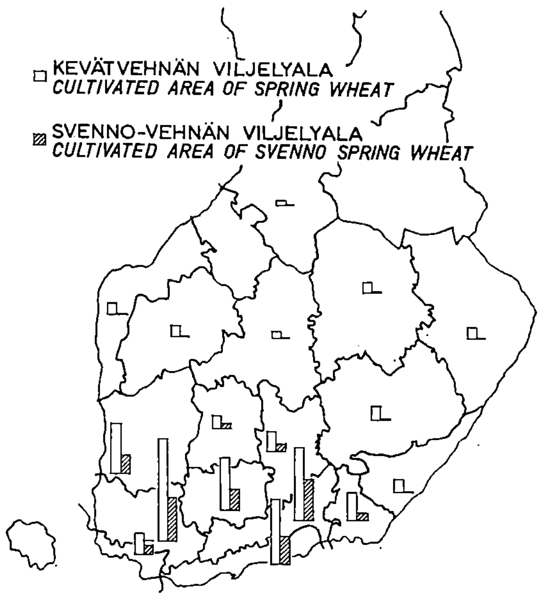
Weibullsholmin Svenno-kevätvehnän tullessa kauppaan 1954, samaan aikaan kun leikkuupuinti oli yleistymässä, siihen kiinnitettiin suuria toiveita nimenomaan leikkuupuintilajikkeena. Se polveutuu meilläkin viljellystä Kärni (Kärn II) -vehnästä. Svennon viljelyalan laajeneminen Suomessa oli huomattavan nopeaa, kuten Maatalous-hallituksen keräämistä tilastotiedoista ilmenee (taul. 1): 1955 2 %, 1960 14 % ja 1965 35 % kevätvehnän viljelyalasta. Svenno korvasi nopeasti Kärni-vehnän, jonka viljelylaajuus 1955 oli 12 % koko kevätvehnäalasta (Anon. 1966).

Svenno-vehnän viljely on sen pitkän kasvuajan takia keskittynyt Etelä-Suomeen (kuva 1). Valtalajikkeena se on Uudenmaan, Uudenmaan ruotsalaisen, Varsinais-Suomen ja Hämeen läänin maanviljelysseurojen sekä Suomen Talousseuran alueilla. Keskimäärin 45 % (61 500 ha) vehnävainioista kasvoi kesällä 1965 Svenno-vehnää

Taulukko 1. Eräiden kevätvehnälajikkeiden yleisyys Suomessa vuosina 1955, 1960 ja 1965
Table 1. Cultivated area of some spring wheat varieties in 1955, 1960 and 1965 in Finland

Lajike *Variety*	Viljelyala — *Cultivated area* 1955 1 000 ha	1955 %	1960 1 000 ha	1960 %	1965 1 000 ha	1965 %
Timantti — *Diamond*	28.9	27.8	9.9	6.9	14.9	6.9
Timantti II — *Diamond II*	26.0	25.0	16.2	11.3	10.4	4.8
Svenno	1.6	1.5	20.0	13.9	76.4	35.3
Apu	11.3	10.9	63.1	43.9	59.5	27.5
Norröna	—	—	17.2	12.0	31.0	14.3
Ring	—	—	—	—	1.7	0.8
Kärni — *Kärn II*	12.5	12.1	1.1	0.8	0.2	0.1
Kevätvehnän ala ha — *Total spring wheat area ha*	103 800		143 700		216 500	
Osuus peltoalasta % — *Percentage of total field area*	4.5		5.4		7.9	



Kuva 1. Kevätvehnän koko viljelyala ja Svenno-vehnän viljelyala maanviljelysseuroittain 1965.
Figure 1. Cultivated area of spring wheat and of Svenno spring wheat in different Agricultural Associations in 1965.

tällä maamme parhaalla vehnänviljelyalueella. Tämä vastasi 70 %:a Svennon koko viljelyalasta.

Svenno-vehnän viljelyalan kehitys vuodesta 1960 vuoteen 1965 oli maanviljelysseuroittain seuraava (ANON. 1963, 1966):

Maanviljelysseura	1960 % kevätvehnän viljelyalasta	1960 1 000 ha:a	1965 % kevätvehnän viljelyalasta	1965 1 000 ha:a
Uudenmaanläänin	22	3.8	55	17.5
Nylands Svenska	18	3.8	42	12.1
Varsinais-Suomen	22	5.8	42	19.0
Suomen Talousseura	42	2.8	43	3.8
Satakunnan	10	1.1	31	6.6
Hämeen-Satakunnan	12	0.5	32	1.5
Hämeen läänin	10	1.4	40	9.1
Itä-Hämeen	7	0.4	32	2.7
Kymenlaakson	6	0.5	20	2.3
Länsi-Karjalan	2	0.1	9	0.4
Mikkelinläänin	1	0.0	5	0.3
Etelä-Suomi	14	18.4	39	75.2
Keski-Suomi	1	0.2	1	0.2

Svenno-vehnän viljely on laajentunut pohjoiseen suuntaan. Huomiota kiinnittää erityisesti sen yleistyminen Satakunnan ja Itä-Hämeen maanviljelysseurojen alueilla, jotka ovat sijaintinsa puolesta Svenno-vehnän viljelyn äärialueita. Tästä huolimatta Svennon viljely oli 1965 varsinkin Satakunnan maanviljelysseuran alueella huomattavan laajaa.

Svenno-kevätvehnä on ollut Suomessa lajikekokeissa mukana vuodesta 1950 lähtien. Tässä tutkimuksessa tarkastelemme niitä koetuloksia, joita Svennosta on saatu vuosina 1950—65 niillä koepaikoilla, jotka sijaitsevat sen pääasiallisimmalla viljelyalueella Etelä-Suomessa.

Käytetty koeaineisto

Koeaineisto käy selville taulukoista 2 ja 3. Tutkimus käsittää seitsemän tutkimuslaitosta ja koeasemaa (taul. 2). Nämä ovat Kasvinviljelylaitos (Tikkurila), Kasvinjalostuslaitos (Jokioinen), Hankkijan kasvinjalostuslaitos Tammisto (Helsingin pitäjä) sekä Lounais-Suomen (Mietoinen), Satakunnan (Peipohja), Karjalan (Anjala) ja Hämeen (Pälkäne) koeasemat. Lounais-Suomen koeaseman tuloksiin sisältyy myös Puutarhantutkimuslaitoksen (Piikkiö 1952—58) ja Lounais-Suomen liikkuvan koetoiminnan (1955—58) tuloksia koeasemaa edeltäneeltä ajalta. Kokeiden lukumäärä vaihtelee eri vuosina, koska kaikilla koeasemilla Svenno-vehnä ei joka vuosi ole ollut mukana kokeissa, joillakin paikoin taas tällaisia lajikekokeita on ollut samana vuonna useita. Mikäli jossakin kokeessa Timantin (Svalöf) ja Svennon lisäksi on ollut mukana Apu (Jokioinen), Norröna (norjalainen) tai Ring (Weibullsholm) -lajikkeet, on myös näiden tuloksia käytetty hyväksi Svenno-vehnän ominaisuuksia arvosteltaessa.

Edellä mainittujen koepaikkojen lisäksi Svenno-vehnä on vuodesta 1954 lähtien ollut Paikalliskoetoimiston lajikekokeissa Etelä-Suomessa. Tätä laajaa neuvontajärjestöjen käytännön viljelyksillä suorittamista kokeista saatua aineistoa tarkastellaan seuraavassa muiden tuloksien

Taulukko 2. Eräiden tutkimuslaitosten ja koeasemien Svenno-vehnää sisältäneiden lajikekokeiden lukumäärä 1950—65
Table 2. Number of variety trials with Svenno spring wheat at some experimental institutions and stations 1950—65

Koepaikka *Locality*	Kokeiden luku — *Number of trials*																Yhteensä *Total*
	1950	-51	-52	-53	-54	-55	-56	-57	-58	-59	-60	-61	-62	-63	-64	-65	
Tikkurila	1	1	1	1	—	1	1	1	1	1	1	1	1	1	1	2	16
Tammisto	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	1	18
Jokioinen	1	—	1	1	1	1	1	1	1	1	1	2	1	2	3	2	20
Mietoinen	—	—	1	1) 1	1) 1	1) 4	1,2) 3	1,2) 6	1,2) 2	1,2) 2	3	3	3	2	2	2	35
Peipohja	—	—	—	1	1	1	1	1	1	1	1	2	2	2	4	2	20
Anjala	—	—	—	1	1	1	1	1	—	—	—	—	—	—	—	—	5
Pälkäne	—	—	1	1	1	1	1	1	1	1	1	1	2	2	2	2	18
Kokeita yht. — *Total trials*	3	2	5	7	6	10	9	12	7	7	8	10	10	10	15	11	132

1) Puutarhantutkimuslaitoksen (Piikkiö) tuloksia — *Results from the Department of Horticulture, Piikkiö*
2) Lounais-Suomen liikkuvan koetoiminnan tuloksia — *Results from S.W. Finland Movable Field Experiments*

Taulukko 3. Kevätvehnälajikkeiden esiintyminen paikalliskokeissa Etelä-Suomessa vuosina 1954—64
Table 3. Spring wheat varieties in trials of Bureau for local experiments in South Finland, 1954—64

Vuosi *Year*	Kokeiden luku — *Number of trials*				
	Timantti *Diamond*	Svenno	Apu	Norröna	Ring
1954	12	8	3	—	—
—55	15	10	15	—	—
—56	8	8	4	2	—
—57	15	14	11	8	—
—58	13	9	8	11	—
—59	24	14	21	24	—
—60	24	24	22	24	—
—61	30	20	21	24	—
—62	38	35	24	11	—
—63	43	40	15	22	19
—64	39	29	12	25	13
Kokeita yht. — *Total trials*	261	211	156	151	32

ohessa. Koska kysymyksessä on suuri aineisto, on kasvuaikoja verrattaessa voitu menetellä siten, että on laskettu jokaiselle lajikkeelle keskiarvotulos kaikista Etelä-Suomessa suoritetuista kokeista, joissa lajike on ollut mukana riippumatta siitä, onko kokeeseen sisältynyt Svenno-vehnää. Satotulokset eri lajikkeista esitetään kuitenkin mittariin verrattuna samoista kokeista. Tätä koeaineistoa selventää taulukko 3.

Kasvukausien 1950—65 lämpö- ja sadeolot

Eri koepaikoilla kasvukausina 1950—65 vallinneet lämpö- ja sadeolot käyvät selville taulukosta 4.

Huomio kiintyy lähinnä normaalista eniten poikkeaviin kasvukausiin. Lämpösuhteiltaan epäedullisimpia ovat olleet kasvukaudet 1952, 1956, 1958 ja 1962. VALLEN (1958, 1962, 1966) mukaan nämä vuodet ovatkin olleet viljanviljelyn kannalta epäsuotuisia. Niinpä kasvukausi 1952 oli kolein 25 vuoteen; myöhäiset viljalajikkeet jäivät silloin kokonaan tuleentumatta. Kasvukautena 1956 heinä-, elo- ja syyskuu olivat 1—2°C nor-

Taulukko 4. Kasvukausien (touko-syyskuun) 1950—65 keskilämpötilojen ja sademäärien poikkeamat normaalista

Table 4. Mean temperature and rainfall in the period May-Sept. in 1950—65, expressed as deviations from normal

	Leveys-aste *Lat.*	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	Normaali *Normal* 1931—60
		Keskilämpötilan poikkeama normaalista °C *Deviation of mean temperature from normal, °C*																
Tikkurila	60° 18′	—0.1	—0.2	—1.6	+0.2	+0.2	+0.4	—1.1	—0.5	—1.0	+0.4	—1.3	±0.0	—1.8	+1.4	—0.3	—0.7	13.3
Tammisto	60° 17′	—0.1	—0.2	—1.4	+0.4	+0.4	+0.6	—0.9	—0.3	—0.8	+0.8	+0.9	—0.1	—1.8	+1.4	—0.2	—0.6	13.0
Jokioinen	60° 44′	+0.2	—0.2	—1.5	+0.4	+0.2	+0.3	—0.9	—0.6	—0.8	+0.5	+0.8	—0.1	—1.8	+1.4	+0.1	—0.8	12.6
Mietoinen [1]	60° 38′	+0.3	±0.0	—1.3	+0.4	+0.1	+0.3	—0.8	—0.1	—0.8	+0.4	+0.6	—0.1	—1.8	+1.2	—1.0	—0.8	13.2
Peipohja	61° 17′	+0.3	—0.2	—1.3	+0.5	+0.4	+0.1	—0.7	—0.8	—0.7	+0.3	+0.9	+0.1	—1.6	+1.1	—0.4	—0.6	12.7
Anjala	60° 42′	—0.2	—0.3	—1.4	—0.1	+0.3	±0.0	—1.2	—0.5	—1.1	±0.0	+0.5	—0.1	—1.9	+1.1	—0.7	—1.1	13.2
Pälkäne	61° 20′	—0.2	—0.7	—1.7	—0.1	—0.1	±0.0	—1.0	—0.8	—1.0	+0.3	+0.7	+0.1	—2.0	+1.0	—0.7	—0.8	13.1
		Sademäärän poikkeama normaalista mm *Deviation of rainfall from normal, mm*																
Tikkurila		—36	—118	+69	+ 98	+145	—27	+71	+119	—45	—134	+133	+ 4	+128	—32	—108	+31	304
Tammisto		—29	—109	+69	+ 79	+123	—89	+75	+ 83	—27	—125	+120	+ 75	+149	—19	—101	+27	287
Jokioinen		+ 8	— 91	+22	+129	+ 96	—94	—21	+127	—44	—136	+ 10	+ 81	+ 29	+11	— 44	+ 7	282
Mietoinen [1]		+10	—128	+20	+ 83	+112	—70	—79	+126	+ 1	—158	+ 18	+201	+ 67	+17	— 7	+ 8	262
Peipohja		—72	—121	— 8	+158	+162	—65	—60	— 32	—32	—129	+ 4	+138	— 34	+50	— 31	—22	269
Anjala		— 3	—147	+16	+101	+ 96	—62	+ 6	+133	—79	—106	— 11	+ 58	+207	—45	— 75	+44	310
Pälkäne		—26	—111	+41	+ 96	+ 32	—44	—13	+ 87	—25	— 89	+ 20	— 9	+ 53	—52	— 28	—68	279

[1]) Vuodet 1950—58 Piikkiön mittausten mukaan — *Years 1950—58 from measurements at Piikkiö*

maalia viileämpiä ja syyskuun alkupuolelle antoivat leimansa poikkeuksellisen ankarat hallat. Niin ikään viileänä kasvukautena 1958 viljelykasvit kehittyivät hitaasti, ja myöhäisimmät kevätviljalajikkeet kärsivät jo ennen syyskuun puoliväliä halloista. Epäedullisuudessaan vertaansa vailla oli kasvukausi 1962. Viljojen tuleentuminen siirtyi silloin myöhäissyksyyn ja sadosta oli vain vähäinen osa laadultaan kunnollista.

Sademäärien vaihtelu eri koepaikkojen välillä on ollut huomattava. Kasvukaudet ovat olleet kuitenkin säätyypiltään samanlaiset puheena olevilla koeasemilla. Normaalia sateisempia kasvukausia olivat 1952, 1953, 1954, 1956, 1957, 1960, 1961 ja 1962. Runsaimmat sateet ovat yleensä sattuneet syyskesällä, jolloin ne ovat haitanneet sadonkorjuuta ja alentaneet viljasadon laatua. Suurimmat tähkäidäntävahingot olivat vuosina 1954, 1956 ja 1962.

Edellä mainitun perusteella voidaan päätellä, että ajanjaksona 1950—65 on ollut lukuisia kasvukausia, jotka joko viileytensä tai sateisuutensa puolesta ovat olleet vehnänviljelylle epäedullisia. Sadon laadun kannalta edullisia olivat varsinkin kasvukaudet 1959 ja 1963, joskin satomäärät kuivuuden johdosta jäivät pieniksi.

Svenno-vehnän ominaisuuksia muihin yleisiin kevätvehnälajikkeisiimme verrattuna

Jyväsato

Taulukossa 5 nähdään tutkimuslaitosten ja koeasemien koetuloksista lasketut keskimääräiset Svenno-vehnän jyväsadot verrattuina mittarin (Timantin) jyväsatoihin. Svenno-vehnä on kaikkina vuosina antanut Timanttia paremman satotuloksen. Kuitenkin kiinnittää taulukossa huomiota eräänlainen jaksoittaisuus. Niinpä vuosina 1951—54, siis ennen kauppaan tuloaan, Svenno-vehnä antoi keskimäärin 19 % Timanttia suuremman sadon. Viitenä seuraavana vuotena, 1955—59, satotulos jäi huomattavasti heikommaksi ja oli vain 4—5 % Timanttia parempi; ainoastaan vuonna 1958 satoero oli tilastollisesti merkitsevä. Vuosina 1960—63 Svenno-vehnän satoero Timanttiin muodostui keskimäärin 13 %:ksi ja tilastollisesti joko hyvin tai erittäin merkitseväksi. Vuosi 1965 oli Svenno-vehnän kannalta jonkin verran edullisempi kuin vuosi 1964. Paikalliskokeista saadut tulokset ovat pääpiirteissään samansuuntaiset (taul. 6). Tutkimuslaitosten ja koeasemien sekä toisaalta paikalliskokeiden keskimääräisten jyväsatojen vertailu osoittaa kokeiden sijainneen kasvukunnoltaan täysin erilaisilla pelloilla.

Jotta vertailu muihin lajikkeisiin olisi mahdollista, on taulukkoon 5 laskettu Timantille ja Svennolle tulokset myös niistä kokeista, joissa kulloinkin kyseessä oleva kolmas lajike on ollut mukana. Yleisistä kevätvehnälajikkeistamme Norröna on ollut (6 %) Svennoa satoisampi. Norröna-vehnän satotaso näyttää pysyneen eri vuosina mittariin verrattuna muuttumattomana, kun taas Svennon sadoissa on havaittavissa edellä mainittuja vaihteluja. Apu-vehnän sadon vaihtelut eri vuosina olivat vielä huomattavampia. Apu on antanut keskimäärin 6 % pienemmän jyväsadon kuin Svenno-vehnä. Vasta kuusi vuotta kokeissa ollut Ring-vehnä on satoisuudeltaan ehkä hieman Svennoa parempi. Paikalliskokeissa (taulukko 6) Svenno ja Norröna ovat olleet jokseenkin yhtä satoisia, Avun jyväsato on ollut 7 % pienempi kuin Svennon. Ring näyttää olleen myös paikalliskokeissa Svennoa satoisampi.

Kun lasketaan keskiarvot koepaikoittain (taul. 7), voidaan todeta Svenno-vehnän antaneen jokaisella koepaikalla keskimäärin Timanttia paremman satotuloksen. Useimmilla koepaikoilla Norröna on ollut satoisampi kuin Svenno. Jokioisissa ja Pälkäneellä Svennon jyväsadot ovat olleet suhteellisesti parhaat ja yltäneet Norrönan tasolle. Huonoimmin Svenno on menestynyt Anjalassa, missä se on jäänyt vertailtavista lajikkeista vähäsatoisimmaksi.

Taulukkoa 8 varten tutkimuslaitosten ja koeasemien tulokset on ryhmitelty Timantin jyvä-

Taulukko 5. Kevätvehnälajikkeiden jyväsadot. Tutkimuslaitosten ja koeasemien tuloksia 1950—65. Timantti kg/ha = 100
Table 5. Grain yields of spring wheat varieties. Trial results from experimental institutions and stations in 1950—65. Diamond kg/ha = 100

	Kokeita *Trials*	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	Keskim. *Average*
Timantti kg/ha — *Diamond kg/ha* ...	132	3 250	2 350	4 070	3 200	2 360	2 270	2 220	2 770	2 840	2 670	3 550	3 140	2 470	2 340	2 500	2 550	2 790
Svenno		105	120*	114**	118***	122***	105	105	104	104*	104	114**	110***	117***	111**	105	109*	110
Timantti kg/ha — *Diamond kg/ha* ...	67	—	1 820	—	3 170	2 310	2 660	2 390	2 820	3 070	2 560	3 430	2 800	2 390	2 480	2 390	3 640	2 710
Svenno		—	125	—	122	122	105	107	105	104	103	112***	110	116**	108	107	107	111***
Apu		—	90	—	122	107	98	102	105	103	107	101	104	120**	102	101	97	104**
Timantti kg/ha — *Diamond kg/ha* ...	69	—	—	—	—	—	2 600	2 340	2 800	2 920	2 630	3 550	3 000	2 310	2 050	2 780	3 120	2 740
Svenno		—	—	—	—	—	108	107	101	103	106	114**	110**	119**	108	107	111	109***
Norröna		—	—	—	—	—	103	116	112*	116	116**	110	119***	128***	116**	115**	111	115***
Timantti kg/ha — *Diamond kg/ha* ...	25	—	—	—	—	—	—	—	—	—	—	3 840	2 700	2 500	2 140	2 530	2 680	2 730
Svenno		—	—	—	—	—	—	—	—	—	—	109	106	120	108	103	110	109**
Ring		—	—	—	—	—	—	—	—	—	—	109	107	128*	117	107	101	112**

Taulukko 6. Kevätvehnälajikkeiden jyväsadot paikalliskokeissa 1954—64. Timantti kg/ha = 100
Table 6. Grain yields of spring wheat varieties. Results of trials of Bureau for local experiments in 1954—64. Diamond kg/ha = 100

Lajike *Variety*	Kokeita *Trials*	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	Keskim. *Average*
Timantti kg/ha — *Diamond kg/ha*	211	1 990	2 080	1 680	2 540	1 790	2 460	2 820	2 510	2 070	2 310	2 210	2 270
Svenno		123	105	100	101	100	101	115*	100	120***	118**	108	111
Timantti kg/ha — *Diamond kg/ha*	156	2 510	1 980	1 650	2 530	1 900	2 220	2 860	2 500	2 050	2 190	2 470	2 300
Apu		104	103	96	107	101	96	100	94	104	105	107	101
Timantti kg/ha — *Diamond kg/ha*	151	—	—	1 430	2 250	1 790	2 190	2 820	2 510	2 030	2 310	2 280	2 330
Norröna		—	—	131	102	118	109	106	108	117	114	112	110***
Timantti kg/ha — *Diamond kg/ha*	32	—	—	—	—	—	—	—	—	2 800	2 200	2 160	2 200
Ring		—	—	—	—	—	—	—	—	83	122	114	118*
Svenno	125	—	2 130	2 030	2 620	1 910	2 610	3 320	2 700	2 370	2 460	2 570	2 470
Apu		—	99	90	107	102	98	86	89	92	94	93	93
Svenno	126	—	—	1 700	2 310	1 890	2 520	3 260	2 540	2 580	2 710	2 380	2 430
Norröna		—	—	111	103	117	112	92	104	92	97	100	100

* = merkitsevyys — *significance* P ≤ 5.0 %
** = » » P ≤ 1.0 %
*** = » » P ≤ 0.1 %

satojen mukaan eri satotasoluokkiin, ja taulukkoon on laskettu kuhunkin luokkaan kuuluvien kokeiden keskiarvot. Kutakin lajiketta varten on laskettu eri mittarin arvot niistä kokeista, joissa lajike on ollut mukana. Taulukon mukaan Svenno-vehnän suhteellinen jyväsato on sitä parempi, mitä korkeammasta satotasoluokasta on kysymys. Apu näyttää suhtautuvan satotasoon vaikuttaviin tekijöihin samalla tavoin kuin Timantti. Sen sijaan Norröna näyttää viihtyvän Timanttia suhteellisesti paremmin epäedullisissa oloissa. Ring on toistaiseksi ollut mukana niin harvoissa kokeissa, ettei niiden perusteella voida esittää johtopäätöksiä.

Satotasoon vaikuttavat mm. kasvupaikan maantieteellinen sijainti, maalaji, maan kasvu-

Taulukko 7. Kevätvehnälajikkeiden jyväsadot tutkimuslaitoksilla ja koeasemilla keskimäärin vuosina 1950—65. Timantti kg/ha = 100

Table 7. Grain yields of spring wheat varieties at experimental institutions and stations on an average in 1950—65. Diamond kg/ha = 100

Lajike *Variety*	Tikkurila	Tammisto	Jokioinen	Mietoinen	Peipohja	Anjala	Pälkäne
Timantti kg/ha — *Diamond kg/ha*	2 720	3 430	3 080	2 440	2 010	2 780	2 940
Svenno	109	113	114	103	113	111	116
Timantti kg/ha — *Diamond kg/ha*	2 290	3 530	2 360	2 470	2 330	2 420	3 030
Svenno	110	111	107	105	114	97	114
Apu	106	101	97	102	114	101	109
Timantti kg/ha — *Diamond kg/ha*	2 430	3 530	3 960	2 520	2 330	2 420	3 070
Svenno	104	111	116	103	115	97	120
Norröna	116	118	115	111	123	111	119
Timantti kg/ha — *Diamond kg/ha*	1 740	3 040	2 330	2 320	2 480	—	3 690
Svenno	101	113	102	108	111	—	110
Ring	106	117	112	105	116	—	121

Taulukko 8. Kevätvehnälajikkeiden satoisuus eri satotasoluokissa. Tutkimuslaitosten ja koeasemien tuloksia 1950—65. Timantti kg/ha = 100

Table 8. Productivity of spring wheat varieties in different yield classes. Results from experimental institutions and stations in 1950—65 Diamond kg/ha = 100

Lajike *Variety*	Satotasoluokka kg/ha *Yield class kg/ha*						
	≤ 1500	—2000	—2500	—3000	—3500	—4000	4000<
Timantti — *Diamond*	1 180	1 790	2 240	2 790	3 250	3 700	4 670
Svenno	102	109	108	109	111	112	115
Kokeita kpl — *Number of trials*	10	17	18	36	17	15	8
Timantti — *Diamond*	1 220	1 860	2 260	2 800	3 200	3 690	4 880
Apu	104	102	102	108	105	102	103
Kokeita kpl — *Number of trials*	5	9	10	25	7	7	2
Timantti — *Diamond*	1 220	1 860	2 210	2 790	3 230	3 760	4 690
Norröna	115	118	119	118	109	112	112
Kokeita kpl — *Number of trials*	6	8	9	23	9	7	4

kunto ja tilapäiset säänvaihtelut. Edellä mainitun perusteella Svenno-vehnä on näissä suhteissa Timanttia vaateliaampi, Apu samanarvoinen ja Norröna vaatimattomampi kuin Timantti.

Svenno-vehnä kuuluu jyväsadoltaan parhaisiin kevätvehnälajikkeisiimme, vaikka vaateliaana lajikkeena se ei Suomen oloissa kykene tuottamaan runsaimpia satojaan.

Kasvuaika

Kevätvehnän kasvuaika tutkimuslaitosten ja koeasemien kokeissa nähdään taulukossa 9. Svenno-vehnä on tänä ajanjaksona tuleentunut keskimäärin 3 päivää myöhemmin kuin Timantti-vehnä. Svennoon verrattuna Apu on ollut 10 päivää ja Norröna 8 päivää aikaisempi. Vielä

Taulukko 9. Kevätvehnälajikkeiden kasvuajat (päiviä) Timanttiin verrattuna. Tutkimuslaitosten ja koeasemien tuloksia 1950—65

Table 9. Growing times (days) of spring wheat varieties compared with Diamond. Trial results of experimental institutions and stations, 1950—65

Lajike *Variety*	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	Keskim. *Average*
Timantti — *Diamond*	110	110	121	107	102	95	114	104	109	103	100	116	135	99	108	123	110
Svenno	+2	+1	+3	+3	+3	+2	+3	+3	+4	+2	+4	+3	+5	+2	+3	+3	+3
Timantti — *Diamond*	—	108	—	98	100	95	112	102	109	101	100	114	134	99	106	120	107
Svenno	—	+2	—	+4	+2	+1	+3	+3	+2	+4	+4	+3	+5	+2	+3	+5	+3
Apu	—	—4	—	—8	—7	—6	—11	—8	—8	—5	—7	—9	—13	—8	—12	—6	—7
Timantti — *Diamond*	—	—	—	—	—	97	114	102	110	104	100	115	135	99	108	123	110
Svenno	—	—	—	—	—	+1	+3	+3	+4	+4	+4	+3	+5	+2	+2	+3	+3
Norröna	—	—	—	—	—	—2	—8	—3	—4	—2	—3	—4	—9	—5	—5	—5	—5
Timantti — *Diamond*	—	—	—	—	—	—	—	—	—	—	104	112	135	97	110	123	114
Svenno	—	—	—	—	—	—	—	—	—	—	+1	+2	+5	+2	+3	+3	+3
Ring	—	—	—	—	—	—	—	—	—	—	±0	+4	+8	+4	+5	+5	+4

Svennoakin myöhäisempi on ollut Ring. Svennovehnän myöhäisyys rajoittaa sen viljelyä Suomessa.

Eri koepaikoilla (taul. 10) lajikkeiden kasvuajat suhtautuvat toisiinsa samansuuntaisesti. Erot vaihtelevat eri lajikevertailuissa niin paljon, että voidaan päätellä niiden johtuvan tilapäisistä tekijöistä. Koepaikan maantieteellisen sijainnin vaikutusta ei tämän taulukon perusteella lajikkeiden kasvuajoissa ole havaittavissa.

Kasvuajat vaihtelevat vuosittain suuresti vehnänviljelylle epäedullisen ilmaston takia (taul. 9). Ero suurimman ja pienimmän keskimääräisen vuotuisen kasvuajan välillä on Timantilla 40 (95—135), Svennolla 43 (97—140), Avulla 33 (89—122) ja Norrönalla 33 (93—126) päivää. Myöhäisten lajikkeiden kasvuaika vaihtelee paljon runsaammin kuin aikaisempien. Lajikkeiden tuleentumispäivien välinen ero muodostuu erityisen suureksi epäsuotuisina kasvukausina, jollaisia olivat mm. vuodet 1956 ja 1962. Sääolothan muuttuvat yleensä sitä epäedullisemmiksi, mitä myöhempään tuleentuminen siirtyy, ja tästä kärsivät erityisesti myöhäiset lajikkeet.

Taulukko 10. Kevätvehnälajikkeiden kasvuajat (päiviä) tutkimuslaitoksilla ja koeasemilla Timanttiin verrattuina 1950—65

Table 10. Growing times (days) of spring wheat varieties at experimental institutions and stations compared with Diamond in 1950—65

Lajike *Variety*	Tikkurila	Tammisto	Jokioinen	Mietoinen	Peipohja	Anjala	Pälkäne
Timantti — *Diamond*	108	110	114	108	114	101	106
Svenno	+3	+1	+4	+5	+3	+3	+4
Timantti — *Diamond*	109	112	105	109	116	99	102
Svenno	+3	+1	+4	+3	+3	+4	+4
Apu	—7	—6	—12	—9	—10	—7	—7
Timantti — *Diamond*	108	112	111	109	116	99	110
Svenno	+2	+1	+2	+3	+3	+4	+4
Norröna	—5	—3	—3	—5	—5	—3	—5
Timantti — *Diamond*	104	112	111	115	121	—	105
Svenno	+2	+2	+4	+3	+1	—	+5
Ring	+3	+2	+3	+6	+5	—	+8

Taulukko 11. Kevätvehnälajikkeiden kasvuajat (päiviä) Timanttiin verrattuina paikalliskokeissa 1954—64
Table 11. Growing times (days) of spring wheat varieties compared with Diamond. Results of trials of Bureau for local experiments in 1954—64

Lajike *Variety*	Kokeita *Trials*	1954	—55	—56	—57	—58	—59	—60	—61	—62	—63	—64	Keskim. *Average*
Timantti — *Diamond*	138	110	103	112	110	111	104	103	112	135	111	115	112
Svenno	112	+3	+4	+5	+4	+2	+8	+7	+1	+7	+4	+4	+4
Apu	88	—	—7	—6	—10	—6	—6	—7	—7	—13	—12	—7	—8
Norröna	87	—	—	—2	—2	—6	—3	—3	—4	—1	—3	—2	—3
Ring	17	—	—	—	—	—	—	—	—	—	+6	+5	+6

Paikalliskokeissa aikaisimman Avun ja myöhäisimmän Ringin kasvuaikojen erotus on muodostunut vielä suuremmaksi, 14 päiväksi (taul. 11). Svenno-vehnä on ollut 12 päivää Apua myöhäisempi.

Korrenlujuus

Svenno-vehnän arvokkaimpia ominaisuuksia on sen luja korsi. Erityisesti viime vuosina, jolloin sateet ovat koetelleet korren lujuutta, tämä ominaisuus on tullut esille ja on ollut omiaan laajentamaan Svenno-vehnän viljelyä. Taulukosta 12 näemme, että Svenno-vehnän korrenlujuus on muihin yleisiin kevätvehnälajikkeisiimme verrattuna omaa luokkaansa. Timantti, Apu ja Norröna ovat lakoutuneet suunnilleen yhtä voimakkaasti.

Jyväsadon laatuominaisuudet

Svenno-vehnä on suurijyväisin kevätvehnälajikkeemme (taul. 12). Keskimäärin sen 1 000 jyvän paino on ollut 3 grammaa korkeampi kuin Timantin ja 5 grammaa korkeampi kuin Avun ja Norrönan; keskiarvot ovat vaihdelleet vuosittain rajoissa 32—42 g. Vastaava vaihtelu Timantilla on 31—37, Avulla 27—36 ja Norrönalla 26—37 g. Svenno-vehnän suurijyväisyys on edullinen myllyteollisuuden kannalta, koska hyvin tuleentuneen suurijyväisen viljan jauhatusprosentti muodostuu suuremmaksi kuin pienijyväisen viljan, mutta on Suomen oloissa erittäin haitallinen Svennon viljelyä rajoittava tekijä. Suurijyväisyys hidastaa tuleentumista ja haittaa hyväitoisen kylvösiemenen tuotantoa.

Svenno-vehnän hehtolitrapaino on keskimäärin muodostunut korkeammaksi kuin Avun ja Norrönan ja ollut yhtä korkea kuin Timantin (taul. 12). Sääoloiltaan erittäin epäedullisena kasvukautena 1962, jolloin kaikkien lajikkeiden hehtolitrapainot jäivät alhaisiksi, heikkolaatuisin sato saatiin kuitenkin myöhäisistä lajikkeista. Timantin ja Svennon hehtolitrapainot olivat tutkimuslaitoksilla ja koeasemilla keskimäärin vain 70 kg. Laadultaan parasta viljaa saatiin aikaisesta Apu-vehnästä (hehtolitrapaino 72 kg), samoin myös Norröna (71 kg) näytti kärsineen

Taulukko 12. Kevätvehnälajikkeiden lakoisuus, 1 000 jyvän painot (g) ja hehtolitrapainot (kg) tutkimuslaitosten ja koeasemien kokeissa keskimäärin vuosina 1950—65
Table 12. Lodging, 1 000-grain weights (g) and hectolitre weights (kg) at experimental institutions and stations on an average in 1950—65

Lajike *Variety*	Kokeita *Trials*	Lako-% *Lodging %*	1 000 jyvän paino g *1 000-grain weight g*	Hehtolitrapaino kg *Hectolitre weight kg*
Timantti — *Diamond*	132	26	34	79
Svenno	132	12	37	78
Apu	67	33	32	76
Norröna	69	28	32	77
Ring	25	5	35	76

epäedullisista sääoloista suhteellisesti vähemmän kuin sitä myöhäisemmät lajikkeet. Vuoden 1956 Svenno-sadon hehtolitrapaino oli myös voimakkaasti alentunut, se oli 73 kg, Timantin 75 kg, Avun 74 kg ja Norrönan 74 kg.

Hehtolitrapainojen vuotuista vaihtelua voitaneen jossain määrin pitää lajikkeen viljelyvarmuuden kuvastajana. Myöhäisillä lajikkeilla vuotuinen vaihtelu on suurempi kuin aikaisemmilla. Timantin ja Svennon hehtolitrapainot vaihtelevat rajoissa 70—83 kg, Avun 70—80 kg ja Norrönan 71—80 kg.

Tarkastelua

Svenno-vehnän suosio johtuu ensi sijassa sen hyvästä satoisuudesta ja korrenlujuudesta. Varsinkin 1960-luvulla, kun korjuuajan sateet ovat useina vuosina lakouttaneet viljakasvustoja ja tähkäidäntä aiheuttanut suuria tappioita, korrenlujuus on saanut entistä enemmän huomiota osakseen. Vaikka Svenno-vehnä on varsin herkkä itämään tähkässä heti keltatuleentumisasteen sivuutettuaan, se lujakortisena lajikkeena välttää tähkäidännän varmemmin kuin fysiologisen idäntäkestävyytensä puolesta vaikkapa parempikin, mutta korreltaan heikko jaloste (Kivi 1961).

Svenno-vehnän tuleentumisen myöhäisyys on eräinä vuosina säästänyt lajikkeen tähkäidäntävaurioilta, kun elo-syyskuun vaihteen sateiset säät ovat muuttuneet myöhemmin, Svennon tuleentumisaikaan, poutaisiksi. Myöhäisestä tuleentumisajankohdasta on yleensä kuitenkin haittaa jyväsadon laadulle. Paatela ja Suomela (1960) mainitsevat kevätviljojen tuleentumisvarmuuden olevan tärkeimpiä niiden viljelyvarmuuteen vaikuttavia tekijöitä. Svenno-vehnän kasvuaika on liian pitkä, jotta se ehtisi tuleentua Etelä-Suomessakaan joka vuosi. Tämä näkyy taulukosta 13. Ajanjaksona 1950—65 on Tikkurilassa kolmena syksynä, siis joka viides syksy, ensimmäinen ankara halla sattunut jo ennen Svenno-vehnän tuleentumista, mistä seurauksena on vähintään itävyyden menetys. Mutta normaalinakin syksynä syyssateiden pelko ajaa viljelijät korjaamaan myöhäisiä lajikkeita tuleentumattomana tai märkänä. Liian kostean viljan leikkuupuinti puolestaan aiheuttaa itävyyden alenemisen.

Puintikosteuden vaikutus itävyyteen riippuu lajikkeesta. Tämä ilmenee Vallen (1965 a) tutkimusten tuloksista. Hän on suorittanut itävyysmäärityksiä vuosina 1953—64 Maatalouden tutkimuskeskuksen koetilalla Tikkurilassa leikkuupuiduista viljaeristä. Kevätvehnälajikkeista on

Taulukko 13. Svenno-vehnän tuleentumispäivä ja ensimmäisen ankaran hallan (—2.2°C tai alle) esiintyminen Kasvinviljelylaitoksella Tikkurilassa

Table 13. Ripening day of Svenno spring wheat and first killing frost (under —2.2°C) at the Department of Plant Husbandry, Tikkurila

Vuosi *Year*	Tuleentumispäivä *Ripening day*	Ankara halla *Killing frost*	Tuleentumispäivästä ankaraan hallaan *From ripening day to killing frost*
1950	30/8	25/8	—5
—51	27/8	11/9	15
—52	9/9	15/9	6
—53	18/8	7/9	20
—54	—	(20/9)	—
—55	28/8	29/9	32
—56	7/9	6/9	—1
—57	23/8	29/9	37
—58	6/9	11/9	5
—59	10/8	9/9	30
—60	16/8	11/9	26
—61	16/8	5/9	20
—62	20/9	16/9	—4
—63	10/8	20/9	41
—64	18/8	10/9	23
—65	8/9	16/9	8
Keskim. — *Average*	29/8	13/9	15

Timantista määrityksiä kuudelta vuodelta ja Svenno-vehnästä yhdeltätoista vuodelta. Koska aineisto on suuri, tulokset antavat selvän käsityksen asiasta.

	Näyteluku	Kosteus-%	Itävyys-% eri vesipitoisuusluokissa								
			alle 20	20—21	22—23	24—25	26—27	28—29	30—34	35—40	yli 40
Timantti	110		—	97	97	93	88	88	82	—	—
Svenno	289		97	94	91	86	83	81	72	61	60

Hyvissäkin korjuuoloissa, viljan kosteuden ollessa 20—21 %, Timantin itävyys on ollut parempi kuin Svennon. Kosteuden vastatessa oloissamme varsin tavallista puintikosteutta, 24—25 %, lajikkeiden itävyyksien ero on ollut vielä useita prosentteja suurempi. Hyvin kosteata (30—34 %) viljaa puitaessa Timantista on saatu vielä varsin kelvollista siementä, Svennon sato ei sen sijaan enää ole ollut siementavaraksi kelpaavaa.

Myös Köylijärven (1965) mukaan puintikosteuden ja puidun erän itävyyden välillä vallitseva vuorosuhde on erilainen eri kevätvehnälajikkeilla. Norrönalla ja Svennolla puintikosteuden on pitänyt olla niin alhainen kuin 18—20 %, ennen kuin on saatu 90 %:sesti itävää viljaa. Samaan tulokseen pääsemiseksi on esim. Timantilla riittänyt 27 %:n kosteus. Siemenviljan puinnin onnistumiseksi vaativat siten Norröna ja Svenno pienintä puintikosteutta, seuraavina ovat järjestyksessä Apu-, Touko- ja Timanttikevätvehnät. Koska myöhään tuleentuvan Svenno-vehnän puintikosteus pyrkii pakostakin olemaan korkea, on sillä saavutetut huonot itävyystulokset edellä mainitusta syystä helppo ymmärtää.

Kylvösiemenliiton vuoden 1965 sadosta tekemässä otantatutkimuksessa määritettiin myös näytteiden itävyys. Jos käyttökelpoisen kevätvehnän siemenen itävyyden alarajana pidetään 80 %:a, niin tutkituista 483 kevätvehnäerästä oli siemeneksi kelpaavia 29 %. Tätä keskiarvoa parempia olivat Timantti- ja Apu-vehnät, sitä huonompia taas Svenno- ja Norröna-vehnät. Jos edellä mainitusta kevätvehnän siemenen itävyyden vähimmäisvaatimuksesta pidetään kiinni, saatiin Timantti-eristä 42 %:sta kelvollista siementä, Svenno-eristä 23 %:sta, Apu-eristä 34 %:sta ja Norröna-eristä 20 %:sta. Ehdottomasti paras oli siis tässä mielessä Timantti-vehnä, josta 18 % iti yli 90 %:sesti, Svenno-eristä vain 1 %.

Siementarkastuslaitoksen vuosien 1958, 1961 ja 1962 sadoista suorittamista kauppasiementutkimuksista laatimassaan yhteenvedossa Hilli (1963) on pannut puheena olevat kevätvehnälajikkeet täysin samaan järjestykseen kuin ne vuoden 1965 otantatutkimuksenkin mukaan ovat: parhaiten itäviä Timantti ja Apu, keskitasoisia Touko, Tammi, Terä ja Drott ja kaikkein heikoimmin itäviä Svenno ja Norröna. Vuoden 1962 sadosta suoritetun tutkimuksen tuloksista mainittakoon seuraavat keski-itävyydet: Timantti 67 % (825 näytettä), Apu 60 % (1 813), Svenno 56 % (2 108) ja Norröna 51 % (1 810).

Svenno-vehnän suuresta viljelylaajuudesta seuraa sen siemenviljelyn epäonnistuessa kevätvehnän siemenpula, josta pääsemiseksi on usein ollut tuotava siementä ulkomailta. Kevätvehnän siemenen tuonti on puolestaan edistänyt Svenno-vehnän nopeaa yleistymistä maassamme. Pohjoismaissa ja Englannissa viljeltävistä kevätvehnälajikkeistahan Suomeen tuotavaksi soveltuu lähinnä vain Svenno. Tämä tuontisiemen on useinkin parasta meillä kaupan olevaa siementä, mikä osaltaan vaikuttaa viljelijöiden lajikevalintaan. Epäedullisten kasvukausien jälkeen viljelijät joutuvat ostamaan Svennon siementä eniten, vaikka juuri tällöin mielessä olisikin siirtyminen aikaisempien kevätvehnälajikkeiden viljelyyn. Niinpä vuoden 1963 kylvöihin kaikesta kaupan viljelijöille välittämästä tuontisiemenestä 53 % (7 400 tn) oli Svenno-vehnää (Valle ja Mela 1965). Vuosina 1958—65 kevätvehnän siemenen tuonti on ollut yhteensä 34 milj. kg, josta Svenno-vehnää n. 20 milj. kg eli lähes 60 % (Valle 1965 b).

Leipäviljan laatuvaatimusten tiukentuessa ja varsinkin sakoluvun tullessa käyttöön leipäviljan hyväksymisen ja hylkäämisen perusteena kevätvehnän lajikekysymykseen on kiinnitettävä entistä enemmän huomiota. Jo suhteellisen vähäiseltä näyttävästä hallan vioituksesta tai tähkäidännästä seuraa, että jyväsato muuttuu rehuviljan arvoiseksi. Samaan suuntaan vaikuttaa viljan puinti ennen tuleentumista, jolloin viljan joukossa on vielä vihreitä jyviä. Aikaisen lajikkeen viljelyllä on näin ollen suuremmat mahdollisuudet onnistua kuin myöhäisen lajikkeen.

Toistaiseksi meillä ei ole kuitenkaan riittävästi tietoa eri tekijöiden vaikutuksista sakolukuun, sillä ensimmäiset sakolukumääritykset ovat vasta vuodelta 1965. Tällöin kuudella tutkimuslaitoksella ja koeasemalla yhteensä yhdeksästä kokeesta tehdyissä määrityksissä saatiin Timantin sakoluvuksi keskimäärin 214, Svennon 129. 1966 Timantin sakoluku oli 265, Svennon 170, seitsemän koepaikan ja kahdentoista kokeen jyväsadoista määritettyinä. Timantti oli siis molempina vuosina huomattavasti viljelyvarmempi kuin Svenno.

Muista kevätvehnälajikkeista sakolukumäärityksiä on tehty vielä vähemmän kuin Timantista ja Svennosta. Niukasta aineistosta huolimatta voidaan nyt jo ennustaa, että juuri sakolukumääritysten käyttöönotto ja leipäviljan laatuvaatimusten kiristyminen aiheuttavatkin Svenno-vehnän viljelyn taantumisen Suomessa.

Edellä on todettu Svenno-vehnä satoisaksi lajikkeeksi. Sen jyväsadon suuruus mittarin satoon verrattuna vaihtelee kuitenkin vuosittain runsaasti. Syynä satojen vaihteluun on lajikkeen Timanttia suurempi vaateliaisuus ja myöhäisyys. Sen korrenlujuuskaan ei pysty eliminoimaan toistuvia laatutappioita. Svenno-vehnän huonosta viljelyvarmuudesta huolimatta sen viljelyä Suomessa on vaikea kokonaan tuomita, koska meillä ei ole käytettävissä ehdottomasti hyvää kevätvehnälajiketta viljeltäväksi Svennon sijasta. Niinpä Svennoa 8 päivää (paikalliskokeissa 7 päivää) aikaisemman ja 6 % (paikalliskokeissa 0 %) satoisamman Norrönavehnän laatutappiot ovat olleet Svennon luokkaa. Eivät myöskään Timantin 10 % (11 %) ja Avun 6 % (7 %) Svennoa pienemmät jyväsadot tunnu tyydyttäviltä. Kylvösiemenhuoltoamme ja tiukentuneita leipäviljan laatuvaatimuksia ajatellen on kuitenkin pidettävä suositeltavana siirtymistä Svennoa aikaisemmin tuleentuvien kevätvehnälajikkeiden viljelyyn. Viljelyvarmuuden kannalta katsoen saattaisi jopa vanhojen Timantti-lajikkeiden viljelyalan lisääminen olla paikallaan.

Tiivistelmä

Svenno-vehnä oli 1965 yleisimmin viljelty kevätvehnälajike Suomessa. Mainittuna vuonna kaikkiaan 35 % kevätvehnävainioistamme kasvoi Svenno-vehnää. Uudenmaan, Uudenmaan ruotsalaisen, Varsinais-Suomen ja Hämeen läänin maanviljelysseurojen sekä Suomen Talousseuran alueilla, siis varsinaisella vehnänviljelyalueellamme, vastaava luku oli 45 %.

Tutkimuksessa tarkastellaan Svenno-vehnän ominaisuuksia muihin yleisiin kevätvehnälajikkeisiimme, Timanttiin (Svalöf), Norrönaan (norjalainen), Apuun (Jokioinen) ja Ringiin (Weibullsholm) verrattuna. Aineistona on käytetty Kasvinviljelylaitoksen, Kasvinjalostuslaitoksen, Hankkijan kasvinjalostuslaitoksen Tammiston, Lounais-Suomen (tulokset vuoteen 1958 saakka Puutarhantutkimuslaitoksen ja Lounais-Suomen liikkuvan koetoiminnan kokeista), Satakunnan, Karjalan ja Hämeen koeasemien lajikekokeiden tuloksia 16 vuoden ajalta (1950—65), sekä Paikalliskoetoimiston Etelä-Suomessa sijainneiden kokeiden tuloksia 11 vuoden ajalta (1954—64).

Näiden lukuisien ja pitkäaikaisten kokeiden tulosten perusteella voidaan Svenno-vehnän ominaisuuksista päätellä seuraavaa:

Svenno-vehnä on jyväsadoltaan keskimäärin 10 % mittarilajiketta Timanttia satoisampi. Mittariin verraten Svenno-vehnän keskimääräiset suhteelliset jyväsadot ovat vuosittain kuitenkin vaihdelleet suuresti, 104—120. Muista yleisistä kevätvehnälajikkeistamme Norrönasta saatiin keskimäärin 6 % (paikalliskokeissa 0 %) runsaampi jyväsato kuin Svennosta, Avusta 6 % (7 %) heikompi. Ringin sato oli hieman parempi kuin Svennon.

Svenno-vehnän arvokkaimpia ominaisuuksia on sen luja korsi. Lakoisuutta on koelaitosten ja koeasemien kokeissa ollut vähän, paljon vähemmän kuin Timantilla, Avulla ja Norrönalla.

Svenno-vehnä on vaatelias lajike. Tulokset osoittavat Svenno-vehnästä saadun Timanttiin verrattuna sitä parempi jyväsato, mitä korkeammasta satotasoluokasta on ollut kysymys. Satotasoluokassa 2 000—2 500 kg/ha, joka käytännön viljelyksillämme on normaali jyväsato, Svenno-vehnä oli 8 % Timanttia satoisampi, satotasoluokassa yli 4 000 kg/ha 15 %.

Svenno-vehnän epäedullisin ominaisuus sitä Suomessa viljeltäessä on sen pitkä kasvuaika. Se on 3 päivää (paikalliskokeissa 4 päivää) Timanttia, 8 (7) päivää Norrönaa ja 10 (12) päivää Apua myöhäisempi, Ringiä sen sijaan pari päivää aikaisempi. Etelä-Suomessakin, Kasvinviljelylaitoksen koekentällä Tikkurilassa, ensimmäinen ankara syyshalla on vuoden 1950 jälkeen kolmena vuotena yllättänyt Svenno-vehnän vielä tuleentumattomana. Vuosina 1956 ja 1962 Svenno-vehnän voimakkaasti alentuneet hehtolitrapainot osoittavat hallan aiheuttaneen suurta vahinkoa.

Myöhäisellä tuleentumisella on merkitystä nimenomaan jyväsadon laadun kannalta. Useiden tutkimusten mukaan Svennon itävyys on jäänyt huomattavasti huonommaksi kuin Timantti- ja Apu-vehnien. Itävyydeltään kaikkia muita lajikkeita huomattavasti parempaa on ollut Timanttivehnä.

On todettava, että Svenno-vehnä ei Etelä-Suomessakaan viljeltynä täytä hyvälle kevätvehnälajikkeelle asetettavaa viljelyvarmuusvaatimusta. Kevätvehnän viljelyämme kehitettäessä olisikin kiinnitettävä huomiota Svennon korvaamiseen jollakin toisella lajikkeella, mahdollisesti jopa vanhoihin Timantti-vehniin turvautuen.

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SUMMARY

Svenno spring wheat under Finnish conditions

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The spring wheat variety Svenno, developed at the Weibullsholm Plant Breeding Station in Sweden, was introduced to the Finnish market in 1954. The cultivation of this variety spread rapidly; in 1955 it made up 2 % of the total area under spring wheat, in 1960 14 % and in 1965 35 % (75 600 ha). In the southernmost parts of the country, where Svenno is best suited owing to its longer maturity period, this variety made up nearly half of the area devoted to spring wheat in 1965. The areas of Svenno cultivation appear to be expanding year by year in increasing amounts towards the interior.

Svenno spring wheat has been included in variety trials in Finland since the year 1950. The present investigation analysis deals with the trials carried out at the Department of Plant Husbandry, Tikkurila, and at six other experimental institutions and stations in South Finland in 1950—65 as well as the trials conducted by the Bureau for local experiments in 1954—64 (Tables 1—13). In these trials the performance of Svenno was compared with that of four other commonly grown spring wheat varieties in Finland: Diamond (Svalöf, Sweden), Apu (Jokioinen, Finland), Norröna (Norway) and Ring (Weibullsholm, Sweden).

On the basis of these long time and numerous trials we can draw the following conclusions about the characteristics of Svenno wheat:

The grain yield of Svenno averaged about 10 % higher than that of the standard variety Diamond (Tables 5—7). However, in comparison with the standard variety, the average yields of Svenno varied widely from year to year, 104—120. Norröna gave an average yield 6 % (in the local experiments 0 %) higher than that of Svenno, while Ring was slightly better and Apu 6 % (7 %) lower than Svenno in grain yield.

One of the most valuable characteristics of Svenno is its straw strength. It lodged only slightly in the trials, and the extent of lodging was much less than that of Diamond, Apu and Norröna (Table 12).

Svenno has high growth requirements. The trials showed that, in comparison with Diamond, Svenno yielded proportionally more in the higher yield classes than in the lower. In the yield class 2 000—2 500 kg/ha, which is the usual level under ordinary conditions in Finland, Svenno yielded 8 % higher than Diamond, while in the yield class exceeding 4 000 kg/ha the figure was 15 % (Table 8).

The most serious drawback of Svenno under Finland's conditions is its late maturity (Tables 9—11). It is 3 days later than Diamond (in the local experiments 4), 8 (7) days later than Norröna and 10 days (12) later than Apu. Even in southern Finland, at the Department of Plant Husbandry at Tikkurila, during three years since 1950 the first killing frost have occurred when Svenno was still immature (Table 13). The greatly reduced hectolitre weights of Svenno in 1956 and 1962 reflect the serious damage caused by frost.

The late ripening of Svenno has a notable influence on the quality of the grain. Production of satisfactory seed has proved to be more difficult in Svenno than in numerous other varieties of Finnish-grown spring wheats. Separate investigations have shown that, even during summers of normal plant growth, Svenno wheat seed has had a significantly inferior germination as compared, for instance, to Diamond and Apu.

Owing to the extensive area grown to Svenno wheat, failure of the crop is followed by shortage of seed, and consequently it is often necessery to import seed from abroad. On the other hand, such imports of spring wheat seed have stimulated the rapid increase in cultivation of Svenno in Finland. Of the spring wheat varieties grown in Scandinavia and England, Svenno is the best one suited to be imported to Finland. In the years 1958—65, the total imports of spring wheat seed amounted to 34 million kg, of which Svenno comprised about 20 million kg, or nearly 60 %.

It must be realized that even in southern Finland Svenno does not meet the requirements of a dependable spring wheat variety. In developing the cultivation of spring wheat in Finland, consideration should be given to the replacement of Svenno by some other variety, perhaps even by returning to the old varieties of Diamond.

ANNALES AGRICULTURAE FENNIAE, VOL. 6: 174—190 (1967)

Seria ANIMALIA NOCENTIA N. 30 — Sarja TUHOELÄIMET n:o 30

STUDIES ON THE HOST PLANT RELATIONSHIPS OF APHIS IDAEI V.D. GOOT AND AMPHOROPHORA RUBI (KALT.) (HOM., APHIDIDAE)

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Received July 7, 1967

Rubus idaeus L. and *R. occidentalis* L. are generally known to be host plants of *Aphis idaei* v.d. Goot (e.g. Börner and Heinze 1957). Dicker (1940) states that the species also lives on some hybrids between raspberry and blackberry, and Janiszewska (1963) found the blackberry species *R. fissus* Lindley to be a host plant.

More than 20 species of raspberry, blackberry and dewberry have been reported to be host plants of *Amphorophora rubi* (Kalt.) (e.g. Patch 1918, Winter 1929, Dicker 1940, Converse 1960, Janiszewska 1963). *A. rubi* also has been found to live on *R. arcticus* L. and *R. chamaemorus* L. (Ossiannilsson 1959) as well as on *R. saxatilis* L. (Winter 1929).

Ever since aphids were shown to be vectors of raspberry viruses the suitability of raspberry varieties as host plants of aphids has been subjected to investigation both in Europe and in North America. The purpose has been to find varieties on which the virus vectors form the sparsest possible populations. Apparently, only one study (Baumeister 1961) has been published on the suitability of raspberry varieties as host plants of *A. idaei*. In contrast, the resistance of raspberries to *A. rubi* has been described in about twenty studies (see Table 3). There have also been investigations of the genetics of resistance (Knight et al. 1959, 1960, Baumeister 1962) and of the host plant relationships of different *A. rubi* strains (e.g. Briggs 1959, 1965, Knight et al. 1959, 1960). The most recent reviewes of previous studies have been presented by Knight et al. (1959) and Baumeister (1961).

The purpose of the present study was to investigate the resistance of the raspberry varieties most commonly cultivated in Finland, *R. idaeus* × *arcticus* hybrids, wild *R. idaeus* populations and some other species of the *Rubus* genus to *A. idaei* and *A. rubi*. At the same time also the biology of both the aphid species was studied (Rautapää 1968). Preliminary information regarding the results of these investigations has already been published (Rautapää 1964).

Numbers of aphids in the field

Material and methods

In 1961—1964 a count was kept of the numbers of the aphids living on the raspberry varieties, *R. idaeus* × *arcticus* hybrids and wild *R. idaeus* populations that were growing in four separate fields. The *R. idaeus* × *arcticus* material employed consisted of the F_1 hybrid and several F_2 and F_3 clones. These are referred to herein by the numbers used at the Agricultural Research Centre's Department of Horticulture at Piikkiö where breeding work is being done with this material. Two methods were employed, an examination being made either of (A) all the leaves of first-year canes or of (B) the tops (topmost open leaf with growing point area above it), one leaf of the middle and the lowest but one leaf of first-year canes. When the significance of differences of frequency was tested by the Tukey-Hartley method three consecutive observations of the original material were combined, and the varying frequency of the aphids on the different parts of the canes was disregarded. The vegetation in the fields was not treated with pesticides during the years of investigation.

Field 1, Dept. of Plant Pathology, Tikkurila

19 raspberry and *R. idaeus* × *arcticus* varieties as well as the wild *R. idaeus* were planted in autumn 1959 in rows of five bushes in a field of approximately 20 × 30 metres. Four rows were selected at random of the Asker, Herbert, Malling Promise and Preussen II varieties. In August 1961 one cane from each bush was examined by method A and one by method B. Rikala and wild *R. idaeus* were growing in two rows, and 10 canes from each of these rows were examined by method A and 10 by method B in 1961. There was one row of other varieties (see Fig. 3), and five canes from each of them were examined by method A and five by method B. The number of leaves on the different varieties inspected varied from 99 to 396.

Field 2, Dept. of Pest Investigation, Tikkurila

4 raspberry varieties were planted in spring 1962 in alternating order in four rows of five bushes each in a field of approximately 5 × 20 metres. In August 1962, 40 canes of each variety were examined by method B. In July and August 1963, 33 canes of each variety were examined by method B.

Field 3, Dept. of Horticulture, Piikkiö

17 *R. idaeus* × *arcticus* hybrids were planted in autumn 1962 in rows of 5—20 metres length in an area of approximately 15 × 30 metres (see Rousi 1965a). 33 canes of each hybrid were examined by method B in June, July and August 1963 and in June and August 1964. 33 canes of the blackberry variety Majestic *(R. fruticosus* L., s. lat.) growing in the Dept. of Horticulture area were also inspected by method B in August 1963 and in June and August 1964.

Field 4, Dept. of Horticulture, Piikkiö

Samples of wild Finnish *R. idaeus* populations were planted in autumn 1961 and spring 1962 in a field of approximately 15 × 30 metres (see Rousi 1965b). The number of aphids on 33 canes were counted by method B in June, July and August 1963 and June and August 1964.

Results

Numbers of aphids in the growing season's different periods

The number of *A. idaei* on three examined leaves averaged 0.1 in June, 4.7 in July and 23.5 in August (Fig. 1). The number of *A. idaei* thus increased almost fiftyfold in the three weeks between the June examination and the July examination, and almost fivefold in the period of about one month between the July and August examinations. The number of *A. rubi* on three leaves averaged 0.1 in June, 2.7 in July and

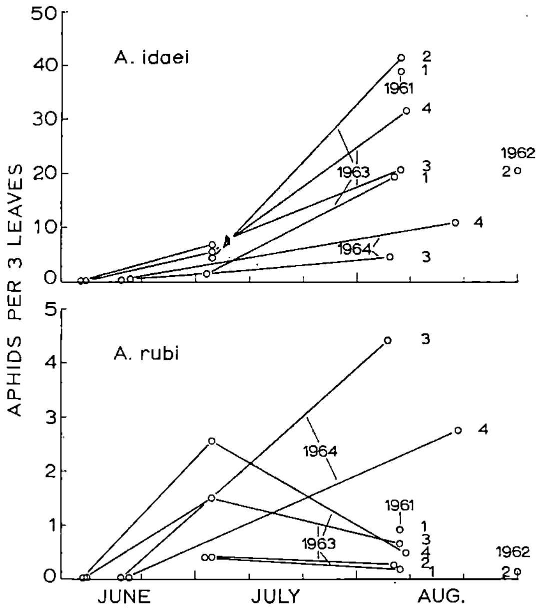

Fig. 1. The mean numbers of *A. idaei* and *A. rubi* per 3 leaves in fields 1—4 at different times of the growing period in 1961—1964.

Kuva 1. A. idaein ja A. rubin keskim. runsaus kolmessa lehdessä kentillä 1—4 eri aikoina kasvukautta vuosina 1961—1964.

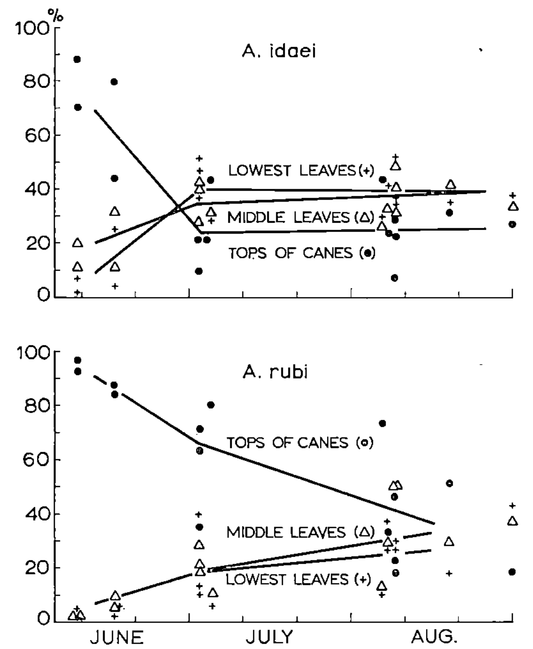

Fig. 2. The relative numbers of *A. idaei* and *A. rubi* at different times of the growing period on the tops of the first-year canes, on the leaves of the middle part, and on the leaves of the lower part. The broken lines indicate the averages for different years and fields.

Kuva 2. A. idaein ja A. rubin suhteellinen runsaus kasvukauden eri aikoina ensimmäisen vuoden verson latvoissa, keskiosan lehdissä ja alaosan lehdissä. Murtoviiva osoittaa kaikkien tarkastusten keskiarvon.

2.5 in August (Fig. 1). The number increased almost thirtyfold between June and July but remained almost constant thereafter for the rest of the summer. If fields 3 and 4 had been examined also in July 1964 and not only in August, the difference between the number of aphids found in July and that found in August might have been great. This is suggested by the fact that the number of *A. rubi* was larger in all the fields in July than in August the same year.

Numbers of aphids on the different parts of the canes

68.9 % of the *A. idaei* females were found on the tops of the canes in June, 22.7 % in July and 26.4 % in August (Fig. 2). 21.4 % of the aphids were found on the leaves of the middle part of the cane in June, 35.9 % in July and 36.7 % in August. 9.6 % of the aphids were living on the leaves of the lower part of the cane in June, 41.5 % in July and 36.9 % in August. The relative numbers of aphids on the different parts of the plants did not, hence, show any considerable change in July and August. The great majority of the *A. rubi* specimens found in June (91.2 %) were at the tops of the canes (Fig. 2). The corresponding relative number was 63.0 % in July and 37.0 % in August. The relative number of aphids at the top of the cane consequently decreased during the growing season. The percentage of aphids was 4.4 on the leaves of the middle part and 4.4 on the leaves of the lower part in June, 19.9 and 17.0 respectively in July and 34.1 and 27.9 in August.

Differences between host plants

In figures 3—6 the raspberry varieties, the *R. idaeus* × *arcticus* hybrids and the wild *R. idaeus* populations have been placed in order according to that examination where the average

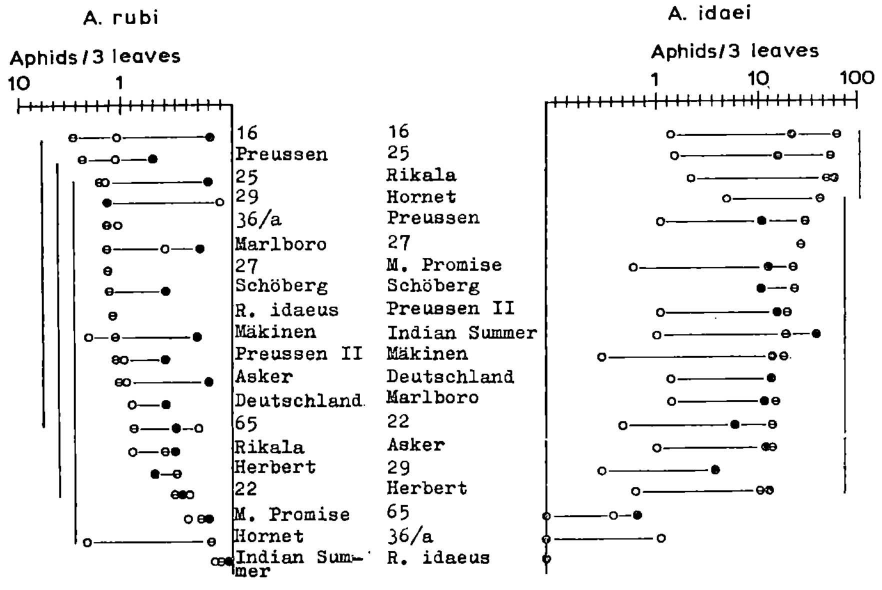

Fig. 3. The numbers of *A. idaei* and *A. rubi* on the varieties of field 1 on 31 August 1962 (⊖), 2 July 1963 (○) and 7 August 1963 (●). The vertical lines connect averages (⊖) whose differences are not significant (P > 0.05).

Kuva 3. A. idaein ja A. rubin runsaus kentän 1 lajikkeissa 31. 8. 1962 (⊖), 2. 7. 1963 (○) ja 7. 8. 1963 (●). Pystysuorat janat yhdistävät keskiarvot (⊖), joiden ero ei ole merkitsevä (P > 0.05).

number of aphids on the canes was greatest. The figures show only the significance of the differences established in these examinations.

R a s p b e r r y   v a r i e t i e s. In no raspberry variety was the number of *A. idaei* repeatedly significantly greater or smaller than in the other varieties. In all the examinations the number of *A. rubi* in field 1 (Fig. 3) was smaller on Indian Summer than on Preussen (P < 0.01). There were fewer aphids on Malling Promise than on Preussen in field 1 in August 1962 and July 1963 (P < 0.01). The difference was not a significant one in August 1963 (P > 0.05). The number of aphids on Malling Promise, Rikala and Asker in field 2 was a little smaller than on Preussen in July and August 1963, but the differences were not significant ones (P > 0.05).

R.   i d a e u s × a r c t i c u s   h y b r i d s. The number of *A. idaei* was repeatedly small on 36/a and great on 16 and 25 (Figs. 3 and 5).

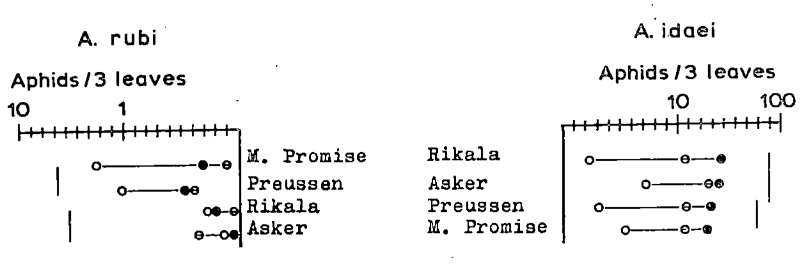

Fig. 4. The numbers of *A. idaei* and *A. rubi* on the varieties of field 2 on 31 August 1962 (○), 3 July 1963 (⊖) and 8 August 1963 (●). The vertical lines connect average (*A. idaei* ●, *A. rubi* ○) whose differences are not significant (P > 0.01).

Kuva 4. A. idaein ja A. rubin runsaus kentän 2 lajikkeissa 31. 8. 1962 (○), 3. 7. 1963 (⊖) ja 8. 8. 1963 (●). Pystysuorat janat yhdistävät keskiarvot (A. idaei ●, A. rubi ○), joiden ero ei ole merkitsevä (P > 0.01).

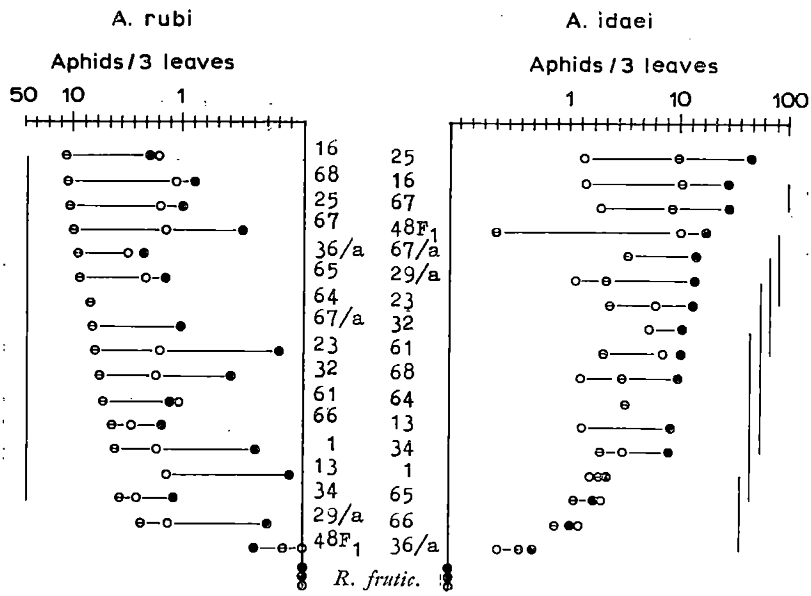

Fig. 5. The numbers of *A. idaei* and *A. rubi* on *R. idaeus* × *arcticus* hybrids in field 3 and *R. fruticosus* on 3 July 1963 (○), 8 August 1963 (●) and 16 August 1964 (⊖). The vertical lines connect averages (*A. idaei* ●, *A. rubi* ⊖) whose differences are not significant (P > 0.01).

Kuva 5. A. idaein ja A. rubin runsaus kentän 3 mesivadelmissa ja R. fruticosuksessa 3. 7. 1963 (○), 8. 8. 1963 (●) ja 16. 8. 1964 (⊖). Pystysuorat janat yhdistävät keskiarvot, (A. idaei ●, A. rubi ⊖), joiden ero ei ole merkitsevä (P > 0.01).

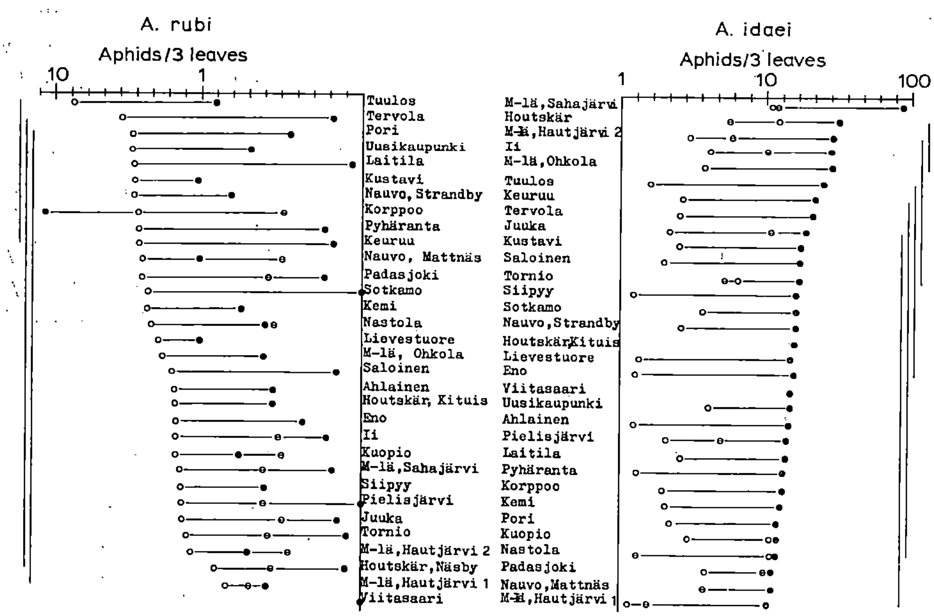

Fig. 6. The numbers of *A. idaei* and *A. rubi* in field 4 on wild *R. idaeus* populations gathered from various parts of Finland on 4 July 1963 (○), 9 August 1963 (●) and 18 August 1964 (⊖). The vertical lines connect averages (*A. idaei* ●, *A. rubi* ○) whose differences are not significant (P > 0.01).

Kuva 6. A. idaein ja A. rubin runsaus Suomen eri osista kerätyissä luonnonvadelmakannoissa kentällä 4 4. 7. 1963 (○), 9. 8. 1963 (●) ja 18. 8. 1964 (⊖). Pystysuorat janat yhdistävät keskiarvot (A. idaei ●, A. rubi ○), joiden ero ei ole merkitsevä (P > 0.01).

The difference between 36/a on one hand and 16 and 25 on the other was significant in field 3 in August 1963 and 1964 ($P < 0.01$) but not in July 1963 ($P > 0.05$). The number of *A. rubi* was repeatedly almost equal on 16, 25 and 36/a (Figs. 3 and 5). No specimens of *A. rubi* were found on the F_1 hybrid 48 growing in field 3 in July 1963, and in August 1964 they were significantly fewer than on e.g. 16, 25 and 36/a (Fig. 5). In contrast, the differences between 48 F_1 and 16, 25 and 36/a were not significant in August 1963 ($P > 0.05$).

Wild R. idaeus. In all the examinations the number of *A. idaei* was significantly greater ($P < 0.01$) on the population originating from Sahajärvi in Mäntsälä commune than on the population no 1 brought from Hautjärvi in Mäntsälä (Fig. 6). In July 1963 the number of *A. rubi* was significantly greater ($P < 0.01$) on the population originating from Tuulos than it was on many other populations (Fig. 6), but the number of aphids was not repeatedly significantly greater or smaller on any population in all the examinations.

On the blackberry variety Majestic examined in 1963 and 1964 neither species of aphid was found (Fig. 5).

The great majority of the *A. rubi* specimens found in the fields were green, but a few red females and larvae were found in all the examinations in fields 3 and 4 in 1963 and 1964.

Effect of host plant on reproduction

Material and methods

The effect of the host plant on reproduction was investigated by tests arranged in fields 1—5. Field 5, in which the number of aphids was not counted, was located on the land of the Department of Horticulture in Piikkiö, where the raspberries had been planted in spring 1963 in rows of 5—20 metres on an area 20 × 50 metres. 10 first-year canes, as similar to one another as possible, were selected from the test plants, and one agamic female was placed upon the region of growing point at the top of each. The top of the cane was protected with a rearing cage made of transparent plastic and terylene gauze (diameter 10 cm, length 10 cm). The aphids, which were raised on the Preussen variety in insectary, were the progeny each year of a single fundatrix and were of equal age within 1—2 days accuracy at the beginning of the test. The test period was 10 days. In 1965 the reproduction of aphids on *R. arcticus* and *R. chamaemorus* was investigated in insectary by placing 15 females each separately upon in rearing corks the young leaves of potted plants (see Markkula 1963). In some experiments the effect of the host plant upon the reproduction of green and red *A. rubi* females was compared. The red aphids were each year the progeny of a female found in field 3. These populations that remained red throughout the summer, were reared on the Preussen variety in insectary. The significance of the differences in number of progeny was calculated by the Tukey-Hartley method.

The index of susceptibility was calculated for the experiment plants from the number of larvae borned as well as from the mortality of adults and larvae during the experiment by means of the following equation:

$$\text{Index} = P\left(\frac{A + L}{200}\right), \text{ where}$$

P = number of progeny per female during 10 days
A = number of females alive after 10 days; in percentages
L = number of larvae alive after 10 days per female; in percentages

Results

The host plants had a great effect upon the number of progeny of the females and upon the mortality of females and of larvae (Tables 1 and 2). Generally, the smaller the total number of progeny the greater the mortality of females

Table 1. The average number of larvae per *A. idaei* female on various host plants and the relative numbers of females and larvae alive at the end of the tests. Unless otherwise stated the females were alate. Number 11 was made in insectary, and the others in the fields. Experiments 1—3 were made in 1962, experiments 4—10 in 1964 and experiment 11 in 1965. Only the date of beginning of each test is mentioned. The *R. idaeus* × *arcticus* hydrids are entered by cardinal number. The vertical lines connect averages whose differences were not significant ($P > 0.01$)

Taulukko 1. A. idaein keskim. toukkaluku eri ravintokasveissa sekä elävien aikuisten ja toukkien suhteelliset määrät kokeiden päätyttyä. Ellei erikseen mainita, olivat kirvat siivellisiä. Koe 11 järjestettiin insektaarioon, muut kentille. Kokeet 1—3 tehtiin 1962, kokeet 4—10 1964 ja koe 11 1965. Mesivadelmat on merkitty numeroin. Pystyviivat yhdistävät keskiarvot, joiden ero ei ollut merkitsevä ($P > 0.01$).

Host plant *Ravintokasvi*	Larvae per female *Toukkia/neitsyt*	Number of living larvae % *Eläviä toukkia %*	Number of living females % *Eläviä neitsyitä %*
Exp. 1. Apterae. 10 July.			
Asker	9.4	93	40
Malling Promise	8.9	90	30
Preussen	7.3	90	10
Rikala	4.5	87	10
Exp. 3. 24 July.			
25	16.5	98	100
Herbert	14.9	93	40
16	13.6	99	100
27	13.4	99	100
29	13.1	97	100
Asker	10.4	93	90
Preussen	10.3	93	30
22	9.3	93	90
Malling Promise	8.0	79	0
36/a	7.6	86	70
Rikala	3.8	72	20
Exp. 5. 25 June.			
25	23.4	100	100
13	13.5	100	100
64	12.8	100	100
18	12.6	100	100
67/a	11.3	100	90
23	11.2	100	100
61	10.8	99	100
30	10.2	100	100
34	9.0	93	90
36/a	1.2	42	30
R. fruticosus, apterae	0.3	0	0
alatae	0	0	0
Exp. 7. 15 July.			
Asker	10.2	100	90
Lloyd George	9.4	95	100
R. idaeus	6.8	96	80
Exp. 9. 16 July.			
25	19.7	99	100
Ottawa	15.3	98	100
Norna	13.3	94	100
Miranda	11.3	94	100
Preussen	10.4	90	100
Asker	9.7	94	90
Veten	9.6	97	100
Chief	9.2	90	80
Malling Exploit	8.4	94	100
65	4.9	65	70
66	3.8	58	50
36/a	1.3	77	10
Exp. 11. 6 July.			
Preussen	10.1	93	87
R. arcticus	3.7	86	47
R. fruticosus	0.5	0	0
R. chamaemorus	0.3	20	33
Exp. 2. 3 July.			
16	14.9	100	50
25	13.3	100	60
39	8.2	100	0
65	7.7	100	0
22	6.7	100	30
Exp. 4. 15 June.			
25	21.1	100	100
67	15.2	99	100
16	14.5	100	100
68	14.3	100	100
1	12.3	99	100
48 F_1	10.7	97	100
66	7.8	98	50
65	7.6	94	80
36/a	4.6	67	40
Exp. 6. 7 June.			
Malling Landmark	10.8	99	90
Preussen	10.4	100	90
Kelleris	7.6	97	80
34	7.2	89	90
Rikala	6.5	91	88
66	5.2	56	20
65	4.8	48	40
36/a	3.3	49	10
Exp. 8. 15 July.			
Preussen	8.9	99	100
R. idaeus	7.8	98	70
Lloyd George	7.8	96	90
Exp. 10. 28 July.			
25	18.9	99	100
Sygna	15.6	97	100
Viking	12.2	98	100
Rideau	11.6	97	100
Madawaska	10.9	97	100
Kelleris	10.5	91	80
Andenken an Paul Camenzid	10.3	96	100
Preussen	9.9	94	90
Muskoka	9.6	94	80
Trent	9.4	96	100
Malling Landmark	9.1	98	100
Rikala	8.0	95	80
Chief	7.5	93	90
66	6.3	92	80
65	5.8	89	70
36/a	3.0	53	20

Table 2. The average number of larvae per *A. rubi* female on various host plants and the relative numbers of females and larvae alive at the end of the tests. All the females were alate. Experiments 1 and 2 were made in 1962, experiments 3—5 in 1964 and experiment 6 in 1965. Numbers 5 and 6 were made in insectary, and the others in the fields. The vertical lines connect averages whose differences were not significant ($P > 0.01$)

Taulukko 2. A. rubin keskim. toukkaluku eri ravintokasveissa sekä elävien aikuisten ja toukkien suhteelliset määrät kokeiden päätyttyä. Kokeet 1 ja 2 tehtiin vuonna 1962, kokeet 3—5 1964 ja koe 6 1965. Kokeet 5 ja 6 järjestettiin insektaarioon, muut kentille. Pystyviivat yhdistävät keskiarvot, joiden ero ei ollut merkitsevä ($P > 0.01$)

Host plant *Ravintokasvi*	Larvae per female *Toukkia/neitsyt*	Number of living larvae % *Eläviä toukkia %*	Number of living females % *Eläviä neitsyitä %*
Exp. 1. 30 July.			
Preussen	20.8	100	100
Rikala	18.8	100	100
Asker	18.4	100	100
Malling Promise	15.6	100	100
R. idaeus	14.6	100	100
Exp. 3. 6 July.			
R. fruticosus			
red females	6.8	47	40
green females	5.2	44	10
Exp. 4. 7 August.			
Rideau	37.3	100	100
Viking	30.5	100	100
Muskoka	29.8	100	100
Ottawa	25.8	100	100
Asker	22.0	99	100
Kelleris	21.6	99	90
Trent	20.8	100	100
Rikala	20.0	99	100
Norna	16.5	99	80
Miranda	15.2	98	80
Sygna	14.9	100	100
Veten	12.7	74	90
Malling Landmark	11.5	91	70
Chief	9.5	88	40

Host plant *Ravintokasvi*	Larvae per female *Toukkia/neitsyt*	Number of living larvae % *Eläviä toukkia %*	Number of living females % *Eläviä neitsyitä %*
Exp. 2. 9 August.			
36/a	18.8	100	100
14	18.6	100	100
8	18.0	100	100
27	17.1	100	100
53	16.2	100	100
16	15.8	100	100
30	14.6	100	100
19	13.7	100	100
9	10.1	100	100
22	4.5	100	100
21	4.3	100	100
Exp. 5. 15 July.			
Preussen	19.4	100	100
Lloyd George	16.6	98	100
R. idaeus	13.1	100	100
Exp. 6. 6 July.			
Asker	18.9	98	100
R. arcticus	11.2	68	47
R. chamaemorus	6.1	56	40
R. fruticosus	6.0	52	30

and larvae. The data obtained from the experiments can be described by the log curves and regression equations presented in Fig. 7. On average, 76.7 % of the *A. idaei* females died, as did 52.0 % of the larvae, on the host plants on which the number of larvae per female was 3.0 or less. At the end of the experiment all the females were alive on the plants on which the number of larvae was greater than 15.1. All the larvae were alive at the end of the experiment on the plants on which the mean number of larvae per female was greater than 21.0. Correspondingly, 40.0 % of the females and 26.1 % of the larvae of *A. rubi* died on the host plants on which the mean number of larvae per female was 3.0 or less. All the females and larvae were alive on the plants on which the number of larvae was greater than 24.1. There was no essential difference between the species.

Differences between the Rubus-species. *A. idaei* produced on *R. fruticosus* only a few larvae, and all the females and larvae died before the end of the experiment (index 0, Fig. 8). *R. arcticus* (ind. 2.4) was somewhat more susceptible than *R. chamaemorus* (ind. 0.1). Wild *R. idaeus* (ind. 6.3) was at a level with most cultivated raspberry varieties and with *R. idaeus* × *arcticus* hybrids. As host plant for green females of *A. rubi*, *R. fruticosus* (ind. 1.4) was somewhat less suitable than *R. chamaemorus*

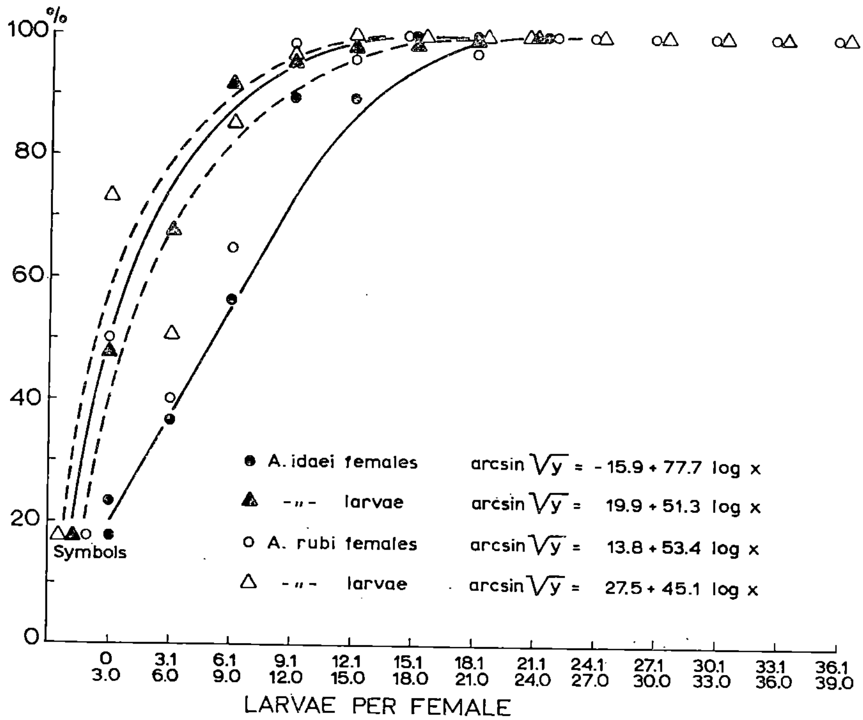

Fig. 7. The relative numbers of females and larvae alive at the end of the reproduction tests in different reproduction groups. The continuous log curves show the means for *A. idaei*, the broken ones for *A. rubi*.

Kuva 7. Lisääntyvyyskokeiden päätyttyä elossa olleiden aikuisten ja toukkien suhteelliset määrät eri lisääntyvyysluokissa. Yhtenäiset viivat = A. idaei, katkoviivat = A. rubi.

(ind. 2.9), and *R. arcticus* (ind. 6.4) was more susceptible than either. On *R. fruticosus* the red females produced on average 1.6 more larvae than did the green females (Table 2), but the difference was not a significant one ($P > 0.05$). The index for *R. fruticosus* was 2.4 as reckoned from experiments made with red females and 1.4 with green females. The wild *R. idaeus* (ind. 13.9) was at a level with most raspberry varieties and with *R. idaeus* × *arcticus* hybrids.

R a s p b e r r y v a r i e t i e s. Among the raspberry varieties it appeared that Sygna (ind. 15.2) and Ottawa (ind. 15.0) were the most susceptible to *A. idaei*, and Rikala (ind. 4.1) and Malling Promise (ind. 4.3) the most resistant. Rideau (ind. 37.3) and Viking (ind. 30.5) were, to judge from the indexes, the most suitable hostplants for *A. rubi* while Chief (ind. 3.4) and Malling Landmark (ind. 7.3) were the least favourable.

R. i d a e u s × a r c t i c u s h y b r i d s. From the reproduction experiments it appears that 25 (ind. 18.2) and 16 (ind. 13.1) were the most susceptible for *A. idaei* and 36/a (ind. 2.3), 65 (ind. 3.8) and 66 (ind. 3.4) the least susceptible. As host plant for *A. rubi*, however, 36/a (ind. 18.8) was the most suitable and 21 (ind. 4.3) the least one.

Host plant selection

Material and methods

The settling of the alate females on the plants was studied in 1962 and 1965. Experiments 1 and 2 were made in 1962. Pieces 20 cm in length, cut from the tops of the first-year canes of raspberry varieties and *R. idaeus* × *arcticus* hybrids, were inserted through the holes of

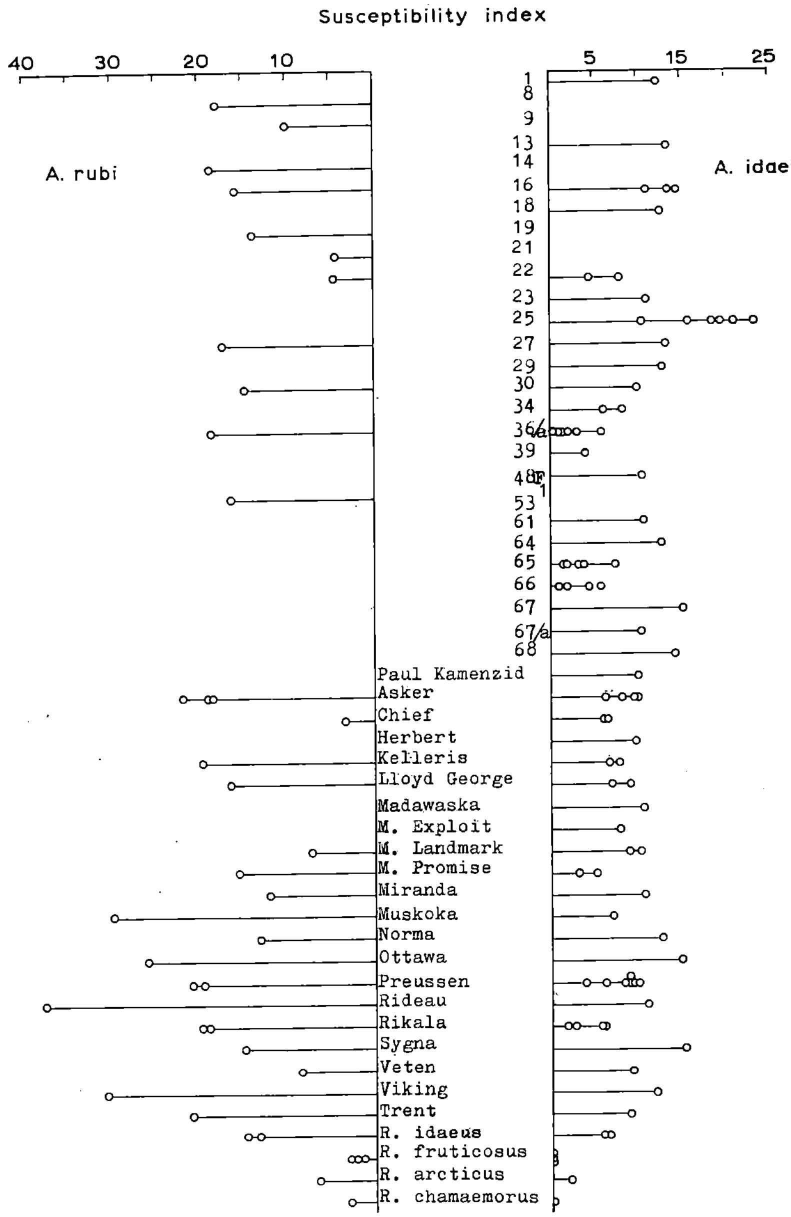

Fig. 8. Susceptibility indexes calculated for host plants from the results of the reproduction tests. One circle indicates the index obtained from one test. For detailed explanation see text.

Kuva 8. Lisääntyvyyskokeiden tulosten perusteella ravintokasveille lasketut alttiusindeksit. Kukin ympyrä osoittaa yhdestä kokeesta saadun indeksin arvon. Yksityiskohtainen selostus tekstissä.

the inner floors of chambers (diameter 40 cm, height 15 cm) made of white non-transparent plastic into water. The aphids were placed at the centre of the circle of the plants, and at certain intervals the number of aphids that had settled on the leaves was counted. In experiment 1 the number of *R. idaeus* × *arcticus* hybrids was 5, and 50 alatae *A. idaei* females and 60 *A. rubi*

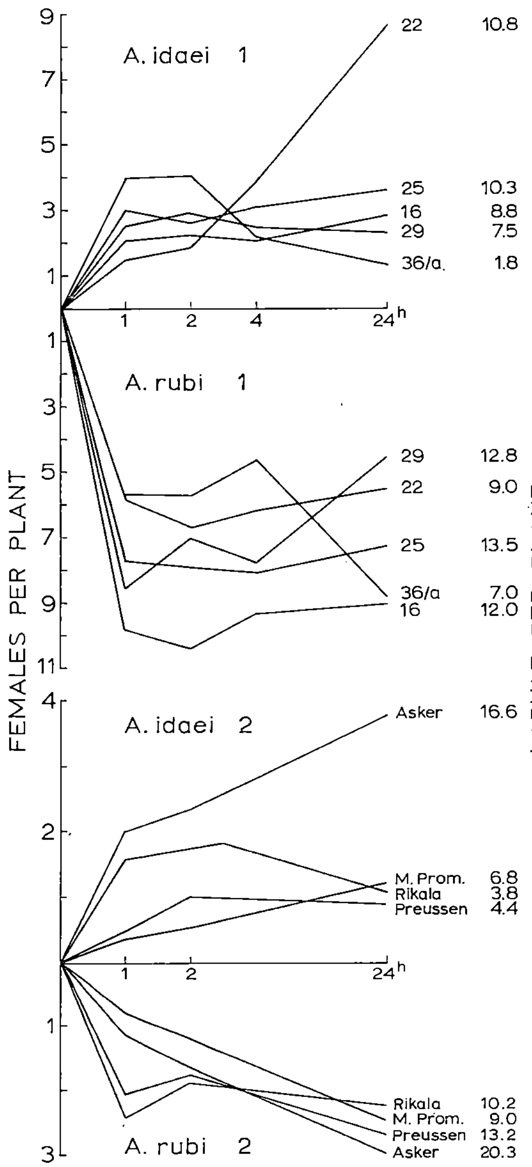

Fig. 9. The number of aphids settling on different plants and the number of larvae on plants at the end of host plant selection tests 1 and 2.

Kuva 9. Ravintokasvinvalintaa selvittävissä kokeissa 1 ja 2 eri kasveille asettuneiden koe-eläinten luku sekä toukkien määrä kasveissa kokeiden päätyttyä.

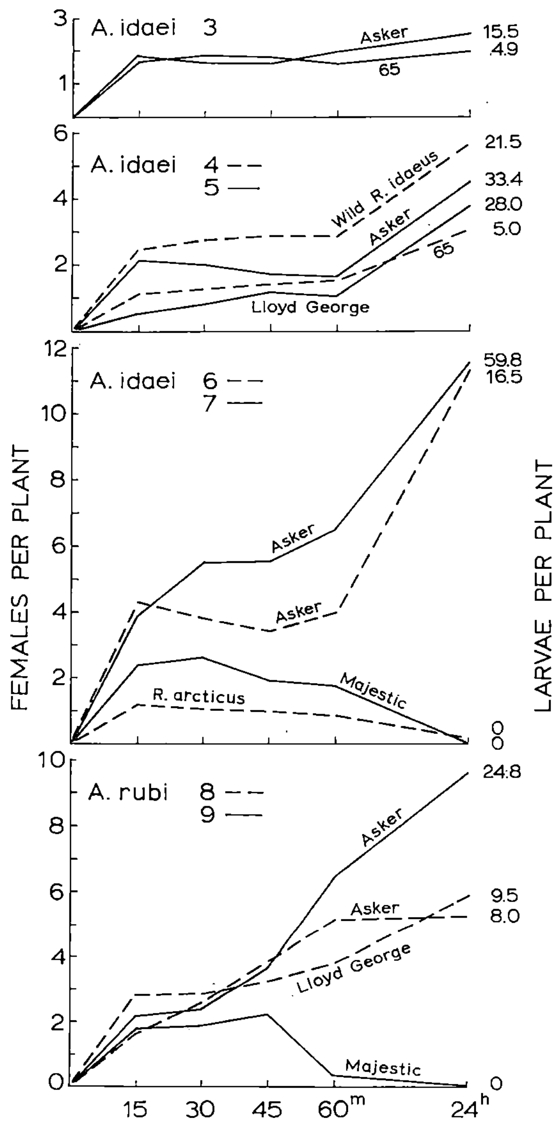

Fig. 10. The number of aphids settling on different plants and the number of larvae on plants at the end of host plant selection tests 3—9.

Kuva 10. Ravintokasvinvalintaa selvittävissä kokeissa 3—9 eri kasveille asettuneiden koe-eläinten luku sekä toukkien määrä kasveissa kokeiden päätyttyä.

females were at the same time placed in the chamber. In experiment 2 there were 4 raspberry varieties and 100 *A. idaei* females and 170 *A. rubi* females. The experiments were made in laboratory in an illumination of 2 500 lux and at a temperature of 21 ± 2°C. Experiments 3—9 were made in 1965. The 5-cm long pieces cut from the tops of first-year canes were sunk into water through the inner bottom of the chambers (diameter 15 cm, height 20 cm) made of PVC plastic. The settling of the aphids was checked on only two varieties at any one time. In every experiment there were four chambers, each having four replications of two variety. The number of aphids in each chamber was 120—260. The experiments were carried out in laboratory in an illumination of 3 000 lux and at a temperature of 20 ± 2°C. The alate females used in experiments were in each year the progeny of a single fundatrix and of equal age within 1—2 days accuracy. The significance of the differences in the numbers of aphids was calculated by the Tukey-Hartley method.

Results

During the first two hours in experiment 1 most of the *A. idaei* females settled on hybrid 36/a but some of them moved later to other ones (Fig. 9). After twenty-four hours the difference between the number of aphids settled on 22 and on 36/a was a significant one ($P < 0.05$). At the end of the experiment the number of larvae was smallest on 36/a. In experiment 2 the aphids did not settle in significantly different numbers on different varieties. At the end of the experiment the number of larvae was greater on Asker than on the others ($P < 0.05$). At the beginning of experiment 3 (Fig. 10) *A. idaei* settled in nearly equal numbers on Asker and 65 but at the end of the experiment there were more larvae on Asker than on 65 ($P < 0.05$). In experiment 4 the number of aphids was nearly the same on *R. idaeus* as on 65 (Fig. 10) but at the end of the experiment there were more larvae on *R. idaeus* than on 65 ($P < 0.05$). *A. idaei* settled in nearly equal numbers on Asker and Lloyd George, and the difference in the number of larvae, was, likewise, not a significant one ($P > 0.05$) (Fig. 10). In experiments 6 and 7 more aphids settled on Asker than on *R. arcticus* and *R. fruticosus* ($P < 0.01$). At the end of the experiments there were on average 1.8 larvae on *R. arcticus*, while no larvae were found on *R. fruticosus.*

In experiment 1 *A. rubi* settled on the different *R. idaeus* × *arcticus* hybrids in nearly equal numbers (Fig. 9). At the end of experiment 2 there were more aphids on Asker than on other varieties ($P < 0.05$). After an hour from the beginning of experiment 9 the number of *A. rubi* was greater on Asker than on *R. fruticosus* ($P < 0.05$). Larvae were found only on Asker.

Conclusions and discussion

The species of the *Rubus* genus that were experimented with can be inferred from the results to be suitable host plants to *A. idaei* and *A. rubi* in the following order: *R. idaeus* > *R. arcticus* > *R. chamaemorus* ≧ *R. fruticosus.*

So far as is known only Janiszewska (1963) has found *A. idaei* living on blackberry. In various parts of Europe there may live different *A. idaei* strains and the blackberries may vary greatly as host plants, too. According to the present study the blackberry variety Majestic (*R. fruticosus*, s. lat.), at least, was not a suitable host plant for *A. idaei.*

The females of *A. rubi* that were used in the present investigation probably belong to the raspberry strain (= *Nectarosiphon idaei* CB; Börner 1952) separated from the species, as the aphids reproduced significantly less on *R. fruticosus* than on *R. idaeus*, and no specimens were found on the *R. fruticosus* in three examinations. According to Hultén (1950) the only blackberry (s. lat.) that has a distribution extending to the present area of Finland is *R. caesius.* As blackberry varieties are not extensively cultivated in Finland, the possibilities of the *A. rubi* blackberry strain (= *N. rubi* Kalt.; Börner 1952) to be very common are evidently slight.

Table 3 shows the correlation coefficients between the susceptibility indexes of the raspberry varieties and the *R. idaeus* × *arcticus* hybrids and the numbers of aphids found on the same varieties in the field. Correlations were not calculated from the small numbers of aphids found in June. 11 of the coefficients proved to

Table 3. The correlation between the susceptibility indexes of certain host plants and the numbers of aphids found on the same plants in the fields. *P < 0.05, **P < 0.01. For detailed explanation see the text

*Taulukko 3. Vadelmien ja mesivadelmien alttiusindeksien sekä samoissa lajikkeissa kentällä todettujen kirvamäärien korrelaatio. Yksityiskohtainen selostus tekstissä. *P < 0.05, **P < 0.01*

Field *Kenttä*	Date of inspection *Tarkastus*	Correlation coefficients *Korrelaatiokertoimet* *A. idaei*	*A. rubi*
1	8. 8. 1961	+0.339	+0.309
	2. 7. 1963	+0.326	+0.821*
	7. 8. 1963	—0.100	+0.079
2	31. 8. 1962	+0.533	+0.418
	3. 7. 1963	+0.445	—0.862
	8. 8. 1963	—0.556	—0.002
3	3. 7. 1963	+0.809**	
	8. 8. 1963	+0.719**	
	6. 8. 1964	+0.350	

be positive — 3 of these were significant ones — and 4 to be negative. The significant coefficients can be interpreted as suggesting that the number of aphids on the plants depended on the susceptibility index, i.e. the mean number of larvae per female and the mortality of the larvae and females. The negative and the near-zero coefficients probably indicate, however, that the numbers of the aphids on the plants growing in the field were affected by factors other than the aphids' reproduction and ability to survive.

Among the raspberry varieties tested, Chief and Malling Landmark seemed to be less suitable host plants than the others to *A. rubi*. The same result has been arrived at in several investigations made in Europe, but in North America both

Table 4. The suitability of certain raspberry varieties as host plant of *A. rubi*, according to investigations made in North America and Europe. * = raspberry strain *(N. idaei)*, ** = blackberry strain *(N. rubi)*

*Taulukko 4. Eräiden vadelmalajikkeiden soveltuvuus A. rubin ravintokasveiksi Pohjois-Amerikassa ja Euroopassa tehtyjen tutkimusten mukaan. * = A. rubin vadelmissa elävä rotu (N. idaei) ** = A. rubin karhunvadelmissa elävä rotu (N. rubi)*

Variety *Lajike*	North-America *Pohjois-Amerikka* Resistant *Kestävä*	Intermed. *Välittävä*	Susceptible *Altis*	Europe *Eurooppa* Resistant *Kestävä*	Intermed. *Välittävä*	Susceptible *Altis*
Andenken an Paul Kamenzid						1, 12,
Asker						1, 12,
Chief			4, 10, 16,	1, 12, 14,		
Deutschland				1*,		1**,
Herbert	16, 18,	15,			1,	
Hornet				1*,		1**,
Indian Summer	4, 6, 10,	11,			1, 13,	
Lloyd George	4, 5, 6, 8, 10, 11, 16, 17,					1, 2, 7, 9, 13, 14,
Madawaska			4,			1,
Malling Exploit						1, 3, 11,
Malling Landmark			8,	1, 2, 9, 12, 13, 14,		
Malling Promise	8,			1**,	3,	1*, 9, 12, 13, 14,
Marlboro					1,	
Miranda	6,			1*,		1**, 14,
Muskoka			4,			
Preussen						12, 14,
Rideau	6,		4,			1,
Viking			6, 16,		9, 13,	
Trent	6,					1,

References: 1 BAUMEISTER 1961; 2 CADMAN 1957; 3 CADMAN and FISKEN 1958; 4 CONVERSE and BAILEY 1961; 5 DARROW 1937; 6 DAUBENY and STACE-SMITH 1963; 7 DICKER 1940; 8 HILL 1956; 9 HILL 1957; 10 HUBER and SCHWARTZE 1938; 11 JEFFERS 1953; 12 KNIGTH et al. 1959; 13 KRONENBERG and DE FLUITER 1951; 14 NYBOM 1960; 15 RANKIN 1927; 16 SCHWARTZE and HUBER 1937; 17 STACE-SMITH 1960; 18 WINTER 1929.

Chief and Malling Landmark have not been so resistant (Table 4). Lloyd George, which *A. rubi* do not live on in North America (Hill 1956), was according to the present study very susceptible to *A. rubi*.

The experiments with the host plant selection indicated that the aphids were able to distinguish between plants of different host-plant value. Presumably, those characteristics of the plants which in the experiment caused the settling of the aphids on the plants in different numbers also had effect in the fields. From this assumption it is possible to conclude that the low number of *A. idaei* on hybrid 36/a, as well as the absence of either species of aphid on *R. fruticosus*, was primarily caused by the fact that few aphids settled on them, the ones that settled produced few larvae, and a large proportion of these larvae died.

Many recent studies have emphasized the significance of amino acids in the reproduction of aphids (see e.g. Auclair 1963). Paper-chromatographic amino-acid analyses were made in 1963 of the top leaves of the first-year canes of six raspberry varieties and sixteen *R. idaeus* × *arcticus* hybrids, by the method presented by Markkula and Laurema (1964). It was not possible to establish any relationship between the reproduction of the aphids and the amino-acid content or composition of the cellular tissue of the leaves. Nor was any relationship found between various features of growth of the wild *R. idaeus* populations (see Rousi 1965 b) and the numbers of the aphids.

Summary

An investigation was made in 1961—65 to clarify the suitability of raspberries, *Rubus idaeus* × *arcticus* hybrids, wild *R. idaeus* populations gathered from different parts of Finland and certain other *Rubus* species as host plants of *Aphis idaei* and *Amphorophora rubi*. The investigation consisted of three parts: the numbers of the aphids on the plants in four separate fields were ascertained, the effect of the host plant on the reproduction and ability to survive of the aphids was studied, and the settling of the aphids on different plants was clarified by host-plant-selection experiments.

The numbers of the aphids on the plants in the fields were counted in the middle of June, in the beginning of July and in the beginning of August. The number of *A. idaei* was smallest in June (0.1 aphids on 3 leaves), somewhat greater in July (4.7) and greatest in August (23.5). Correspondingly, the number of *A. rubi* on 3 leaves averaged 0.1 in June, 2.7 in July and 2.5 in August.

In June a considerable majority of the specimens of each of the species were found at the tops of first-year canes (*A. idaei* 68.9 % and *A. rubi* 91.2 %). For July the corresponding percentages were 22.7 and 63.0, and for August 26.4 and 37.0. In August nearly equal proportions of the specimens of each of the species were found on the tops of the canes, on the leaves of the middle part, and on the leaves of the lower part.

The species of the *Rubus* genus that were studied were suitable as host plants for both *A. idaei* and *A. rubi* in the following order: *R. idaeus* > *R. arcticus* > *R. chamaemorus* ≥ *R. fruticosus*. The differences between the raspberry varieties were concluded to be insufficient to cause repeatedly different numbers of aphids on the same varieties. Nevertheless, from the results of the reproduction experiments it was established that the differences between the susceptibility indexes calculated for the different varieties were quite large ones. Sygna and Ottawa were the most suitable host plants for *A. idaei*, and Rikala and Malling Promise were the least suitable. In contrast, Rideau and Viking were the most suitable host plants for *A. rubi*, and Chief and Malling Landmark the least.

The *R. idaeus* × *arcticus* hybrids were of greatly varying value as host plants of *A. idaei*. 36/a, which had the smallest susceptibility index and repeatedly in the field the smallest number of

aphids, proved to be the least suitable. In contrast, *A. rubi* reproduced in great numbers on 36/a, and the number of aphids on this hybrid was great in the field. None of the *R. idaeus* × *arcticus* hybrids proved clearly and repeatedly to be less suitable as host plants of *A. rubi.*

The number of *A. idaei* was repeatedly greater on one wild *R. idaeus* population than it was on the others. The number of *A. rubi* on any one population did not repeatedly vary from that on any other.

The results of the host-plant-selection experiments suggested that the alate aphids were able to distinguish between plants of varying host value and that they settled on them in different numbers.

No connection was established between the reproduction of the aphids and the amino-acid content and composition of the leaf tissue of the raspberries and the *R. idaeus* × *arcticus* hybrids. Nor was it possible to find any connection between the morphological characteristics of the various wild *R. idaeus* populations and the numbers of the aphids found on these in the fields.

Acknowledgements. — I wish to express my sincerest thanks to Professor Veikko Kanervo, Dr. Agr. and For., and to Martti Markkula, Dr. Ph., for suggesting this subject and for continuous advices and criticism during the study. My gratitude is also due to Professor Jaakko Säkö, Dr. Agr. and For., Associate Professor Arne Rousi, Dr. Ph., Professor E. A. Jamalainen, Dr. Agr. and For., and Mrs. Eeva Tapio, Lic. Agr. and For., for working facilities and helpful co-operation. My best thanks are due to Mr. Seppo Laurema, M. Sc., for determining the amino-acids of the leaf samples.

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SELOSTUS

Eräiden Rubus-suvun kasvien soveltuvuus vadelman kirvojen ravintokasveiksi

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Yleisimpien Suomessa viljeltyjen vadelmalajikkeiden, mesivadelmien (*Rubus idaeus* × *arcticus*), maan eri osista kerättyjen luonnonvadelmakantojen sekä eräiden muiden *Rubus*-suvun lajien soveltuvuutta pienen vattukirvan (*Aphis idaei* v. d. Goot) ja ison vattukirvan (*Amphorophora rubi* (Kalt.)) ravintokasveiksi tutkittiin vuosina 1961—1965. Tutkimus oli kolmiosainen: selvitettiin kirvojen runsautta neljän erillisen kentän kasveissa, tutkittiin ravintokasvin vaikutusta kirvojen lisääntymiseen ja elinkykyyn sekä selvitettiin ravinnonvalintakokein koe-eläinten asettumista eri kasveille.

Kirvojen runsaus kenttien kasvustoissa laskettiin kesäkuun puolivälissä sekä heinäkuun ja elokuun alussa. *A. idaein* runsaus oli pienin kesäkuussa (0.1 kirvaa kolmessa lehdessä), hieman suurempi heinäkuussa (4.7) ja suurin elokuussa (23.5). Vastaavasti oli *A. rubin* luku kolmessa lehdessä kesäkuussa keskim. 0.1, heinäkuussa 2.7 ja elokuussa 2.5.

Kesäkuussa oli valtaosa kummankin lajin yksilöistä ensimmäisen vuoden versojen latvoissa (*A. idaei* 68.9 % ja *A. rubi* 91.2 %). Heinäkuussa vastaavat määrät olivat 22.7 % ja 63.0 % sekä elokuussa 26.4 % ja 37.0 %. Elokuussa lähes yhtä suuri osa kummankin lajin yksilöistä eli verson latvoissa, keskiosan lehdissä ja alaosan lehdissä.

Tutkitut *Rubus*-suvun lajit soveltuivat sekä *A. idaein* että *A. rubin* ravintokasveiksi seuraavassa järjestyksessä: *R. idaeus* > *R. arcticus* > *R. chamaemorus* ≧ *R. fruticosus*. Vadelmalajikkeiden erot pääteltiin riittämättömiksi aiheuttamaan toistuvasti samoihin lajikkeisiin merkitsevästi erisuuret kirvamäärät. Silti todettiin lisääntyvyyskokeiden perusteella eri lajikkeille laskettujen alttiusindeksien erot varsin suuriksi. *A. idaein* ravintokasveiksi soveltuivat Sygna ja Ottawa parhaiten ja Rikala sekä Malling Promise huonoiten. Sitä vastoin *A. rubin* ravintokasveina olivat Rideau ja Viking parhaat ja Chief sekä Malling Landmark huonoimmat.

Mesivadelmat olivat *A. idaein* ravintokasveina hyvin eriarvoiset. Epäedullisimmaksi osoittautui 36/a, jonka alttiusindeksi oli pienin ja jossa kentillä tavattiin toistuvasti vähiten kirvoja. *A. rubi* sitä vastoin lisääntyi 36/a:ssa runsaasti, ja kentillä oli kirvojen luku tässä mesivadelmassa suuri. Mikään mesivadelma ei selvästi ja toistuvasti osoittautunut *A. rubi*n ravintokasvina muita epäedullisemmaksi.

Eräässä luonnonvadelmakannassa oli *A. idaei*n runsaus toistuvasti suurempi kuin muissa. *A. rubi*n määrä ei ollut missään kannassa toistuvasti muista poikkeava.

Ravinnonvalintakokeiden tulokset viittasivat siihen, että siivelliset kirvat erottivat ravintokasveina eriarvoiset kasvit toisistaan ja asettuivat niihin erisuurin määrin.

Kirvojen lisääntymisen ja vadelmien sekä mesivadelmien lehtisolukon aminohappopitoisuuden ja -koostumuksen välillä ei todettu olleen mitään yhteyttä. Ei myöskään voitu löytää yhteyttä luonnonvadelmakantojen erilaisten morfologisten ominaisuuksien ja kentillä kasvavissa vadelmissa eläneiden kirvamäärien välillä.

ANNALES AGRICULTURAE FENNIAE, VOL. 6: 191—196 (1967)
Seria AGRICULTURA N. 28 — Sarja KASVINVILJELY n:o 28

SÄÄTEKIJÖIDEN VAIKUTUS JYVÄN KUIVUMISEEN KEVÄTVILJOISSA

Zusammenfassung: **Einfluss der Witterungsfaktoren auf der Abnahme des Wassergehaltes des Kornes von Sommergetreide**

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Saapunut 14. 9. 1967

Seuraavassa tarkastellaan Kasvinviljelylaitoksella Tikkurilassa v. 1953—66 ns. leikkuupuintiruuduilta saatuja tuloksia, joista on julkaistu väliaikatietoja jo aikaisemmin (VALLE 1953, 1954, 1955, 1956, 1958, 1962, 1965, vrt. myös HIIVOLA 1958). Mainituissa kirjoituksissa on tulokset esitetty lähinnä havainnollisina piirroksina. Kun tutkimuksessa on vuosien kuluessa kertynyt huomattavan laaja aineisto, on paikallaan suorittaa yhteenveto tilastollisia menetelmiä hyväksi käyttäen.

Tutkimuksen järjestelystä mainittakoon lyhyesti seuraavaa. Eri viljalajikkeita kylvettiin näyteruuduille, jotka sijaitsivat hietasavimaalla. Keskimääräinen kylvöaika oli 13/5 (eri vuosina 29/4—25/5). Viljelytoimenpiteet olivat suunnilleen samat kuin muissa viljakokeissa. Jyvänäytteiden otto aloitettiin muutamia päiviä ennen keltatuleentumisasteen alkua. Näyte (15—20 tähkää) otettiin käsin, jyvät irroitettiin hieromalla tähkiä kangassäkissä, roskat puhallettiin pois ja jyvistä suoritettiin kuiva-ainemääritys kaappikuivatusta käyttäen (16 tuntia/130°C). Näytteet otettiin yleensä klo 13—14. Vesipitoisuusmuutoksia pyrittiin seuraamaan päivittäin, mikäli sade- ja muut olot sen sallivat. Sateen sattuessa näytteen otto siirtyi seuraavaan päivään. Tähän yhteenvetoon on otettu vain Timanttikevätvehnällä (v. 1953—54 Kärni, v. 1960 Svenno), Balder-ohralla ja Sisu-kauralla saadut tulokset ja niistäkin vain osa.

Tutkimuksen aikana vallinneista sääoloista mainittakoon, että elokuun lämpötila (keskim. 14.9°C) oli hieman alempi, sademäärä (93 mm) sitä vastoin suurempi kuin mitä pitkä-aikaiset (1931—60) havainnot Tikkurilassa osoittavat.

Aineiston käsittelyn yhteydessä laskettiin aluksi muutamia keskiarvoja. Kun vuosia oli paljon (yht. 14), kuvaavat näin saadut luvut suunnilleen keskimääräisiä oloja Etelä-Suomessa. Kun ei ollut tietoja siitä, minkä muotoinen jyvän kuivumiskäyrä on, jaettiin kuivumisaika kahteen jaksoon. Ensimmäinen jakso käsitti ajan, joka kului vesipitoisuuden alenemiseen noin 40 %:sta noin 30 %:iin ja toinen jakso vastaavasti ajan 30 %:sta 20 %:iin. Kuivumisnopeuden kuvaajaksi valittiin jyvän vesipitoisuuden lasku vuorokaudessa %-yksikköinä lausuttuna.

Keskiarvojen lisäksi pyrittiin selvittämään kuivumisnopeuden riippuvaisuutta säätekijöistä. Tällainen tarkastelu oli mahdollista sen vuoksi, että säähavaintoasema sijaitsi lähellä koealueita.

Tarkastelun kohteeksi otettiin lämpötilan (vuorokauden keski- ja ylimmän lämpötilan), ilman suhteellisen kosteuden, sademäärän ja sadepäivien (sadetta vähintäin 0.1 mm vrk:ssa) lukumäärän vaikutukset.

Tulokset ja niiden tarkastelu

Mainittakoon aluksi, että kevätviljojen satovaihtelu oli eri vuosina huomattava. Esimerkiksi Timantin jyväsato oli lajikekokeissa, vuodesta riippuen, 1 450—3 470 kg/ha. Tällä seikalla oli vaikutusta myös tuleentumiseen ja jyvän vesipitoisuuden muutoksiin.

Tutkitut kevätviljat t u l e e n t u i v a t (saavuttivat keltatuleentumisasteen) keskimäärin seuraavasti: Timantti-kevätvehnä 23/8 (eri vuosina 8/8—8/9), Balder-ohra 14/8 (3/8—26/8) ja Sisu-kaura 20/8 (7/8—7/9). Tuleentumisajan vaihtelu oli siis erittäin suuri johtuen lähinnä säästä. Poikkeuksellisina vuosina 1956, 1958, 1962 ja 1965 kevätvehnä ja kaura tuleentuivat vasta syyskuun puolella.

Jyvän v e s i p i t o i s u u s oli tuleentumispäivänä, ottaen huomioon kaikki vuodet, keskimäärin seuraava: Timantti 37.9 %, Balder 41.7 % ja Sisu 34.7 %. Mainitut luvut ovat suuria verrattuna esim. GESSLEINin (1959) julkaisemiin lukuihin, joiden mukaan vehnässä ja ohrassa on keltatuleentumisasteella vettä 30—35 % ja kaurassa noin 30 %. Tällaiset erot saattavat johtua keltatuleentumisasteen määritystavasta ja sääoloista. Tikkurilassa katsottiin vilja tuleentuneeksi silloin, kun jyvä taittui helposti ja sen taittopinta jäi tasaiseksi. Sen lisäksi otettiin huomioon kasvuston yleiskuva, erityisesti sen väri.

Leikkuupuinnin kannalta on mielenkiintoista tietää, milloin kevätviljat saavuttivat ns. l e i k k u u p u i n t i a s t e e n. Mainittu käsite on epämääräinen. Ulkomaisten kokemusten mukaan viljan kosteuden pitäisi olla leikkuupuitaessa noin 20 % (vrt. esim. DODDS ja PELTON 1967, GESSLEIN 1959). Näin alhaista vesipitoisuutta ei Tikkurilassa läheskään kaikkina vuosina saavutettu. Useina vuosina vei jo 25 %:n kosteusrajan saavuttaminen liian paljon aikaa, jos asiaa tarkastellaan sadon laadun kannalta. Kokemus onkin osoittanut, että leikkuupuintiin on epäedullisissa oloissa ryhdyttävä jo aikaisemmin.

Taulukko 1. Jyvän vesipitoisuuden aleneminen (% -yksikköä per vrk) Kasvinviljelylaitoksella Tikkurilassa v. 1953—66.
Tabelle 1. Abnahme des Wassergehaltes des Kornes in % -Einheiten pro Tag in der Abt. f. Pflanzenbau in Tikkurila in den Jahren 1953—66.

Vuosi — *Jahr*	Kevätvehnä *Sommerweizen* 40—30 %[1]	Kevätvehnä *Sommerweizen* 30—20 %	Ohra *Gerste* 40—30 %	Ohra *Gerste* 30—20 %	Kaura *Hafer* 40—30 %	Kaura *Hafer* 30—20 %
1953	2.5	1.4	2.3	0.8	0.9	2.3
1954	1.7	1.2	3.0	3.5	2.0	1.4
1955	3.3	1.0	2.1	2.1	2.0	0.7
1956	0.5	1.4	3.4	3.5	0.4	1.3
1957	0.8	2.1	1.4	0.6	1.8	0.8
1958	1.2	1.7	2.3	5.3	1.3	1.9
1959	2.4	4.9	5.1	6.3	3.0	2.3
1960	1.2	3.3	1.1	5.3	2.0	5.8
1961	1.1	1.0	1.1	1.3	1.9	0.8
1962	0.6	1.6	0.4	0.8	0.5	0.8
1963	1.4	3.0	4.6	1.0	2.3	2.1
1964	0.9	1.9	1.8	0.8	1.8	1.3
1965	1.8	0.6	0.9	0.5	1.3	1.2
1966	2.1	3.5	2.1	3.4	1.0	1.6
Keskim. — *Mittel*	1.5	2.0	2.3	2.5	1.6	1.7
s %[2]	57	62	56	81	44	78

[1]) Aikana, jolloin jyvän vesipitoisuus laski 40:stä 30 prosenttiin jne. — *Während d. Zeit der Abnahme des Wassergehaltes der Kornes vom 40 % bis zum 30 % u.s.w.*
[2]) Vaihtelukerroin — *Variationskoeffizient.*

Taulukosta 1 selviää kuivumisnopeuden erittäin suuri vuosivaihtelu, joka oli esimerkiksi Timantilla ensimmäisen jakson (40—30 %) aikana 0.5—3.3 %-yksikköä. Mainittu seikka oli luonteenomainen muillekin viljoille, kuten vaihtelukertoimet (s %) taulukon alaosassa osoittavat. Vaihtelu oli toisen jakson (30—20 %) aikana suurempi (keskim. s = 74 %) kuin ensimmäisen jakson aikana (52 %). Vertailun vuoksi mainittakoon kevätviljojen ha-satojen vaihtelukertoimet, jotka ovat Tikkurilan kokeissa olleet vain noin 30 %. Suuri vuosivaihtelu viittaa siihen, että jyvän kuivuminen on herkästi riippuvainen vallitsevasta säästä.

Ottaen huomioon kaikki vuodet jyvän kuivumisnopeus oli eri jaksoina keskimäärin seuraava: Timantti 1.5 ja 2.0, Balder 2.3 ja 2.5, Sisu 1.6 ja 1.7 %-yksikköä vuorokaudessa (taul. 1). Kuivuminen oli ensimmäisen jakson aikana hieman hitaampi (keskim. 1.8 %-yks.) kuin toisen jakson aikana (2.1 %-yks.), mutta erot eivät olleet tilastollisesti merkitseviä. Jyvän kuivumiskäyrä oli siis mainitussa vesipitoisuusrajoissa (40—20 %) keskimäärin jokseenkin suoraviivainen.

Huomioon ottaen molemmat jaksot kuivui Balder nopeammin (2.4 %-yks./vrk:ssa) kuin Timantti ja Sisu (1.7 %). Mainitut erot eivät olleet tilastollisesti merkitseviä. Eri kevätviljat kuivuivat siis keskimäärin suunnilleen yhtä nopeasti. Eri vuosina oli kuitenkin suuria eroja. Erot johtuivat todennäköisesti kasvien erilaisesta kehitysrytmistä ja sääolojen erittäin suuresta vaihtelevaisuudesta. Esimerkiksi Balderin tuleentuminen sattui aikaisempaan ja usein lämpimämpään ajankohtaan kuin Timantin ja Sisun tuleentuminen. Mainittakoon, että viljankuivatuksessa kaura kuivuu eräiden tietojen mukaan nopeammin kuin ohra. Vehnä sijoittuu kuivumisnopeudessa edellä mainittujen väliin (ZAUSSINGER 1966). Tässä tutkimuksessa olivat olot kentällä luonnollisesti kokonaan toiset kuin kuivurissa.

Seuraavassa asetelmassa esitetään tärkeimmät tiedot keskimääräisistä sääoloista kummaltakin jaksolta.

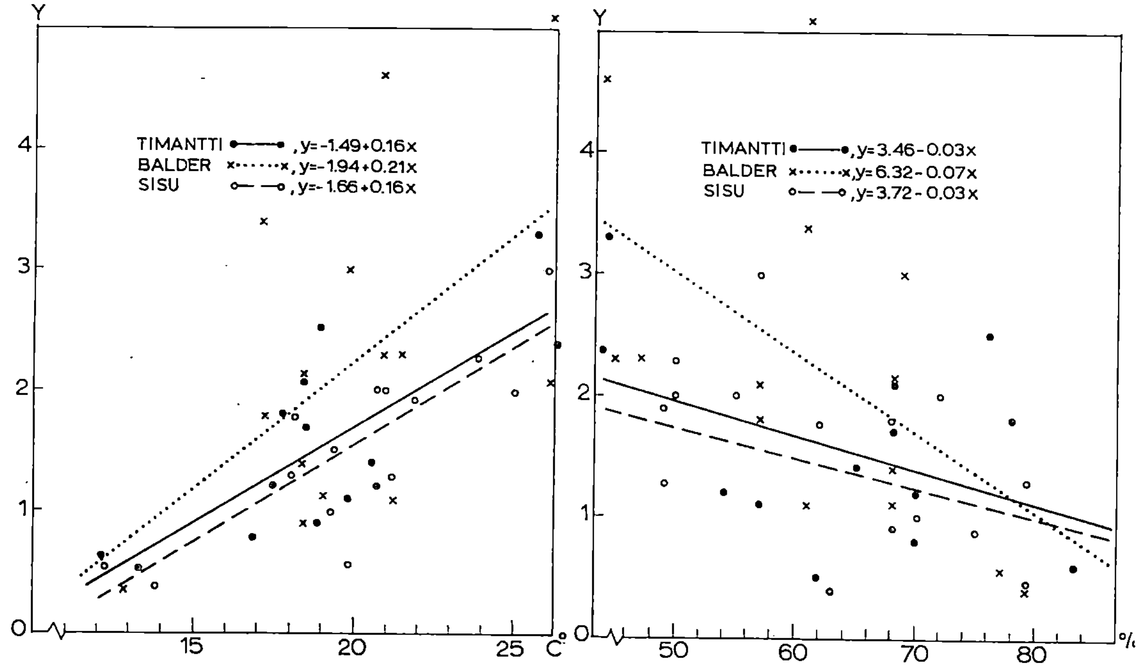
	40—30 %	30—20 %
Keskilämpötila °C	14.4	13.5
Ylin lämpötila °C	19.6	18.5
Ilman keskim. suht. kost. — % klo 8, 14, 20	76	75
Ilman suht. kost. klo 14, %	63	60
Sademäärä mm	22	18
Sadepäivien lukumäärä	5.3	4.2

Lämpötilan lasku toisen jakson aikana on ymmärrettävissä. Kosteusolojen kehityksen suunta poikkesi sitä vastoin normaalista. Poikkeamat olivat kuitenkin pieniä.

Taulukko 2. Kevätviljojen jyvän kuivumisnopeuden (y) riippuvuus eräistä säätekijöistä Tikkurilassa v. 1953—66.
Tabelle 2. Beziehungen zwischen einigen Witterungsfaktoren und Abnahmegeschwindigkeit des Wassergehaltes des Kornes (y) von Sommergetreide in Tikkurila in den Jahren 1953—66.

	Kevätvehnä *Sommerweizen*		Ohra *Gerste*		Kaura *Hafer*	
	40—30 %	30—20 %	40—30 %	30—20 %	40—30 %	30—20 %
	r =	r =	r =	r =	r =	r =
y — Keskilämpötila °C — *Mittl. Temp. °C*	0.72**	0.51	0.48	0.31	0.82***	0.27
y — Ylin lämpötila °C — *Max. Temp. °C*	0.76**	0.59*	0.54*	0.53	0.85***	0.30
y — Suht. kosteus 8—20 [1]) *Rel. Luftf. % 8—20*	—0.39	—0.75**	—0.28	—0.84***	—0.69**	—0.48
y — Suht. koskeus 14 [2]) — *Rel. Luftf. % 14*	—0.41	—0.54*	—0.53	—0.71**	—0.54*	—0.44
y — Sademäärä mm — *Regenmenge, mm*	—0.48	—0.44	—0.61*	—0.68**	—0.55*	—0.43
y — Sadepäiv. lukum. — *Zahl d. Regentage*	—0.72**	—0.68**	—0.68**	—0.79***	—0.62*	—0.49

[1]) Ilman keskim. suht. kosteus klo 8, 14, 20, — *mittl. rel. Luftfeuchtigkeit um 8, 14, 20 Uhr.*
[2]) Suht. kosteus klo 14 — *rel. Luftfeuchtigkeit um 14 Uhr.*



Kuva 1. Jyvän kuivumisnopeuden y (%-yksikköä vrk:ssa) riippuvuus ylimmästä lämpötilasta (vas.) ja ilman suhteellisesta kosteudesta klo 14 (oik.) vesipitoisuuden alenemisen aikana 40 %:sta 30 %:iin Tikkurilassa 1953—66.

Abbildung 1. Abhängigkeit der Abnahmegeschwindigkeit des Wassergehaltes des Kornes y (in %-Einh. pro Tag) von der max. Tagestemperatur (links) und der rel. Luftfeuchtigkeit um 14 Uhr (rechts), während der Zeit der Abnahme des Wassergehaltes vom 40 % bis zum 30 % in Tikkurila in den Jahren 1953—66.

Kuten taulukosta 2 havaitaan, edisti lämpötilan kohoaminen erityisesti kevätvehnän ja kauran kuivumisnopeutta ensimmäisen jakson aikana (r = 0.72—0.82). Myös toisen jakson aikana kertoimet olivat positiivisia, mutta pieniä (r = 0.27—0.51). Ylimmän lämpötilan vaikutus tuli hieman selvemmin esiin (r = keskim. 0.60) kuin vuorokauden keskilämpötilan vaikutus (r = 0.52).

Kosteutta lisäävien tekijöiden vaikutus jyvän kuivumisnopeuteen oli päinvastainen, kuten negatiiviset korrelaatiokertoimet osoittavat. Ilman keskimääräisen suhteellisen kosteuden vaikutus tuli kevätvehnällä ja ohralla selvemmin esiin toisen jakson (r = —0.75 ja —0.84), kauralla sitä vastoin ensimmäisen jakson aikana (r = —0.69). Mainituista eroista ei ole syytä tehdä pidemmälle meneviä johtopäätöksiä. Todettakoon vain, että niin päivän keskimääräisillä kuin myös klo 14 aikaan mitatuilla ilman suht. kosteusluvuilla saatiin riippuvuussuhteet suunnilleen yhtä selvästi esiin.

Sateen vaikutus jyvän kuivumiseen oli melko selvä ohran ja jossakin määrin myös kauran osalta. Ensimmäisen ja toisen jakson kesken ei ollut mainittavia eroja. Sadepäivien lukumäärä osoittautui kuivumisnopeutta tutkittaessa paremmin soveliaaksi tekijäksi (r = keskim. —0.66) kuin sademäärä (r = —0.53).

Kuvassa 1 on esitetty jyvän kuivumisnopeuden riippuvuus ylimmästä lämpötilasta ja ilman suht. kosteudesta klo 14 ensimmäisen jakson aikana. Kevätvehnän ja kauran regressiosuorat ovat melkein samanlaisia. Ohra poikkeaa jonkin verran niistä lähinnä lämpimien vuosien 1959 ja 1963 ansiosta. Poikkeamat eivat olleet tilastollisesti merkitseviä. Kuvasta selviää havainnollisesti erittäin suuri, monista eri syistä johtuva hajonta. Suunta on kuitenkin selvä erityisesti lämpötilan kohdalla. Kysymyksessä ovat ns. kokonaisregressiosuorat. Regressiokertoimien mukaan lisäsi yhden asteen ylimmän lämpötilan kohoaminen mainituissa kosteusrajoissa jyvän kuivumisnopeutta, riippuen viljasta, 0.13—0.21 %-yksiköllä vuorokaudessa. Ilman suhteellisen kosteuden suureneminen esim. 10 %:lla sitä vastoin hidasti kuivumista 0.3—0.7 %-yksiköllä. Viimeksi mainituista regressiokertoimista vain kauran kerroin oli tilastollisesti merkitsevä. Kun lämpötila ja kosteussuhteet ovat keskenään negatiivisessa korrelaatiossa, suoritettiin aineistosta myös osaregressiolasku. Tulokset eivät oleellisesti muuttaneet edellä esitettyjä riippuvuussuhteita.

Tiivistelmä

Kasvinviljelylaitoksella Tikkurilassa vuosina 1953—66 suoritetuissa tutkimuksissa tuleentuivat kevätviljat keskimäärin seuraavasti: Timanttikevätvehnä 23/8, Balder-ohra 14/8 ja Sisukaura 20/8.

Timantin jyvien vesipitoisuus oli tuleentumispäivänä keskimäärin 37.9 %, Balderin 41.7 % ja Sisun 34.7 %.

Jyvän kuivumisnopeus oli ensimmäisen jakson aikana keskimäärin: Timantti 1.5, Balder 2.3 ja Sisu 1.6 %-yksikköä vuorokaudessa. Erot eivät olleet tilastollisesti merkitseviä. Toisen jakson aikana kuivumisnopeus oli suunnilleen sama.

Lämpötilan kohoaminen edisti erityisesti kevätvehnän ja kauran jyvien kuivumista ensimmäisen jakson aikana (r = 0.72—0.82). Ylimmän lämpötilan vaikutus tuli ainakin yhtä selvästi esiin kuin vuorokauden keskilämpötilan vaikutus.

Ilman suht. kosteuden negatiivinen vaikutus oli kevätvehnällä ja ohralla selvin toisen (r = —0.75 ja —0.84), kauralla sitä vastoin ensimmäisen jakson aikana (r = —0.69). Kello 14 mitatut suht. kosteudet olivat riippuvuussuhteita tutkittaessa suunnilleen yhtä hyviä kuin päivän keskimääräiset kosteudet.

Sadepäivien lukumäärän avulla saatiin riippuvuussuhteet hieman paremmin esiin (r = keskim. —0.66) kuin sademäärän avulla (r = —0.53). Sademäärää kuvaavat luvut olivat tulosten kannalta suunnilleen samanarvoisia kuin ilman suhteelliset kosteusluvut. Sateen hidastava vaikutus jyvän kuivumiseen ilmeni eri kevätviljoilla keskimäärin suunnilleen samalla tavoin.

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ZUSAMMENFASSUNG

Einfluss der Witterungsfaktoren auf der Abnahme des Wassergehaltes des Kornes von Sommergetreide

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In den Jahren 1953—1966 wurden in der Abteilung für Pflanzenbau in Tikkurila Untersuchungen über die Veränderung des Wassergehaltes der Körner verschiedener Getreidearten von Versuchsparzellen durchgeführt, die auf sandigem Lehmboden angelegt worden waren. In der gleichen Anbautechnik wie die eigentlichen Getreideversuche ausgeführt, war der durchschnittliche Aussaattermin des Sommergetreides der 13.5, während mit der Probenentnahme einige Tage vor Beginn der Gelbreife begonnen wurde. Die Ähren wurden mit der Hand in kleinen Säcken ausgedroschen und anschliessend der Trockensubstanzgehalt der Körner im Trockenschrank (16 Stunden bei 130°C) bestimmt. Die Probenahme erfolgte zwischen 13 und 14 Uhr. Die Untersuchungen wurden an Diamant-Sommerweizen (Svalöf), an Sommergerste Balder (Weibullsholm) und Hafer Sisu (Tammisto) durchgeführt und brachten folgende Ergebnisse:

Im Durchschnitte wurde bei den angeführten Getreidearten die Gelbreife am 23.8. (Diamant), 14.8. (Balder) und 20.8. (Sisu) erreicht, wobei erwähnt sei, dass in den verschiedenen Jahren erhebliche Abweichungen auftraten. Zu Beginn der Gelbreife lag der Wassergehalt des Sommerweizens durchschnittlich bei 37.9 %, bei Gerste hingegen bei 41.7 % und bei Hafer durchschnittlich bei 34.7 %. In der Zeit, als der Wassergehalt von 40 % auf 30 % sank, betrug die Abnahme des Wassergehaltes pro Tag bei Diamant durchschnittlich 1.5 %, bei Balder 2.3 und bei Sisu 1.6 %-Einheiten (Tabelle 1). Diese Unterschiede waren jedoch statistisch nicht gesichert und weichen in den einzelnen Jahren erheblich von einander ab. Während des zweiten Abschnittes (30—20 %) erfolgte die Abnahme ein klein wenig schneller, doch waren auch diese Unterschiede nicht gesichert. Im unteren Teil der Tabelle 1 sind die Variationskoeffizienten angeführt, die relativ ungefähr doppelt so gross waren als bei den Kornerträgen in dem Versuchen in Tikkurila.

Während des ersten Zeitabschnittes (40—30 %) wirkte sich ein Ansteigen der Temperatur besonders bei Sommerweizen und Hafer aus. Das Temperaturmaximum zeigte einen etwas grösseren Einfluss als es dieser der Tagesdurchschnittstemperatur war. Der negative Einfluss der relativen Luftfeuchtigkeit war bei Sommerweizen und Gerste im zweiten Abschnitt klarer, im Gegensatz zu Hafer, wo dieser im ersten Zeitabschnitt stärker hervortrat. Die Unterschiede können infolge der grossen Streuung aufgetreten sein. Die durchschnittliche Tagesluftfeuchtigkeit gab keine klareren Beziehungen als die nur um 14 Uhr gemessene relative Luftfeuchtigkeit wider. Der Einfluss der Regenmenge zeigte sich ziemlich klar bei Gerste und in einigen Fällen zum Teil auch bei Hafer. Auch die Anzahl der Regentage war gut brauchbar, bei denen die Beziehungen sogar besser als bei der Hilfenahme der Niederschlagsmenge zum Ausdruck kamen (Tabelle 2).

In der Abbildung 1 ergeben sich die Beziehungen zwischen der Abnahmegeschwindigkeit des Wassergehaltes und der maximalen Tagestemperatur sowie der rel. Luftfeuchtigkeit um 14 Uhr. Selbstverständlich haben ausser den erwähnten Witterungsfaktoren auch weitere Verhältnisse die Ergebnisse beeinflusst. Bei der Teilregressionsberechnung veränderte sich das vorausgezeigtes Bild nicht wesentlich.

ANNALES AGRICULTURAE FENNIAE VOL. 6: 197—207 (1967)
Seria AGROGEOLOGIA, -CHIMICA ET -PHYSICA N. 31
Sarja MAAPERÄ, LANNOITUS JA MUOKKAUS n:o 31

STRONTIUM IN FINNISH SOILS

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Received September 21, 1967

The behaviour of strontium in soil and plants has lately been of special interest to investigators, in spite of the fact that Sr is not at present considered an essential element for plant growth. This is due to the danger of radioactive strontium to human health. The uptake of strontium by plants is usually studied with the aid of Sr^{89} and Sr^{90} but knowledge of the normal amounts and behaviour of inactive strontium is also of material importance when efforts are made to channel the Sr reactions in the biosphere in the desired direction. Because of the chemical similarity of strontium and calcium, investigations of the ratio of Ca to Sr and factors affecting this are essential.

In the present investigation the occurrence and behaviour of native strontium in Finnish soils has been studied by means of chemical and statistical analyses.

Materials and methods

The material, consisting of 221 surface soil samples (0—20 cm layer), was collected from various parts of Finland from grass fields. Of the material, 94 samples represent fine mineral soils (silt, clay), 66 coarse mineral soils (moraine, sand, finesand) and 61 organogenic soils (mould, peat). The samples were air-dried and passed through a 2 mm sieve.

The humus content was determined colorimetrically after sulphuric acid — potassium dichromate wet digestion, and nitrogen by the Kjeldahl method. Soil pH was determined from both soil: water and soil: 0.01 M $CaCl_2$ suspensions (1 : 2.5).

Total strontium: The organic matter of a weighed sample was removed by combustion at 450°C; the sample was ground and mixed with a twofold quantity of carbon powder containing 25 ppm Pd as an internal standard. Sr was determined with a 2 metre ARL grating Spectrograph (D.C. arc 12 A, 75 sec., cathode layer excitation) by reading lines Sr 4077.7 Å and Pd 3421.2 Å.

Cation exchange capacity was determined with a modified Mehlich's method: percolation with $BaCl_2$ triethanolamine solution (pH 8.1), washing with $BaCl_2$ solution and with water, Ba displacement with $MgCl_2$ solution and Ba determination with a Beckman DU flame photometer.

Exchangeable cations (Ca, Mg, K and Sr) were extracted by shaking the soil samples with acid ammonium acetate (0.5 N CH_3COOH, 0.5 CH_3COONH_4, pH 4.65) for one hour in a volumetric ratio 1 : 10. The method is the same as that used in soil testing in Finland and gives approximately 85 per cent of the total exchangeable calcium and potassium (VUORINEN and MÄKITIE 1955). The determinations were made by flame photometry. The interferences caused by alkalis and alkaline earths as well as by aluminium and phosphates were eliminated by using standards containing the average amounts of interfering components in acid ammonium acetate. When Mg and Sr were determined with an oxygen-acetylene flame, addition of 1 ml ethanol to 5 ml of soil extract was found to increase the sensitivity. Strontium determinations were made by reading the differences between the Sr line (4607 Å) and the background (4660 Å).

Table 1. Mean values and variations of analytical data
Taulukko 1. Analyysitulosten keskiarvot ja vaihtelurajat

Soil group *Maalajiryhmä*	n	Vol. weight g/cm³ *Tilav.paino*	$pH_{(H_2O)}$	$pH_{(CaCl_2)}$	C %	N %	Sr ppm
Fine mineral soils *Hienot kivenn.maat*	94	0.971 (0.73—1.18)	5.47 (4.6—5.9)	5.18 (4.6—5.9)	3.74 (1.74—8.34)	0.296 (0.151—0.522)	738 (222—1 716)
Coarse mineral soils *Karkeat kivenn.maat*	66	1.066 (0.80—1.28)	5.55 (4.6—6.7)	5.25 (4.4—6.3)	3.54 (1.10—7.94)	0.227 (0.098—0.465)	905 (236—2 730)
Organogenic soils *Eloperäiset maat*	61	0.552 (0.22—0.84)	4.99 (4.3—5.6)	4.62 (3.7—5.2)	21.55 (8.7 —48.0)	1.89 (0.423—2.40)	578 (109—1 280)
All soils *Kaikki maat*	221	0.884 (0.22—1.28)	5.36 (4.3—6.7)	5.05 (3.7—6.3)	8.60 (1.10—48.0)	0.522 (0.098—2.40)	744 (109—2 730)

Soil group *Maalajiryhmä*	CEC me/100 g *Kat.vaiht. kap.*	Acid NH_4-acetate extractable *Happamalla NH_4-asetaatilla uuttuvat*						Sol. of Sr *Sr:n liuk.* %
		Ca^{2+} me/100 g	Mg^{2+} me/100 g	K^{+} me/100 g	Sr^{2+} µe/100 g	P^{5-} me/100 g	Ca/Sr	
Fine mineral soils *Hienot kivenn.maat*	26.93 (11.5—47.8)	10.44 (1.86—17.41)	4.09 (0.45—11.57)	0.621 (0.200—1.489)	41.24 (9.50—74.93)	0.161 (0.031—0.498)	253 (161—401)	2.45 (0.60—7.66)
Coarse mineral soils *Karkeat kivenn.maat*	18.15 (5.8—34.8)	6.99 (1.22—15.85)	1.28 (0.10—5.00)	0.313 (0.059—0.940)	26.89 (5.34—61.89)	0.258 (0.058—0.941)	260 (104—408)	1.30 (0.34—4.32)
Organogenic soils *Eloperäiset maat*	74.15 (25.0—123.0)	18.15 (3.21—36.30)	5.71 (0.52—19.33)	0.412 (0.115—1.175)	66.13 (9.22—145.6)	0.334 (0.075—1.256)	274 (180—430)	5.01 (0.58—26.21)
All soils *Kaikki maat*	37.34 (5.8—123.0)	11.54 (1.22—36.30)	3.70 (0.10—19.33)	0.470 (0.059—1.489)	43.83 (5.34—145.6)	0.238 (0.031—1.256)	263 (104—430)	2.58 (0.34—26.21)

R e a d i l y   s o l u b l e   p h o s p h o r u s was determined colorimetrically as molybdenum blue from the acid ammonium acetate extract.

V o l u m e   w e i g h t of soils was calculated after weighing the measured 25 ml subsamples.

Results and discussion

The analytical data, mean values and variation ranges are given in Table 1.

The sample material represents typical acid Finnish soils, the pH of which usually varies between 4 and 6 in mineral soils and is somewhat lower in organic soils. The pH values from water suspensions are about 0.3 pH units higher on the average than those from $CaCl_2$ suspensions. The organic matter content of soil varies considerably, which largely explains the variations in the volume weight and in the cation exchange capacity. The content of exchangeable calcium is rather low and so, therefore, is the base saturation degree, especially in organic soils.

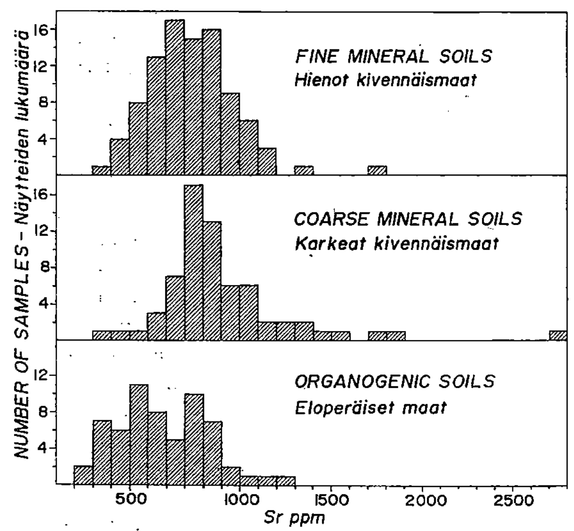

Fig. 1. Distribution of total contents of strontium.
Kuva 1. Strontiumin totaalimäärän jakautuminen eri pitoisuuksiin.

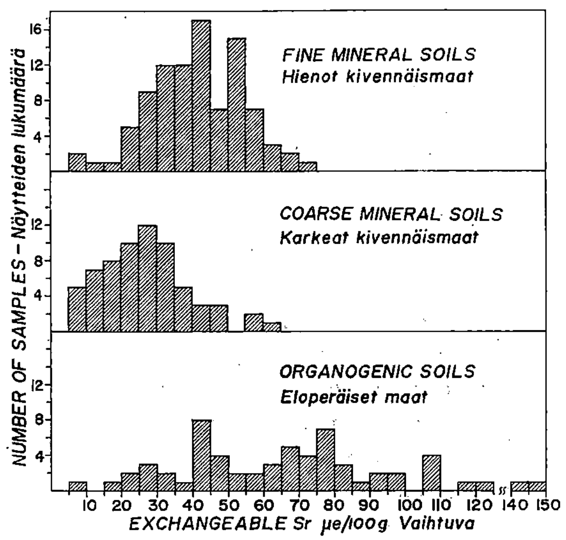

Fig. 2. Distribution of exchangeable strontium.
Kuva 2. Vaihtuvan strontiumin jakautuminen eri pitoisuuksiin.

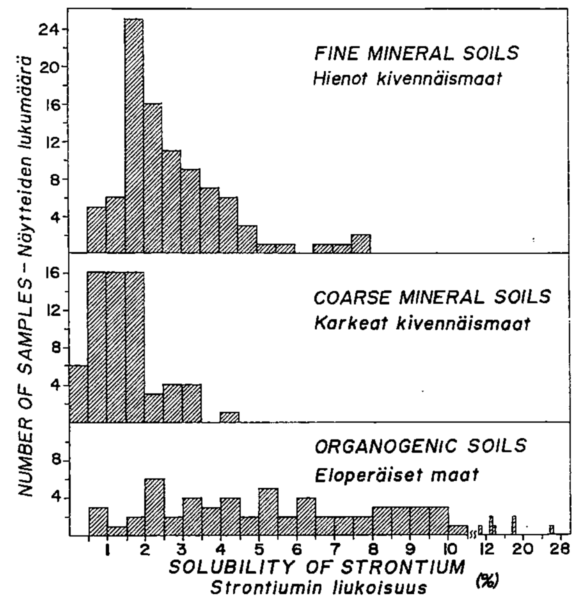

Fig. 3. Distribution of solubility percentage of strontium.
Kuva 3. Strontiumin liukoisuuden jakautuminen.

The distribution of the total strontium in various soil groups is given in Fig. 1. The total strontium content of Finnish soils seems to be higher than that reported elsewhere. The mean for all soils (744 ppm) is about twice as high as the results (270, 380 and 430 ppm) obtained by SWAINE (1955) from Scottish soils. The results reported by LAKANEN and SALO (1964) are also in agreement with the present data. The total contents of many trace elements are generally lower in organic than in mineral soils in Finland (SILLANPÄÄ 1962, VUORINEN 1958) and strontium seems to be no exception. The wide variation of the organic matter content of organogenic soils is probably responsible for the wider variation of total Sr in these soils.

The distribution of exchangeable strontium (µe/100 g) in the three soil groups is given in Fig. 2. Expressed as ppm the mean values for soil groups vary from 11.8 to 29 ppm. These values are somewhat higher than those (up to 20 ppm) reported by SWAINE (1955) in Scottish soils when using neutral N ammonium acetate as extractant. In Finnish wooded moraine soils, which were extremely low in calcium, the neutral N ammonium acetate-exchangeable Sr values were markedly lower (VIRO 1952).

The solubility percentage of strontium is highest in organogenic soils and obviously higher in fine than in coarse mineral soils (Fig. 3). For organogenic soils heterogeneity of the Sr solubility is characteristic, apparently owing to the variation in the organic and mineral matter contents of these soils.

Exchangeable strontium

The effects of various soil factors on the exchangeable strontium were studied with the aid

Table 2. Partial regressions of exchangeable strontium (μe/100 g) on total strontium (ppm), organic matter content (C %), nitrogen (N %), pH, cation exchange capacity (me/100 g), exchangeable calcium, magnesium and potassium (me/100 g) and readily soluble phosphorus (me/100 g). R, F, b and t are given. Significances at 10˙, 5*, 1** and 0.1*** per cent levels

Taulukko 2. Maan vaihtuvan strontiumin (μe/100 g) riippuvuus (osittaisregressiot) strontiumin totaalimäärästä (ppm), orgaanisen aineksen määrästä (C %), typpipitoisuudesta (N %), pH:sta, kationinvaihtokapasiteetista (me/100 g), vaihtuvan kalsiumin, magnesiumin ja kaliumin määristä (me/100 g) sekä helppoliukoisen fosforin määrästä (me/100 g). R, F, b ja t on esitetty. Merkitsevyydet 10˙, 5, 1** ja 0.1*** prosentin tasoilla*

Soil group *Maalajiryhmä*	n	a	bSr (t)	bC (t)	bN (t)	bpH (t)	bCEC (t)	bCa (t)	bMg (t)	bK (t)	bP (t)	R (F)
Fine mineral soils *Hienot kivenn.maat*	94	37	0.008 (1.83˙)	—0.899 (0.43)	—11.15 (0.35)	—6.975 (1.15)	0.077 (0.29)	2.762 (5.04***)	0.955 (1.63)	9.684 (2.52*)	14.95 (1.31)	0.843 (22.88***)
Coarse mineral soils *Karkeat kivenn.maat*	66	21	0.004 (1.61)	—2.416 (2.22*)	30.69 (1.47)	—4.734 (1.31)	0.211 (0.60)	3.015 (5.74***)	—0.065 (0.07)	6.698 (1.31)	14.69 (2.25*)	0.895 (25.14***)
Organogenic soils *Eloperäiset maat*	61	—123	0.026 (3.18**)	0.016 (0.03)	5.384 (0.61)	19.05 (2.67*)	0.359 (2.95**)	1.519 (5.01***)	0.960 (1.64)	11.37 (1.39)	24.30 (1.96˙)	0.928 (35.15***)
All soils *Kaikki maat*	221	— 27	0.009 (4.00***)	—0.539 (1.51)	13.78 (2.46*)	3.482 (1.60)	0.180 (2.57*)	2.021 (10.89***)	1.304 (4.83***)	9.810 (3.77***)	15.06 (3.12**)	0.931 (153.38***)

Table 3. Mean values of analytical data at various CEC levels

Taulukko 3. Analyysitulosten keskiarvot kationinvaihtokapasiteetin eri tasoilla

CEC level *Kationinvaihtokapasiteetin taso*	n	Vol. weight g/cm³ *Tilav.paino*	$pH_{(H_2O)}$	$pH_{(CaCl_2)}$	C %	N %	Sr ppm	CEC me/100 g *Kat.vaiht. kap.*	Acid NH_4-acetate extractable *Happamalla NH_4-asetaatilla uuttuvat*						Sol. of Sr *Sr:n liuk.* %
									Ca^{2+} me/100 g	Mg^{2+} me/100 g	K^+ me/100 g	Sr^{2+} μe/100 g	P^{5-} me/100 g	Ca/Sr	
30—123 me/100 g	98	0.693	5.12	4.76	15.12	0.869	585	59.98	15.51	5.74	0.504	57.44	0.245	270	4.30
40—123 »	61	0.575	5.02	4.65	20.95	1.162	535	75.22	18.56	6.31	0.436	67.36	0.299	276	5.51
50—123 »	47	0.520	4.98	4.61	23.90	1.301	520	84.32	20.46	6.55	0.433	74.26	0.328	276	6.25
70—123 »	35	0.485	5.01	4.63	26.60	1.437	520	94.01	23.08	7.36	0.442	83.45	0.344	277	7.02
80—123 »	25	0.476	4.99	4.58	27.76	1.488	477	101.77	23.57	7.05	0.450	83.47	0.346	282	7.67
< 30 »	123	1.036	5.54	5.27	3.39	0.246	870	19.30	8.36	2.07	0.445	32.97	0.232	254	1.66
30—80 »	73	0.767	5.17	4.82	10.80	0.657	623	45.66	12.75	5.29	0.523	48.52	0.211	263	3.42

Table 4. Partial regressions of exchangeable strontium (μe/100 g) at various CEC levels on total strontium (ppm), organic matter content (C %), nitrogen (N %), pH, cation exchange capacity (me/100 g), exchangeable calcium, magnesium and potassium (me/100 g) and readily soluble phosphorus (me/100 g). R, F, b and t are given. Significances at 10˙, 5*, 1** and 0.1*** per cent levels

Taulukko 4. Maan vaihtuvan strontiumin määrän (μe/100 g) riippuvuus (osittaisregressiot) kationinvaihtokapasiteetin eri tasoilla strontiumin totaalimäärästä (ppm), orgaanisen aineksen määrästä (C %), typpipitoisuudesta (N %), pH:sta, kationinvaihtokapasiteetista (me/100 g), vaihtuvan kalsiumin, magnesiumin ja kaliumin määristä (me/100 g) sekä helppoliukoisen fosforin määrästä (me/100 g). R, F, b ja t on esitetty. Merkitsevyydet 10˙, 5, 1** ja 0.1*** prosentin tasoilla*

CEC level *Kationinvaihtokapasiteetin taso*	n	a	bSr (t)	bC (t)	bN (t)	bpH (t)	bCEC (t)	bCa (t)	bMg (t)	bK (t)	bP (t)	R (F)
30—123 me/100 g	98	—88	0.016 (2.98**)	—0.732 (1.45)	13.61 (1.81˙)	13.31 (2.67**)	0.360 (3.46***)	1.626 (6.36***)	1.207 (3.01**)	8.821 (1.91˙)	35.23 (3.06**)	0.930 (63.00***)
40—123 »	61	—141	0.030 (3.44**)	0.002 (0.003)	5.486 (0.61)	22.26 (3.13**)	0.341 (2.83**)	1.412 (4.66***)	0.537 (1.00)	17.34 (2.17*)	35.54 (2.52*)	0.926 (34.35***)
50—123 »	47	—188	0.045 (4.75***)	0.478 (0.61)	2.418 (0.25)	31.23 (3.79***)	0.282 (1.92˙)	1.090 (3.27**)	0.387 (0.59)	24.93 (2.43*)	27.92 (1.81˙)	0.929 (25.74***)
70—123 »	35	—206	0.051 (3.69**)	0.282 (0.31)	2.049 (0.18)	35.29 (3.56**)	0.334 (1.65)	0.750 (1.53)	0.645 (0.78)	28.04 (1.93˙)	28.86 (1.57)	0.905 (12.53***)
80—123 »	25	—148	0.018 (1.16)	—0.891 (0.94)	—1.770 (0.16)	25.48 (2.49*)	0.594 (2.19*)	1.344 (2.88*)	—0.179 (0.23)	—0.308 (0.02)	94.21 (4.94***)	0.960 (19.63***)
< 30 »	123	39	0.005 (2.52*)	—1.430 (1.49)	6.057 (0.40)	7.731 (2.43*)	0.016 (0.07)	3.158 (8.13***)	0.938 (1.72˙)	8.087 (2.42*)	15.51 (2.99**)	0.883 (44.49***)
30—80 »	73	—18	0.012 (2.38*)	—0.332 (0.44)	21.28 (1.66)	1.037 (0.18)	0.174 (1.08)	2.713 (7.78***)	0.147 (0.31)	13.44 (3.17**)	—36.31 (2.24*)	0.923 (40.44***)

Table 5. Partial regressions of exchangeable strontium (µe/100 g) on total strontium (ppm), organic matter content (C %), nitrogen (N %), pH, exchangeable magnesium and potassium (me/100 g) and readily soluble phosphorus (me/100 g). R, F, b and t are given. Significances at 10·, 5*, 1** and 0.1*** per cent levels

Taulukko 5. Maan vaihtuvan strontiumin (µe/100 g) riippuvuus (osittaisregressiot) strontiumin totaalimäärästä (ppm), orgaanisen aineksen määrästä (C %), typpipitoisuudesta (N %), pH:sta, vaihtuvan magnesiumin ja kaliumin määristä (me/100 g) sekä helppoliukoisen fosforin määrästä (me/100 g). R, F, b ja t on esitetty. Merkitsevyydet 10·, 5, 1** ja 0.1*** prosentin tasoilla*

Soil group *Maalajiryhmä*	n	a	bSr (t)	bC (t)	bN (t)	bpH (t)	bMg (t)	bK (t)	bP (t)	R (F)
Fine mineral soils — *Hienot kivenn.maat*	94	—90	0.098 (1.97·)	—1.120 (0.48)	39.10 (1.11)	18.00 (4.51***)	2.017 (4.23***)	15.23 (3.62***)	0.685 (0.05)	0.777 (18.74***)
Coarse mineral soils — *Karkeat kivenn.maat*	66	—62	0.002 (0.55)	—1.404 (1.26)	75.37 (3.03**)	10.98 (3.08**)	0.880 (0.68)	20.41 (3.61***)	26.01 (3.40**)	0.798 (14.54***)
Organogenic soils — *Eloperäiset maat*	61	—198	0.043 (3.38**)	2.495 (2.82**)	—8.524 (0.62)	36.14 (3.65***)	1.030 (1.12)	30.83 (2.59*)	—10.67 (0.70)	0.801 (13.54***)
All soils — *Kaikki maat*	221	—75	0.010 (2.80**)	1.364 (2.89**)	8.[illegible]12 (1.05)	14.63 (5.18***)	2.049 (5.23***)	19.81 (5.32***)	— 0.097 (0.02)	0.838 (72.07***)

Table 6. Partial regressions of exchangeable strontium (µe/100 g) at various CEC levels on total strontium (ppm), organic matter content (C %), nitrogen (N %), pH, exchangeable magnesium and potassium (me/100 g) and readily soluble phosphorus (me/100 g). Significances at 10·, 5*, 1** and 0.1*** per cent levels

Taulukko 6. Maan vaihtuvan strontiumin määrän (µe/100 g) riippuvuus (osittaisregressiot) kationinvaihtokapasiteetin eri tasoilla strontiumin totaalimääristä (ppm), orgaanisen aineksen määrästä (C %), typpipitoisuudesta (N %), pH:sta, vaihtuvan magnesiumin ja kaliumin määristä (me/100 g) sekä helppoliukoisen fosforin määrästä (me/100 g). Merkitsevyydet 10·, 5, 1** ja 0.1*** prosentin tasoilla*

CEC level *Kationinvaihto-kapasiteetin taso*	n	a	bSr (t)	bC (t)	bN (t)	bpH (t)	bMg (t)	bK (t)	bP (t)	R (F)
30—123 me/100 g	98	—137	0.025 (2.94**)	2.095 (3.06**)	— 2.571 (0.22)	26.27 (3.93**)	1.159 (1.85·)	16.61 (2.39*)	0.257 (0.02)	0.812 (24.96***)
40—123 »	61	—215	0.054 (4.43***)	2.759 (3.45**)	—14.13 (1.10)	38.90 (4.25***)	—0.031 (0.04)	34.59 (3.16**)	5.850 (0.33)	0.823 (15.92***)
50—123 »	47	—277	0.068 (5.52***)	2.450 (3.11**)	—10.65 (0.91)	50.68 (5.80***)	—0.297 (0.37)	41.21 (3.48**)	7.832 (0.48)	0.875 (18.13***)
70—123 »	35	—231	0.059 (4.03***)	1.330 (1.47)	— 6.11 (0.50)	46.60 (4.99***)	—0.024 (0.03)	33.57 (2.13*)	25.32 (1.25)	0.867 (11.68***)
80—123 »	25	—224	0.054 (3.14***)	0.992 (0.93)	—11.32 (0.74)	48.43 (4.55***)	—0.429 (0.42)	26.68 (1.04)	57.21 (2.04·)	0.912 (12.07***)
< 30 »	123	—60	0.005 (1.97·)	—1.389 (1.23)	37.76 (1.98)	12.32 (4.21***)	2.162 (3.28**)	19.23 (4.84***)	8.823 (1.39)	0.771 (24.01***)
30—80 »	73	—84	0.018 (1.96·)	2.535 (2.12*)	—22.32 (1.04)	17.55 (2.31*)	2.193 (2.86**)	12.33 (1.77·)	—0.021 (0.001)	0.732 (10.72***)

of multiple regression analysis. Nine factors were included: C %, N %, cation exchange capacity, $pH_{(H_2O)}$, total Sr, exchangeable Ca, Mg and K and readily soluble P.

The statistical analyses for the three soil groups are given in Table 2. The multiple correlation coefficient for the whole material was highly significant (R = 0.931***). The same is true for organogenic soils, while in the two mineral soil groups two or three soil factors seem to dominate. A closer examination of the analytical data, applying the principle of moving averages, revealed three relatively distinct levels of CEC and exchangeable strontium in the material. Because of this, multiple regression analyses with the same nine variables were also carried out separately for soils having cation exchange capacities of less than 30, from 30 to 80 and over 80 me/100 g.

The average values of the soil properties at the different CEC levels are given in Table 3 and the results of the multiple regression analyses in Table 4.

Concerning the whole material (Table 2) the significances of the partial regression coefficients decrease in the following order: Ca, Mg, total Sr, K, P, CEC, N, pH and C. The significance of calcium is clearly highest in the subgroups as well. It can be assumed that such a strong regression may diminish the apparent significance of other factors involved in multiple regression analysis. Moreover, the significance of C % may partly be diminished by CEC, between which factors the mutual correlation is obvious. Because of this, the multiple regression analyses were repeated on the same basis of grouping as before but without Ca and CEC as variables. The results are given in Tables 5 and 6. The order of significance of the seven variables in the whole material is somewhat changed, being now: K, Mg, pH, C, total Sr, N and P. The exclusion of calcium has strongly increased the significance of pH but also that of potassium and magnesium. The regression between exchangeable strontium and humus content (C %) is also more apparent after excluding CEC from the calculations. The multiple correlation coefficients are somewhat lower but still at a high level of significance.

Exchangeable Ca, Mg and K are in positive correlation with exchangeable Sr, especially at lower CEC levels, while towards higher CEC the correlation seems to decrease or disappear. Because of the similar character of Sr and Ca a strong positive correlation exists between these elements.

Total Sr. The increase of total Sr in more weatherproof coarse mineral soils does not markedly increase the exchangeable Sr fraction. In the more weathered fine mineral soils a slight increase is to be expected. The correlation between exchangeable and total Sr is strongest in the group of organogenic soils, which is apparently due to the high solubility of Sr in these soils. In general, the correlation increases with increasing organic matter content and CEC (Tables 3 and 4).

Soil pH and exchangeable Ca are usually strongly correlated, which makes it difficult to evaluate the influence of pH alone. The exclusion of Ca from the multiple regression gave significant positive correlations between pH and exchangeable Sr in all soil groups, which is apparently due to the indirect effect of calcium. In the group of CEC less than 30 me/100 g the increase of pH significantly lowers the content of exchangeable Sr. In coarse and fine mineral soils exchangeable Sr also decreases with increasing pH, although the correlation is without statistical significance. In other subgroups of lower pH level, higher C % and CEC, soil pH is positively correlated with exchangeable Sr.

Many trace elements in the soil are typical heavy metals, the fixation of which is clearly increased by increasing pH (e.g. SILLANPÄÄ 1962). The effect of pH on the solubility of alkalis and alkaline earths is less marked. On adding inactive or radioactive strontium to soils of various types, several investigators have found that more strontium is adsorbed by those of high pH (e.g. RHODES 1957, MCHENRY 1958, PROUT 1958, SCHROEDER and BUSSCHE 1962, LAKANEN 1967).

Cation exchange capacity. The CEC of soils depends mainly on their organic matter and clay contents, which makes interpretation of the role of CEC in multiple regression analysis more difficult. CEC is not correlated with exchangeable Sr in mineral soils representing the lowest level of CEC, while it is in significant positive correlation in organogenic soils, with high CEC and C %. Thus increase of C % increases both the CEC and the solubility of Sr.

The behaviour of Sr as a function of CEC and of C % has also been studied by adding strontium and radiostrontium to soils. von REICHENBACH and von dem BUSSCHE (1963) found that the non-exchangeable fraction of strontium increased with increasing humus content and exchange capacity. A small increase was also obtained with decreasing clay content and pH values. However, the material consisted of soils with a very low humus content (C % = 0.435) and low CEC level (20.8 me/100 g) compared with the soils examined in this study.

Organic matter. The influence of this component can be interpreted in two ways. In mineral soils with very low C % an increase of humus content increases the number of active groups capable of binding cations. A decrease of exchangeable Sr may follow. With further increase of organic matter the fraction of exchangeable Sr increases. In pure peat soils, however, an increase of exchangeable Sr is not to be expected, owing to their low total Sr content.

The influence of organic matter on exchangeable Sr can also be seen from the results of multiple regression analysis (9 variables, Table 2.), although only in coarse mineral soils is a statistically significant negative correlation reached. Organic matter has probably lost statistical significance to CEC (Table 6).

Nitrogen. The total N % of the soils is closely related to C % and its influence seems at least partly similar to that of C %. The active cation-binding groups of humus are probably composed of carbon and oxygen, mainly carboxyl groups, and thus the influence of N % on cation binding is small, as can be seen from the results. A positive correlation exists between N % and exchangeable Sr in the whole material.

R e a d i l y s o l u b l e p h o s p h o r u s. Exchangeable Sr and readily soluble phosphorus are in significant positive correlation in the whole material and in several subgroups. It should be noticed, however, that at the same time calcium and pH are positively correlated with strontium. An exception is the CEC level 30—80 me/100 g, in which phosphorus and strontium are in significant negative correlation. Samples from both fine mineral soils and organogenic soils belong to this subgroup. In this group the content of exchangeable Sr varies but little with increasing CEC and organic matter content.

The ratio of exchangeable calcium to exchangeable strontium

The calcium/strontium ratio (equivalent basis) is calculated from the amounts extracted with acid ammonium acetate. The distribution of the Ca/Sr ratio in various soil groups is given in Fig. 4. The differences between the soil groups are relatively slight, apparently owing to the similarity of the chemical behaviour of these elements. The ratio in the whole material varies from 104 to 430 (Table 1), i.e. the difference between the lowest and highest ratio is about fourfold.

In the study of VIRO (1952), the exchangeable Ca and Sr contents (extracted with neutral N NH_4-acetate) were 98.1 and and 1.01 ppm on the average and correspondingly the Ca/Sr ratio 212. This is somewhat lower than the corresponding average value (263) in the present investigation, apparently owing to the lower Ca content of the wooded moraine soils in the former study. The average Ca/Sr ratio in 93 plough-layer samples from Maryland was 770 (MENZEL and HEALD 1959) or about three times as high as the ratio in Finnish soils. In 114 Australian

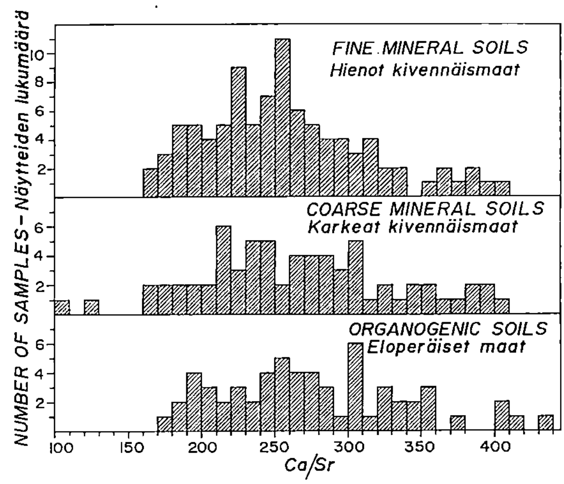

Fig. 4. Distribution of Ca/Sr ratio.
Kuva 4. Ca/Sr -suhteen jakautuma.

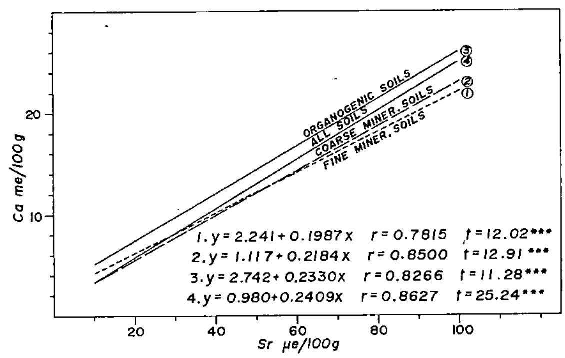

Fig. 5. Regressions of exchangeable Ca on exchangeable Sr.
Kuva 5. Vaihtuvan kalsiumin ja strontiumin välinen korrelaatio.

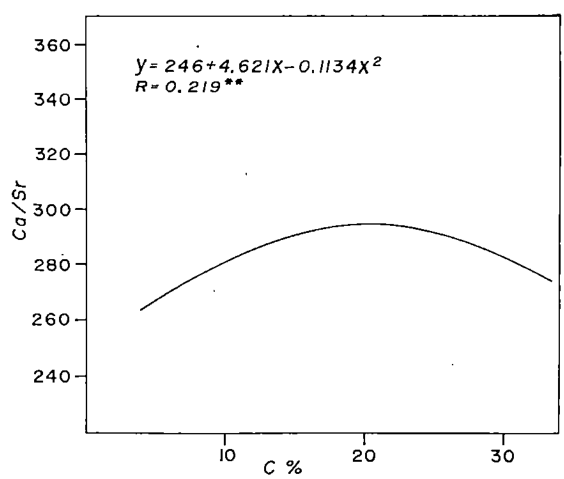

Fig. 6. Regression of Ca/Sr- ratio on organic matter content (C %).
Kuva 6. Ca/Sr -suhde maan orgaanisen aineksen pitoisuuden funktiona.

soils the Ca/Sr ratio varied from 109 to 328 in 88 % of the samples when extracted with 1 N NH_4Cl (WILLIAMS and DAVID 1963). A direct comparison between the results reported in the literature is of dubious value, because of the considerable variability of the methods used by different investigators.

A strong correlation exists between calcium and strontium exchanged with acid ammonium acetate (Fig. 5). The ratio of Ca to Sr is highest in organogenic soils even though the differences from other soil groups are relatively small (Table 1). Since the data in Table 3 indicate a possible regression of Ca/Sr on CEC and C %, both linear and curvilinear regressions between these factors were calculated. No linear correlations were found but a significant curvilinear correlation existed between C % and Ca/Sr (Fig. 6).

Summary

The contents of total and exchangeable strontium in Finnish soils (221 samples) were found to be higher than values reported elsewhere.

The behaviour of exchangeable strontium and the Ca/Sr ratio as a function of soil pH, organic matter content, N, total Sr, cation exchange capacity, exchangeable Ca, Mg, K and readily soluble P was studied with the aid of multiple regression analysis and the results are discussed.

Acknowledgements. — The authors wish to thank the State Commission for Agricultural and Forest Science of Finland for financial aid and Mr. Seppo Hyvärinen, M. A., for valuable help with the statistical treatment of the results.

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SELOSTUS

Strontium viljelysmaissamme

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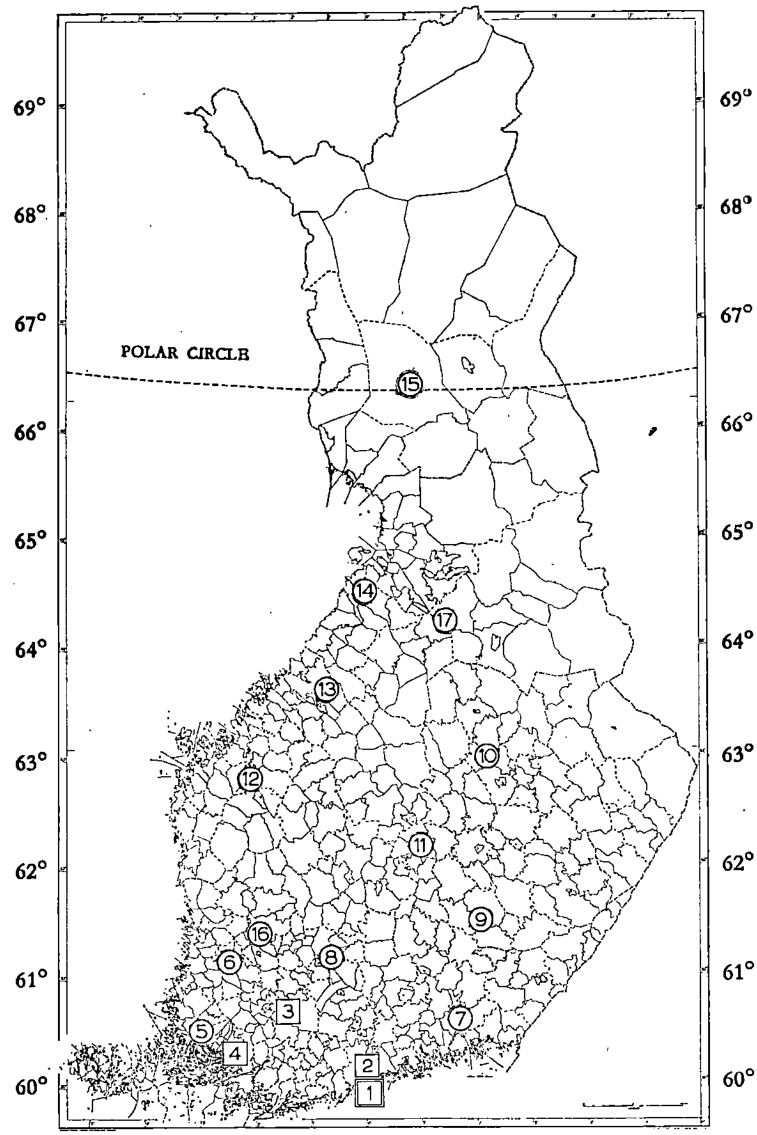
Strontium on kalsiumin lähisukuinen hivenaine, jota ei vielä ole kyetty osoittamaan välttämättömäksi ravinteeksi. Kiinnostus strontiumia kohtaan johtuu radiostrontiumin (Sr-89 ja Sr-90) vaarallisuudesta. Tässä tutkimuksessa selvitettiin strontiumin määrää ja käyttäytymistä viljelysmaissamme kemiallisten ja tilastomatemaattisten analyysien avulla.

Aineisto käsitti 221 kpl heinäpeltojen pintamaanäytteitä eri puolilta Suomea. Analyysitulosten keskiarvot ja vaihtelurajat maalajiryhmittäin ja koko aineistossa nähdään taulukossa 1. Maan totaalistrontiumin jakautuminen eri pitoisuuksiin esitetään kuvassa 1. Koko aineiston keskiarvo 744 ppm ja erityisesti karkeiden kivennäismaiden keskiarvo 905 ppm ovat selvästi korkeampia kuin tiedossa olevat ulkomaiset analyysitulokset. Vaihtuvan Sr:n jakauma on esitetty kuvassa 2. Kun pitoisuudet ilmoitetaan ppm:na ovat maalajiryhmien keskiarvot 11.9—29 ppm. Luvut ovat jälleen korkeampia kuin muualla saadut. Tarkastettaessa strontiumin liukoisuutta eri maalajiryhmissä (kuva 3) nähdään, että liukoisuus kasvaa järjestyksessä karkeat kivennäismaat, hienot kivennäismaat, eloperäiset maat. Jakauma eloperäisten maiden ryhmässä poikkeaa jälleen muista. Syynä on suuri eloperäisen ja kivennäisaineksen pitoisuuksien vaihtelu.

Vaihtuvan Sr:n pitoisuuden riippuvuutta eri tekijöistä selvitettiin 9:n muuttujan moniregressioanalyysin avulla tietokonetta käyttäen. Tulokset ovat maalajiryhmittäin taulukossa 2. Koko aineistolle on kokonaisselvitys erittäin korkea ($R = 0.931^{***}$). Liukuvien keskiarvojen avulla todettiin, että vaihtuvan strontiumin pitoisuuden kasvu voidaan ryhmitellä eri kationinvaihtokapasiteettien tasoille, raja-arvoina 30 ja 80 milliekvivalenttia/100 g. Taulukossa 3 esitetään analyysitulosten keskiarvot uuden ryhmittelyn mukaisesti. Suoritettiin myös uusi 9:n muuttujan analyysi, jonka tulokset ovat taulukossa 4. Tuloksia koko aineistossa (taul. 2) tarkasteltaessa nähdään, että eri tekijäin merkitsevyys vähenee järjestyksessä Ca, Mg, totaali Sr, K, P, kationinvaihtokapasiteetti, N, pH ja C. Koska vahvin muuttuja Ca on saattanut riistää merkitsevyyttä muilta samansuuntaisilta muuttujilta ja heikoin muuttuja C % on mahdollisesti menettänyt merkitsevyyttään kationinvaihtokapasiteetille, suoritettiin uusi 7:n muuttujan analyysi ilman Ca:ta ja kationinvaihtokapasiteettia (taul. 5 ja 6.) Eri tekijäin merkitsevyys alenee järjestyksessä K, Mg, pH, C, totaali Sr, N, P. Kalsiumin jättäminen pois lisäsi pH:n positiivista merkitsevyyttä, mikä lienee epäsuora seuraus Ca:n ja pH:n välisestä voimakkaasta korrelaatiosta. Myös kaliumin, magnesiumin ja humuksen merkitsevyydet kasvoivat.

Vaihtuvan kalsiumin ja strontiumin suhteen (ekvivalentteina laskien) jakauma esitetään maalajiryhmittäin kuvassa 4. Koko aineiston Ca/Sr -suhteen vaihtelu 104—430 ei ole suuri, mikä todistaa näiden aineiden samankaltaisuutta. Kuvasta 5 ilmenee vaihtuvan kalsiumin ja strontiumin välinen voimakas positiivinen korrelaatio. Myös tutkittiin Ca/Sr -suhteen muuttumista eri maaperätekijäin funktiona. Merkitsevimmän korrelaation antoi C % paraabelina (kuva 6).

Moniregressioanalyysi osoittautui käyttökelpoiseksi menetelmäksi. Se antaa tapahtumista kuitenkin vain yleiskuvan. Tuloksia on tulkittava kriittisesti ja monet yksityiskohdat vaativat lähempää tarkastelua.



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Helsinki 1968. Valtion painatuskeskus