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STUDIES ON THE BIOLOGY OF THE CABBAGE ROOT FLY (HYLEMYA BRASSICAE BOUCHÉ) AND THE TURNIP ROOT FLY (HYLEMYA FLORALIS FALL.)

ANNA-LIISA VARIS

Agricultural Research Centre, Department of Pest Investigation, Tikkurila, Finland

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Studies on the biology of *Hylemya brassicae* Bouché are quite numerous, but those on biology of *H. floralis* Fall. are relatively few in number. Among the workers who have studied the biology of *H. brassicae* can be mentioned de WILDE (1947), MILES (1950, 1953, 1954 and 1955) and SWAILES (1957, 1961). VODINSKAYA (1928) presented data on the life cycle of both *H. brassicae* and *H. floralis* in Soviet Union. LUNDBLAD (1933) dealt with the morphology and biology of both species and directed attention especially to the damage inflicted by *H. floralis*. JØRGENSEN (1957) published a study on the biology of *H. floralis*, with special emphasis on the time of adult emergence.

In the annual reports of the Finnish state entomologists, *H. brassicae* has been reported nearly every year since 1895 as a damaging pest (REUTER 1897), but information about injuries caused by *H. floralis* was not received until the 1940's (SAALAS 1943, VAPPULA 1944, KANERVO 1945), In a congressional paper KANERVO (1954) reported on the emergence time of adult root flies in southern Finland. Other studies carried out in Finland pertained to the effect of sowing time of crucifer crops in preventing damage caused by cabbage maggots (VARIS 1958 a) as well as the susceptibility of different turnip varieties to cabbage maggot injuries (VARIS 1958 b). A brie congressional report has also been made on the emergence time of *H. brassicae* and *H. floralis* in different parts of the country (VARIS 1960).

Materials and methods

Studies on the biology of cabbage root flies were carried out at Tikkurila (near Helsinki) in an insectary with environmental conditions closely resembling those outdoors. In addition, the emergence time of adults was also studied at the Arctic Circle Agricultural Experiment Station near Rovaniemi and at Muddusniemi Experimental Farm in Inari.

Emergence, egg number and oviposition time. Adults were reared from larvae and pupae collected in the previous season and placed in wooden boxes provided with wire screen bottoms and partially buried in the ground outdoors. On the day of emergence the flies were collected from cages attached above the boxes. A number of them were transferred

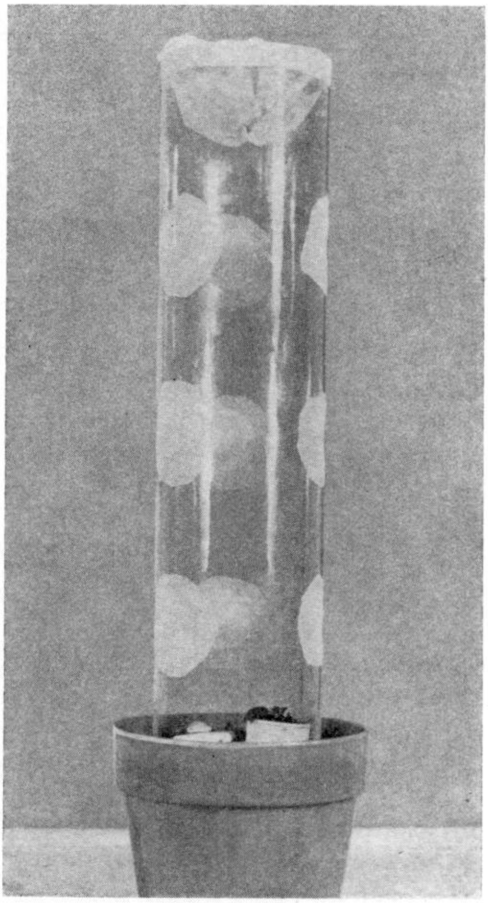

Fig. 1. PVC cylinder used for rearing cabbage root flies in the insectary.

to plastic rearing cylinders (Fig. 1), with one male and one female in each cylinder. For oviposition, a small dish filled with soil and containing a turnip seedling was placed in each cylinder. A mixture of food devised by SHERWOOD and POND (1954) was used. In addition, clover and turnip rape flowers and dilute sugar solution were kept in each cylinder. Examinations were made daily and the eggs were then removed.

The duration of egg stage was determined by placing the newly deposited eggs between moist filter paper in Petri dishes and examining them daily at the same time for hatching.

Duration of larval and pupal stages. Newly deposited eggs were placed on a piece of swede on the surface of soil in a flower pot covered by gauze. Fresh pieces of swede were added occasionally. At one-week intervals the occurence of different developmental stages was examined. When the pupal stage approached, the gauze cover was removed and replaced by a celluloid rearing cylinder, into which the newly emerged adults were daily collected. The unemerged pupae were placed outdoors in the autumn and the duration of their pupal stage was ascertained in the following spring.

Life-stages and their biology

Egg

Size of eggs. Since the literature contains only few reports of the egg size of cabbage root flies, measurements of the eggs of both species were made in July 1961.

	Number of eggs	Length mm av.	Length mm range	Breadth mm av.	Breadth mm range	Ratio of length to breadth
H. brassicae	141	1.02 ± 0.014	0.83—1.14	0.31 ± 0.004	0.26—0.37	3.3
H. floralis	130	1.10 ± 0.008	1.01—1.22	0.33 ± 0.002	0.28—0.38	3.3

According to the measurements made by MILES (1952), the egg length of *H. brassicae* was 0.90—0.95 mm, averaging 0.93. This average value is smaller than obtained by the author, but all of MILES' (op. cit.) measurements fall within the range found in the present study. The lengths of 25 eggs measured by de WILDE (1947) were 1.02—1.07 and breadth was reported to be about onehalf the length. These eggs were thus sligthly larger than those measured in the present study.

Table 1. The number of eggs and duration of oviposition time of *Hylemya brassicae* and *H. floralis*.

Year	The number of eggs av.	Range	Av. per day	Max. per day	Total duration of oviposition days	Days of oviposition av.	Av. no of eggs per day of oviposition
H. brassicae 1961 ...	132 ± 16.8	84—217	5.1 ± 0.81	42	29 ± 4.80	17 ± 1.99	8.0 ± 0.72
H. floralis 1960 ...	119 ± 31.6	38—252	6.0 ± 1.22	57	20 ± 2.50	10 ± 1.54	10.7 ± 1.47
» 1961 ...	97 ± 17.4	31—154	5.0 ± 0.86	49	21 ± 4.44	7 ± 1.23	15.1 ± 2.16

VODINSKAYA (1928) reported the eggs of *H. floralis* to be 1.2—1.5 mm long, while MILES (1952) gave values of 1.1—1.2 mm and JØRGENSEN (1957) 1—1.2 mm. The measurements of JØRGENSEN agree very closely with those in the present study.

The measurements show that the eggs of *H. brassicae* are on the average smaller than those of *H. floralis*. The difference is highly significant (P = 1 %). Otherwise, the eggs have the same ratio of length to breadth.

Egg number. In rearings carried out by VODINSKAYA (1928), the maximum number of eggs of *H. brassicae* was 149 and that of *H. floralis* 287. SWAILES (1961) reared *H. brassicae* in 18—24°C and found that 42 females which lived for at least eight days after mating laid an average of 78 eggs. The egg number per female ranged from 4 to 165.

In the present studies (Table 1) the total number of eggs of *H. brassicae* appeared to be greater and the duration of oviposition time longer than in the case of *H. floralis*. The differences were, however, not statistically significant. During the oviposition time, the average number of eggs of *H. floralis* per day was significantly greater

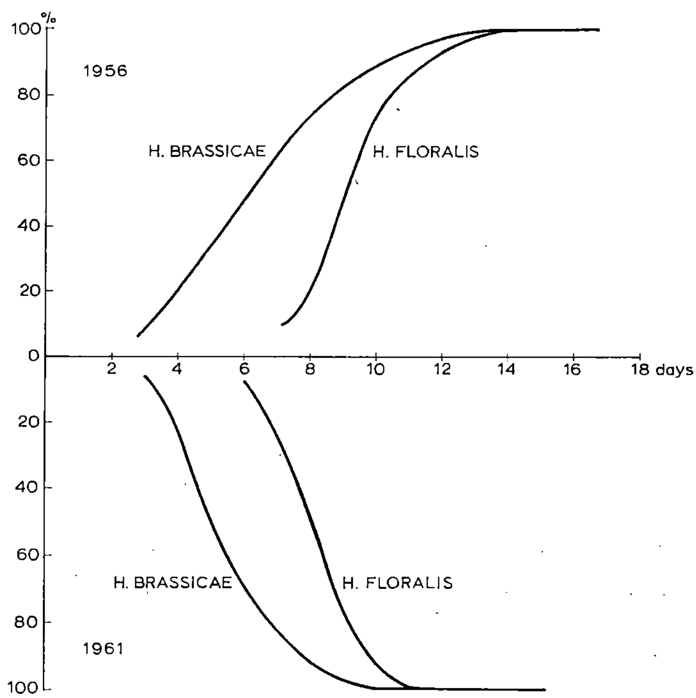

Fig. 2. The duration of the egg stage of *Hylemya brassicae* and *H. floralis* in the years 1956—61, presented in the form of a cumulative percentage curve.

Table 2. The combined duration of the egg + larval stages of *Hylemya brassicae* in 1956—58. The major part of the material is shown in parantheses.

Year	Duration of egg + larval stages, days	No. of pupae
1956	28.8—37.5 (30.0—33.4)	196
1957	24.5—34.6 (27.2—30.7)	750
1958	30.2—39.5 (32.2—35.2)	443
Average	27.8—37.2 (29.8—33.1)	

than that of *H. brassicae*. *H. brassicae* had a more prolific oviposition than that mentioned by SWAILES (op. cit.).

Duration of egg stage. *H. brassicae*. According to different investigators, the duration of the egg stage varies from two to ten days. In the studies of de WILDE (1947) the optimum temperature for egg development in moisture-saturated air was 23—25°C. At this temperature the egg stage lasted 2.5—3 days. SWAILES (1957) found mean durations of the egg stage range from 2.7 days (at 25°) to 12.2 days (at 10°C). At the optimum constant temperature, 20°C, 93.6 % of the eggs hatched.

In the rearings made at Tikkurila in 1956 and 1961, the egg stage lasted from 3 to 16 days (Fig. 2). In 1956 50 % of the eggs hatched within 6 days and in 1961 within 5 days. The mean daily temperature in 1956 ranged from 12 to 22°C and in 1961 from 11 to 20°C.

H. floralis. According to VASINA (1927) the duration of the egg stage was 7—8 days. In the studies of JØRGENSEN this stage lasted 5—20 days; the maximum day temperature was 18—22°C and the minimum night temperature 7—9°C.

In the present studies the egg stage of *H. floralis* lasted 7—18 days in 1956, and 5—17 days in 1961 (Fig. 1). In 1956 50 % of the eggs hatched within 9 days and in 1961 within 8 days. The mean daily temperature in 1956 was from 10 to 21°C and in 1961 from 13 to 19°.

The results in both years were quite similar, as were also the weather conditions. In both 1956 and 1961 June was warmer than normal while the rest of the summer was cool. These values on duration of the egg stage agree well with those mentioned above.

Larva.

Duration of larval stage. According to data in the literature, the duration of larval stage of *H. brassicae* is 18—75 days. De WILDE (1947) found that pupation was delayed as the temperature dropped but took place nevertheless at 3.2—4.8°C. The larval stage of *H. floralis* lasted 30—40 days in studies made by JØRGENSEN (1957) in Denmark. During this time the maximum temperature was 22—24° and the minimum temperature 5—13°.

In the present investigation observations on pupation were made at one-week intervals. In the following tables the beginning date of pupation has been taken to be half-way between the two observation dates during which period pupation commenced. Similarly, the ending date of pupation is taken to be half-way between the two observations which were made just before and after the end of pupation.

Duration of the egg stage of *H. brassicae* was 6 days and its larval stage lasted from 3 to 4.5 weeks with wide variations occuring.

The larvae which had hatched from second-generation eggs in mid-August 1957 pupated during the period September 14—21, so that the combined egg and larval stages lasted about one month.

The duration of the egg and larval stage combined (Table 2) was shortest in 1957 and longest in 1958. This difference was obviously due to the different temperature conditions prevailing. In 1958 all the months of the growing season were cooler than normal. In 1956 July and August were cooler than normal, but June was warm. In 1957, on the other hand, June was cool, but July and August were warm.

Table 3. The combined duration of the egg + larval stages of *Hylemya floralis* in 1956 and 1958. The major part of the material is shown in parantheses.

Year	Duration of egg + larval stages, days	No. of pupae
1956	44.3—66.9 (46.7—59.0)	804
1958	41.8—54.0 (43.5—52.3)	87
Average	43.1—60.5 (45.1—44.7)	

The egg stage of *H. floralis* lasted about 8 days on the average and the larval stage 5—7.5 weeks. The duration of egg + larval stages (Table 3) was slightly longer in 1956 than in 1958. In both years July, August and September were cooler than normal, but in 1956 the divergences were greater.

In 1956 and 1958 the duration of egg + larval stages of *H. floralis* averaged 2—3 weeks longer than that of *H. brassicae*. In the former year, when June was warm, but the other months cool, the difference was more pronounced than in 1958, in which the entire summer was cool.

Pupa

Size of pupae. The size of the pupae of *H. brassicae* varies widely. De WILDE (1947) measured 132 pupae and found their length to range from 3 to 7.5 mm, with the majority being between 5.5 and 6.5 mm long. In the autumn of 1963 measurements were made of the pupae of *H. brassicae*. The following results were obtained:

	No. of pupae	Length mm av.	Length mm range	Breadth mm av.	Breadth mm range
Normal	337	6.2 ± 0.04	5.0—7.1	2.2 ± 0.06	1.6—2.7
Parasitised by *Trybliographa rapae*	76	5.7 ± 0.14	4.5—7.0	2.0 ± 0.05	1.6—2.5

The pupae parasitised by *Trybliographa rapae* were significantly smaller than the normal pupae (Figs. 3 and 4).

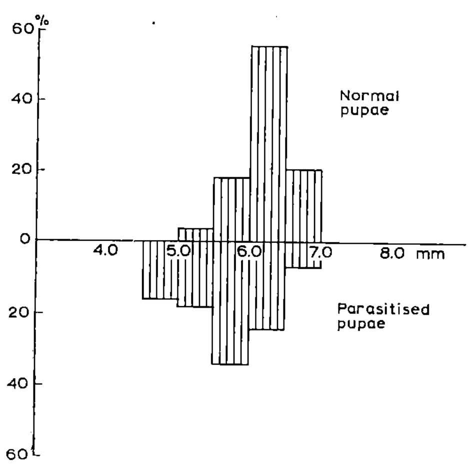

Fig. 3. Variations in length of normal pupae of *Hylemya brassicae* and those parasitised by *Trybliographa rapae*.

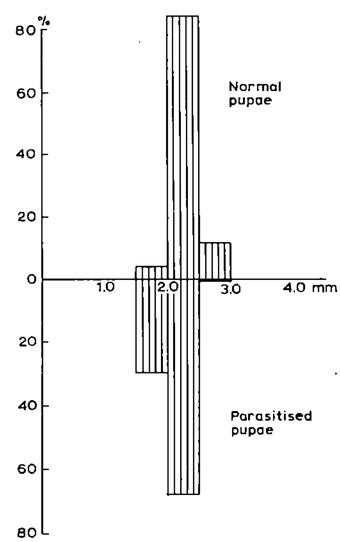

Fig. 4. Variations in breadth of normal pupae of *Hylemya brassicae* and those parasitised by *Trybliographa rapae*.

D u r a t i o n o f p u p a l s t a g e. Considerable data on the duration of the pupal stage of *H. brassicae* based partly on field observations is to been found in literature. According to them the pupal stage duration of summer generation varies from 8 (SLINGERLAND 1894) or 10 (LEIN 1955) days to three months (SLINGERLAND op. cit.). The duration of the hibernating pupal stage is reported to be 6—7 months in Holland (de WILDE 1947) and about 200 days in England (HUGHES 1960).

In the present studies the second generation of *H. brassicae* began to emerge on an average 48 days after oviposition in 1956, 46 days in 1957 and 50 days in 1958. These results agree with those of GIBSON and TREHERNE (1916) according to which the development of *H. brassicae* from egg to adult lasts an average of 54 days in Canada. In the present studies the duration of egg + larval stages was 29—37 days in 1956, 24—35 days in 1957 and 30—39 days in 1958, so that emergence began about three weeks after pupation. The pupal stage of the individual pupae varies widely, with some as short as less than two weeks. — Some of the pupae which developed as early as the beginning of July did not emerge but hibernated, evidently as a consequence of diapause. Since the emergence of *H. brassicae* generally begins around the 20th of May, the duration of the pupal stage in Finland may be as long as 10.5 months.

In the entire area of occurence of *H. floralis*, this species usually has only one generation per year. In certain places in Denmark, on the other hand, two generations have been encountered (JØRGENSEN 1957). In the studies at Tikkurila the first pupae of *H. floralis* developed around the end of July, and pupation continued into October. Since this species usually emerges in mid-June, the duration of the pupal stage is approximately 8—10.5 months. According to MORISON (1939), the pupal stage of *H. floralis* in northern Scotland generally lasts 8—10 months or even longer. In 1960 cabbage maggots were taken at Maaninka (in Central Finland) on July 9 and at Rovaniemi on July 11 and subsequently reared outdoors at Tikkurila. Some of the specimens of *H. floralis* emerged already in this same summer. The first adults from the Maaninka samples appeared on August 4, and those from Rovaniemi on August 1, so that the maximum pupal stage duration of the former was 25 and of the latter 20 days.

Adult

E m e r g e n c e. The number of generations of *H. brassicae* varies from one to four according to the following workers:

	Generations
Sweden (LUNDBLAD 1933)	1—2
Norway (RYGG 1962)	1—2
Denmark (WAGN 1953)	2—3
Soviet Union, Leningrad (VODINSKAYA 1928)	2
Germany (TOMASZEWSKI 1934)	2—3
England (MILES 1955)	2—3
Holland (de WILDE 1947)	3—4
Switzerland (GÜNTHART 1949)	3—4
USA, North Carolina (FULTON 1942)	3
Finland (KANERVO 1954)	1—2

H. floralis has generally only one generation per year in its entire area of occurrence.

Adults of *H. brassicae* emerge from hibernated pupae in the vicinity of Stockholm, Sweden (LUNDBLAD 1933) and in Norway (LEIN 1955) toward the end of May and beginning of June. *H. floralis* emerges from the middle of June to the end of July. In Denmark the first generation of *H. brassicae* appears at the end of May or beginning of June (WAGN 1953).

The emergence of *H. floralis* varies greatly from year to year. In Denmark (JØRGENSEN 1957), it may take place in July, August or September. In some places along the coast of North Jutland, an unusual form of emergence has been noted. Most of the adults emerge late in the summer, but some of them as early as the beginning of June. In these areas two generations per year have been encountered.

In the neighbourhood of Leningrad, Soviet Union, the flies of the first generation of *H. brassicae* are on the wing during the period April 25 — May 25 and the second generation between July 5 and 30. The flies of *H. floralis* are on the wing in late June or early July (VODINSKAYA 1928).

In England the first generation of *H. brassicae* begins to oviposit at the end of April (Miles 1955). In Scotland the emergence of *H. floralis* starts in June (Morison 1939) but does not reach its peak until the first week of August and continues then until the end of August.

In Canada all stages of *H. brassicae*, from egg to adult, may be found throughout the season from April to October (Brooks 1951). *H. floralis* emerges between the beginning of July and the beginning of August (Stewart 1955). In South Finland adults of *H. brassicae* emerge at the end of May and those of *H. floralis* one month later (Kanervo 1954).

In the years 1951—61 larvae and pupae of cabbage root flies were collected in different parts of Finland to be reared outdoors at Tikkurila. In 1952—56 and 1958—59 similar outdoor rearings were also made at Rovaniemi and in 1955—1956 at Inari. At Tikkurila, *H. brassicae* which had been taken from Tikkurila began to emerge, depending on the weather conditions in the different years, between May 10 (in 1959) and June 1 (in 1955). Emergence was most prolific just at the beginning. Males commenced their emergence earlier than females: this process continued until the end of June or sometimes to the beginning of July. The second generation began to emerge in July.

H. floralis in the Tikkurila samples started to emerge around June 15—30, or one month later than *H. brassicae*. Emergence continued until mid-July, and some individual flies emerged later, even as late as the beginning of August. Males started to emerge earlier than females. In the warm summer of 1960 the partial second generation of *H. floralis* emerged in early August; this material had been taken from central and northern Finland. Fig. 5 presents the emergence of cabbage flies in five successive years from sam-

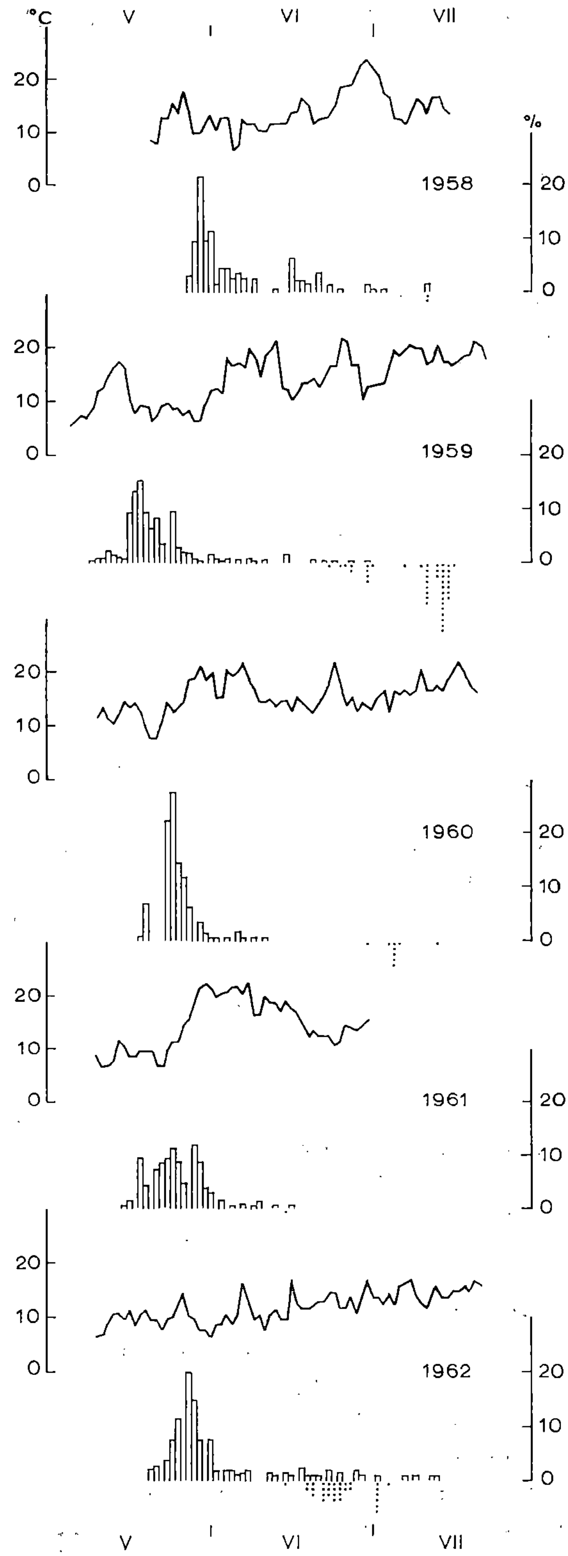

Fig. 5. Emergence of *Hylemya brassicae* and *H. floralis* from samples taken from swedes and turnip at Tikkurila in 1958—1962 as well as the mean daily temperatures during the emergence period.
The columns indicate the amounts of emerged *H. brassicae* calculated as percentage of the total emerged flies of this species.
The dots show the numbers of emerged *H. floralis*.

ples taken at the same time from swedes and turnips. *H. floralis* was very scanty in these samples.

At Rovaniemi *H. brassicae* in the samples taken in that region began to emerge around the middle of June. In the exceptionally warm summer of 1960, emergence began as early as the 31st of May; this month was 3.4° warmer than normal. On the other hand, in the cool summer of 1955 emergence did not begin until July. In this summer the temperature of May was 2.1° cooler and that of June 2.6° cooler than normal.

In normal years emergence of *H. brassicae* at Rovaniemi continues beyond the middle of July. In 1960 some adults of the second generation, arising from samples taken July 15 from big-leafed turnip, emerged between the 22nd and 27th of August. This was a warm summer, with the temperature of June being 1.5°, July 2.2° and August 0.9° higher than normal.

H. floralis in the Rovaniemi samples began emerging between mid-June (in 1953) and early July (in 1955) and continued appearing until the beginning or end of July. The difference in commencement of emergence between the two species was 0—18 days.

At Inari the emergence of *H. brassicae* in the samples taken in that area in 1956 began on June 19 and proceeded until July 12. Adults of *H. floralis* appeared between June 26 and July 13. In this year the temperature of May was 1.2° and of June 1.6° higher than normal. *H. brassicae* began its emergence one week earlier than *H. floralis*. In the same year the difference in the Tikkurila rearings was over three weeks and in the Rovaniemi rearings 10 days; at both locations June was warmer than normal.

Transferring larvae and pupae from one locality to another was mentioned by JØRGENSEN (1957) to have no effect on the time of emergence when *H. floralis* was transferred from Jutland to the vicinity of Copenhagen. Observations made in connexion with the present studies (VARIS 1960) showed that when *H. brassicae* was transferred from the North to the South, its emergence was hastened but took place nevertheless slightly later than the emergence of the local *H. brassicae* flies. Likewise, when the species was transferred from south to north, its emergence was delayed but occurred somewhat earlier than that of the local northern material.

In the case of *H. floralis*, when it was transported from north to south, it emerged earlier than normally and sometimes even earlier than the local southern material. A similar observation was also made by RYGG (1962) in Norway.

Oviposition

According to SCHOENE (1916), oviposition of *H. brassicae* under favourable conditions may begin 3—5 days after emergence. GIBSON and TREHERNE (1916) found that oviposition could start 6 days and SMITH (1927) about 9 days after emergence. According to de WILDE (1947), the time was 4 days. As for *H. floralis*, the period preceding oviposition has been reported as 6—7 days (VASINA 1927, MORISON 1939) and 7—10 days (STEWART 1955).

In the present studies adults of *H. brassicae* which were transferred to the insectary on their day of emergence, began to oviposit 5—15 (av. 8.7) days after emergence. The temperature during this period averaged 13.9°C. Oviposition ceased an average of 39.0 (21—62) days after emergence, so that it lasted about one month. During oviposition the average temperature was 15.7°. There was only a small amount of second generation oviposition. In 1957 it began 10—17 days after emergence around the middle and end of August. The last eggs of the second generation were deposited on September 14.

H. floralis began to oviposit from 7 to 22 days after emergence (average 12.3 days). The temperature prior to oviposition averaged 15.6°C. The period between emergence and oviposition was 3.6 days longer for *H. floralis* than for *H. brassicae*. Deposition of eggs ended from 19 to 59 days (av. 34.2) after emergence, so that oviposition period had a duration of about three weeks. During this time the average temperature was 15.7°C. There was no significant difference in the duration of the oviposition period between the two species studied.

Longevity

In studies made by SCHOENE (1916) some females of *H. brassicae* lived as long as 63 days. FOOTT (1954) found the average longevity of females to be 29 days and that of males 19 days. SWAILES (1961) obtained an average longevity of mated females of 22.2 days, with the maximum 44 days.

In the present studies the longevity of seven females of *H. brassicae* in 1961 ranged from 21 to 63 days, averaging 43 days. Correspondingly, for five males the average longevity was 34 (14—58) days.

H. floralis was reared both in 1960 and 1961. In the former year, the average longevity of five females was 35 days (29—42) and that of three males 28 days (17—38). In 1961 six females lived for 19—58 days (av. 39) and four males 14—55 days (av. 33). No significant differences were found in the longevity between the two species. The longevity of *H. brassicae* was greater than that reported by SWAILES (op. cit.). The maximum longevity of *H. brassicae* females agreed with the figures mentioned by SCHOENE (op. cit.).

Occurrence of life-stages

First-generation adults of *H. brassicae* are encountered between the end of May and the end of July (Fig. 6). Second-generation adults begin to emerge in July, so that adults of this species occur during the entire summer, up to the end of September. They are most numerous in June. Eggs and larvae are found in the entire summer beginning toward the end of May. Pupae begin to appear at the end of June and are at a peak around the middle of July. At the end of June hibernated specimens emerge, so that there are nearly always pupae of *H. brassicae* on the ground. The numbers of pupae, however, are small between the beginning of June and the beginning of July.

In the years 1956—58 studies were made to determine how large a proportion of eggs deposited at different times developed into adults during the same summer and furthermore how great a percentage of the first-generation pupae from such eggs hibernated (Fig. 7). It was found that about one-fourth of the eggs of *H. brassicae* deposited at the beginning of June remained in the pupal stage for hibernation. Of the eggs deposited at the end of June, 68 % hibernated as first-generation pupae, while the figure was 81 % for eggs produced in the early part of July and virtually 100 % for those produced at the end of July. — Considering the overall material, comprising 1.128 specimens, it was established that 48.6 % emerged in the same year and 51.4 % not until in the following year, after hibernation. This is evidently a case of diapause. MISSONIER (1963) found that in France, diapause of *H.*

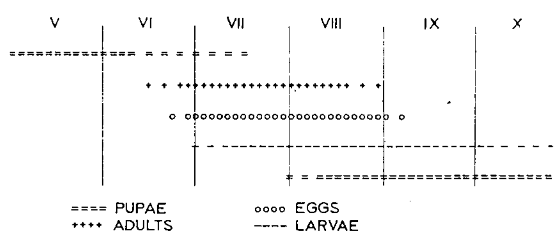

Fig. 6. Times of occurrence of life-stages of *Hylemya brassicae.*

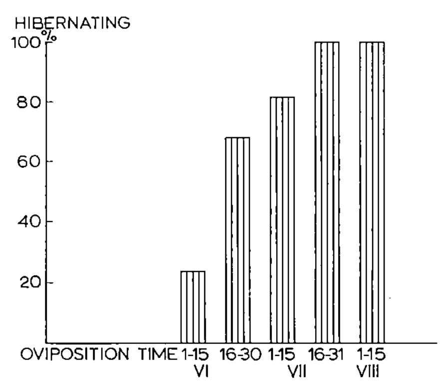

Fig. 7. Effect of oviposition time on the amounts of hibernating first generation pupae of *Hylemya brassicae.* Average figures from 1956—1958.

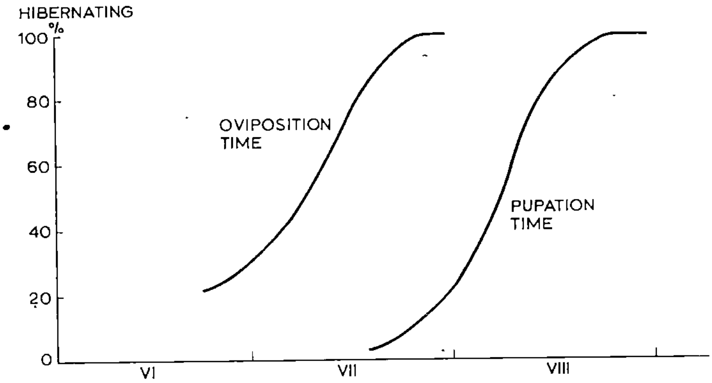

Fig. 8. Effect of oviposition and pupation time on the a amounts of hibernating first-generation pupae of *Hylemya brassicae* in 1957.

brassicae begins in September and affects all the individuals at the end of September and beginning of October.

In 1957 the influence of pupation time on the hibernation of first-generation pupae was investigated (Fig. 8). Larvae were collected during the summer from turnip and observations on pupation were made at two-week intervals.

About one-fourth of the specimens which pupated around the end of July or beginning of August hibernated as first-generation pupae, while nearly all of those which pupated at the end of August remained in the pupal stage over the winter.

Rygg (1962) mentioned the occurrence of the second generation of *H. brassicae* in northern Norway (70°N. lat.). In Finland, rearings were made at Rovaniemi (66°N). In 1960, which was a warmer summer than normal, some pupae taken on July 15 from turnip subsequently developed into second generation adults during the period August 22—27.

In southern Finland the emergence of *H. floralis* begins at the end of June, continuing until the end of July or even into August (Fig. 9).

Adults are to be found until the end of August. Larvae are encountered from the beginning of

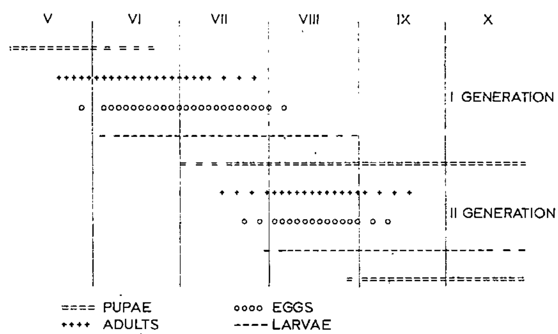

Fig. 9. Times of occurrence of life stages of *Hylemya floralis*.

July to the end of October. In samples collected in southern Finland, larvae of *H. floralis* occurred between the beginning of July and the end of the growing season. Since pupation takes place approximately 6—8 weeks after oviposition, pupae are not found in normal years in southern Finland until at the earliest around the end of July or beginning of August.

In the warmer than normal summer of 1960, the partial second generation of *H. floralis* emerged at Tikkurila. The material had been transferred from central and northern Finland, and emergence commenced at the beginning of August.

Summary

Studies on the biology of the cabbage root fly (*Hylemya brassicae* Bouché) and the turnip root fly (*Hylemya floralis* Fall.) were carried out at Tikkurila (near Helsinki). The time of adult emergence was also determined at the Arctic Circle Agricultural Experiment Station near Rovaniemi and at the Muddusniemi Experimental Farm in North Lapland near Inari.

The eggs of *H. brassicae* were significantly smaller than those of *H. floralis*. The ratio of egg length to breadth was 3.3 in the case of both species. The average number of eggs of *H. floralis* per day of oviposition was greater than that of *H. brassicae*.

The duration of egg stage of *H. brassicae* was considerable shorter than that of *H. floralis*. 50 % of *H. brassicae*-eggs hatched within six days in 1956 and within five days in 1961. Correspondingly, 50 % of *H. floralis*-eggs hatched within nin(and eight days.

The average duration of the larval stage of *H. floralis* was 5—7.5 weeks which was 2—3 weeks longer than for *H. brassicae*.

H. brassicae pupae which were parasitised by *Trybliographa rapae* were significantly smaller than normal pupae. — The average duration of the pupal stage of the first generation of *H. brassicae* was three weeks. The hibernating pupal stage lasted as long as 10.5 months. The duration of the pupal stage os *H. floralis* ranged from 8 to 10.5 months.

The difference in the commencement of emergence between the both species was smaller in the north than in the south. In 1956 it was more than three weeks at Tikkurila, ten days near Arctic Circle and seven days in Northern Lapland.

H. brassicae began to oviposit 5—15 days after emergence. The oviposition period averaged one month. The oviposition of *H. floralis* began 7—22 days after emergence and the oviposition period had a duration of about three weeks. The period between emergence and start of oviposition was 3.6 days longer for *H. floralis* than for *H. brassicae*.

Adults of *H. brassicae* are found in southern Finland from the end of May to September. Likewise, eggs and larvae may be encountered from the end of May throughout virtually the entire season. Pupae first begin to appear at the end of June and are at their peak in the middle of July. An average of one-forth of the eggs of *H. brassicae* deposited at the beginning of June developed into first-generation pupal stage which subsequently hibernated. When eggs were deposited at the end of June, 68 % of the specimens hibernated in the first generation pupal stage, while for those deposited at the beginning of July the proportion was 81 % and for those at the end of July practically all hibernated as first-generation pupae. In warm summers partial second generation can occur at Arctic Circle.

Adults of *H. floralis* are found in southern Finland between the end of June and the end of August and larvae from early July to October. Pupae first appeared around the end of July or beginning of August. In the warm summer of 1960 the partial second generation of *H. floralis*, occurring in samples taken from central and northern Finland, began to emerge at Tikkurila in early August.

Acknowledgements. — During the course of these studies I have received valuable advice from the Head of the Department of Pest Investigation, Professor Veikko Kanervo. Furthermore, Dr. Wolter Hellén has determined the *Trybliographa* species and Mrs. Silja Mäkelä has been technical assistant. To these persons I express my sincere appreciation.

REFERENCES

Brooks, A. R. 1951. Identification of the root maggots (*Diptera: Anthomyiidae*) attacking cruciferous garden crops in Canada, with notes on biology and control. Can. Ent. 83: 109—120.

Foott, W. H. 1954. The biology of the adults of *Hylemya brassicae* (Bouché) (*Diptera: Anthomyiidae*). Ent. Soc. Ont. Ann. Rep. 85: 42—53.

FULTON, B. B. 1942. The cabbage maggot in North Carolina. North Carolina Agric. Exp. Sta. Bull. 335: 1—24.

GIBSON, A. & TREHERNE, R. C. 1916. The cabbage root maggot and its control in Canada. Dom. Can. Dept. Agric. Ent. Branch Bull. 12: 1—58.

GÜNTHART, E. 1949. Beiträge zur Lebensweise und Bekämpfung von *Ceuthorrhynchus quadridens* Panz. und *Ceuthorrhynchus napi* Gyll. Mitt. Schw. Ent. Ges. 22: 441—591.

HUGHES, R. D. 1960. Induction of diapause in *Erioischia brassicae* Bouché (*Dipt., Anthomyiidae*). J. Exp. Biol. 37: 218—223.

JØRGENSEN, J. 1957. Den store kålflue (*Chorthophila floralis* Fall.). Ber. Stat. Fors. virks. Pl.kultur 533: 657—712.

KANERVO, V. 1945. Sipulin ja kaalin kärpästuhojen torjunnasta. Koetoim. ja Käyt. 2: 3—7.

— 1954. Grönsaksflugornas biologi och bekämpning. Nord. Jordbr.forskn. 36: 333—338.

LEIN, H. 1955. Kålfluene (*Hylemyia brassicae* Bouché & *H. floralis* Fallen). Meld. Stat. Plantevern 9: 1—65.

LUNDBLAD, O. 1933. Kålflugorna. Medd. Stat. Växtskyddsanst. 3: 1—103.

MILES, M. 1950. Observations on the biology and control of cabbage root fly *Erioischia brassicae* (Bché). Ann. Appl. Biol. 37: 260—267.

— 1952. Studies of British Anthomyiid flies. Bull. Ent. Res. 43: 83—90.

— 1953. Field studies on the influence of weather conditions on egg laying by the cabbage root fly *Erioischia brassicae* Bché I. Ann. Appl. Biol. 40: 717—725.

— 1954. Field studies on the influence of weather conditions on egg laying by the cabbage root fly *Erioischia brassicae* Bché. II. Ibid. 41: 586—590.

— 1955. Studies of British Anthomyiid flies VI. The annual cycle of generations in some Anthomyiid root flies. Bull. Ent. Res. 46: 11—19.

MISSONIER, J. 1963. Etude écologique du développement nymphal de deux Diptéres-Muscides phytophages: *Pegomyia betae* Curtis et *Chorthophila brassicae* Bouché. Diss. Paris. Ann. Epiph. 14: 1—186.

MORISON, G. D. 1939. The turnip root fly (*Phorbia floralis* Fallen) in Northern Scotland. Verh. 7. Intern. Kongr. Ent. Berlin 1938: 2576—2584.

REUTER, E. Kertomus tuhohyönteisten ilmestymisestä Suomessa vuosina 1895 ja 1896. Maanvilj.hall. Tied. 21: 1—52.

RYGG, T. 1962. Kålfluene *Hylemyia brassicae* (Bouché) og *H. floralis* (Fallen) (*Dipt.: Anthomyiidae*). Meld. Stat. Plantevern 19: 85—114.

SAALAS, U. 1943. Maatalouden tuho- ja hyötyeläimet. 497 p. Helsinki.

SCHOENE, W. J. 1916. The cabbage maggot, its biology and control. N. Y. Agric. Exp. Sta. Bull. 419: 99—160.

SHERWOOD, R. C. & POND, D. D. 1954. A simple method of rearing *Hylemyia brassicae* (Bouché) (*Dipt., Anthomyiidae*). Can. Ent. 86: 178—179.

SLINGERLAND, M. W. 1894. The cabbage root maggot. Cor. Univ. Agric. Exp. Sta. Bull. 78: 481—577.

SMITH, R. H. 1927. A study of *Hylemyia* (*Chorthophila*) *brassicae* Bouché, the cabbage root fly and its parasites. Ann. Appl. Biol. 16: 312—330.

STEWART, W. W. A. 1955. Control of the turnip maggot in rutabagas in Saskatchewan. Can. Dept. Agric. Publ. 950: 1—4.

SWAILES, G. E. 1957. Ecology of the cabbage root maggot, *Hylemya brassicae* (Bouché), in Southern Alberta. J. Sci. 31: 524—525.

— 1961. Laboratory studies on mating and oviposition of *Hylemya brassicae* (Bouché) (*Diptera: Anthomyiidae*). Can. Ent. 93: 940—943.

TOMASZEWSKI, W. 1934. Zur Taxonomie der Kohlfliegen *Chorthophila brassicae* Bouché und *Ch. floralis* Fallen. Arb. morph. taxon. Ent. Berlin-Dahlem 1: 60—66.

VAPPULA, N. A. 1944. Maataloustuholaisten esiintymisestä Suomessa kesällä 1943. Ann. Ent. Fenn. 10: 133.

VARIS, A.-L. 1958 a. On the importance of the sowing time of crucifers in preventing the damage caused by cabbage maggots (*Hylemyia* spp.), on the basis of tests made on big-leafed turnip. Maatal.tiet. Aikak. 30: 264—270.

— 1958 b. On the susceptibily of the different varieties of big-leafed turnip to damage caused by cabbage maggots (*Hylemyia* spp.). Ibid. 30: 271—275.

— 1960. Kläckningen av imagines i Sydfinland och Nordfinland av *Hylemyia*-arter på korsblomstriga växter. Nord. Jordbr.forskn. suppl. 1: 307—310.

VASINA, A. N. 1927. The cabbage fly (*Hylemyia brassicae* Bché and *Hylemyia floralis* Fall.). Trud. Opuitno-Issl. Uch. Stanz. Zashch. Rast. Vred. Mosk. Zem. Otd. 63—89. (Ref. Rev. Appl. Ent. 16: 412).

VODINSKAYA, K. L. 1928. On the biology and ecology of *Hylemyia brassicae* Bché and *Hylemyia floralis* Fall. Isv. Otd. prikl. Ent. Leningr. 3: 229—249. (Ref. Rev. Appl. Ent. 17: 141—142).

WAGN, O. 1953. Om den store kålflue (*Chorthophila floralis* Fall.). Tidskr. Planteavl 56: 470—477.

WILDE, J. de. 1947. Onderzoek betreffende de koolvlieg en zijn bestrijding. Versl. Landbowk. Onderz. 53: 1—118.

SELOSTUS

Tutkimuksia kaalikärpäsen (Hylemya brassicae) ja ison kaalikärpäsen (Hylemya floralis) biologiasta

Anna-Liisa Varis

Maatalouden tutkimuskeskus, Tuhoeläintutkimuslaitos, Tikkurila

Kaalikärpäset ovat ristikukkaisten viljelykasviemme pahimmat tuholaiset, jotka aiheuttavat vuosittain tuntuvia satotappioita. Tämän vuoksi Tuhoeläintutkimuslaitos on pitänyt tärkeänä näiden lajien biologian selvittämistä.

Tutkimustyöt tehtiin pääosaltaan Tikkurilassa. Aikuisten kuoriutumisaikoja selvitettiin lisäksi Perä-Pohjolan koeasemalla Rovaniemellä ja Helsingin yliopiston koetilalla Inarissa.

Kaalikärpäsen ja ison kaalikärpäsen kokonaismunamäärissä ei ollut merkitseviä eroja. Kaalikärpäsen muna-aika oli tuntuvasti ison kaalikärpäsen muna-aikaa lyhyempi. 50 % kaalikärpäsen munista kuoriutui 1956 kuuden ja 1961 viiden vuorokauden kuluessa. Vastaavasti 50 % ison kaalikärpäsen munista kuoriutui 1956 yhdeksän ja 1961 kahdeksan vuorokauden kuluessa.

Ison kaalikärpäsen toukka-ajan keskimääräinen pituus oli 5—7.5 viikkoa eli 2—3 viikkoa pitempi kuin kaalikärpäsen.

Kaalikärpäsen ensimmäisen sukupolven koteloaika oli keskimäärin kolme viikkoa. Osa jo heinäkuun alkupuolella kehittyneistä koteloista jäi talvehtimaan. Talvehtivan koteloasteen kestoaika oli siten jopa 10.5 kuukautta. Ison kaalikärpäsen koteloaika kesti 8—10.5 kuukautta. Normaalia lämpimämpänä kesänä 1960 kuoriutui heinäkuussa Keski- ja Pohjois-Suomesta Tikkurilaan toukkina tuodusta aineistosta isoa kaalikärpästä vielä samana kesänä. Koteloajan pituus näissä kasvatuksissa oli enintään 20—25 vrk.

Ero kaalikärpäsen ja ison kaalikärpäsen aikuistumisen alkamisessa pieneni pohjoiseen mentäessä. Vuonna 1956 oli ero Tikkurilassa yli kolme viikkoa, Rovaniemellä 10 vrk ja Inarissa 7 vrk.

Kaalikärpäsen muninta-aika alkoi keskimäärin 8.7 vrk kuoriutumisen jälkeen ja kesti noin kuukauden. Ison kaalikärpäsen muninta-aika alkoi keskimäärin 12.3 vrk kuoriutumisen jälkeen ja kesti noin kolme viikkoa.

Kaalikärpäsen aikuisia tavataan Etelä-Suomessa toukokuun loppupuolelta syyskuulle. Samoin munia ja toukkia tavataan toukokuun lopulta lähtien koko kasvukauden ajan. Koteloita alkaa esiintyä kesäkuun lopulla, runsaammin kuitenkin vasta heinäkuun puolivälissä. Viimeiset edelliseltä vuodelta peräisin olevat kotelot kuoriutuvat kesäkuun lopussa. Vuosina 1956—1958 jäi keskimäärin neljännes kesäkuun alussa munituista kaalikärpäsyksilöistä talvehtimaan ensimmäisen sukupolven koteloina. Kesäkuun loppupuolella munituista yksilöistä jäi 68 %, heinäkuun alkupuolella munituista yksilöistä 81 %, ja heinäkuun lopulta lähtien miltei kaikki yksilöt jäivät talvehtimaan ensimmäisen sukupolven koteloina. Lämpimänä kesänä 1960 kuoriutui Rovaniemellä asti pohjoisessa kaalikärpäsestä osittainen toinen sukupolvi.

Ison kaalikärpäsen aikuisia tavataan Etelä-Suomessa kesäkuun loppupuolelta elokuun loppuun ja toukkia heinäkuun alusta lokakuulle asti. Koteloita esiintyy aikaisintaan heinä—elokuun vaihteessa. Vuonna 1960 kuoriutui Tikkurilassa isosta kaalikärpäsestä toisen sukupolven aikuisia elokuun alussa. Aineisto oli siirretty Tikkurilaan Keski- ja Pohjois-Suomesta.

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Seria ANIMALIA DOMESTICA N. 22 — Sarja KOTIELÄIMET n:o 22

NUTRITIONAL FACTORS PROMOTING THE IN VITRO GROWTH OF RUMEN BACTERIA OF THE COW FED ON A PURIFIED PROTEIN-FREE DIET

MARTTI LAMPILA

Agricultural Research Centre, Department of Animal Husbandry, Tikkurila, Finland *)

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During recent years experiments have been carried out at the Biochemical Research Institute, Helsinki, using purified nutrients (starch, cellulose and sucrose) as a source of energy, and urea and some ammonium salts as the only source of nitrogen for lactating dairy cows. With this kind of feeding, a relatively high milk production has been achieved (VIRTANEN and LAMPILA 1962) and further improvement of the diet, especially an increase in the amount of urea, has led to surprisingly high yields of milk (VIRTANEN 1964, 1966).

When, in the beginning of the investigations, the cows had become adapted to the experimental diet, the question arose whether and in what way it is possible further to accelerate the growth and reproduction of the rumen bacteria dependent solely on ammonia (the product of hydrolysis of urea) as their source of nitrogen.

If such a course were possible, one could also consider practical methods of increasing the production of bacterial protein and at the same time the production of amino acids, which are minimum factors in the nourishment of the cow.

The measures taken may either improve the growth conditions of the micro-organisms or eliminate possible deficiencies in their nutrition. With such an exceptional and one-sided diet, it was not unreasonable to suppose that deficiencies might indeed occur. On the other hand, the whole question of nutrition, as well as investigations on the subject, is complicated by the fact that the flora being fed is not a constant, single entity but is capable of changing with the conditions. Furthermore, the symbiotic and syntrophic relations between various bacteria may influence their nutrition in many unknown ways.

One example of this interdependence was demonstrated by the fact that the cultivation of certain normal rumen bacteria in synthetic growth media became possible only after the importance of certain volatile fatty acids as their growth factors was established (BENTLEY et al. 1954, BRYANT and DOETSCH 1955). In mixed cultures, some species obviously »feed» these bacteria by producing the required acids.

NURMIKKO (1954) has studied the symbiotic interrelationship between lactic acid bacteria,

*) This study was carried out in 1962, when the author was conducting experiments under the leadership of Prof. A. I. Virtanen at the Biochemical Research Institute, Helsinki, on feeding dairy cows with pure nutrients and urea nitrogen.

observing that certain strains excreted into the medium growth factors required by other strains. Thus the symbiotic growth of two organisms was possible in a medium where neither grew when cultured alone. The growth factors excreted were six amino acids and two B-group vitamins (folic acid and B_{12}).

Similar interrelationships are likely to occur between different species and strains of rumen bacteria, especially when the diet of the host animal is virtually lacking in proteins and their components, as well as in many other nutritional factors contained in normal feeds.

Presumably the composition of the prevailing mixed bacterial flora is at least partly dependent on symbiosis and/or syntrophism. However, as long as there is a minimum factor limiting the growth rate of the bacterial population, propagation can be accelerated by addition of this factor.

Preliminary studies concerning the VFA in rumen fluid indicated that under the prevailing feeding conditions there was no deficiency of acids known to be growth factors of the bacteria. Neither did the addition of B-group vitamins in yeast hydrolysate to the nutrient solution seem to raise the growth rate above the point reached with amino acids given as casein hydrolysate. Under these circumstances and also because the research was planned primarily with practical applications in mind, the principal part of the investigation was concentrated on determining which of the 18 amino acids contained in casein is or are able to increase the growth rate of the bacteria.

Experimental methods

Preparation of bacterial cultures

In all cultures, the basal substrate consisted of rumen fluid from which the cells were separated by centrifuging for 15 min. at 12 500—15 000 g. The rumen fluid was taken with a stomach tube from cows fed on purified diets. As mentioned by Virtanen (1964), the rations given to the cows did not contain proteins as a source of nitrogen but urea and ammonium salts instead.

The rumen fluid was usually taken from an experimental cow named Pella II. On account of the long transport, the fluid was chilled immediately after removal and kept cold while the cultures were prepared. During all phases of handling, care was taken to prevent air from coming in contact with the rumen fluid.

The fluid was centrifuged to remove cells and 0.5 % sucrose and 50 mmol./l Na bicarbonate were added (calculated to the final volume of the cultures). In order to promote solution and furthermore to replace the air, carbon dioxide was passed into the solution.

When the above substances had dissolved, the cultures were inoculated with fresh rumen fluid corresponding to 1 % of the final volume of the cultures; the bulk of the fodder particles in this inoculum had been removed beforehand by sedimentation. Seventy per cent (v/v) of this solution, which besides the inoculum contained the energy source and buffer, was used to prepare the cultures. The remainder of the volume was reserved for addition of the growth factors to be tested and urea nitrogen (or ammonia N). The spare volume was filled with distilled water.

The growth factors tested in the first experiment and their proportions are listed in Table 1. The amount of nitrogen varied between the culture groups. Control cultures contained no additions other than water to fill the volume or a solution of urea which brought the amount of nitrogen added to each culture to 280 mg/l. This urea supplement was also added to the cultures in which the growth factors were tested.

In all the other experiments the total amount of nitrogen provided by all the supplements together was supplemented by adding urea (or NH_4Cl) to make up a total of 140 mg per litre, except in individual cases mentioned separately.

Table 1. Growth factors added to the bacterial cultures in experiment 1

Taulukko 1. Kasvutekijäin lisääminen bakteeriviljelmiin kokeessa 1

Substances	per litre of culture
Mixture I:	
Aspartic acid	2.5 mmol.
Asparagine	2.5 »
Glutamic acid	2.5 »
Glutamine	2.5 »
Mixture II:	
Folic acid	12.5 μg
Auxin	37.5 mg
Orotic acid	2.5 mg
Mixture III:	
Mixt. 1 + Mixt. II	as above
Casein hydrolysate (dry) (Bacto-Casitone = pancreatic digest of casein, 8.25 % N)	1.726 g
Yeast hydrolysate (dry)	1.0 g
Mixture IV:	
Casein hydrolysate + Yeast hydrolysate	as above

In studying the effect of the amino acids on the growth rate of the bacterial population, each of them was added to the cultures as shown in Table 2. Thus when all 18 amino acids were added, the total quantity of amino acid nitrogen was 64 mg/l. When casein hydrolysate was as control, it was added so as to supply the same amount of nitrogen. In both cases urea was added so that the total amount of nitrogen in the supplements was 140 mg/l of the culture. When some of the amino acids were excluded, their part of the nitrogen was substituted by the same method.

All the amino acids used, as well as the three growth factors listed in Table 1, were pure chemicals (pro analysi or equivalent) supplied by reliable manufacturers. A concentrated stock solution of each amino acid was made up in distilled water so that the supplement volume of each would be equal. When the solubility of the amino acid in water was too low, the required amount of 0.1 or 1.0 N NaOH was used.

Each separate type of culture was prepared in one lot and then divided into two or three parallel 15-ml cultures in test tubes (16 × 160 mm). The air in the test tubes was replaced beforehand with carbon dioxide and they were closed with rubber stoppers immediately after preparation. The test tubes were kept in ice water until incubation was started, as a rule immediately after all the cultures were prepared.

Table 2. Amino acid mixture simulating the composition of casein. The composition of the mixture was used as a basis for the addition of different acids to bacterial cultures [1])

Taulukko 2. Eri aminohappojen lisäämisen perusteena käytetty kaseiinin koostumusta jäljittelevä aminohapposeos [1])

Amino acid	Percentage in the mixture	Added mg/l of culture	Added N	
			mg/l	% of total
l-alanine	2.71	13.6	2.14	3.3
l-argine	3.68	18.4	5.92	9.2
l-aspartic acid	5.69	28.5	3.00	4.7
l-cystine	0.35	1.8	0.21	0.3
l-glutamic acid	20.65	103.3	9.84	15.4
glycine	1.84	9.2	1.72	2.7
l-histidine	2.62	13.1	3.55	5.5
l-isoleucine	5.78	28.9	3.10	4.8
l-leucine	8.84	44.2	4.72	7.4
l-lysine	7.18	35.9	6.88	10.7
l-methionine	2.89	14.5	1.36	2.1
l-phenylalanine	5.08	25.4	2.15	3.4
l-proline	10.76	53.8	6.55	10.2
l-serine	5.51	27.6	3.68	5.7
l-threonine	3.94	19.7	2.32	3.6
l-tryptophan	1.31	6.6	0.91	1.4
l-tyrosine	5.51	27.6	2.13	3.3
l-valine	6.47	32.4	3.88	6.1
Sum	**100.61**	**504.5**	**64.06**	**99.8**

[1]) The composition is the same as that presented for casein in the book »Milk: The mammary gland and its secretion», (Vol. 2, p. 210) edited by S.K. Kon and A.T. Cowie, 1961, Academic Press INC. New York.

Cultivation and growth rate measurement

Incubation was carried out at 39—40°C in a water bath provided with a thermostat and an agitator. The cultivation time was counted from the moment the test tube was transferred from the ice water to the water bath.

Growth was measured turbidimetrically. Because of this, tubes optically as identical as possible were selected. A nephelometer (nephelometer head of EEL, with galvanometer of Cambridge Instrument, Ltd.) was used to measure the turbidities. The nephelometer sensitivity was standardized against two standards. The parameter used for measuring the growth rate was the alteration of turbidity during the logarithmic phase of growth.

Results and discussion

Experiment 1: Mixtures of growth factors

The growthfactors tested in this first experiment are shown in Table 1 and the results in Fig. 1.

It is clear that neither aspartic nor glutamic acids or their amides increased the growth rate as compared with the controls, nor did orotic and folic acid plus auxin, when the two mixtures were added separately. However, when they were added together a slight increase in growth rate was achieved. The addition of urea did not have any effect either, showing that the rumen fluid obviously contained enough soluble nitrogen.

In the cultures to which hydrolysates of casein and yeast were added (separately or together), the growth rate of the bacterial population in the logarithmic phase was entirely different. At 6½ h after the beginning of cultivation, the turbidity had exceeded the upper limit of the measuring range. When the sensitivity of the measuring device was reduced, it was seen that the turbidity was about the same in all three cultures, and thus the growth rate with these three treatments could be considered virtually equal.

Auxin was tested primarily because MÜLLER and KRAMPITZ (1955) had observed that it increased the net synthesis of protein in cultures of rumen bacteria. In the present work it did not seem to have the same effect when added together with orotic and folic acid, as far as this can be judged on the basis of culture turbidity. The dosage, however, was lower (37.5 mg/l) than that (25 mg/150 ml) used by the above authors.

From the theoretical standpoint, it would have been interesting to study in greater detail why culture no. 5 showed a small but distinct increase in growth rate, even though the factors added produced no observable effect when given separately (cultures 3 and 4). The growth rate attained with casein hydrolysate, however, was so much better that the investigation was continued to discover the growth-promoting factor or factors which it contained. The addition of yeast hydrolysate induced equally rapid growth, but as both compounds contain amino acids, the effect of the B-vitamins contained in the latter remains unknown.

Experiment 2: Different concentrations of casein hydrolysate

The effect of adding different amounts of casein hydrolysate on the bacterial growth rate is shown in Fig. 2.

The effect of the growth factors was not apparent until the logarithmic phase of growth, since the length of the lag phase was independent of the additions made. (Later, however, divergent results were also seen). The growth acceleration effect achieved by raising the concentration is clearly and consistently visible in the growth curves. Even one milligram of casein hydrolysate nitrogen per litre of culture brought about a distinct difference in growth rate as compared with the cultures containing urea supplement alone.

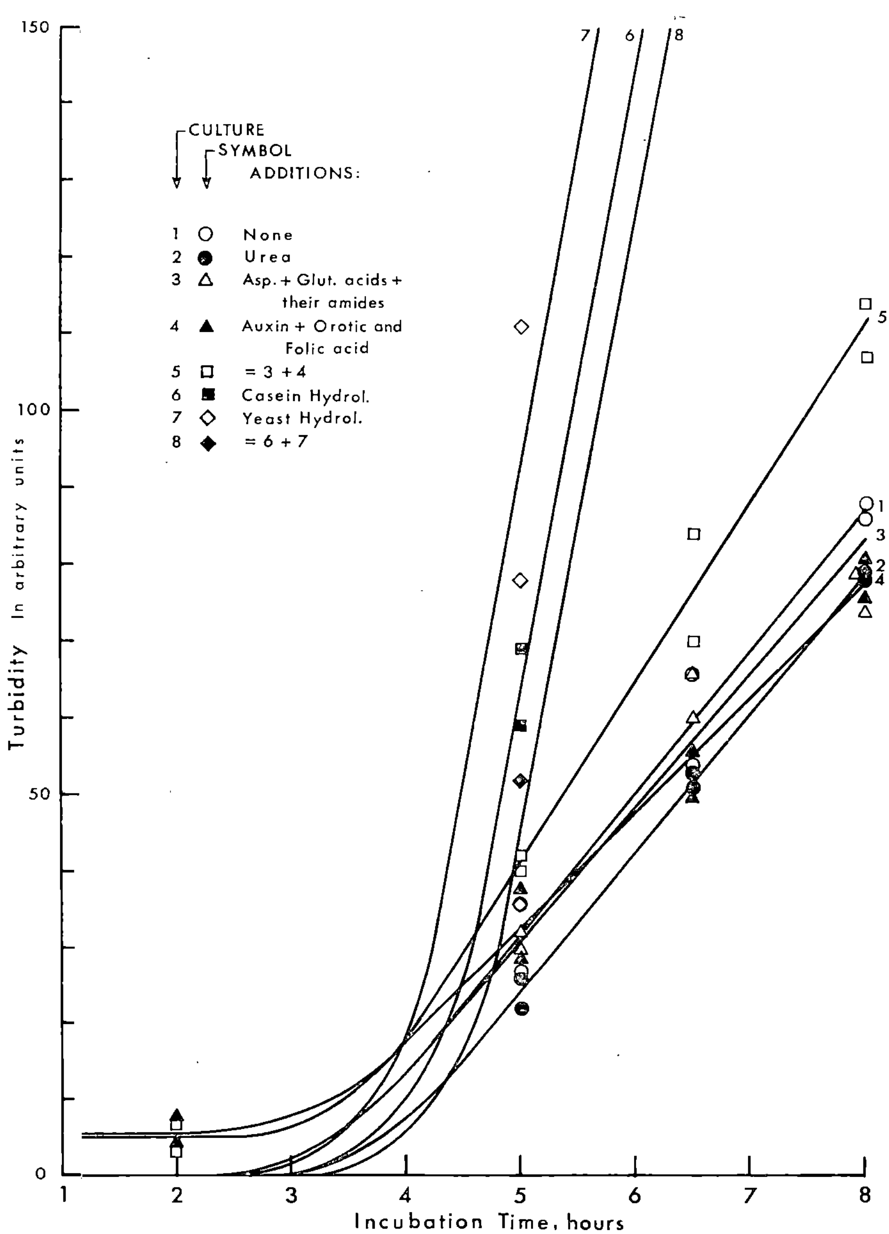

Fig. 1. The effect of nutrient mixtures on the growth rate, determined turbidimetrically, of the mixed bacterial flora of the rumen. The amounts added are shown in Table 1.

Kuva 1. Seoksina annostettujen ravintotekijäin vaikutus pötsibakteeriston kasvunopeuteen sekaviljelmissä turbidimetrisesti määritettynä. Lisättyjen aineiden määrät on esitetty taulukossa 1.

The results clearly demonstrate that the acceleration of growth is actually due to the concentration of growth factors and not to an indirect effect of the casein hydrolysate, for instance via the redox potential of the cultures. Other observations supporting this view are described later.

In this, as well as in later experiments, the total nitrogen added to the cultures was adjusted to the same value (140 mg per l) with an appropriate amount of urea for each particular culture. In the preceding experiment this adjustment seemed to be insignificant because the addition of urea alone did not improve the growth rate

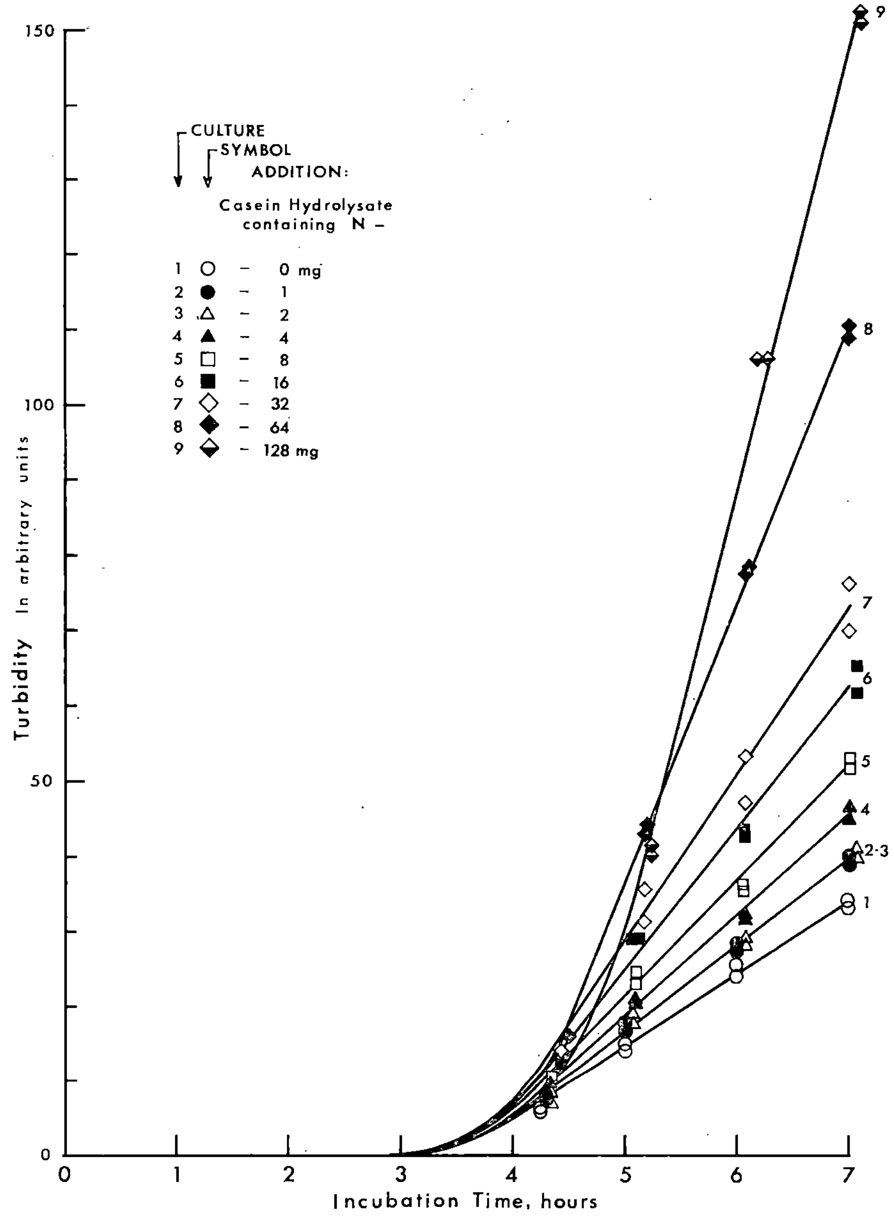

Fig. 2. The effect of amount of casein hydrolysate on the growth rate of rumen bacteria in culture.

Kuva 2. Annoksen suuruuden vaikutus pötsibakteeriston kasvunopeuteen viljelmissä kaseiinihydrolysaattia lisättäessä.

as compared with cultures to which no nitrogen at all was added to supplement the rumen fluid. However, since the extent of hydrolysis of urea to ammonia (in which form it is usually belived to be utilized) remained uncertain, the adequacy of ammonium nitrogen was not established. For this reason, and also to confirm the result obtained, the experiment was repeated using ammonium chloride instead of urea. As the result was in agreement with that presented here, there was clearly no shortage of ammonium nitrogen. Thus lack of utilizable nitrogen does not account for the growth-promoting effect of casein hydrolysate.

The results of investigations presented by Bryant and Robinson (1962, 1963) suggest that a significant proportion of the rumen bacterial population of normally fed cattle prefers to synthesize many of its cellular constituents from NH_3—N and carbon sources other than amino acids. Some species of the predominant culturable rumen bacteria, on the other hand, needed amino acids but not ammonia.

The results presented in this work clearly indicate that bacteria requiring amino acids do survive in the rumen flora even when no amino acids are present in the feed. In addition, these species seem to be important in the bacterial population.

An alternative or complementary interpretation might, of course, be that the amino acids had only had a stimulating effect.

Experiment 3: Subgroups of 18 amino acids

As mentioned in the description of the culture preparation, the maximum amount of amino acid nitrogen added to the cultures was 64 mg/l, when all 18 amino acids listed in Table 2 were added, as was the case here. When casein hydrolysate was used as control, it was added in such quantities that the amount of nitrogen was the same. When only some of the 18 amino acids were used, the total quantity of amino acid nitrogen fell by the amount contained in the omitted acids, which can be computed from the figures in Table 2. The cultures were always supplemented with urea to bring the total added nitrogen to 140 mg/l.

In the preceding experiment it was demonstrated that even 64 mg/l nitrogen of casein hydrolysate did not give the maximum possible growth rate. In fact, the dose required for such a maximum was not determined, although the highest dose (128 mg N/l) seemed to be at least close to it. The reason that the addition was nevertheless limited to 64 mg N/l was to allow the manifestation of a better growth rate when pure amino acids were to be added. It can be seen from Fig. 3 that this procedure was well founded, because the 18 acids produced a significantly faster growth rate than the same amount of nitrogen given as casein hydrolysate. It thus seems that the casein hydrolysate either did not contain the growth-promoting acids in the same proportions as the mixture of 18 amino acids simulating its composition, or they were not in such a readily utilizable form.

In Fig. 3 the grouping of the amino acids can also be seen. In the group of the ten amino acids indispensable to the animal organism (rat), the semi-essential arginine was included. In the group of non-essential acids there thus remained eight acids. The other groups were composed of partly structurally and partly biosynthetically related acids according to the classification presented by Oginsky and Umbreit (1950, pp. 292—306). Histidine was thus left in a group on its own, while threonine was included in two of the latter-mentioned groups.

In this experiment the sensitivity of the measuring device was adjusted to be less than previously, in order to keep all the readings on the galvanometer scale. Regardless of the different numerical values, the turbidity of the cultures which had reached the stationary phase was, when visually judged, about the same as in the previous experiments.

In examining the results, attention is above all drawn to the great increase in growth rate in the two most rapidly growing cultures. Their growth rate in the logarithmic phase was so rapid that the time elapsing from the start level to the final turbidity would have been only about 1—1½ hours. Because the inoculation was 1 % of the final culture volume and the highest turbidity was (at least) as great as that of the inoculated rumen fluid, the bacterial population can be estimated to have increased about 100-fold. This takes 6½ generations, which means that the generation time would be only about 9—13 minutes in the logarithmic phase. Also the time passing between the first signs of growth and the stationary phase was only about two hours. Such being the case, it does not seem probable that one or more minor

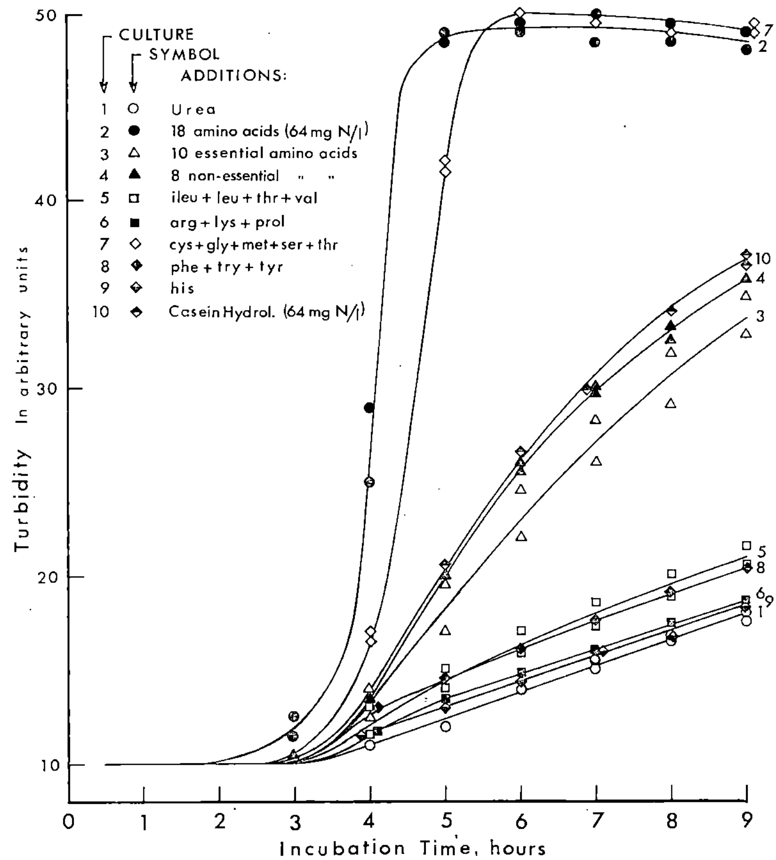

Fig. 3. The growth rate of rumen bacteria in culture when the 18 amino acids of casein were added, together and variously grouped. The dosage of each acid is shown in Table 2.

Kuva 3. Pötsibakteeriston kasvunopeus viljelmissä lisättäessä kaseiinin 18 aminohappoa yhdessä ja eri tavoin ryhmiteltynä. Eri happojen annostus on esitetty taulukossa 2.

bacterial species in the inoculum could have been responsible for the result.

The dosing of amino acids in groups of biosynthetically related acids seemed rather successful, because those most active as growth factors were concentrated in one of the groups, while the effect of the other combinations was quite insignificant. This one active group (Culture 7) produced a growth almost as rapid as that induced by all the 18 amino acids together. The greater effect of the latter was seen only as a slightly shorter lag phase.

The division into groups of essential and non-essential acids, on the other hand, showed that there was obviously more than one active factor. As the subgroup which induced the best growth rate (cys + gly + met + ser + thr) contained acids from both of the above-mentioned main groups, the investigations were subsequently concentrated on the effect of the acids in this group.

Experiment 4: Subgroup of five amino acids

This part of the work comprised four different tests intended to disclose which are the active amino acids in the group mentioned above. The results depicted in Fig. 4 show that cystine and methionine together are as effective as the whole group, which here, as in the pre-

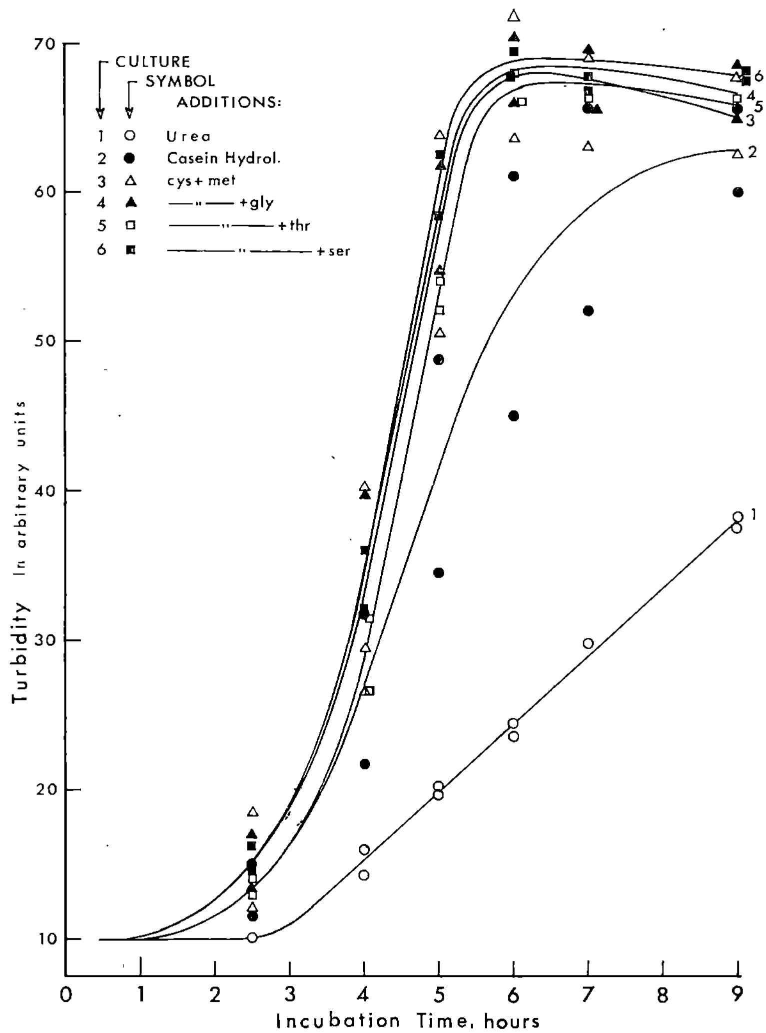

Fig. 4. The growth rate of rumen bacteria in culture when various numbers of five amino acids were added. If only one symbol is shown per culture and time of measurement, this means that the parallel cultures gave identical results.

Kuva 4. Pötsibakteeriston kasvunopeus viljelmissä lisättäessä eri suuria osia viiden aminohapon ryhmästä. Mikäli vain yksi symboli viljelmää ja mittaushetkeä kohti on esitetty, merkitsee se sitä, että rinnakkaisviljelmät ovat antaneet saman tuloksen.

vious experiment, had a greater effect than the casein hydrolysate. Cystine and methionine were inadvertently not tested separately. This was, however, done later (cf. Fig. 7).

As the other three acids were always added to the cultures together with the two mentioned, any individual effect that they may have had was masked. On the basis of the preceding experiment, however, an estimation of their significance can be made.

From Fig. 3 it can be seen that threonine, besides being in this experimental group, was also tested in Culture 5, which exhibited slow growth. It can thus be concluded that threonine alone had no appreciable effect. Glycine and serine were in the group of non-essential amino acids (Culture 4) together with cystine, which later proved effective. As the growth-promoting effect produced by this group of acids was distinctly weaker than the effect seen in Culture

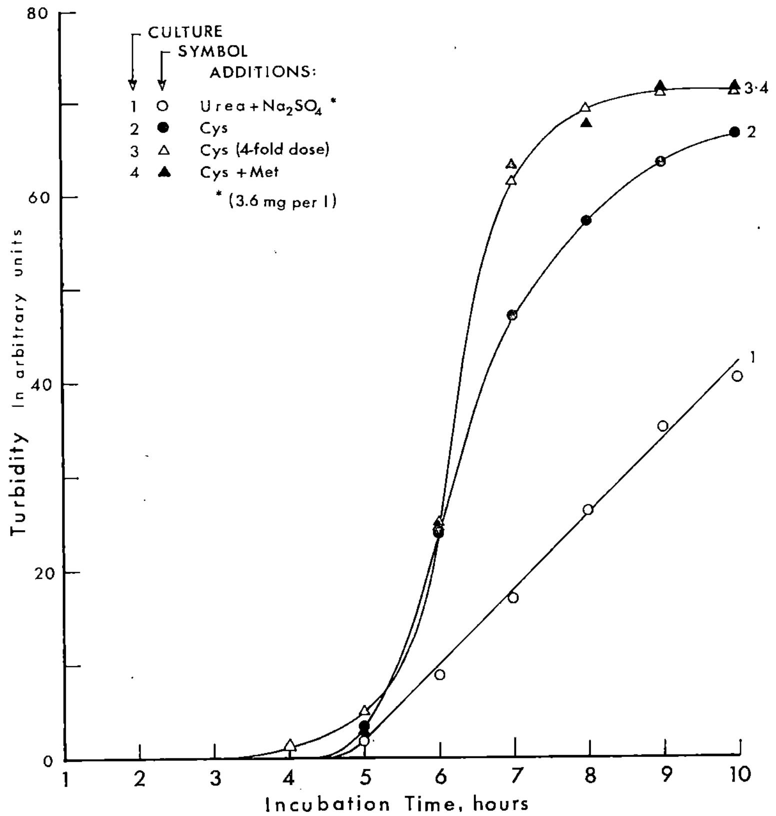

Fig. 5. The effect of cystine and cystine + methionine on the growth rate of rumen bacteria in culture. Each symbol represents the mean of three parallel cultures. The standard error of the means was insignificant as regards comparison of the results.

Kuva 5. Cystiinin ja cystiinin + metioniinin vaikutus pötsibakteeriston kasvunopeuteen viljelmissä. Kukin symboli edustaa kolmen rinnakkaisviljelmän keskiarvoa. Keskiarvojen keskivirheet olivat tulosten vertailun kannalta merkityksettömät.

7, glycine and serine in the former combination can be considered unimportant (cf. Fig. 6).

The results seen in Fig. 5 show that cystine, when alone, produced a slightly weaker growth than when in combination with methionine. In four-fold dose, however, cystine raised the growth rate to the same level as the combination. In the control culture (Culture 1), in addition to urea, sodium sulphate had been added to assure an adequate supply of sulphur.

To confirm the results and to test the possible necessity of a sulphur supplement, the experiment was amplified as shown in Fig. 6. These results indicate first that supplementing rumen fluid with sulphur and urea did not increase the growth rate. The effect of a basal cystine dose remained smaller than when it was supplemented with methionine, but the growth rate achieved with the four-fold dose was the same, as was also found in the preceding experiment. The effect of the basal dose, however, was about the same as that of casein hydrolysate. In experiment 3 (Fig. 3) an analogous result was obtained with the group of non-essential acids, demonstrating that the effect of this group can be considered to be dependent on its cystine content.

In the following experiment (Fig. 7) cystine and methionine were compared in more detail and at the same time the effect of dosage was studied. The basal dose used earlier (cf. Table 2) was 1.8 mg/l cystine and 14.5 mg/l methionine.

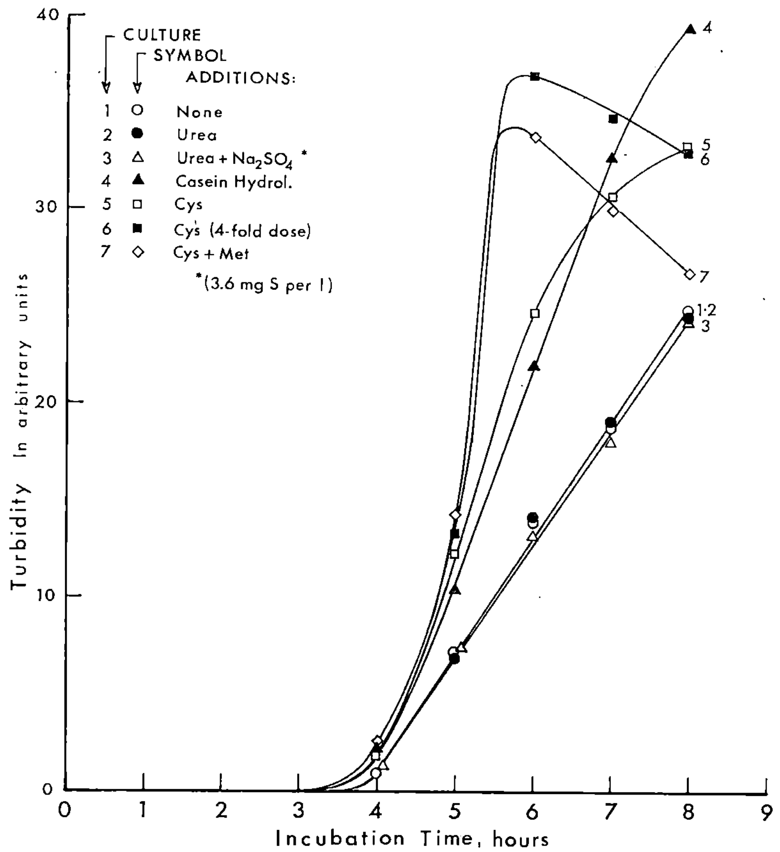

Fig. 6. The effect of urea, sodium sulphate, cystine and cystine + methionine on the growth rate of rumen bacteria. Each symbol represents the mean of three parallel cultures. The standard error of the means was insignificant as regards comparison of the results.

Kuva 6. Urean, natriumsulfaatin, cystiinin ja cystiinin + metioniinin vaikutus pötsibakteeriston kasvunopeuteen. Kukin symboli edustaa kolmen rinnakkaisviljelmän keskiarvoa. Keskiarvojen keskivirheet olivat tulosten vertailun kannalta merkityksettömät.

The results obtained differ from the earlier ones in that the cultures supplemented with urea alone grew exceptionally slowly. Furthermore, growth in the cultures given 2 mg/l cystine (Culture 3) was retarded early in the logarithmic phase, even though the dose was larger than the basal dose which produced a relatively better rate of growth (Figs. 5 and 6). Even in Culture 4, in which the supplement was 4 mg/l and the growth rate optimal until the middle of the logarithmic phase, growth decreased markedly before the stationary phase was reached. These facts, together with the distinct concentration effect of cystine, demonstrate that the rumen fluid used in this experiment contained an exceptionally small amount of cystine or nutrients producing a similar effect.

The above facts already point to the conclusion that the increase achieved in bacterial growth rate depended on the rise of nutrient concentration in the solution. A possible interpretation based on the redox potential does not seem plausible, since cystine was specifically used and not its reduced form cysteine. The retardation in growth rate in the midst of the optimal logarithmic phase also argues against such an interpretation. If the redox-potential had had an important effect on the results, this must have

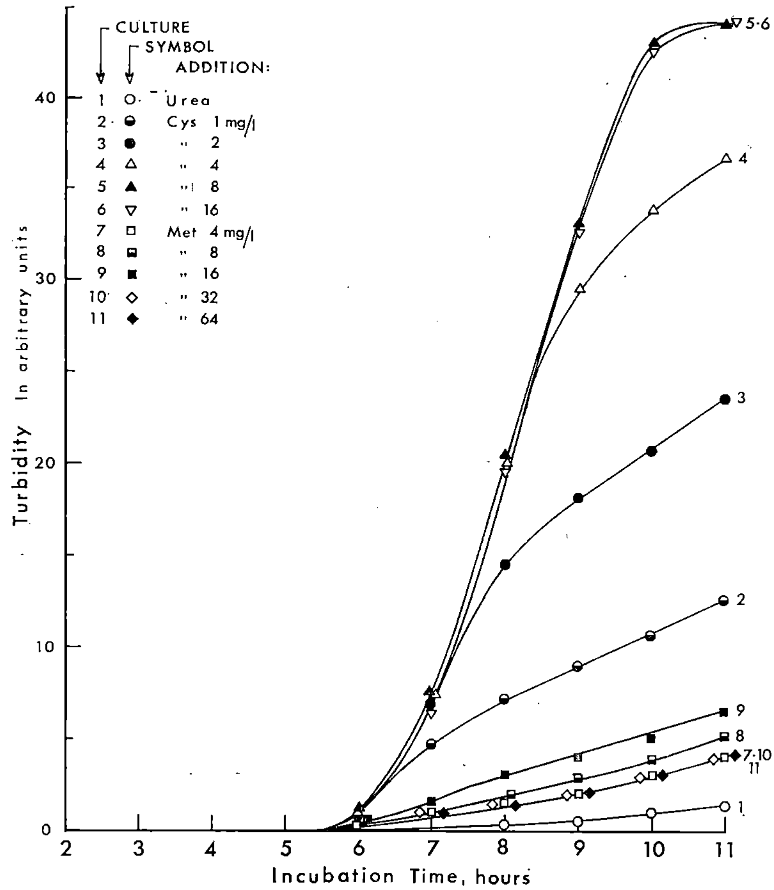

Fig. 7. The effect of different doses of cystine and methionine on the growth rate of rumen bacteria. Each symbol represents the mean of three parallel cultures. The standard error of the means was insignificant as regards comparison of the results.

Kuva 7. Cystiinin ja metioniinin vaikutus erisuurina annoksina pötsibakteeriston kasvunopeuteen. Kukin symboli edustaa kolmen rinnakkaisviljelmän keskiarvoa. Keskiarvojen keskivirheet olivat tulosten vertailun kannalta merkityksettömät.

appeared as a distinct shortening of the lag phase, which was not noticeable even in this experiment.

Comparison of the effects of the acids clearly shows that as a nutritional factor cystine is more important than methionine both totally and relatively. As little as 1 mg of cystine per litre of culture produced a clearly better growth than any dose of methionine. Nevertheless, it should be noted that methionine increased the growth rate both alone and in combination with cystine (Figs. 5 and 6).

In this experiment addition of 8 mg of cystine per litre of culture medium gave the best possible growth rate, although the rumen fluid obviously contained lesser amounts of growth-promoting factor(s) than usual. From the results presented in Figs. 5 and 6 it was seen that the four-fold dose of cystine (7.2 mg/l) alone gave a growth rate as rapid as the initial dose together with methionine. Thus the latter can be replaced with cystine. (On the contrary, it does not seem possible to do the opposite.) In Fig. 4 it was seen that cystine and methionine together had the same effect as the group of five acids (cys + gly + met + ser + thr). As it appears that the latter group had the same effect as all 18 amino acids together, it is obvious

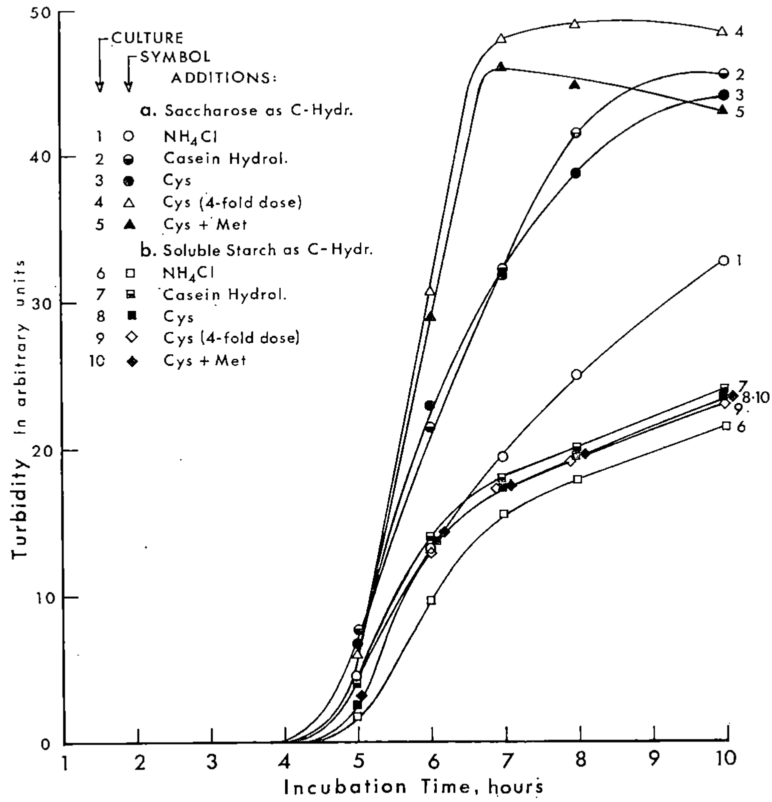

Fig. 8. The influence of source of energy on the growth-promoting effect produced by amino acids on rumen bacteria. Each symbol represents the mean of three parallel cultures. The standard error of the means was insignificant as regards comparison of the results.

Kuva 8. Energianlähteen merkitys pötsibakteeriston kasvua stimuloivien aminohappojen vaikutuksen ilmenemisessä. Kukin symboli edustaa kolmen rinnakkaisviljelmän keskiarvoa. Keskiarvojen keskivirheet olivat tulosten vertailun kannalta merkityksettömät.

that the same result can be obtained by merely adding 7.2—8 mg/l of cystine to the cultures.

Experiment 5: The role of carbohydrate

The sugar in the diet of the experimental animals was sucrose, which was therefore used as the source of energy in the experiments reported above. The largest carbohydrate fraction in the diet, however, was starch (approx. 57 % of the total). Because of this, it was decided to study the effect of the amino acids in stimulating bacteria with starch as sole source of energy. Owing to the method of investigation, only soluble starch was suitable. The starch dose was the same as sucrose (5 g/l), which was also the energy source in the cultures used for comparison in this experiment.

The results (Fig. 8) clearly show that the effect of cystine and methionine as well as that of caseine hydrolysate was very small when starch was the source of energy. This small growth acceleration appeared in the beginning of growth when the nutrient solution — judging from the shape of the growth curves — obviously contained small amounts of sugar from the rumen fluid.

In the control cultures containing sucrose, on the other hand, the effect was almost the same as in the earlier cultures similarly supplemented. Even the addition of ammonium nitrogen alone (which furthermore had earlier been proved to be unnecessary) gave a better growth in these comparative cultures than any kind of organic nitrogen when starch was the carbohydrate. This shows that in the latter case it was the difficulty of obtaining energy that primarily limited the rate of growth. The presence of casein hydrolysate also eliminates the possibility that one or more of its amino acids besides cystine and methionine could have accelerated the growth rate when starch was the sole energy source.

Lampila (1966) made an *in vitro* study of the significance of carbohydrate concentration in the protein synthesis of rumen microbes, using as a measure the changes in the concentration of ammonia in the culture. Glucose and maize starch were used as carbohydrates. In these experiments it was found that even the smallest dose of glucose added (1 %, w/v) produced maximal net synthesis. To attain the same result with starch, it had to be added in three-fold amounts — calculated in glucose units. In the optimal case, the two carbohydrates produced an approximately equally rapid decrease in ammonia concentration.

Such a concentration effect of carbohydrates is primarily to be attributed to the fact that the surface area of granular starch exposed to bacterial enzymes is relatively small compared with its mass. The favourable effect of increasing the mass may thus appear at a comparatively high concentration level. Since the starch used in this experiment was water-soluble, the result can hardly be attributed to its low concentration. Thus the only satisfactory explanation for the results obtained here is that the hydrolysis of starch to sugar occurred at a slower rate than the bacterial synthesis of amino acids.

General considerations

In pure cultures of rumen bacteria, cysteine is commonly used to lower the redox potential of the growth medium, but the role of this substance, or of its oxidized form cystine, in nutrition has probably not yet been demonstrated. Neither is it known how many and which of the already identified bacterial strains respond to this amino acid or whether the phenomenon depends on an absolute need or a stimulating effect only. Tests perfomed with mixed cultures do not, of course, answer the latter question either, because some organism or organisms might produce cystine for those strains for which this amino acid is essential, in which case the effect of a supplement would appear to be only stimulating. Future detailed research on the amino acid requirements of rumen bacteria will probably make it possible to examine more closely the factors which affected the results obtained here.

From the viewpoint of the main object of this investigation, namely milk production based on urea nitrogen, the results are interesting firstly because adding amino acids did not seem to be of significance when starch was the source of energy. Secondly, from the standpoint of practical application, the results are noteworthy because a single amino acid — and this even in an extraordinarily small dose — apparently had the same effect as a mixture of 18 acids simulating the composition of casein.

The effect of adding cystine to a purified diet containing only urea and ammonium nitrogen was also tested with one experimental cow. In this trial the cow ate its food pellets slowly over a long period of time. When cystine in aqueous solution was poured over the pellets, the cow consumed the whole portion immediately. When, however, this cystine supplementation was continued, the expected effect on feed intake and milk production failed to appear, and consequently the treatment was discontinued as being incompatible with the general principles of the study. On the basis of later observations, however, it appears that the scarcity of nitrogen (= urea) at that time was the minimum factor in the nutrition of the animal. Thus, the significance of the cystine supplement apparently was not conclusively settled.

Summary

In the present investigation, a study was made on the effect of some nutritional factors, chiefly the 18 amino acids included in a mixture simulating the composition of casein, on the growth rate of rumen bacteria in culture. The mixed bacterial population was taken from a cow which was fed on a purified diet and was entirely dependent on urea and ammonium nitrogen. The bacteria were cultured in rumen fluid from a cow on the same diet and was supplemented with the substances tested in order to study their effect on the growth rate of the bacterial population during the logarithmic phase of growth. Sodium bicarbonate was always added to the rumen fluid as buffer, sucrose as source of energy and urea or ammonium chloride as nitrogen supply. The main results were as follows:

Auxin, orotic and folic acids added in conjunction with aspartic and glutamic acids and their amides slightly increased the growth rate of the bacteria.

The positive effect of yeast and casein hydrolysates on bacterial growth was very clear and pronounced. They had approximately the same effect. When the dosage of casein hydrolysate was raised, the growth rate gradually increased within the dosage range of 0—128 mg N/l culture. A mixture of 18 amino acids simulating the composition of casein hydrolysate had a relatively better growth-promoting effect than casein hydrolysate.

When the 18 amino acids in the mixture were divided into groups of essential (10) and non-essential (8) acids, the two groups had approximately the same effect, which was distinctly smaller, however, than all together. With a different grouping, the total positive effect of all 18 acids occurred in one group of only 5 acids, while the other groups were practically inactive. In this group of five acids, cystine alone and supplemented with methionine possessed the effect of the whole group. Methionine alone had only a weak stimulatory influence. In order to achieve the total effect, cystine alone had to be added in amounts of 7.2—8 mg per litre of culture.

When the source of energy in the cultures was soluble starch instead of sucrose, the bacterial growth in the logarithmic phase was distinctly slower, and the amino acids had no certain observable effect on the growth rate.

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REFERENCES

Bentley, O. G., Johnson, R. R., Vanecko, S. & Hunt, C. H. 1954. Studies on factors needed by rumen micro-organisms for cellulose digestion *in vitro*. J. Animal Sci. 13: 581—593.

Bryant, M. P. & Doetsch, R. A. 1955. Factors necessary for the growth of *Bacteroides succinogenes* in the volatile acid fraction of rumen fluid. J. Dairy Sci. 38: 340—350.

— & Robinson, I. M. 1962. Some nutritional characteristics of predominant culturable ruminal bacteria. J. Bact. 84: 605—614.

Bryant, M. P. & Robinson, I. M. 1963. Apparent incorporation of amino acid carbon during growth of selected species of ruminal bacteria. J. Dairy Sci. 46: 150—154.

Lampila, M. 1966. Valkuaisen korvaaminen urealla märehtijän ruokinnassa. Karjatalous 42: 114—119.

Müller, R. & Krampitz, G. 1955. Die Stimulierung der Pansen-Mikroorganismen durch β-Indolylessigsäure (Heteroauxin). Naturwiss. 42: 648—649.

Nurmikko, V. 1954. Symbiosis experiments concerning the production and biosynthesis of certain amino acids and vitamins in associations of lactic acid bacteria. Ann. Acad. Sci. Fenn. A II. Chemica 54.

Oginsky, E. L. & Umbreit, W. W. 1959. An introduction to bacterial physiology. 2nd Ed. San Francisco.

Virtanen, A. I. 1964. Om produktion av komjölk utan protein med urea- och ammoniumkväve som kvävekälla och renade kolhydrater som energikälla. Nord. Jordbr.forskn., Suppl. 8: 29—42.

Virtanen, A. I. 1966. Milk production of cows on protein-free feed. Studies of the use of urea and ammonium salts as the sole nitrogen source open new important perspectives. Science 153: 1603—1614.

— & Lampila, M. 1962. Production of cow's milk on purified nutrients without proteins. Suomen Kemistilehti B 35: 244.

SELOSTUS

Ravitsemuksellisia tekijöitä, jotka edistävät puhtaalla dieetillä ja ilman valkuaista ruokitun lehmän pötsibakteeriston kasvua viljelmissä

Martti Lampila

Maatalouden tutkimuskeskus, Kotieläinhoidon tutkimuslaitos, Tikkurila

Työssä on selvitelty eräiden ravitsemuksellisten tekijäin, lähinnä kaseiinin koostumusta jäljittelevään 18 aminohapon seokseen sisältyvien happojen vaikutusta pötsibakteeriston kasvunopeuteen viljelmissä. Sekaviljelmänä käytetty bakteeristo otettiin lehmältä, jota ruokittiin puhtaalla dieetillä ja käytännöllisesti katsoen yksinomaan urea- ja ammoniumtypen varassa. Viljely tapahtui samaa dieettiä edustavassa pötsinesteessä, jota täydennettiin tutkituilla aineilla tarkoituksena selvittää niiden vaikutusta bakteeriston kasvunopeuteen logaritmisessa kasvuvaiheessa. Pötsinesteeseen oli aina lisätty natriumbikarbonaattia puskuriksi, sakkaroosia energian sekä ureaa tai ammoniumsuolaa typen lähteeksi. Työssä saatiin seuraavat tulokset:

Auksiini, orotiini- ja foolihappo annostettuina yhdessä asparagiini- ja glutamiinihapon sekä niiden amidien kanssa nopeuttivat bakteeriston kasvua vähäisessä määrin.

Hiiva- ja kaseiinihydrolysaatin stimuloiva vaikutus bakteeriston kasvuun oli erittäin selvä ja voimakas. Kummankin vaikutusteho oli suunnilleen yhtä suuri. Kaseiinihydrolysaatin annosta suurennettaessa kohosi kasvunopeus asteittain annoksen mukana alueella 0—128 mg N/l viljelmää. Kaseiinin koostumusta jäljittelevällä 18 aminohapon seoksella oli suhteellisesti suurempi kasvua nopeuttava vaikutus kuin kaseiinihydrolysaatilla.

Kun 18 aminohapon seos jaettiin välttämättömien (10) ja ei-välttämättömien (8) happojen ryhmiin, havaittiin kummallakin suunnilleen samansuuruinen tehovaikutus, mikä oli kuitenkin selvästi pienempi kuin kaikilla yhdessä. Muulla tavoin ryhmiteltäessä saatiin kaikkien 18 hapon yhteinen stimuloiva vaikutus ilmenemään 5 hapon ryhmässä muiden jäädessä käytännöllisesti katsoen tehottomiksi. Viiden hapon ryhmässä kystiini yksinään ja yhdessä metioniinin kanssa omasi koko ryhmän vaikutustehon. Metioniini yksinään stimuloi kasvua verrattain heikosti. Täyden stimulointivaikutuksen aikaansaamiseksi oli kystiiniä yksinään lisättävä viljelmiin 7.2—8 mg/l.

Liukoisen tärkkelyksen ollessa sakkaroosin asemesta energianlähteenä viljelmissä oli bakteeriston kasvu logaritmisessa vaiheessa selvästi hitaampaa eikä aminohapoilla ollut varmuudella havaittavaa vaikutusta kasvunopeuteen.

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THE COMPOSITION OF THE THRIPS SPECIES IN CEREALS IN FINLAND

PEKKA KÖPPÄ
Agricultural Research Centre, Department of Pest Investigation, Tikkurila, Finland

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Thrips have long been known as pests in grain crops. Already in 1795 has been observed the damage causing by *Limothrips cerealium* in wheat (HALIDAY 1836, CURTIS 1883).

Thrips living on cereals began to attract special attention towards the close of the 19th century (BELING 1872, SZANISZLO 1879, LINDEMAN 1886, 1887, TRYBOM 1894, 1895). A new impetus to thrips research was provided in the first half of the 20th century and by the systematic classification of thrips made by UZEL (1895) and PRIESNER (1926—28) and by the studies of white heads on grass leys and cereals. Attempts were made to clarify the chief biological characteristics of the most important thrips species as well as their economic significance (HINDS 1900, SHARGA 1933, KÖRTING 1934, HUKKINEN 1936, von OETTINGEN 1942).

The damage that thrips cause to grass has been studied fairly extensively. Among the most valuable studies in this respect are those by REUTER (1900), KAUFMANN (1925), von OETTINGEN (1930, 1942) and HUKKINEN (1936), who all stress the importance of thrips in causing white heads.

There has been much less investigation of the thrips species on cereals and of the damage they cause. REUTER (1902) made an extensive summary of white heads on grain and the causes there of, primarily in Finnish conditions. Proper investigations based on samples and providing clarification of the species of thrips on cereals have been made by JOHANSSON (1938, 1946), BRUMMER (1939), KANERVO (1950), von OETTINGEN (1952), TANSKY (1961) and HOLTMANN (1963 a). The ecology of thrips has also been clarified, primarily by HOLTMANN (1963 b) and CEDERHOLM (1963).

The material and method of the study

This study is based chiefly on samples taken by sweeping net at the Department of Pest Investigation in Tikkurila (60°17′N, 25°04′E) in 1960—1965 and at Somero (60°40′N, 23°36′E) in 1961—1965. Samples of sprouts, ears and panicles of a specified size were gathered along with the sweeping-net samples at Tikkurila in 1960—61. The results of the sweeping-net samples taken by TIITTANEN (1954) from winter and spring wheat in 1950—51 were also available.

Test areas

Cultivated farm fields were generally employed as test areas. Only the netted samples from winter wheat for 1960—63 were taken from the additional plots of the test fields at Tikkurila.

At Tikkurila there was generally a test area for every species of cereal each year. There was, however, no test area for spring wheat in 1963 or for winter wheat in 1964—65. Samples were taken by net sweeping from three different blocks of oats in 1963—64.

At Somero series of sweeping-net samples from all species of cereals except winter wheat were taken in 1963—65, and from winter rye from 1961 on.

Samples

A sweeping net with a circular mouth of 33 cm diameter was employed in the taking of samples. The handle of the net was 75 cm in length. The samples were taken by proceeding at walking speed through the test area at least 5 metres from its borders. Samples were taken throughout the period of growth at intervals of 1—2 weeks during the period between 12 noon and 2 p.m., weather permitting. If the vegetation was wet the taking of samples was postponed to the next rainless day. No samples were taken during very windy weather. Every sampling consisted of 25 sweeps back and forth.

The samples of sprouts, ears and panicles were taken along with the sweeping-net samples in 1960—61. In 1960 the size of the samples was 25 plants, and in 1961 it was 50 plants.

The netted material taken from the various species of grain for species studies comprised 163 725 specimens of thrips altogether. The distribution of this material among the various species of cereals is following: winter rye 120 netted samples and 21 624 specimens of thrips, winter wheat 38 netted samples and 3 903 specimens of thrips, spring wheat 68 netted samples and 35 724 specimens of thrips, barley 76 netted samples and 33 122 specimens of thrips and oats 129 netted samples and 69 352 specimens of thrips. An additional 1 345 specimens of thrips were obtained from the samples of sprouts, ears and panicles.

Results

The species of thrips in the cereals

The following 29 species of thrips appeared in the samples taken from the cereals:

Limothrips denticornis Hal.
Anaphothrips obscurus Müll.
Frankliniella tenuicornis Uz.
Haplothrips aculeatus Fabr.
Chirothrips hamatus Tryb.
Chirothrips manicatus Hal.
Aptinothrips stylifer Tryb.
Aeolothrips albicinctus Hal.
Aeolothrips fasciatus Hal.
Belothrips acuminatus Hal.
Oxythrips brevistylis Tryb.
Oxythrips ajugae Uz.
Odontothrips uzeli Bagn.
Frankliniella intonsa Tryb.
Taeniothrips pini Uz.
Taeniothrips vulgatissimus Hal.
Taeniothrips atratus Hal.
Taeniothrips picipes Zett.
Thrips physapus L.
Thrips validus Uz.
Thrips hukkineni Pr.
Thrips major Uz.
Thrips nigropilosus Uz.
Thrips flavus Schr.
Thrips tabaci Lind.
Baliothrips dispar Hal.
Haplothrips niger Osb.
Haplothrips leucanthemi Schr.
Phloeothrips annulipes Reut.

Only the seven first of the above species might be included among the cereal pests proper. *L. denticornis*, *A. obscurus*, *F. tenuicornis* and *H. aculeatus* have been found to cause damage to cereals, and the next three species are known to live in and to be able to cause similar damage to cultivated and uncultivated grasses. The *Aeolothrips* species are predatory insects. Most of the other species got into the netted samples from plants other than grass plants that were growing in the field of grain.

The concept of dominant species is often employed in surveys of species. A species is understood to be a dominant one if its frequency comprises more than 5 % of the total number of individuals of the fauna in question (Palmgren 1930, Krogerus 1932, Brundin 1934, Tischler 1949). Some investigators do not approve this fixed limit because in their opinion there can only be one dominant species in general. It would seem that the manner of interpretation of KONTKANEN (1950) would be far superior in this respect; in this interpretation a species is dominant if the number of its individuals comprises 15.1—100.0 % of the total number of individuals in the whole fauna. In the present study dominance is interpreted according to the definition of KONTKANEN. Nevertheless, two or three dominant species of thrips may occur in some species of cereals.

The netted samples

Winter rye

F. tenuicornis and *L. denticornis* were dominant in the winter rye (Tables 1 and 2).

At both places these two species of thrips in combination averaged over 70.0 % of the total number of thrips. According to the investigations made by KANERVO (1950) this percentage was much greater still at Ylistaro in 1931. *L. denticornis* has also been mentioned as a dominant species of thrips in winter rye abroad (von OETTINGEN 1942, TANSKY 1961, HOLTMANN 1963 a), while *F. tenuicornis* is hardly mentioned as a species of thrips in winter rye. *A. obscurus* was found at Tikkurila in 1963 in quantities greater than normal, and *H. aculeatus* appeared in great quantities at the test area in Somero in 1961—62. In general, too, the quantity of *H. aculeatus* was greater each year at Somero than at Tikkurila. On the basis of samples of sprouts and ears that he took in 1937—38 BRUMMER (1939) had previously shown that the species occurs in great quantities in Finland. It is also mentioned as a dominant species in winter rye in Germany by von OETTINGEN (1942) and in the Soviet Union by TANSKY (1961). *C. manicatus* was observed every year at all the test areas, but the quantity never rose to a level of dominance. In the netted material there was even less *C. hamatus* and *A. stylifer* in the winter rye, and some years they were totally absent.

L. cerealium (HOLTMANN 1963 a) and *H. tritici* (TANSKY 1961), for example, are species of thrips in winter rye that occur in quantity abroad but are totally absent in Finland.

Winter wheat

The relative frequencies of the various species of thrips taken from the winter wheat are shown in Table 3.

F. tenuicornis occurred as a clearly dominant species of thrips in winter wheat. *A. obscurus* and *L. denticornis* were also found in abundance.

Table 1. The frequencies of various species of thrips in winter rye according to the netted samples taken at Tikkurila in 1960—1965

Taulukko 1. Ripsiäislajien esiintymisrunsaus syysrukiissa Tikkurilassa vuosina 1960—65 otettujen haavintanäytteiden perusteella

Year *Vuosi*	Number of samples *Näytteiden luku*	Sampling season *Näytteidenottokausi*	Number of thrips *Ripsiäismäärä kpl*	% of number of thrips *% ripsiäismäärästä*							
				L. denticornis	*A. obscurus*	*F. tenuicornis*	*H. aculeatus*	*C. hamatus*	*C. manicatus*	*A. stylifer*	Other species of thrips *Muut ripsiäislajit*
1960	11	15 June—23 Aug.	6 979	14.2	5.2	70.4	6.5	—	0.5	1.1	2.1
1961	14	16 May—19 Aug.	1 340	21.7	1.5	44.6	18.0	—	1.4	—	12.8
1962	17	15 May—30 Aug.	710	32.2	1.1	34.8	9.9	—	3.3	—	18.7
1963	14	14 May—15 Aug.	815	58.6	18.4	6.4	1.4	3.8	3.8	1.8	5.8
1964	12	29 May—26 Aug.	1 234	15.7	8.0	65.5	0.1	< 0.1	1.1	< 0.1	9.6
1965	12	6 May—25 Aug.	1 984	13.6	7.1	68.5	0.2	0.2	0.9	3.5	6.0
Total *Yhteensä*	80		13 062	27.2	6.7	46.1	6.4	0.7	2.0	1.0	9.9

Table 2. The frequencies of various species of thrips in winter rye according to the netted samples taken at Somero in 1961—1965

Taulukko 2. Ripsiäislajien esiintymisrunsaus syysrukiissa Somerolla vuosina 1961—65 otettujen haavintanäytteiden perusteella

Year *Vuosi*	Number of samples *Näytteiden luku*	Sampling season *Näytteiden-ottokausi*	Number of thrips *Ripsiäismäärä kpl*	% of number of thrips *% ripsiäismäärästä*							
				L. denticornis	*A. obscurus*	*F. tenuicornis*	*H. aculeatus*	*C. hamatus*	*C. manicatus*	*A. stylifer*	Other species of thrips *Muut ripsiäislajit*
1961	6	22 May— 1 Aug.	1 208	12.4	1.8	36.0	43.3	0.1	1.5	—	4.9
1962	6	19 May—16 Sept.	289	15.5	0.7	26.0	55.9	—	1.1	—	0.8
1963	9	19 May—28 July	658	56.3	6.6	24.6	9.0	—	1.3	—	2.2
1964	8	29 May— 9 Aug.	3 384	13.8	7.0	73.0	0.5	0.3	0.8	< 0.1	4.6
1965	11	29 May—28 Aug.	3 023	36.6	5.0	47.6	2.4	< 0.1	0.4	2.3	5.7
Total *Yhteensä*	40		8 562	30.5	4.7	42.5	17.7	0.1	0.9	0.7	2.9

Corresponding values for the relative frequencies of *F. tenuicornis* and *L. denticornis* in winter wheat have been previously ascertained in Finland (Kanervo 1950). *A. obscurus* also occurred in abundance in winter wheat during the present period of study. It occurred in abundance, i.e. comprising nearly 70.0 % of the total number of thrips in 1963. It is evident that in the said year thrips of this species had entered the winter wheat from nearby grassland in which the development of the first generation of the species was a very vigorous one. It is also possible that some of the specimens of *F. tenuicornis* had chanced to enter the spring cereals in the same year before the taking of sweeping-net samples had begun. The amounts of this species were consequently smaller than expected in the winter wheat. *H. aculeatus* was found in winter wheat every year but it fell far behind the preceding three species in quantity. It appears, however, that *H. aculeatus* may occur some years in winter wheat in very great abundance. This is shown, for instance, by the netted samples taken at Tikkurila in 1950—51 by Tiittanen (1954) (Table 4); although her material was small in quantity it was nevertheless taken during the entire period of growth. *C. manicatus* appeared in surprising quantity in the winter wheat, especially in 1962 (Table 3), but *C. hamatus* and *A. stylifer* occurred only occasionally. In the

Table 3. The frequencies of various species of thrips in winter wheat according to the netted samples taken at Tikkurila in 1960—1963

Taulukko 3. Ripsiäislajien esiintymisrunsaus syysvehnässä Tikkurilassa vuosina 1960—63 otettujen haavintanäytteiden perusteella

Year *Vuosi*	Number of samples *Näytteiden luku*	Sampling season *Näytteiden-ottokausi*	Number of thrips *Ripsiäismäärä kpl*	% of number of thrips *% ripsiäismäärästä*							
				L. denticornis	*A. obscurus*	*F. tenuicornis*	*H. aculeatus*	*C. hamatus*	*C. manicatus*	*A. stylifer*	Other species of thrips *Muut ripsiäislajit*
1960	11	17 June— 8 Sept.	2 000	10.8	6.5	73.3	2.9	—	1.1	0.1	5.3
1961	10	16 May — 4 Aug.	435	16.5	6.4	43.6	7.7	0.5	4.6	—	20.7
1962	11	28 May —20 Aug.	497	19.5	9.4	29.8	16.1	0.5	17.4	—	7.3
1963	6	14 June— 1 Aug.	971	8.4	68.6	19.4	< 0.1	—	1.6	—	2.0
Total *Yhteensä*	38		3 903	14.0	17.0	43.2	7.3	0.3	6.7	< 0.1	11.5

Table 4. The frequencies of various species of thrips in winter wheat according to the netted samples taken at Tikkurila in 1950—1951. Sample size 5 net sweepings

Taulukko 4. Ripsiäislajien esiintymisrunsaus syysvehnässä Tikkurilassa vuosina 1950—51 otettujen haavintanäytteiden perusteella. Näytteen suuruus 5 haavinvetoa

Year *Vuosi*	Number of samples *Näytteiden luku*	Sampling season *Näytteidenottokausi*	Number of thrips *Ripsiäismäärä kpl*	% of number of thrips *% ripsiäismäärästä*				
				L. denticornis	*A. obscurus*	*F. tenuicornis*	*H. aculeatus*	Other species of thrips *Muut ripsiäislajit*
1950	13	17 May—8 Aug.	228	15.9	10.8	23.2	41.1	9.0
1951	14	15 May—7 Aug.	225	30.3	5.4	9.4	39.3	15.6
Total *Yhteensä*	27		453	23.4	8.0	16.0	40.2	12.4

netted samples taken from winter wheat a few specimens of *Taeniothrips vulgatissimus* were found together with some other species of thrips. One of the specimens belonged to the variation *adusta*, which had not been encountered previously in Finland. HUKKINEN (1942) states that he found only the variation *atricornis* in addition to the ordinary variation of the species. TIITTANEN (1954) found *Thrips angusticeps* — 1.9 % in 1950 and 6.5 % in 1951 based on the total number of the specimens — in winter wheat. This species, which was totally absent from the material netted from winter wheat in 1960—63, probably came originally from flax that was growing in 1949 in the immediate vicinity of the plot of winter wheat. In Germany *F. tenuicornis* is totally absent and *A. obscurus* almost totally absent from winter-wheat thrips, while *L. denticornis* is clearly a dominant species among them (von OETTINGEN 1952, HOLTMANN 1963 a). *L. cerealium* or *H. tritici* is even more abundant than *L. denticornis* in winter wheat in Germany. In contrast, the frequency of occurrence of *H. aculeatus* and *C. manicatus* is about the same in Germany as in Finland. Although *F. tenuicornis* is one of the species of thrips in winter wheat in the Soviet Union it is clearly less frequent than the above mentioned *Haplothrips* species and *C. manicatus* and *L. denticornis*.

Table 5. The frequencies of various species of thrips in spring wheat according to the netted samples taken at Tikkurila in 1960—1962 and 1964—1965

Taulukko 5. Ripsiäislajien esiintymisrunsaus kevätvehnässä Tikkurilassa vuosina 1960—62 ja 1964—65 otettujen haavintanäytteiden perusteella

Year *Vuosi*	Number of samples *Näytteiden luku*	Sampling season *Näytteidenottokausi*	Number of thrips *Ripsiäismäärä kpl*	% of number of thrips *% ripsiäismäärästä*						
				L. denticornis	*A. obscurus*	*F. tenuicornis*	*H. aculeatus*	*C. manicatus*	*A. stylifer*	Other species of thrips *Muut ripsiäislajit*
1960	11	17 June— 1 Sept.	6 680	2.8	17.2	73.2	0.1	0.4	1.8	4.5
1961	11	20 June— 5 Sept.	205	6.8	5.6	58.2	2.5	3.1	—	23.8
1962	8	22 June—31 Aug.	206	15.0	3.4	30.5	14.7	12.8	—	23.6
1964	15	26 June— 2 Sept.	20 349	0.4	9.6	75.8	0.1	0.4	< 0.1	13.7
1965	9	30 June—14 Sept.	4 368	0.9	4.0	91.8	0.6	0.5	—	2.2
Total *Yhteensä*	54		31 808	4.4	8.5	67.7	2.8	2.8	0.4	13.4

Table 6. The frequencies of various species of thrips in spring wheat according to the netted samples taken at Somero in 1964—1965

Taulukko 6. Ripsiäislajien esiintymisrunsaus kevätvehnässä Somerolla vuosina 1964—65 otettujen haavintanäytteiden perusteella

Year *Vuosi*	Number of samples *Näytteiden luku*	Sampling season *Näytteidenottokausi*	Number of thrips *Ripsiäismäärä kpl*	% of number of thrips *% ripsiäismäärästä*						
				L. denticornis	*A. obscurus*	*F. tenuicornis*	*H. aculeatus*	*C. manicatus*	*A. stylifer*	Other species of thrips *Muut ripsiäislajit*
1964	6	15 July—29 Aug.	2 304	0.6	2.8	90.4	0.1	1.0	—	5.1
1965	8	26 June—28 Aug.	1 612	5.6	9.1	75.1	0.2	0.6	< 0.1	9.4
Total *Yhteensä*	14		3 916	3.4	6.4	81.7	0.1	0.8	< 0.1	7.6

Spring wheat

The frequency of the various species of thrips netted from the spring wheat in different years and at different test areas appears in Tables 5 and 6.

F. tenuicornis was much more abundant than the other species in the spring wheat. It averaged 67.7 % of the total number of thrips at Tikkurila in 1960—62 and 1964—65 and 81.7 % at Somero in 1964—65. *A. obscurus* also occurred in fairly great abundance in spring wheat. No samples were taken from spring wheat in 1963, when *A. obscurus* occurred in abundance in other spring cereals (Tables 8, 9, 10 and 11). If samples had been taken at that time the percentage of this species would have been a lot greater. *L. denticornis* appeared in a far smaller quantity in spring wheat than in winter cereals. Still less *H. aculeatus* was found although, according to Tiittanen (1954), it came second in order of frequency to *F. tenuicornis* in spring wheat in 1950—51 and was also a clearly dominant species (Table 7).

C. manicatus occurred in some amount in spring wheat at every test area, and was on average about as frequent as *H. aculeatus*. *C. hamatus* and *A. stylifer* were, in contrast, found only rarely in the netted samples taken from spring wheat.

Tiittanen (1954) found plenty of *Thrips angusticeps* in spring wheat in 1950—51, but it was totally absent in the present period of study. The species amounted to 14.4 % of the total number of thrips in 1950 and to 12.4 % in 1951. The species apparently originated in the flax that was the crop in 1949 previous to the spring wheat. The species may, however, live in cereals

Table 7. The frequencies of various species of thrips in spring wheat according to the netted samples taken at Tikkurila in 1950—1951. Sample size 5 net sweepings

Taulukko 7. Ripsiäislajien esiintymisrunsaus kevätvehnässä Tikkurilassa vuosina 1950—51 otettujen haavintanäytteiden perusteella. Näytteen suuruus 5 haavinvetoa

Year *Vuosi*	Number of samples *Näytteiden luku*	Sampling season *Näytteidenottokausi*	Number of thrips *Ripsiäismäärä kpl*	% of number of thrips *% ripsiäismäärästä*				
				L. denticornis	*A. obscurus*	*F. tenuicornis*	*H. aculeatus*	Other species of thrips *Muut ripsiäislajit*
1950	13	14 June—15 Sept.	408	1.9	3.4	55.3	22.2	17.2
1951	12	19 June— 4 Sept.	455	2.0	2.0	60.9	16.1	19.0
Total *Yhteensä*	25		863	2.0	2.7	58.0	19.3	18.0

Table 8. The frequencies of various species of thrips in barley according to the netted samples taken at Tikkurila in 1960—1965

Taulukko 8. Ripsiäislajien esiintymisrunsaus ohrassa Tikkurilassa vuosina 1960—65 otettujen haavintanäytteiden perusteella

Year *Vuosi*	Number of samples *Näytteiden luku*	Sampling season *Näytteidenottokausi*	Number of thrips *Ripsiäismäärä kpl*	% of number of thrips *% ripsiäismäärästä*						
				L. denticornis	*A. obscurus*	*F. tenuicornis*	*H. aculeatus*	*C. manicatus*	*A. stylifer*	Other species of thrips *Muut ripsiäislajit*
1960	10	18 June—23 Aug.	18 221	12.9	10.8	70.6	4.0	0.3	0.1	1.3
1961	10	14 June—29 Aug.	572	35.6	3.9	43.7	0.4	3.3	1.2	11.9
1962	10	22 June—31 Aug.	328	46.9	1.1	26.1	5.1	9.8	0.5	10.5
1963	6	1 July—15 Aug.	951	10.2	27.1	59.2	0.3	2.1	—	1.1
1964	8	3 July—22 Aug.	4 500	5.4	15.3	75.4	< 0.1	0.7	0.3	2.9
1965	8	5 July—14 Sept.	2 162	32.8	4.9	50.7	—	1.4	—	10.2
Total *Yhteensä*	52		26 734	25.4	9.3	53.3	1.8	3.1	0.4	6.7

and may cause damage to them (FRANSSEN and MANTEL 1965). *Taeniothrips atratus* occurred in great abundance in the netted samples taken from spring wheat in 1964, the main reason probably being that many plants on which the species thrives were growing as weeds on the second plot of spring wheat at Tikkurila.

When the species of thrips in winter wheat are compared with those in spring wheat a clear difference is discernible both in the order of frequency of the species and in their relative amounts (Tables 3, 5 and 6). It appears in some cases that the thrips fauna in winter wheat has not been distinctly differentiated from that in spring wheat. This applies, for instance, to JOHANSSON (1938), whose extensive studies can for this reason not be clearly interpreted.

Barley

The distribution of the material netted from the barley among the various species is shown in Tables 8 and 9).

F. tenuicornis is a clearly dominant species in the barley. *L. denticornis* also occurred as a dominant species at the test areas at Tikkurila but was much less frequent at Somero. In combination these species averaged above 75.0 % of the total number of thrips both at Tikkurila and at Somero. According to the studies of KANERVO (1950) their combined percentage was as high

Table 9. The frequencies of various species of thrips in barley according to the netted samples taken at Somero in 1963—1965

Taulukko 9. Ripsiäislajien esiintymisrunsaus ohrassa Somerolla vuosina 1963—65 otettujen haavintanäytteiden perusteella

Year *Vuosi*	Number of samples *Näytteiden luku*	Sampling season *Näytteidenottokausi*	Number of thrips *Ripsiäismäärä kpl*	% of number of thrips *% ripsiäismäärästä*						
				L. denticornis	*A. obscurus*	*F. tenuicornis*	*H. aculeatus*	*C. manicatus*	*A. stylifer*	Other species of thrips *Muut ripsiäislajit*
1963	6	21 June—25 Aug.	691	8.7	39.9	47.9	—	1.0	0.2	2.3
1964	10	18 July—29 Aug.	2 997	6.9	9.8	70.7	0.1	0.6	0.2	11.7
1965	8	26 June—28 Aug.	2 700	9.6	3.9	77.9	0.1	0.6	0.2	7.7
Total *Yhteensä*	24		6 388	8.3	15.4	67.4	0.1	0.7	0.2	7.9

Table 10. The frequencies of various species of thrips in oats according to the netted samples taken at Tikkurila in 1960—1965

Taulukko 10. Ripsiäislajien esiintymisrunsaus kaurassa Tikkurilassa vuosina 1960—65 otettujen haavintanäytteiden perusteella

Year *Vuosi*	Number of samples *Näytteiden luku*	Sampling season *Näytteidenottokausi*	Number of thrips *Ripsiäismäärä kpl*	% of number of thrips *% ripsiäismäärästä*						
				L. denticornis	*A. obscurus*	*F. tenuicornis*	*H. aculeatus*	*C. manicatus*	*A. stylifer*	Other species of thrips *Muut ripsiäislajit*
1960	12	18 June— 8 Aug.	8 040	1.5	18.2	78.6	0.7	0.2	< 0.1	0.8
1961	12	20 June— 5 Sept.	537	3.4	10.4	78.6	3.5	1.1	—	3.0
1962	12	23 June— 6 Oct.	314	10.2	13.1	39.1	6.7	10.0	—	20.9
1963	25	28 June—16 Aug.	8 273	2.8	49.0	44.4	0.1	1.9	—	1.8
1964	25	26 June— 2 Sept.	40 970	0.3	21.1	70.5	< 0.1	0.3	< 0.1	7.8
1965	10	30 June—24 Sept.	2 030	0.3	8.2	82.6	0.1	0.8	0.1	7.9
Total *Yhteensä*	96		60 164	2.8	24.5	61.6	1.3	1.8	< 0.1	8.0

as 97.0 at Ylistaro in 1931. *L. denticornis* has been found to be a dominant species in barley abroad, too (Johansson 1946, von Oettingen 1952, Tansky 1961, Holtmann 1963 a). The abundance of this species is apparently, or at least to some extent, dependent on nearby crops — especially of winter rye — in which the first generation of the species largely develops and from which a transfer to the barley can take place. The specimens of the new generation may also transfer from foxtail to spring cereals, chiefly to barley. In 1962, when the species occurred in abundance in barley, the barley was growing in the immediate vicinity of winter rye. In addition to the above species there is also a fair abundance of *A. obscurus*, but its abundance shows considerable variation in different years. Its amount was at its greatest in 1963 at both Tikkurila and Somero. In that year the species developed very vigorously in leys from which specimens of the new generation transferred to the spring cereals in great numbers. In contrast, *A. obscurus* occurred very infrequently in 1962, at least in Tikkurila (Table 8). *H. aculeatus* occurred in quantities worth mention in only a couple of years. Its proportion among thrips in barley abroad appears to be considerably greater (Holtmann 1963 a). *C. manicatus* was found in barley at every test area, but on average in only slightly greater numbers than *H. aculeatus*. The netted samples included only a very small amount of *A. stylifer*.

Table 11. The frequencies of various species of thrips in oats according to the netted samples taken at Somero in 1963—1965

Taulukko 11. Ripsiäislajien esiintymisrunsaus kaurassa Somerolla vuosina 1963—65 otettujen haavintanäytteiden perusteella

Year *Vuosi*	Number of samples *Näytteiden luku*	Sampling season *Näytteidenottokausi*	Number of thrips *Ripsiäismäärä kpl*	% of number of thrips *% ripsiäismäärästä*						
				L. denticornis	*A. obscurus*	*F. tenuicornis*	*H. aculeatus*	*C. manicatus*	*A. stylifer*	Other species of thrips *Muut ripsiäislajit*
1963	11	16 June—25 Aug.	1 939	2.1	61.6	32.8	0.1	0.4	0.3	2.7
1964	12	18 July—29 Aug.	6 161	0.2	9.4	76.1	0.1	0.3	0.1	13.8
1965	10	26 June— 2 Oct.	1 088	1.2	8.1	81.5	—	0.6	0.6	8.0
Total *Yhteensä*	33		9 188	1.2	26.4	63.3	0.1	0.4	0.3	8.3

Oats

The relative frequencies of the various species of thrips taken from the oats are shown in Tables 10 and 11.

F. tenuicornis and *A. obscurus* were fairly distinctly dominant in the oats. Their combined amount was on average more than 85.0 % of the total number of thrips both at Tikkurila and at Somero. According to the studies of KANERVO (1950) *F. tenuicornis* amounted alone to about 94.0 % of the total number of thrips in oats in 1931. As with the barley, a clear peak is discernible in 1963 in the frequency of *A. obscurus*. This can clearly be seen in the netted samples of both Tikkurila and Somero. *L. denticornis* did not seem particularly to prefer oats. It appeared considerably less frequently on the oats than on the other cereals. There were even less *C. manicatus*, *H. aculeatus* and *A. stylifer* on the oats, and they occurred in that order of frequency.

In Germany only a small part of the thrips fauna is made up of *F. tenuicornis* and *A. obscurus* — altogether only 0.2 % (HOLTMANN 1963 a). The reigning species there is *L. cerealium*. *L. denticornis* and *H. aculeatus* seem to be somewhat more frequent in oats in Germany than in Finland, the proportion of these species being as great as 40.0 % of the total number of thrips according to von OETTINGEN (1952). TANSKY (1961) states that *C. manicatus* occurs as the most abundant species of thrips in oats in the Soviet Union.

Samples were taken by sweeping net from three different blocks of oats at Tikkurila in 1963—64. These various test areas differed from one another primarily in respect of soil and location.

The results of the netted samples indicate clearly that there were no differences worth mentioning between the thrips fauna of the various test areas (Table 12). In contrast, the differences between the different years are quite clear ones. It emerges quite distinctly from the Table that in 1963 there was a great abundance of *A. obscurus;* although there was slightly less

Table 12. The frequencies of various species of thrips in oats growing on different soils according to the netted samples taken at Tikkurila in 1963—1964. Variation Pendek

Taulukko 12. Ripsiäislajien esiintymisrunsaus eri maalajeilla kasvavassa kaurassa Tikkurilassa vuosina 1963—64 otettujen haavintanäytteiden perusteella. Lajike Pendek

Year and soil *Vuosi ja maalaji*	Number of samples *Näytteiden luku*	Sampling season *Näytteidenottokausi*	Number of thrips *Ripsiäismäärä kpl*	% of number of thrips *% ripsiäismäärästä*						
				L. denticornis	*A. obscurus*	*F. tenuicornis*	*H. aculeatus*	*C. manicatus*	*A. stylifer*	Other species of thrips *Muut ripsiäislajit*
1963										
finesand — *hieta* .	8	28 June—16 Aug.	3 861	2.2	49.3	45.0	0.2	1.2	—	2.1
sandy clay — *hietasavi*	8	28 June—16 Aug.	2 603	2.9	44.3	46.9	<0.1	3.1	—	2.8
sandy clay containing humus — *mullasp. hietasavi* .	8	28 June—16 Aug.	1 618	2.2	55.5	40.3	0.1	1.4	—	0.5
Total *Yhteensä*	24		8 082	2.4	49.4	44.3	0.1	1.9	—	1.9
1964										
finesand — *hieta* .	8	26 June—18 Aug.	14 614	0.5	17.4	71.0	<0.1	0.4	>0.1	10.7
sandy clay — *hietasavi*	8	26 June—18 Aug.	6 210	0.4	23.8	68.3	<0.1	0.4	—	7.1
sandy clay containing humus — *mullasp. hietasavi* .	8	26 June—18 Aug.	19 807	0.2	23.8	69.7	—	0.2	>0.1	6.1
Total *Yhteensä*	24		40 631	0.3	21.7	69.6	<0.1	0.3	>0.1	8.1

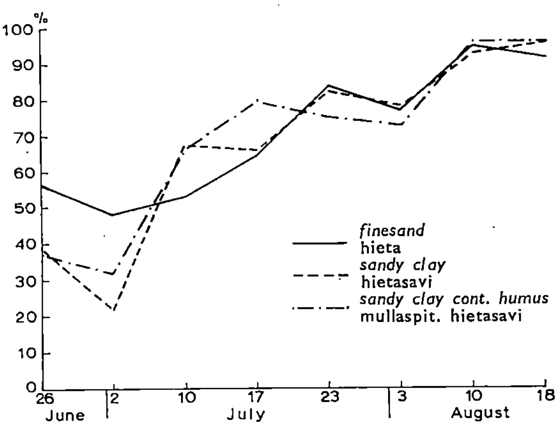

Fig. 1. The percentage of *F. tenuicornis* of the total number of thrips in oats growing on different soils according to netted samples taken in 1964.

Kuva 1. Kauraripsiäisen (F. tenuicornis) prosenttinen määrä ripsiäisten kokonaismäärästä eri maalajeilla kasvavassa kaurassa v. 1964 otettujen haavintanäytteiden perusteella.

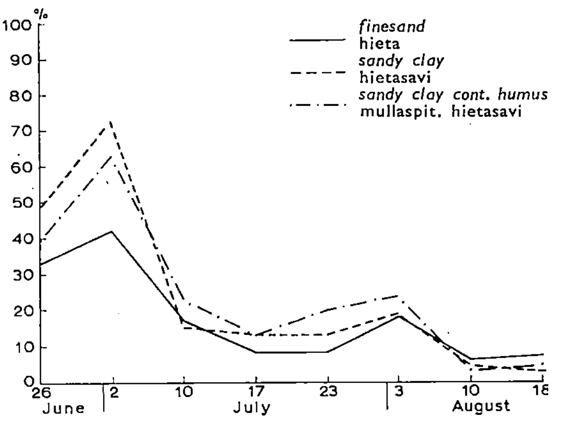

Fig. 2. The percentage of *A. obscurus* of the total number of thrips in oats growing on different soils according to netted samples taken in 1964.

Kuva 2. Ruohoripsiäisen (A. obscurus) prosenttinen määrä ripsiäisten kokonaismäärästä eri maalajeilla kasvavassa kaurassa v. 1964 otettujen haavintanäytteiden perusteella.

of this species on the sandy loam block than *F. tenuicornis*, but there was correspondingly more of the species on the other blocks. The very similar results presented by the various test areas do not support the opinion put forward by von Oettingen (1942) according to which the composition of thrips fauna in pure grass biotopes depends little on the species of grass but instead very distinctly upon the soil. von Oettingen found particularly distinct differences especially in the relationships to various soil conditions of *F. tenuicornis* and *A. obscurus*, species so commonly occurring in Finland.

The results of all the netted samples taken from each test area in the seasons 1963—64 have been calculated in Table 12. The relative frequencies of the various species, however, varied considerably in the same area over the period of growth. The variation in the relative frequency between *F. tenuicornis* and *A. obscurus* in the summer of 1964 can best be seen from Figs. 1 and 2. In the early summer *A. obscurus* was

Table 13. The frequencies of various species of thrips in cereals according to samples of sprouts, ears and panicles taken at Tikkurila in 1960—61

Taulukko 13. Ripsiäislajien esiintymisrunsaus viljakasveissa Tikkurilassa vuosina 1960—61 otettujen verso-, tähkä- ja röyhynäytteiden perusteella

Species of cereal *Viljalaji*	Number of samples *Näytteiden luku*	Sampling season *Näytteidenottokausi*	Number of thrips *Ripsiäismäärä kpl*	% of number of thrips *% ripsiäismäärästä*						
				L. denticornis	*A. obscurus*	*F. tenuicornis*	*H. aculeatus*	*C. manicatus*	*A. stylifer*	Other species of thrips *Muut ripsiäislajit*
Winter rye — *Syysruis*	32	15 April—23 Aug.	501	35.8	5.1	41.0	14.2	1.3	1.1	1.5
Winter wheat — *Syysvehnä*	37	16 May —13 Sept.	308	25.8	4.2	47.9	10.7	1.2	1.8	8.4
Spring wheat — *Kevätvehnä*	27	20 June— 8 Sept.	126	14.4	7.1	68.8	—	1.2	6.6	1.9
Barley — *Ohra*	30	20 June— 1 Sept.	218	45.3	1.2	46.9	3.3	0.8	1.7	0.8
Oats — *Kaura*	28	28 June— 8 Sept.	192	1.2	21.6	67.9	3.0	—	—	6.3
Total *Yhteensä*	154		1 345							

the more frequent, but from the beginning of July it began to fall behind and finally *F. tenuicornis* made up more than 90.0 % of the total number of thrips. It must be noted, however, that the changes in the relative frequency at all the test areas for oats at Tikkurila in 1964 were fairly exactly parallel. The slight differences observed in the early summer fairly soon levelled out, and in early August the curves almost coincided.

The samples of sprouts, ears and panicles

With the samples of sprouts, ears and panicles that were taken along with the netted samples in 1960—61 an attempt was made primarily to ascertain the occurrence of the various species of thrips in the different parts of the plants. It was possible at the same time to check the accuracy of the results obtained from the netted samples.

When the results of the samples of sprouts, ears and panicles shown in Table 13 are compared with the results of the netted samples taken in 1960—62 (Tables 1, 3, 5, 8 and 10) it will be first noted that *L. denticornis* occurs more abundantly in the cereal plants than there would be reason to conclude from the netted samples except in the case of oats, in which the species is rare. This circumstance will be discussed later in connection with the evaluation of the method of net sweeping (page 41).

A comparison of the frequencies of the other species shows that the variations are not even nearly so great, although they do occur in both directions. The primary causes of the differences in the results obtained by various sampling methods are the variations in habits and habitats of the various species of thrips.

Discussion

In their investigations of species of thrips CEDERHOLM (1963) and HOLTMANN (1963 a) deal with the reliability of results obtained from samples taken by net sweeping.

The influence of surrounding vegetation on the thrips fauna of cereal crops is an evident one. *A. obscurus* may enter grain crops from nearby grassland. This happened especially in 1963, when the development of this species in grassland was particularly lively. Likewise, *L. denticornis* may transfer to barley cultivations from the foxtail or from winter rye.

Impurity and weeds in the crops bring alien species to the thrips fauna of cereals. There was scentless mayweed (*Matricaria* sp.) growing in the test area for winter rye at Puistola in 1964, and a lot of specimens of *H. leucanthemi* occurred in the mayweed. Likewise, the abundancy of *Taeniothrips atratus* in some years and at some test areas has evidently been connected with the occurrence of the *Caryophyllaceae* and *Labiatae* plants that it finds so attractive (PRIESNER 1926).

Some species of thrips, such as *L. denticornis* and *H. aculeatus*, generally hibernate outside the crops in the grass at the edges of roads and forest (WETZEL 1963). They do not move into the winter cereals until spring. It is consequently possible that the transfer in the spring is chiefly limited to those parts of the field that are near the edge of the forest. von OETTINGEN (1952) states that *H. aculeatus* behaves in this fashion. At Somero in 1965 a series of net sweepings were taken from the winter rye at various distances from the edge of the forest at a stage when *L. denticornis* and *H. aculeatus* had already moved in. It was found (Fig. 3) that *L. denticornis* occurred in greater numbers near the edge of the forest and decreased evently with increasing distance. No equally great variation could be observed in the quantities of other species, with the exception that the number of *A. obscurus* was much greater at the very edge of the forest than in other parts of the field.

An erroneous picture of the thrips fauna of the cereal will be obtained if samples are taken by net sweeping too close to a forest edge or elsewhere at the edges of a field where thrips may gather after leaving winter cereals or grass leys.

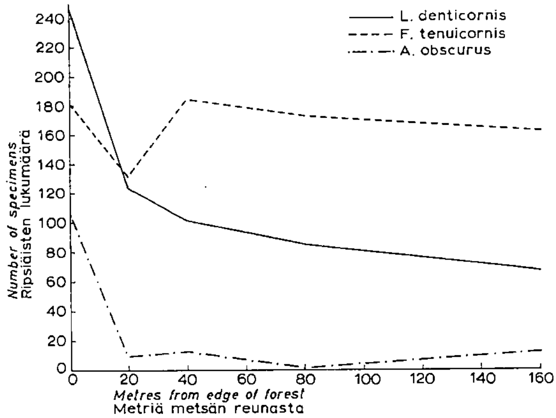

Fig. 3. The frequencies of certain species of thrips in winter rye at various distances from edge of forest. Testing place and time: Somero, July 12th 1965.

Kuva 3. Eräiden ripsiäislajien esiintymisrunsaus syysrukiissa eri etäisyyksillä metsän reunasta. Koepaikka ja -aika: Somero 12. 7. 1965.

Samples of sprouts or sprouts and ears or panicles were taken on the same day as netted samples in order to analyse how great a proportion of the thrips living on a square metre are caught up in net sweeping. If it assumed with Holtmann (1963 a) that 25 strokes back and forth with the net of a early mentioned size will cover a surface area equivalent to 30 square metres, it is possible from the results of the samples to calculate the figures shown in the Table 14.

Only a small proportion of the thrips in the area will be caught up in the netted samples (Table 14). There are also distinct differences between various species. A considerably smaller proportion of *L. denticornis* than of *F. tenuicornis* and *A. obscurus* will be caught up into the netted samples. The difference is particularly great after the ears and panicles have come out, and it appears in the frequency of *F. tenuicornis* as well as *L. denticornis*. In contrast, species that live on leaves, such as *A. obscurus*, did not show this kind of difference.

It is thus evident that *L. denticornis* and *H. aculeatus*, the former of which lives chiefly in the sheath of the leaf and the latter chiefly in the ears of grain, are more common in cereals than could be assumed from the results of the netted samples. This factor should be given special attention in the evaluation of the results of fauna studies of winter rye, winter wheat and barley.

The activity of thrips in plants is greatly dependent on the prevailing weather conditions (von Oettingen 1942). On cool and windy days, and also when it rains, the thrips seek the protective parts of plants and will not be caught up into the netted samples as easily as they will in favourable conditions. During the present period of study the attempt was made to take netted samples in as favourable conditions as possible (cf. page 31). The time for net-sweeping was around mid-day, from 12 noon to 2 p.m. In 1964 the samples for comparison were taken from winter rye also during other times of the day. The results are shown in Fig. 4 (page 42). It seems that *L. denticornis* is most active at mid-day when the relative humidity is low and the temperature high. The netted samples taken from barley at different times of the day give the same indication, as do also the studies carried out by Cederholm (1963). The behaviour of *A. obscurus* was

Table 14. The percentage of adult thrips obtained by net of the true number of specimens on one square metre
Taulukko 14. Haavilla saatujen ripsiäisaikuisten prosenttinen määrä 1 m²:llä olevien yksilöiden todellisesta määrästä

Species of cereal *Viljalaji*	Number of samples for comparison *Vertailunäytteiden luku*	% of all specimens living on cereals *% ripsiäisten todellisesta määrästä viljoissa*		
		L. denticornis	*F. tenuicornis*	*A. obscurus*
Winter rye before coming into ear — *Syysruis ennen tähkimistä*	8	1.5	5.0	5.3
Barley after coming into ear — *Obra tähkimisen jälkeen*	5	0.3	1.5	5.6
Oats after coming into panicle — *Kaura röyhylletulon jälkeen*	5	—	1.9	5.0

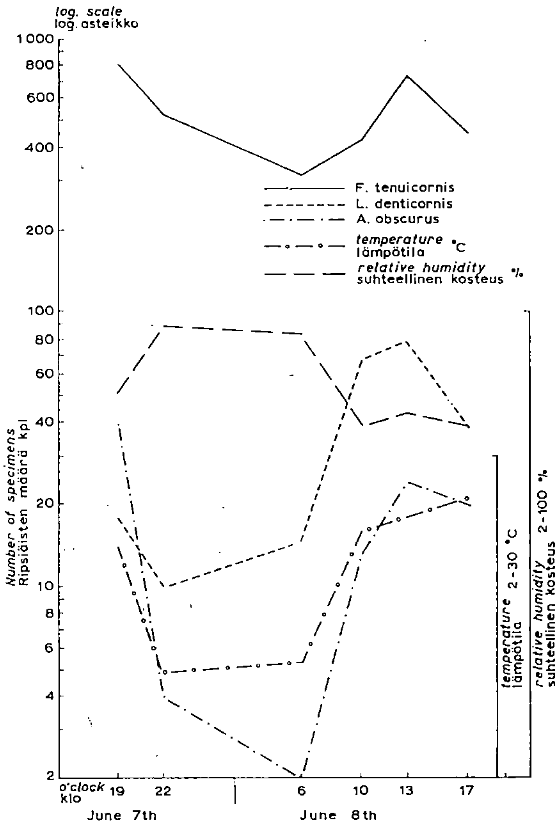

Fig. 4. The frequencies (= activity) of various species of thrips at different times of the day according to netted samples taken from winter rye at Somero on June 7th — 8th 1964.

Kuva 4. Eri ripsiäislajien esiintymisrunsaus (= aktiivisuus) eri vuorokaudenaikoina 7.—8. 6. 1964 syysrukiista Somerolla otettujen haavintanäytteiden perusteella.

not quite so distinct. It may be most active at mid-day (Fig. 4), but on July 18th 1964 it was netted at about 9 p.m. from the barley in an abundance almost as great as that at 1 p.m. CEDERHOLM (1963) found the peaks of activity of this species in June to be 7 a.m. and 7 p.m. von OETTINGEN (1942) regards *A. obscurus* as an afternoon species that has its peak of activity at 2—4 p.m. When the results obtained are evaluated it is evident that the reaction of the species with regard to temperature and humidity is not constant but varies with the age and the state of nutrition of the individual specimen; as CEDERHOLM (1963), for instance, interprets the variations found in laboratory tests. On June 8th 1964 in winter rye and on July 18th 1964 in barley the activity of *F. tenuicornis* was at its greatest about 1 p.m. (Fig. 4), but on July 25th 1964 in oats the corresponding situation occurred at 8 p.m. In fact, in a series of net sweepings taken from winter rye the number of specimens of this species, as well as of *A. obscurus*, was on June 8th 1964 not at its greatest at 1 p.m. but on the previous evening at about 7 p.m. The reason for this seems to have been an increase in the force of the wind when the last samples in the series of net sweepings were being taken. The wind does not seem so distinctly to affect the activity of *L. denticornis*. According to a study by CEDERHOLM (1963) the peak of activity of *F. tenuicornis* in a mixed crop of barley and oats in June was between 11.30 a.m. and 2 p.m. *H. aculeatus* is regarded as a morning species, but it was not possible to check this information in our conditions because of the rare occurrence of this species in 1964. In accordance with the above it seems expedient that the netted samples were always taken between 12 noon and 2 p.m.

Despite its shortcomings the sweeping net method is quite important in the analysis of the thrips fauna of cereals. Thus, HEIKINHEIMO and RAATIKAINEN (1962) regard it as being superior to the suction method, especially in the study of thrips. The handling of the netted material is moreover quicker, and the fragile thrips can in this way be caught up in good condition for examination. Species of thrips that occur only in small numbers on an area are more easily detected by netted samples than by the use of an suction method.

Summary

The present studies on the thrips fauna of cereals have been carried out chiefly at the Department of Pest Investigations at Tikkurila in 1960—65. Part of the netted material was obtained at Somero. During the period of study 431 samples were taken by sweeping net from

the various cereals. The material obtained from these comprised 163 725 specimens of thrips. A further 1 345 specimens of thrips were obtained from the 154 samples taken of sprouts, ears and panicles.

In the material taken from the cereals 29 species of thrips were found; these have been listed in connection with the presentation of the material. Only the following 7 species from among these might be regarded as belonging to the actual pests of cereals: *L. denticornis*, *A. obscurus*, *F. tenuicornis*, *H. aculeatus*, *C. hamatus*, *C. manicatus* and *A. stylifer*.

One variation new to Finland was found: *Taeniothrips vulgatissimus f. adusta*, which was obtained from winter wheat.

F. tenuicornis and *L. denticornis* were dominant species in the thrips fauna of winter rye while *A. obscurus* and *H. aculeatus* also occurred in fair abundance during some of the years. In contrast, *C. manicatus*, *C. hamatus* and *A. stylifer* were rarely found in winter rye.

F. tenuicornis was a dominant species of thrips in winter wheat. *L. denticornis* and *A. obscurus* were also found in winter wheat, some years in abundance. *H. aculeatus* was found in winter wheat on average about as frequently as *C. manicatus*. *C. hamatus* and *A. stylifer*, however, occurred only occasionally in winter wheat.

F. tenuicornis was a dominant species of thrips in spring wheat also. The frequency of *L. denticornis*, *A. obscurus*, *H. aculeatus* and *C. manicatus* was distinctly smaller than in winter wheat. *A. stylifer* was also found in spring wheat to some extent but *C. hamatus* was totally absent from this fauna.

F. tenuicornis and *L. denticornis* were dominant in the thrips fauna of barley. *A. obscurus* also occurred very abundantly both at Tikkurila and at Somero, especially in 1963. The frequency of *H. aculeatus*, *C. manicatus* and *A. stylifer* was, however, relatively slight in barley. *C. hamatus* was totally absent from the barley.

F. tenuicornis and *A. obscurus* were dominant species of thrips in oats. There was, however, distinctly less *L. denticornis* than in other cereals. The proportions of *H. aculeatus* and *C. manicatus* in the thrips fauna of oats were also relatively small. *A. stylifer* was found only occasionally in oats, and *C. hamatus* was totally absent from it.

The proportions of frequency between the various species of thrips in oats growing in different blocks were coincident, but the differences between different years were quite distinct ones. The amount of *A. obscurus* was especially great in 1963, when the first generation of the species developed into unusual strength in winter rye and grassland.

So far as the frequency of the various species in different cereals is concerned, the thrips material obtained from the samples of sprouts, ears and panicles in general gave results similar to those presented above. With the exception of oats the proportion of *L. denticornis*, however, was much greater than in the netted material. It is evident as a consequence of the differing habits of the various species that *L. denticornis* and *H. aculeatus* are commoner in cereals than could be expected on the basis of the netted samples. This applies, above all, to the results obtained in the studies of the fauna of the winter rye, winter wheat and barley.

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REFERENCES

Beling, T. 1872. Ein dem Getreide schädliches Insekt. Verh. Zool. Bot. Ges. Wien 22: 651—654.

Brummer, V. 1939. Beiträge zum Problem der durch Thysanopteren verursachten Schartigkeit des Roggens. Maatal.tiet. Aikak. 11: 127—145.

Brundin, L. 1934. Die Coleopteren des Torneträskgebietes. Akad. Abh. 436 p. Lund.

Cederholm, L. 1963. Ecological studies on Thysanoptera with special reference to species found in mixed grain (oats and barley). Opuscula Ent. Suppl. 22: 1—215.

CURTIS, J. 1883. Farm insects. 528 p. London.

FRANSSEN, C. J. H. & MANTEL, W. P. 1965. Tripsen in graangewassen (Levenswijze, economische betekenis en bestrijding). I. Levenswijze. Inst. Pl.ziektenk. Onderz. Meded. 381: 1—97.

HALIDAY, A. H. 1836. An epitome of the British genera in the order Thysanoptera with indications of a few of the species. Ent. Mag. 3: 439—451.

HEIKINHEIMO, O. & RAATIKAINEN, M. 1962. Comparison of suction and netting method in population investigations concerning the fauna of grass leys and cereal fields, particularly in those concerning the leafhopper, *Calligypona pellucida* F. Valt. Maatal. koetoim. Julk. 191: 1—31.

HINDS, W. E. 1900. The grass thrips (*Anaphothrips striata* Osb.) Rep. Mass. Agric. Coll. 37: 81—105.

HOLTMANN, H. 1963 a. Untersuchungen zur Biologie der Getreide Thysanopteren. I. Z. Angew. Ent. 51: 1—41.

— 1963 b. Untersuchungen zur Biologie der Getreide Thysanopteren. II. Ibid. 51: 285—299.

HUKKINEN, Y. 1936. Tutkimuksia nurmipuntarpään (*Alopecurus pratensis* L.) siementuholaisista. I. *Chirothrips hamatus* Tryb. Puntarpääripsiäinen. Valt. Maatal.koetoim. Julk. 81: 1—131.

— 1942. Blick auf die Erforschung der Thysanopterenfauna Finnlands, besonders ihrer schädlichen Arten. Suom. Hyönt.tiet. Aikak. 8: 25—45.

JOHANSSON, E. 1938. Studier rörande de på gräs och sädesslag levande tripsarnas biologi. I. I vetefält och vallar förekommande associationsformer samt skadegörelsens natur och omfattning. Växtskyddsanstaltens Medd. 24: 1—65.

— 1946. Studier och försök rörande de på gräs och sädesslag levande tripsarnas biologi och skadegörelse. II. Tripsarnas frekvens och spridning i jämförelse med andra sugande insekters samt deras fröskadegörande betydelse. Ibid 46: 1—59.

KANERVO, V. 1950. *Frankliniella tenuicornis* Uzel. (*Thysanoptera*) als intrafloraler Schädling der Gerste. 8. Intern. Congr. Ent. Proc. Stockholm. p. 647—653.

KAUFMANN, O. 1925. Die Weissährigkeit der Wiesengräser und ihre Bekämpfung. I—II. Arb. Biol. Reichsanst. Land. Forstw. 13, 5: 497—567.

KONTKANEN, P. 1950. Quantitative and seasonal studies on the leafhopper fauna of the field stratum on open areas in North Karelia. An. Zool. Soc. Vanamo 13, 8: 1—91.

KROGERUS, R. 1932. Über die Ökologie und Verbrutung der Arthropoden der Triebsandgebiete an den Küsten Finnlands. Acta. Zool. Fenn. 12: 1—308.

KÖRTING, A. 1934. Beitrag zur Kenntnis der Entwichlung von *Haplothrips aculeatus* F. Z. Angew. Ent. 20: 281—295.

LINDEMAN, K. 1886. Die am Getreide lebenden Thrips-Arten Mittelrusslands. Bull. Soc. Imp. Nat. Moscou 62: 296—337.

— 1887. Om de på säd lefvande arterna av slägtet Thrips i mellersta Ryssland. Ent. Tidskr. 8: 119—127.

OETTINGEN, H. von 1930. Beitrag zur Ökologie der Thysanopteren auf den norddeutschen Grasfluren. Pfl.bau 7: 166—170.

— 1942. Die Thysanopteren des norddeutschen Graslandes. Ent. Beih. 9: 79—141.

— 1952. Die Thysanopterenfauna des Harzes. V. Beitr. Ent. 5: 69—80.

PALMGREN, P. 1930. Quantitative Untersuchungen über die Vogelfauna in den Wäldern Südfinnlands. Acta Zool. Fenn. 7: 1—209.

PRIESNER, H. 1926. Die Thysanopteren Europas. I—II. 342 p. Wien.

— 1927—1928. Die Thysanopteren Europas III—IV. 412 p. Wien.

RENKONEN, O. 1938. Statistisch-ökologische Untersuchungen über die terrestrische Käferwelt der finnischen Bruchmoore. An. Zool. Soc. Vanamo 6, 1: 1—231.

REUTER, E. 1900. Über die Weissährigkeit der Wiesengräser in Finnland. Acta Soc. F. Fl. Fenn. 19: 1—136.

— 1902. Weissährigkeit der Getreidearten. Z. Pfl. krankh. 12: 324—338.

SHARGA, U. S. 1933. Biology and life history of *Limothrips cerealium* Haliday and *Aptinothrips rufus* Gmelin feeding on *Graminae*. Ann. Appl. Biol. 20: 308—326.

SZANISZLO, A. VON 1879. Beiträge zur Lebensweise von *Thrips frumentarius* Bel. Verh. Zool. Bot. Ges. Wien 29: 33—36.

TANSKY, V. I. 1961. The formation of the thrips fauna (*Thysanoptera*) on wheat crops in new soil of northern Kazakhstan. Rev. Ent. USSR 40, 4: 785—793.

TIITTANEN, K. 1954. Imentävioituksista vehnän jyvissä. Manuscr. 52 p. [Available at the Department of Pest Investigation, Tikkurila, Finland].

TISCHLER, W. 1949. Grundzüge der terrestrischen Tierökologie. 220 p. Braunschweig.

TRYBOM, F. 1894. Iakttagelser om blåsfotingar (Physapoder) från sommaren 1893. Ent. Tidskr. 15: 41—58.

— 1895. Iakttagelser om vissa blåsfotingars (Physapoders) uppträdande i gräsens blomställningar jämte några drag ur släktet *Phloeothrips* utvecklingshistoria. Ibid. 16: 157—194.

UZEL, H. 1895. Monografie der Ordnung Thysanoptera. 472 p. Königgrätz.

WETZEL, T. 1963. Zur Frage der Überwinterung der Gräser-Thysanopteren. Z. Angew. Ent. 51: 429—441.

SELOSTUS

Viljakasvien ripsiäislajisto

PEKKA KÖPPÄ

Maatalouden tutkimuskeskus, Tuhoeläintutkimuslaitos, Tikkurila

Aikaisemmin ovat O. M. Reuter, E. Reuter ja Y. Hukkinen suorittaneet meillä ripsiäislajistoa koskevia tutkimuksia. Hukkinen on lisäksi valkotähkäisyyskysymystä tutkiessaan antanut varsin yksityiskohtaisen selvityksen heinäkasveissa elävistä ripsiäislajeista. Viljakasvien ripsiäislajistoa selvitteleviä tutkimuksia on meillä aikaisemmin suorittanut lähinnä V. Kanervo.

Tuhoeläintutkimuslaitoksessa on 1960—65 pyritty selvittelemään viljakasvien ripsiäislajistoa pääasiassa eri viljakasveista otetun haavinta-aineiston perusteella. Lisäksi on saatu jonkin verran aineistoa verso-, tähkä- ja röyhynäytteistä. Pääosa tutkimuksista on suoritettu Tikkurilassa. Osa haavinta-aineistosta on otettu Somerolta.

Tutkimuskauden aikana otettiin yhteensä 431 haavintanäytettä viidestä eri viljakasvista. Näistä saatu aineisto käsittää yhteensä 163 725 ripsiäisyksilöä. Lisäksi saatiin 154:stä verso-, tähkä- ja röyhynäytteestä 1 345 ripsiäisyksilöä.

Viljakasveista otetuissa näytteissä todettiin 29 ripsiäislajia. Näistä seuraavia seitsemää lajia voitaneen pitää varsinaisina viljakasvien tuholaisina: viljaripsiäinen (*Limothrips denticornis*), ruohoripsiäinen (*Anaphothrips obscurus*), kauraripsiäinen (*Frankliniella tenuicornis*), kahuripsiäinen (*Haplothrips aculeatus*), puntarpääripsiäinen (*Chirothrips hamatus*), röyhyripsiäinen (*Chirothrips manicatus*) ja heinäripsiäinen (*Aptinothrips stylifer*). *Aeolothrips*-lajit puolestaan tunnetaan yleisesti petohyönteisinä. Useimmat muut lajit ovat joutuneet haavintanäytteisiin viljapelloissa kasvaneista heinäkasveihin kuulumattomista kasveista.

Lajistotutkimuksia varten otetussa ripsiäisaineistossa todettiin yksi Suomelle uusi muoto, *Taeniothrips vulgatissimus f. adusta*, joka saatiin syysvehnästä.

Dominoivalla lajilla tarkoitetaan tässä tutkimuksessa Kontkasen mukaisesti sellaista lajia, jonka osuus koko ripsiäismäärästä on vähintään 15.1 %.

Kauraripsiäinen ja viljaripsiäinen dominoivat syysrukiin ripsiäislajistossa. Ruohoripsiäistä ja kahuripsiäistä esiintyi niitäkin eräinä vuosina melko runsaasti. Sitä vastoin röyhyripsiäistä, puntarpääripsiäistä sekä heinäripsiäistä tavattiin syysrukiissa vain vähän.

Syysvehnässä oli kauraripsiäinen dominoiva laji. Myös viljaripsiäistä ja ruohoripsiäistä tavattiin siinä eräinä vuosina runsaasti. Kahuripsiäistä oli syysvehnässä keskimäärin suunnilleen yhtä paljon kuin röyhyripsiäistä. Puntarpääripsiäistä ja heinäripsiäistä esiintyi siinä sen sijaan vain satunnaisesti.

Kauraripsiäinen oli dominoiva laji myös kevätvehnässä. Sen sijaan viljaripsiäisen, ruohoripsiäisen, kahuripsiäisen sekä röyhyripsiäisen esiintymisrunsaus oli siinä selvästi vähäisempi kuin syysvehnässä. Heinäripsiäistä tavattiin myös kevätvehnässä jonkin verran, mutta puntarpääripsiäinen puuttui lajistosta täysin.

Ohrassa dominoivat kauraripsiäinen ja viljaripsiäinen. Myös ruohoripsiäistä esiintyi erityisesti 1963 erittäin runsaasti sekä Tikkurilassa että Somerolla. Sen sijaan kahuripsiäisen, röyhyripsiäisen sekä heinäripsiäisen esiintymisrunsaus ohrassa oli suhteellisen vähäinen. Puntarpääripsiäistä ei siinä tavattu lainkaan.

Kauraripsiäinen ja ruohoripsiäinen dominoivat kaurassa. Sen sijaan viljaripsiäistä oli siinä selvästi vähemmän kuin muissa viljalajeissa. Samoin kahuripsiäisen ja röyhyripsiäisen osuus kauran ripsiäislajistossa oli suhteellisen pieni. Heinäripsiäistä tavattiin kaurassa vain satunnaisesti eikä puntarpääripsiäistä lainkaan.

Eri lohkoilla kasvavassa kaurassa olivat eri ripsiäislajien runsaussuhteet samana vuonna yhtäpitävät, mutta eri vuosien välillä erot olivat hyvinkin selvät. Ruohoripsiäisen määrä oli erityisen suuri 1963, jolloin lajin ensimmäinen sukupolvi kehittyi syysrukiissa ja nurmissa harvinaisen voimakkaaksi.

Verso-, tähkä- ja röyhynäytteistä saatu ripsiäisaineisto antoi lajien esiintymisrunsaudesta eri viljakasveissa yleensä samanlaisia tuloksia kuin edellä on esitetty. Kuitenkin viljaripsiäisen osuus oli siinä kauraa lukuunottamatta huomattavasti suurempi kuin haavinta-aineistossa.

Eri ripsiäislajien erilaisten elämäntapojen vuoksi on ilmeistä, että viljaripsiäistä ja kahuripsiäistä on viljoissa runsaammin kuin haavintanäytteiden tulosten perusteella olisi odotettavissa. Ennen kaikkea tämä koskee syysrukiin, syysvehnän ja ohran lajistotutkimuksissa saatuja tuloksia.

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ÜBER DIE BESTIMMUNG DER AUSTAUSCHBAREN BASEN DES BODENS, SEINES WASSERSTOFFES UND IHRER SUMMEN

EUGEN BARKOFF
Zentrale für Landwirtschaftliche Forschung, Abteilung für Agrikulturchemie und -physik, Tikkurila, Finnland

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Eine allgemeine Methode, nach der man den austauschbaren Wassersfoff des Bodens, seine austauschbaren Basen (S-Wert) und die Summe dieser Zahlen (T-Wert) oder die Kationenadsorptionskapazität schnell, aber doch mit hinreichender Genauigkeit bestimmen könnte, ist noch nicht gefunden worden. In Finnland wird gegenwärtig der Kalkbedarf des Bodens auf Grund des von saurem Ammoniumazetat ausgetauschten Kalziums und der pH-Werte einer Bodensuspension (Volumverhältnis 1 Boden : 2.5 Wasser) vorhergesagt. Dass wir uns fortfahrend um eine genauere Schnellmethode bemühen, erweisen die Veröffentlichungen, die in geringen Zeitabständen hier erscheinen (SALONEN 1952, TERÄSVUORI 1959, MÄKITIE 1965, KERÄNEN 1966). In Schweden ist ebenfalls dieser Sachverhalt untersucht und u.a. eine kolorimetrische Methode dargestellt worden, nach der für den Austausch der Basen des Bodens ein farbiges Kobaltion angewandt wird (JOHANSSON 1961).

In der vorliegenden Arbeit werden anfangs die nach den verschiedenen Methoden erhaltenen Werte miteinander verglichen, deren Mittelwerte, sowohl für Gruppen als auch für das gesamte Material berechnet, in Tabelle 1 dargestellt sind.

Die benutzten Verfahrensweisen werden im folgenden genauer beschrieben:

Die für das Bestimmen des austauschbaren Wasserstoffes benutzte und auf die Untersuchungen VON TERÄSVUORI (1959) gegründete Methode, nach der die Werte von Tabelle 1, Spalte 2, erhalten worden sind, ist folgende:

In Flaschen wurden nach dem Volumgewicht 20 ml Boden eingewogen, dazu 50 ml 0.02 n $CaCl_2$ Wasserlösung gegeben, eine Stunde maschinell geschüttelt und die pH-Werte gemessen. Danach wurde bei der elektrometrischen Messung des pH aus einer Bürette fortgesetzt der Bodensuspension eine Lösung zugesetzt, deren Normalität in bezug auf NaOH 0.1 und in bezug auf $CaCl_2$ 0.02 betrug. Der Endpunkt der Titrierung wurde erreicht, wenn pH auf fast 7.00 stieg und dort eine Weile stehenblieb. Während der Titrierung wurde die Suspension unter Anwendung eines magnetischen Mischgeräts homogenisiert. In jede Flasche kamen zur Verhinderung von Schimmelbildung 5 Tropfen Toluen, und die Flaschen wurden mit Korken verschlossen. Zur Herstellung von Gleichgewicht liess man die Flaschen 4mal 24 St stehen, und in dieser Zeit wurden sie wenigstens drei Stunden täglich noch maschinell geschüttelt. Schliesslich mass man die von den Suspensionen angenommenen neuen pH-Werte, die meistens zwischen 5.5 und 6.0 lagen. Unter Anwendung der vor und nach dem Basenzusatz gemessenen pH-Werte der 0.02 n $CaCl_2$-Bodensuspension sowie der zugesetzten Basenmengen ergab sich durch geradlinige Extrapolation bei Berechnung in Milliäquivalenten diejenige Basenmenge, die zur Erlangung des pH_{CaCl_2}-Wertes 7 zugesetzt werden müsste und die der Menge des austauschbaren Wasserstoffes des Bodens entspräche, wenn sich die Geradlinigkeit auch oberhalb von pH 6.00 fort-

Tabelle 1. Die Mittelwerte der H-, S-, T- und pH-Werte in 0.02 n $CaCl_2$, die nach den in der Untersuchung benutzten Methoden erhalten worden sind, sowohl bei den verschiedenen Gruppen als auch allen Böden

Taulukko 1. Tutkimuksessa käytetyillä menetelmillä saatujen H-, S-, T- ja pH-arvojen 0.02 n $CaCl_2$:ssa sekä eri ryhmien että kaikkien tutkittujen maiden keskiarvot.

Anzahl der Proben *Maanäytteiden lukumäärä*	Die Gruppen nach den extrapolierten H-Werten *Ryhmät ekstrapoloitujen H-arvojen mukaan*	Austb. Wasserstoff, H-Werte *Vaiht. vety, H-arvot*		Austb. Basen, S-Werte *Vaiht. emäkset, S-arvot*			Adsorptionsvermögen der Kationen, T-Werte *Kationien pidätyskyky, T-arvot*		pH 0.02 n $CaCl_2$ Susp. 1 : 2.5
		Extrap. auf pH: 7.00 *Ekstrap. pH: 7.00:ään*	Johansson	Titrimetrisch *Titrimetrinen*	Johansson	Ca + Mg + K + Na	Extrap. + titrim. *Ekstrap. + titrim.*	Johansson	
		mval/1 Boden — *mval/1 maata*							
1	2	3	4	5	6	7	8	9	10
4	0— 49	37	38	107	57	87	144	95	5.74
28	50— 99	81	82	144	109	138	225	191	5.18
32	100—149	123	103	111	88	111	234	191	4.72
14	150—199	182	143	100	88	99	282	231	4.47
16	200—247	217	154	81	67	81	297	221	4.27
94 (alle) *(kaikki)*	0—247	131	109	114	89	111	246	198	4.79

Korrelationskoeffizienten:
Korrelaatiokertoimet:

Austb. Wasserstoff, H-Werte, Spalten 3 und 4 : $r = 0.815^{***}$, $R = 32.8 + 0.576^{*}$
Vaiht. vety, H-arvot, sarakkeet 3 ja 4
Austb. Basen, S-Werte, Spalten 5 und 6 : $r = 0.898^{***}$
Vaiht. emäkset S-arvot, sarakkeet 5 ja 6
Austb. Basen, S-Werte, Spalten 5 und 7 : $r = 0.965^{***}$
Vaiht. emäkset, S-arvot, sarakkeet 5 ja 7
Austb. Basen, S-Werte, Spalten 6 und 7 : $r = 0.897^{***}$
Vaiht. emäkset, S-arvot, sarakkeet 6 ja 7
Adsorptionsvermögen der Kationen, T-Werte, Spalten 8 und 9 : $r = 0.815^{***}$
Kationien pidätyskyky, T-arvot, sarakkeet 8 ja 9

setzte. TERÄSVUORIS (1959) Kurven für pH/austb. H· beginnen sich oberhalb des pH-Wertes 6.00 abwärts zu krümmen, wahrscheinlich durch die Anwesenheit von in Tonmineralien und organischem Stoff des Bodens enthaltenen schwach dissoziierenden Säuregruppen, deren Wasserstoffionen erst dann ausgetauscht werden, wenn der pH-Wert der Suspension über 6.00 steigt. Der Wasserstoff der schwach dissoziierenden Säuregruppen kann jedoch nicht gegen die Kationen der Neutralsalzlösungen eingetauscht werden.

Die in Schweden entwickelte Kobaltmethode JOHANSSONS (1961) ist in dieser Untersuchung für den Vergleich herangezogen worden, und die nach ihr erhaltenen durchschnittlichen H-, S- und T-Werte sind in Tabelle 1 in den Spalten 4, 6 und 9 angegeben. Nach dieser Methode werden 10 g Boden mit 50 ml 0.1 n $Co(NO_3)_2$-Lösung behandelt, wobei die im Boden enthaltenen Basenionen ihren Platz mit den Kobaltionen wechseln und die Auslaugungslösung zum Teil ihre Farbe verliert. Die Farbintensitäten sowohl der 0.1 n $Co(NH_3)_2$-Lösung als auch der Auszüge werden kolorimetrisch gemessen und aus den erhaltenen Extinktionswerten die S-Werte berechnet. Wenn weitere 10 g Boden erst mit 500 mg $CaCO_3$ vermischt, dann aber auf ganz gleiche Weise wie das vorherige Mal behandelt werden, erhält man die T-Werte. Im allgemeinen geben die Methoden, nach denen der austauschbare Wasserstoff dadurch bestimmt wird, dass man die Menge der austauschbaren Basen von der austauschbaren Gesamtkapazität subtrahiert, weniger zuverlässige Werte des austauschbaren Wasserstoffes, da die Analysenfehler bei getrennter Bestimmung der T- und S-Werte den Betrag des austauschbaren Wasserstoffes sogar sehr belasten können.

Die Menge der austauschbaren Basen ist auch titrimetrisch (VALMARI 1921) nach SALONEN und TAINIO (1956) bestimmt worden (Tabelle 1 Spalte 5). Dabei wird Boden mit 0.01 n Salzsäure im Verhältnis 1 : 2.5 dem Volumen gemäss 3 St geschüttelt. Den S-Wert berechnet man nach der vom Boden neutralisierten Salzsäuremenge, die aus dem Filtrat durch Titrieren mit 0.01 n NaOH -Lösung und unter Verwendung von Bromthymolblau als Indikator bestimmt wird. Das pH des Auszugs wurde stets gemessen, und es belief sich im allgemeinen auf beinahe pH 2.5, aber wenn es fast 3 oder darüber war, wurde eine neue Schüttelung mit einer kleineren Bodenmenge angestellt.

Dieses Verfahren scheint gut zu sein und sich besonders für sehr saure Böden ohne freie oder überschüssige Basen zu eignen. Boden kann im allgemeinen als schwacher Ionenaustauscher angesehen werden, und in diesem Falle tauscht das Wasserstoffion der Salzsäure sehr wirksam Basen aus dem Boden in die Lösung ein, und ihr Anion neutralisiert sie.

Die nach den obigen Verfahren bestimmten Mengen austauschbarer Basen werden des weiteren in Tabelle 1 verglichen mit der Summe von Ca, Mg, K und Na (Spalte 7), welche Kationen unter Anwendung sauren NH_4-Azetats (pH 4.65) oder der sog. Bodenfruchtbarkeitsmethode aus dem Boden extrahiert wurden (VUORINEN und MÄKITIE 1955). Ca, K und Na wurden flammenphotometrisch bestimmt, aber Mg durch komplexometrische Titrierung unter Anwendung der HENRIKSENschen (1964) Methode in einer für sauren Azetatauszug geeigneten Abwandlung.

Die Methode der Magnesiumbestimmung ist in ihrer endgültigen Form wie folgt:

Man pipettiert 50 ml gewöhnlichen Azetatauszug in eine 100 ml-Messflasche, versetzt ihn mit 5 ml gesättigter Ammoniumoxalatlösung, 10 ml 2.5 n Ammoniumhydroxydlösung, 1 ml 2 % Kaliumferrocyanidlösung, füllt bis zur Marke mit destilliertem Wasser auf, lässt alles eine Stunde möglichst im Dunkeln stehen, schüttelt dabei dann und wann und filtert.

Für die Titrierung nimmt man 50 ml Filtrat (wenn die Farbveränderung beim Titrieren nicht scharf genug ist, 25 ml Filtrat + 25 ml Wasser), dem 10 ml Ammoniumchloridpufferlösung (70 g NH_4Cl + 73 mval NH_4OH bis zu einem Liter), 2 ml Kaliumcyanidtriäthanolamin und 6 Tropfen Eriochromschwarzlösung zugesetzt werden (HENRIKSEN 1964 S. 741 die Lösungen 5 und 6), unmittelbar danach wird mit AeDTE-Lösung (Komplexon III) titriert.

In Tabelle 1, Spalte 10, stehen ferner in verschiedenen Gruppen die Mittelwerte der pH_{CaCl_2} -Werte, gemessen in einer Suspension von 1 Boden : 2.5 0.02 n $CaCl_2$.

Aus der Tabelle ist zu ersehen, dass zwischen den nach den verschiedenen Methoden erhaltenen H-, S- und T -Werten eine ziemlich gute Korrelation besteht, obschon absolut die JOHANSSONsche Methode geringere Werte gibt als die übrigen angewandten Verfahrensweisen. Des weiteren sei angeführt, dass die für die vorliegende Untersuchung benutzten 58 Proben verschiedener Bodenarten auch KERÄNEN (1966) in bezug auf den austauschbaren Wasserstoff nach seiner Ammoniumazetatmethode analysiert und dabei festgestellt hat, dass zwischen seinen Werten und unseren durch das Extrapolationsverfahren erhaltenen Zahlen eine gute Korrelation bestanden habe (linearer Korrelationskoeffizient r = 0.953). Nach der Extrapolationsmethode bestimmt, enthielten diese Proben an austauschbarem Wasserstoff im Mittel 134 mval/1 und nach der Ammoniumazetatmethode 132 mval/1.

Die Werte der Kobaltmethode sind durchweg geringer als die entsprechenden übrigen, und die Abweichung ist am grössten bei hohen Werten, wobei das Kobaltion offenbar am unvollständigsten vom Boden absorbierte Kationen eintauscht. In gewissen Fällen, in denen das Kationenabsorptionsvermögen des Bodens ziemlich stark gewesen war, wie z.B. bei gewissen humushaltigen Böden, wurden für die Analyse nach der Kobaltmethode auch 5 g Boden statt 10 g genommen,

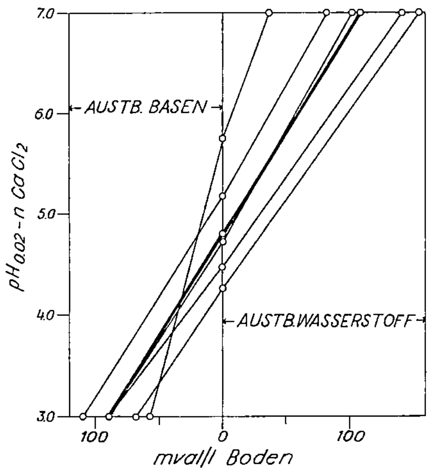

Abb. 1. Graphische Darstellung der nach der Johanssonschen Methode erhaltenen Mittelwerte der H-, S- und T-Zahlen gemäss Tabelle 1. Die breite Linie: Die Mittelwerte aller Fälle. Ordinate: pH-Werte in 0.02 n $CaCl_2$. Von der Ordinate nach links: Austauschbare Basen, mval/l Boden. Von der Ordinate nach rechts: Austauschbarer Wasserstoff, mval/l Boden.

Kuva 1. Graafinen esitys Johanssonin menetelmällä saaduista H-, S- ja T-arvojen keskiarvoista taulukon 1 mukaan. Paksu viiva: Kaikkien tapausten keskiarvot. Ordinaatta: pH-arvot 0.02 n $CaCl_2$:ssa. Ordinaatasta vasemmalle: Vaihtuvat emäkset mval/l maata. Ordinaatasta oikealle: Vaihtuva vety, mval/l maata.

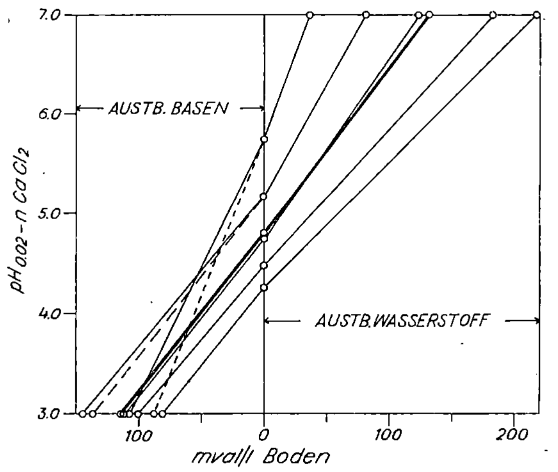

Abb. 2. Graphische Darstellung der nach der neuen Methode erhaltenen Mittelwerte der H-, S- und T-Zahlen gemäss Tabelle 1. Gestrichelte Linie: Durch saures Ammoniumazetat ausgelaugtes Ca + Mg + K + Na, mval/l Boden. Die breite Linie: Die Mittelwerte aller Fälle. Ordinate und Abszisse wie bei Abb. 1.

Kuva 2. Graafinen esitys uudella menettelytavalla saaduista H-, S- ja T-arvojen keskiarvoista taulukon 1 mukaan. Katkoviiva: Happamalla ammoniumasetaatilla uutettujen Ca + Mg + K + Na, mval/l maata. Paksu viiva: Kaikkien tapausten keskiarvot. Ordinaatta ja abskissa kuten kuvassa 1.

und dadurch erhielten wir bedeutend höhere S- und T-Werte und in anderen Fällen sogar gleich beträchtliche wie gemäss den übrigen genannten Methoden.

Auf Abb. 1 sind die nach Johanssons Methode erhaltenen Werte von Tabelle 1 sowie die pH-Werte einer im Mischungsverhältnis 1 : 2.5 dem Volumen gemäss stehenden Suspension von Boden und 0.02 n $CaCl_2$-Lösung graphisch dargestellt. Hier sind auf der Ordinate die pH_{CaCl_2} -Werte, von ihr nach links in der Höhe von $pH_{CaCl_2} = 3.00$ die S-Werte und nach rechts in der Höhe von $pH_{CaCl_2} = 7.00$ die Werte des austauschbaren Wasserstoffes (T—S) abgetragen und die entsprechenden Punkte durch Geraden miteinander verbunden worden. Jede schmale Linie vertritt eine Bodengruppe der Tabelle und die breite Linie das gesamte Material. Auf dieser Abbildung fallen die entsprechenden Punkte sehr gut auf die entsprechenden Geraden.

Auf Abb. 2 sind gleicherweise die nach anderer Methode für austauschbaren Wasserstoff und S erhaltenen Werte von Tabelle 1 wiedergegeben. Ausserdem sind hier durch eine gestrichelte Linie die Summen der durch saures Ammoniumazetat ausgelaugten Elemente Ca, Mg, K und Na vereinigt. Auch auf dieser Abbildung fallen die Punkte der Mittelwerte des gesamten Materials gut auf eine Gerade.

Des weiteren wurde untersucht, mit welchem Erfolg der H-Wert des Extrapolierungsverfahrens zur Bestimmung des Kalkbedarfs des Bodens angewandt werden kann. Deswegen wurde nach dem Volumgewicht eine 20 ml entsprechende Menge Boden in eine geeignete Flasche eingewogen, eine dem obigen H-Wert äquivalente Menge Kalziumkarbonat, 50 ml Wasser, 5 Tropfen Toluen zugesetzt und 4mal 24 St bei täglich 3stündigem maschinellen Schütteln zum Reagieren stehengelassen. Dann mass man den pH-Wert der Suspension, versetzte sie mit 5 ml 0.22 n $_{CaCl_2}$-Lösung, so dass sie dann in bezug auf $CaCl_2$ 0.02 n war, schüttelte aufs neue 1 Stunde und mass den $pH_{0.02\ n\ CaCl_2}$-Wert. Auf diese Weise wurden 58 verschiedene Bodenproben untersucht. Die Ergebnisse über die Böden

Tabelle 2. Die H-, S- und T-Werte der Kalkungsversuchsböden, bestimmt nach den hier benutzten Methoden, sowie die nach den H-Zahlen der Extrapolationsmethode bei gekalkten Bodensuspensionen erhaltenen pH-Werte in 0.02 n $CaCl_2$ nach Einwirkung von viermal 24 St.

Taulukko 2. Kalkituskoemaiden H-, S- ja T-arvot määritettyinä tässä käytetyillä menetelmillä sekä ekstrapolointimenetelmän H-arvojen mukaan kalkittujen maasuspensioiden pH-arvot 0.02 n $CaCl_2$:ssa neljän vuorokauden vaikutuksen jälkeen

Bodenart und Ortschaft *Maalaji ja paikkakunta*	Volumgewicht *Tilavuuspaino*	$CaCO_3$ tn/ha	pH 0.02 n $CaCl_2$ susp. 1 : 2.5 zu Beginn *alussa*	Austb. Wasserstoff, H-Werte *Vaiht. vety, H-arvot*		Austb. Basen, S-Werte *Vaiht. emäkset S-arvot*			Adsorptionsvermögen der Kationen, T-Werte *Kationien pidätyskyky, T-arvot*		Zugesetzt *Lisätty* $CaCO_3$ mg/20 ml Boden *maata*	pH der Suspension nach 96 St *Suspension pH mitattuna 4 vrk:n kuluttua*
				Extrap. auf pH: 7.00 *Ekstrap. pH: 7.00-ään*	Johansson	Titrimetrisch *Titrimetrinen*	Johansson	Ca + Mg + K + Na	Extrap. + titrim. *Ekstrap. + titrim.*	Johansson		
				mval/l Boden — *mval/l maata*								
1	2	3	4	5	6	7	8	9	10	11	12	13
Feinsand		0	3.82	145	71	24	16	50	169	87	145	6.34
Ht	1.24	4	4.71	72	69	75	19	67	147	88	72	6.30
		8	5.12	58	57	115	35	113	173	92	58	6.27
Himanka		12	5.45	47	55	160	49	146	207	104	47	6.32
Gyttjaton		0	4.03	148	113	43	29	38	191	142	148	6.25
LjS	0.82	4	4.31	135	112	73	46	63	208	158	135	6.33
		8	4.57	124	111	88	62	82	212	173	124	6.40
Nakkila		12	4.80	96	96	99	68	93	195	164	96	6.40
Sandiger		0	4.68	108	118	126	120	118	234	238	108	6.45
Ton		4	4.75	100	101	134	127	120	234	228	100	6.50
HtS	1.09	8	4.98	84	83	137	131	125	221	214	84	6.57
		16	5.50	71	78	182	157	164	253	235	71	6.68
Tikkurila		32	5.95	55	73	226	191	198	281	264	55	6.78

dreier Kalkungsversuche sind in Tabelle 2 dargestellt. Aus ihr geht hervor, dass die wechselnden $pH_{0.02\ n\ CaCl_2}$-Werte der verschiedenen Glieder desselben Versuchs (Spalte 4) alle auf etwa 6.4 steigen. Dies lässt sich dadurch erklären, dass das pH der $CaCO_3$-haltigen Bodensuspension anfangs über 7.00 liegt, wobei auch der Wasserstoff der schwach dissoziierenden Säuregruppen einen Teil des zugeführten Kalkes neutralisiert. Zu annähernd gleichen Ergebnissen ist man auch bei allen anderen in diese Kontrolluntersuchung einbezogenen Böden gekommen.

Das Bestimmen des austauschbaren Wasserstoffes in der Praxis kann etwa auf folgende Weise vor sich gehen: nach Messung der elektrolytischen Leitfähigkeit und des pH_{H_2O}-Wertes in der Fruchtbarkeitsanalyse kann man der Bodensuspension (25 ml Boden und 62.5 ml Wasser) z.B. 5 ml 0.27 n $CaCl_2$-Lösung zusetzen, so dass sie 0.02 n in bezug. auf $CaCl_2$ wird, 1 Stunde schütteln und $pH_{0.02\ n\ CaCl_2}$ messen. Jetzt wird entweder 0.1 n NaOH, 0.02 n $CaCl_2$-Lösung oder festes $CaCO_3$ in solcher Menge zugesetzt, dass das Gleichgewichts-pH in der Suspension nach viermal 24 St fast 5.5 wäre, woraus man dann durch geradlinige Extrapolation auf den pH-Wert 7.00 den theoretischen Wert für den austauschbaren Wasserstoff erhält. Annäherungsweise ist auf Grund des beschränkten Materials der vorliegenden Untersuchung berechnet worden, dass, um den pH_{CaCl_2}-Wert des Bodens auf eine Einheit zu steigern, der Suspension 0.8 mval Basen zuzusetzen sind, wenn sein Volumgewicht grösser als 1.5 ist, 1.3 mval, wenn es zwischen 0.8 und 1.5 liegt, und 1.8 mval, wenn es unter 0.8 fällt. Nach dem Basenzusatz gibt man in die Mischung 5 Tropfen Toluen, lässt sie 4mal 24 St bei zeitweiligem Mischen stehen, misst pH und berechnet durch Extrapolieren die Menge des austauschbaren Wasserstoffes. Dies sind nur Richtwerte, und sie sind zu prüfen, wenn mehr Material zusammenkommt.

Schlussfolgerungen

Um den austauschbaren Wasserstoff, die austauschbare Basen des Bodens und ihre Summe für die Praxis zu bestimmen, kann auf Grund dieser Untersuchung eine der drei folgenden Methoden vorgeschlagen werden:

Den $pH_{0.02\ n\ CaCl_2}$-Wert des Bodens braucht man bei allen dargestellten Verfahrensweisen, und er kann für dieselbe Bodensuspension bestimmt werden, bei der zuvor der pH_{H_2O}-Wert gemessen worden ist, wenn so verfahren wird, wie es oben beschrieben worden ist.

1. Nach Messung dieses pH_{CaCl_2}-Wertes wird der Bodensuspension die auf die früher beschriebene Weise bewertete geeignete Basenmenge entweder in Form von kalziumchloridhaltiger NaOH-Lösung oder von trockenem $CaCO_3$ und etwas Toluen zugesetzt. Nach viertägigem Ausbalancieren wird das pH der Suspension aufs neue gemessen. Unter Anwendung der vor dem Zuführen der Base und danach erhaltenen pH_{CaCl_2}-Werte sowie der Menge der zur Suspension hinzugefügten Base (mval/1 Boden) ergibt sich durch geradlinige Extrapolation für den Stand pH = 7.00 die Basenmenge, die theoretisch für das Neutralisieren des Bodens zu verwenden wäre und die der Menge des austauschbaren Wasserstoffes oder dem H-Wert entspricht. Bei Extrapolieren auf den Stand von pH = 3.00 lässt sich die Menge der austauschbaren Basen oder der S-Wert annähernd ermitteln.

2. Ausser den nach der Fruchtbarkeitsmethode bestimmten Kalzium- und Kaliummengen wird aus der Azetatlösung noch das Magnesium entweder titrimetrisch oder atomabsorptionsflammenphotometrisch mengenmässig festgelegt. Natrium ist im Boden wenig vorhanden, und es bleibt ausser acht. Das mval der Summe (Ca + K + Mg) je Liter Boden ist ungefähr gleich gross wie die Menge der austauschbaren Basen des Bodens oder sein S-Wert. Durch Ansetzen dieser Summe links von der Ordinate des Diagrammes in der Höhe von pH = 3.00 und durch Abtragen des $pH_{0.02\ n\ CaCl_2}$-Wertes auf der Ordinate ergibt sich durch geradlinige Extrapolation auf das Niveau pH 7.00 die Menge des austauschbaren Wasserstoffes oder der H-Wert.

3. Austauschbare Basen lassen sich auch auf die angeführte titrimetrische Weise dadurch bestimmen, dass der Boden mit 0.01 n Salzsäurelösung behandelt wird, wobei sich der ungefähre S-Wert ergibt. Die Menge des austauschbaren Wasserstoffes oder der H-Wert wird auch durch Extrapolieren wie in Fall 2 ermittelt.

Bewertet man nach dem austauschbaren Wasserstoff des Bodens seinen Kalkbedarf, so sind natürlich auch die chemische Zusammensetzung des Kalksteins und seine Struktur zu berücksichtigen.

LITERATUR

Henriksen, A. 1964. Om danske landbrugsjorders magnesiumtilstand og afgrødernes magnesiumforsyning. Summary: On the magnesium status of danish agricultural soils and the magnesium supply of crops. Tidsskr. Planteavl 67: 733—783.

Johansson, A. 1961. Cobalt — an expedient agent in soil testing for T, S and exchangeable Ca, Mg and Mn. Soil Sci. 91: 364—368.

Keränen, T. 1966. Das Bewerten des Kalkbedarfs durch pH-Messung von NH_4-Azetatsuspension des Bodens. Selostus: Kalkintarpeen arvioiminen maan NH_4-asetaattilietoksen pH-mittauksella. Ann. Agric. Fenn. 5: 225—236.

Mäkitie, O. 1965. On determination of lime requirement of soils. Selostus: Maan kalkitustarpeen määrittämisestä. Ibid. 4: 238—252.

Salonen, M. 1952. Vaihtuvien emästen ja vaihtuvan vedyn kokonaismäärien käytöstä maan kalkintarpeen arvioimisessa. Summary: On the use of exchangeable hydrogen and the sum of exchangeable bases at determining the lime requirement of soil. Maatal.tiet. Aikak. 24: 135—144.

— Tainio, A. 1956. Savimaan lannoitusta koskevia tutkimuksia. Summary: Investigations concerning the manuring and fertilizing of clay soil. Valt. Maatal.koetoim. Julk. 146: 1—86.

Teräsvuori, A. 1959. Über das Bestimmen der Kationensorptionskapazität und des Basensättigungsgrades des Bodens. Selostus: Maan kationienpidätyskyvyn ja emäskyllästysasteen määrittämisestä. Ibid. 175: 1—80.

Valmari, J. 1921. Beiträge zur chemischen Bodenanalyse. Acta For. Fenn. 20. Sonderdr. 67 p.

Vuorinen, J. & Mäkitie, O. 1955. The method of soil testing in use in Finland. Selostus: Viljavuustutkimuksen analyysimenetelmästä. Agrogeol. Julk. 63: 1—44.

SELOSTUS

Maan vaihtuvien emästen ja vaihtuvan vedyn sekä niiden summan määrittämisestä

Eugen Barkoff

Maatalouden tutkimuskeskus, Maanviljelyskemian ja -fysiikan laitos, Tikkurila

Tutkimuksessa on kehitetty maan vaihtuvan vedyn määrittämiseksi ekstrapolointimenetelmä, joka perustuu Teräsvuoren (1959) esittämään ns. »maan suoran» hyväksi käyttämiseen.

Tutkimuksessa on vertailtu keskenään (taul. 1):

1. Vaihtuvan vedyn määriä, jotka on saatu a) esitetyllä uudella menetelmällä ja b) Johanssonin (1961) esittämällä kobolttimenetelmällä.
2. Vaihtuvien emästen summia eli ns. S-arvoja määritettyinä a) titraamalla (Valmari 1921, Salonen ja Tainio 1956), b) edellä mainitulla kobolttimenetelmällä ja c) laskemalla happamalla ammoniumasetaatilla saatujen kationien summa (Ca + Mg + K + Na).
3. Maan koko kationien pidätyskykyjä eli ns. T-arvoja, jotka on saatu a) laskemalla yhteen uudella menetelmällä saatu vaihtuvan vedyn määrä ja titraamalla saatu vaihtuvien emästen summa, sekä b) kobolttimenetelmällä.

Taulukon 1 lisäksi esitetään kobolttimenetelmällä saatuja tuloksia kuvassa 1 ja uudella menetelmällä saatuja kuvassa 2. Taulukossa 2 on vertailtu menetelmien käyttökelpoisuutta soveltamalla niitä kalkituskoekentistä otettuihin maanäytteisiin.

Maan vaihtuvien emästen ja vaihtuvan vedyn sekä niiden summan määrittämiseksi käytännön tarpeita varten esitetään seuraavat vaihtoehdot:

1. Maalietteeseen lisätään sen kalsiumkloridiliuoksessa mitatun pH-arvon ja tilavuuspainon mukaan arvioitu määrä emästä (joko kalsiumkloridipitoista natriumhydroksidia tai kuivaa kalsiumkarbonaattia). Neljän vuorokauden vaikutusajan jälkeen mitataan pH-luku uudestaan. Asettamalla saadut kaksi pH-lukua akselistolle lisätyn emäsmäärän (mval/l maata) huomioon ottaen saadaan suoraviivaisesti ekstrapoloimalla se pH 7:n emäsmäärä, joka teoreettisesti kuluisi maan neutraloimiseen ja joka siis vastaa vaihtuvan vedyn määrää. Ekstrapoloimalla suoraviivaisesti pH 3:n tasolle saadaan likimääräinen emästen määrä eli S-arvo.
2. Ammoniumasetaattimenetelmässä määritetään kalsiumin ja kaliumin lisäksi myös magnesium (natriumia on yleensä niin vähän, että se voidaan jättää huomiotta). Summa Ca + K + Mg (mval/l maata) on hyvin lähellä koko vaihtuvien emästen summaa eli S-arvoa. Kun tämä arvo asetetaan akselistossa ordinaatasta vasemmalle pH 3:n tasolle ja vedetään siitä suora ordinaatalle asetetun maan kalsiumkloridiliuoksessa mitatun pH-arvon kautta, saadaan suoraviivaisella ekstrapoloinnilla pH 7:n tasolle maan vaihtuvan vedyn määrä.
3. Vaihtuvien emästen summa saadaan myös titraamalla 0.01 n suolahappoliuoksella saatu uute. Sitä voidaan soveltaa kuten eri emäskationien summaa vaihtoehdossa 2.

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Seria HORTICULTURA N. 10 — Sarja PUUTARHANVILJELY n:o 10

TALVEN 1965—66 AIHEUTTAMAT VAURIOT HEDELMÄTARHOISSA

Summary: **Injuries in Finnish orchards caused by winter 1965—66**

JAAKKO SÄKÖ ja TAPANI PESSALA

Maatalouden tutkimuskeskus, Puutarhantutkimuslaitos, Piikkiö

Saapunut 23. 11. 1966

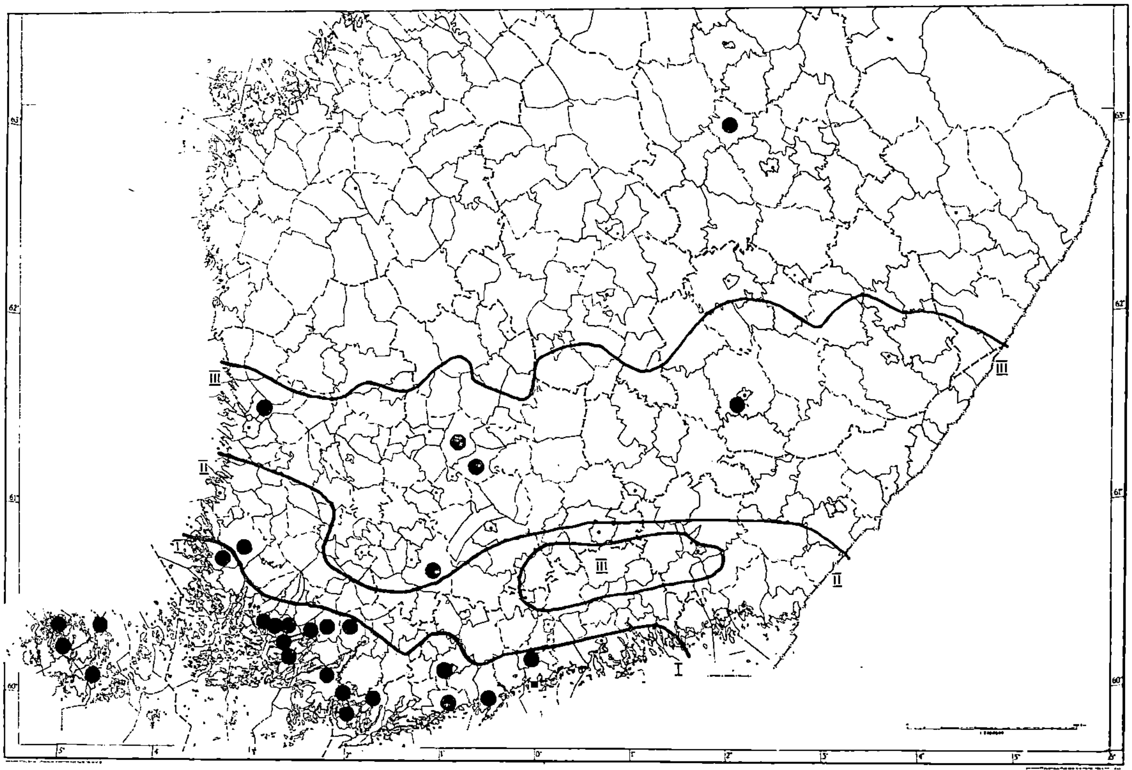
Talvi 1965—66 oli poikkeuksellisen ankara. Sen aikana mitattiin eri puolilla Suomea uusia, jopa vuosisadankin pakkasennätyksiä. Tällainen talvi aiheutti luonnollisesti myös hedelmätarhoissa suuria pakkasvaurioita. Hedelmäpuuaineiston vaurioitumisen ja menetyksen lisäksi olivat seurauksena myös varsin suuret sadonalennukset kasvukaudella 1966.

Vaurioiden laajuuden ja merkityksen selvittämiseksi lähettivät Puutarhantutkimuslaitos ja Hedelmänviljelijäin yhdistys tiedustelun viljelijöille. Tiedustelu osoitettiin vain suurimpiin hedelmätarhoihin. Vastauksia saatiin 39 viljelijältä. Tähän lukuun sisältyvät tiedot myös kuudesta ahvenanmaalaisesta viljelyksestä. Vastauksia antaneiden hedelmätarhojen koko vaihteli suuresti. Puiden lukumäärä hedelmätarhaa kohti oli keskimäärin 2 257 kpl; pienimmässä tarhassa ilmoitettiin puuluvuksi 331. Kaikkiaan saatiin hyväksyttävät tiedot 80 690 omenapuusta ja 1 027 luumupuusta.

Tiedustelulomakkeissa pyydettiin tietoja eri hedelmäpuulajien ja lajikkeiden terveinä säilyneiden sekä vaurioituneiden ja kuolleiden puiden määristä erikseen alle 5-vuotiaista ja sitä vanhemmista puista. Lisäksi pyydettiin tietoja perusrungoista, hedelmätarhan maanlaadusta, maaston viettävyydestä, maanpinnan hoitotavasta hedelmätarhassa sekä tuulensuojasta ja talvea edeltäneen kasvukauden lannoituksesta. Kaikista viimeksi mainituista seikoista ei kuitenkaan saatu niin selviä ja yhtenäisiä tietoja, että niitä olisi voitu koota yhteen ja käsitellä tilastollisesti. Seuraavassa selvitetään talvivauriotiedustelun antamia tuloksia. Sitä ennen luodaan kuitenkin katsaus sääoloihin talvella 1965—66.

Sääolot

Taulukossa 1 esitetään tietoja talven 1965—66 lämpöoloista muutamilla paikkakunnilla. Nämä paikkakunnat on valittu siten, että ne edustavat alueita, joista tietoja on saatu. Lounais-Suomessa esiintyi jo marraskuun puolivälissä poikkeuksellisen alhaisia lämpötiloja. Marraskuun keskilämpötila olikin huomattavasti normaalia kylmempi. Maarianhaminassa, Turussa ja Lohjalla mitattiin sen aikana —22° ja —23°C:n pakkasia, jotka ovat tässä vaiheessa harvinaisia näillä paikkakunnilla. Joulu-, tammi- ja helmikuun aikana jatkuivat erittäin kovat pakkaset. Talven alhaisimmat lämpötilat mitattiin helmikuun alkupuolella. Näiden kuukausien keskilämpötilat olivat Etelä-Suomessa paljon normaalia alhaisempia. Maaliskuun lämpöolot sen sijaan olivat lähes normaalit, mutta huhtikuu oli jälleen normaalia kylmempi.



Kuva 1. Paikkakunnat, joista saatiin vastauksia hedelmäpuiden talvehtimistiedusteluun 1966.
Fig. 1. Localities, from which replies were received for the questionnaire of fruit tree hibernation in 1966.

Taulukko 1. Kuukauden keski-, normaali- ja minimilämpötilat syyskuusta huhtikuuhun 1965—66 eräillä paikkakunnilla.
Table 1. Monthly mean, normal and minimum temperatures from September 1965 to April 1966 in certain localities

1966	Syyskuu *September*	Norm. — *Normal*	Min. — *Min.*	Lokakuu *October*	Norm. — *Normal*	Min. — *Min.*	Marraskuu *November*	Norm. — *Normal*	Min. — *Min.*	Joulukuu *December*	Norm. — *Normal*	Min. — *Min.*
Maarianhamina	12.7	11.4		7.1	6.5		—1.3	2.8	—22	—2.8	0.0	—26
Turku	12.6	10.6		6.2	5.2		—4.2	0.9	—23	—4.6	—2.7	—16
Lohja	12.7	10.9		6.4	5.5		—4.0	1.1	—23	—3.6	—2.5	—16
Tikkurila	12.5	10.4		5.4	5.1		—4.1	0.7	—25	—3.2	—2.6	—20
Pälkäne	12.0	10.4		5.2	4.4		—5.3	—0.2	—23	—6.1	—4.1	—24
Mikkeli	11.2	9.4		4.1	3.6		—6.7	—1.1	—27	—5.7	—5.4	—23
1965	Tammikuu *January*			Helmikuu *February*			Maaliskuu *March*			Huhtikuu *April*		
Maarianhamina	— 9.0	—3.1	—30	—12.7	—4.2	—34	—2.7	—2.3	—25	—0.6	2.6	—15
Turku	—11.7	—6.0	—32	—13.5	—6.6	—37	—2.7	—3.6	—24	0.2	2.2	—12
Lohja	—13.0	—6.2	—32	—13.5	—6.7	—38	—2.4	—3.5	—24	0.2	2.7	18
Tikkurila	—13.9	—6.5	—35	—13.5	—7.1	—39	—2.4	—3.6	—27	—0.1	2.9	—23
Pälkäne	—14.4	—7.8	—30	—15.1	—7.9	—40	—4.0	—4.3	—26	—0.5	2.0	—15
Mikkeli	—17.7	—9.1	—35	—16.5	—9.2	—40	—5.0	—5.3	—31	—0.8	1.8	—23

Taulukko 2. Omenapuiden talvehtimisvauriot talven 1965—66 johdosta eri hedelmätarhoissa.

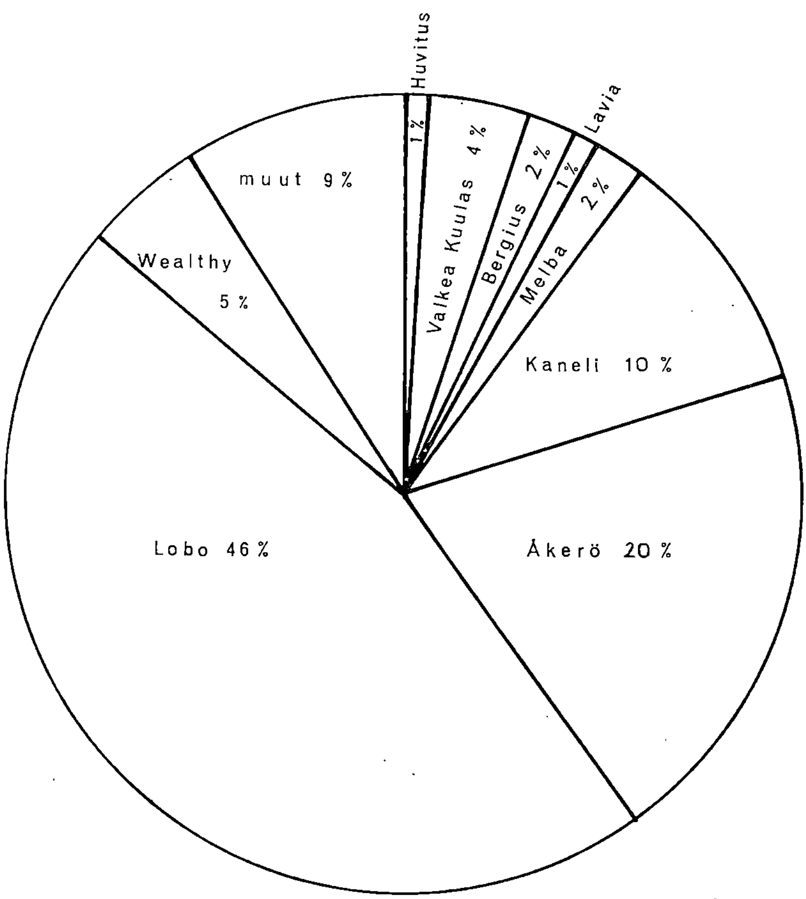
Table 2. Winter injuries on various apple farms in 1965—66

Alue ja tarhan n:o *Region and order of farms*	Puita yht. kpl *Number of trees*	Alle 5-v. *Trees under 5 years*	Voim. vaur. ja kuoll. puut *Seriously damaged and dead trees*
A Ahvenanmaa — *Aland islands*			
1.	743	28	11
2.	3 542	25	14
3.	366	92	22
4.	491	28	28
5.	342	47	30
6.	331	39	47
B Varsinais-Suomen rannikko ja Uudenmaan läntinen rannikko			
1.	5 840	14	1
2.	1 553	86	1
3.	1 704	35	5
4.	506	7	7
5.	1 740	28	9
6.	2 280	—	10
7.	1 920	19	11
8.	764	75	15
9.	675	58	16
10.	13 350	22	17
11.	2 045	28	18
12.	1 250	60	26
13.	894	9	31
14.	3 560	60	32
15.	3 345	32	38
16.	1 434	21	39
17.	1 054	57	57
18.	1 350	22	62
19.	1 072	79	62
C Lohjan seutu			
1.	7 335	100	1
2.	983	59	12
3.	1 044	—	24
4.	4 120	39	25
5.	1 651	66	37
6.	2 700	100	46
D Muu Suomi			
1. Uusimaa	2 005	—	4
2. Etelä-Savo	71	—	6
3. Etelä-Häme	523	—	9
4. Pohjois-Häme	549	25	13
5. » »	3 704	49	20
6. Satakunta	3 754	59	69

Lunta oli Etelä-Suomessakin erittäin runsaasti joulukuun puolivälistä maaliskuun loppuun. Helmi—maaliskuussa oli lumipeitteen paksuus paikoitellen maan lounais-osissakin yli 80 cm. Marraskuun kovissa pakkasissa, jolloin lunta ei vielä ollut, maa routaantui verrattain syvään. Niinpä Puutarhantutkimuslaitoksen hedelmätarhassa oli roudan syvyys koko talven 40—50 cm.

Tiedustelun tulokset

Tiedustelun vastaukset on ryhmitelty alueittain seuraavasti: A Ahvenanmaa, B Varsinais-Suomen rannikko ja Uudenmaan läntinen rannikko, C Lohjan seutu ja D muu Suomi. Taulukossa 2 esitetään talvehtimistietoja eri alueiden hedelmätarhoista. Tarhat, joista ilmoitetaan omenapuiden luku sekä alle 5-vuotiaiden puiden osuus koko



Kuva 2. Omenapuiden lajikekoostumus I-hedelmänviljelyvyöhykkeellä 1966 tiedusteluaineiston perusteella.
Fig. 2. The proportion of different varieties in apple tree stand in 1st fruit farming zone 1966 according collected data. muut = other varieties.

puustosta, on numeroitu siinä järjestyksessä mitä vähemmän niissä on todettu vaurioita. Vaurioituneiden puiden joukkoon ei ole luettu myyrien vioittamia puita. Voimakkaasti vaurioituneet ja kuolleet puut on laskettu yhteen. Puu on katsottu voimakkaasti vaurioituneeksi silloin, kun sen latvuksesta on paleltunut 25 % tai enemmän. Tavallisesti tällaiset puut ovat jo menetettyjä, sillä ne menehtyivät yleensä myöhemmin runkovikoihin.

Vaurioiden määrä on ollut eri hedelmätarhoissa varsin erilainen. Niinpä Varsinais-Suomen rannikon ja Uudenmaan läntisen rannikon tietoja antaneissa 19:ssä hedelmätarhassa voimakkaasti vaurioituneiden ja kuolleiden omenapuiden määrä vaihteli 1—62 %:iin. Nämä eroavuudet eivät johtune ainakaan pääasiallisesti tarhojen lajikekoostumuksen eroista, sillä lajikkeisto on käsittänyt valtaosaltaan vakiolajikkeita; niistä Lobon ja Åkerön osuus on ollut keskimäärin kaksi kolmannesta koko puumäärästä. I-hedelmänviljelyvyöhykkeen tarhoista saaduissa tiedoissa vakiolajikkeet käsittivät 86 % puustosta (kuva 2).

Esimerkkinä erilaisesta talvehtimisesta mainittakoon B-alueen tarhat 1 ja 17. Ne sijaitsevat n. 3 km:n päässä toisistaan. Ensiksi mainitun tarhan omenapuista vaurioitui voimakkaasti tai kuoli vain 1 %, kun taas jälkimmäisessä tarhassa vastaava prosenttiluku oli 57. Molemmissa tarhoissa oli päälajikkeena Lobo. Tarhassa 1 olivat vauriot senkin osalta vain 1 %. Sen sijaan tarhassa 17 Lobo-puista vaurioitui voimakkaasti tai kuoli

Taulukko 3. Hedelmäpuiden talvehtiminen manner-Suomessa 1965—66
Table 3. Data on the hibernation of fruit trees on the mainland in 1965—66

Lajike *Variety*	Puita yht. kpl *Number of trees*	Alle 5-v. *Trees under 5 years* %	Terveitä *Sound* %	Vaurioituneita *Injured* liev. *sligth* %	voim. *serious* %	Kuolleita *Dead* %	Kuinka monessa tarhassa lajike esiintynyt *Number of farms*
OMENAPUUT — APPLE TREES							
Vakiolajikkeet - *Standard varieties*							
Huvitus	755	48	93	6	0.4	0.1	12/32
Valkea kuulas — *Transparente bl.*	2 997	40	59	29	8	4	30
Bergius	1 464	21	65	10	13	12	23
Lavia	544	38	86	3	4	7	12
Melba	1 512	18	79	13	3	5	24
Kaneli	7 840	21	91	5	2	2	30
Åkerö	14 878	46	47	35	12	6	29
Lobo	34 131	55	51	19	18	12	30
Vakiolajikkeet - *Standard varieties* yht./keskim. — *Total/Average*	64 121	46	57	21	13	9	
Muut lajikkeet — *Other varieties*							
Antonovka	1 616	12	89	7	2	2	13/32
Wealthy	3 545	0	70	10	8	12	16
Muut	5 593	32	64	15	8	13	25
Muut lajikkeet — *Other varieties* yht./keskim. — *Total/Average*	10 754	19	70	12	7	11	
Koko omenapuuaineisto — *All apple trees*	74 875	42	59	20	12	9	
LUUMUPUUT — PLUM TREES	988	43	31	10	33	26	11/32

Myyrien vaurioittamia puita 5 880 kpl. — *Mice injured 5 880 trees*

67 %. Molemmat tarhat sijaitsevat meren lähettyvillä. Erilaiseen talvehtimistulokseen ovat tässä tapauksessa ilmeisesti vaikuttaneet tarhojen lähiilmastojen eroavuudet. Heikommin menestynyt tarha sijaitsee maaston painumassa, johon kylmä ilma pysähtyy. Toisen tarhan kohdalla kylmä ilma pääsee valumaan pois paikalta.

Myös Lohjan seudun hedelmätarhoissa talvehtimistulokset vaihtelivat suuresti. Esim. tarhojen 1 ja 6 talvehtiminen oli hyvin erilaista. Kummassakin on valtalajikkeena Lobo. Ensiksi mainitussa tarhassa Lobo-puista vaurioitui voimakkaasti tai kuoli 0.6 % ja jälkimmäisessä 78 %. Heikommin menestyneessä tarhassa maa on jäykempää ja tuulensuoja huonompi kuin paremmin menestyneessä.

Talvi 1965—66 oli Ahvenanmaallakin poikkeuksellisen ankara ja mannermainen, koska Itämeri oli sen ympärillä yhtenäisenä jääkenttänä. Hedelmätarhojen talvehtimisvauriot olivat sielläkin huomattavan suuret. Tähän oli kuitenkin suurelta osalta syynä se, että Ahvenanmaan hedelmätarhojen puusto käsittää myös melko arkoja lajikkeita (taul. 4). Vaurioita esiintyi eniten niissä tarhoissa, jotka sijaitsevat alavilla sekä tuulelta suojaamattomilla paikoilla.

Voimakkaimmat vauriot ko. aineiston piirissä ilmenivät eräässä satakuntalaisessa hedelmätarhassa, jonka puista kuoli tai vaurioitui voimakkaasti 69 %. Myönteisenä yllätyksenä taas voidaan pitää Etelä-Savon koeaseman hedelmätarhaa Mikkelissä (muu Suomi n:o 2), jonka menetykset olivat vain 6 %. Tämä tarha sijaitsee loivasti kaakkoon viettävässä rinteessä. Esim. Lobo, Melba ja Valkea kuulas selviytyivät siellä hyvin.

Eri lajikkeiden menestyminen

Taulukoissa 3 ja 4 esitetään tietoja eri omenalajikkeiden talvehtimisesta erikseen manner-Suomessa ja Ahvenanmaalla. Manner-Suomea koskevasta omenapuiden määrästä on 88 % peräi-

Taulukko 4. Omena- ja luumupuiden talvehtiminen Ahvenanmaalla 1965—66

Table 4. Data on the hibernation of apple and plum trees in the Aland islands in 1965—66

Lajike *Variety*	Puita yht. kpl *Number of trees*	Alle 5-v. *Trees under 5 years* %	Terveitä *Sound* %	Vaurioituneita *Injured* *sligth* %	*serious* %	Kuolleita *Dead* %	Kuinka monessa tarhassa lajike esiintynyt *Number of farms*
OMENAPUUT — APPLE TREES							
Vakiolajikkeet - *Standard varieties*							
Valkea kuulas — *Transparente bl.*	170	0	96	3	0	1	5/6
Bergius	13	31	100	0	0	0	2
Melba	4	0	100	0	0	0	1
Kaneli	1	0	100	0	0	0	1
Åkerö	500	2	95	2	2	1	6
Lobo	2 740	53	80	6	5	9	6
Cox's Pomona	847	19	80	10	6	4	6
Ingrid Marie	286	60	9	6	20	65	6
Vakiolajikkeet - *Standard varieties* yht./keskim. — *Total/Average*	4 561	40	78	6	5	11	
Muut lajikkeet — *Other varieties*							
Cellini	302	0	72	17	6	5	2/6
Signe Tillisch	186	0	31	21	42	6	5
Filippa	150	0	29	67	3	1	5
Linda	145	3	78	7	8	7	5
Wealthy	131	0	87	9	4	0	3
James Grieve	129	3	17	0	17	66	4
Alice	50	100	100	0	0	0	1
Rupert	43	0	88	12	0	0	2
Stenkyrke	33	0	43	33	15	9	3
Gravenstein	31	0	0	0	0	100	3
Muut (9 lajik.)	54	20	48	22	30	0	5
Muut lajikkeet — *Other varieties* yht./keskim. — *Total/Average*	1 254	6	55	19	13	13	
Koko omenapuuaineisto — *All apple trees*	5 815	32	73	9	7	11	
LUUMUPUUT — PLUM TREES	39	0	0	38	62	0	3/6

Taulukko 5. Talvehtimisvauriot alle 5-vuotiaissa ja sitä vanhemmissa omenapuissa

Table 5. Winter injuries of under 5 years-old and older apple trees

Tiedot I-hedelmänviljelyvyöhykkeeltä — *Data from 1st fruit farming zone*

a = alle 5-vuotiaat puut — *trees under 5 years*

b = 5 v. ja sitä vanhemmat puut — *5 year-old and older trees*

Lajike *Variety*	Puita yht. kpl *Number of trees*	Alle 5-v. *Trees under 5 years* %	Voimakkaasti vaurioituneet tai kuolleet puut *Badly injured or dead trees* % a	b
Huvitus	567	55	0	0
Valkea kuulas — *Transparente bl.*	2 194	32	16	14
Bergius	1 180	18	0	24
Lavia	386	25	0	12
Melba	1 354	19	3	10
Kaneli	5 601	24	4	5
Åkerö	10 589	41	5	17
Lobo	24 686	49	40	10

Taulukko 6. Omenapuulajikkeiden talvehtiminen I-hedelmänviljelyvyöhykkeellä sekä Ahvenanmaalla kerättyjen tietojen perusteella

Table 6. Hibernation of apple tree varieties in 1st fruit farming zone and Aland islands on the basis of collected data

+ + + = hyvin talvehtineet — *well hibernated*
+ + = kohtalaisesti talvehtineet—*moderately hibernated*
+ = heikonlaisesti talvehtineet — *poorly hibernated*
— = huonosti talvehtineet — *badly hibernated*

I-hedelmänviljelyvyöhyke
1st fruit farming zone

		Pisteitä *Points*
Vakiolajikkeet — *Standard varieties*		
Huvitus	+ + +	299
Valkea kuulas — *Transparente bl.*	+ +	239
Bergius	+ +	238
Lavia	+ +	270
Melba	+ +	267
Kaneli	+ + +	284
Åkerö	+ +	234
Lobo	+	214
Muut lajikkeet — *Other varieties*		
Alice	+	192
Antonovka	+ + +	281
Atlas	+ + +	275
Cellini	—	83
Charlottenthal	+ +	234
Cox's Pomona	+ +	257
Filippa	—	16
Gyllenkrok	+ +	246
Joyce	—	100
Kesto	+ + +	285
Kirkniemen talvi	+ + +	300
Lantun talvi	+ + +	300
Linda	—	83
Linnan omena	+ + +	300
Rupert	+ + +	300
Sariola	+ + +	291
Snygg	+ + +	300
Syysjuovikas	+ +	232
Särsö	+	218
Valkealan syys	+ + +	300
Valkea Nalif	+ + +	279
Wealthy	+ +	239
Williams	+ + +	300

Ahvenanmaa
Aland islands

		Pisteitä *Points*
Vakiolajikkeet — *Standard varieties*		
Valkea kuulas — *Transparente bl.*	+ + +	294
Åkerö	+ + +	291
Lobo	+ +	257
Cox's Pomona	+ +	266
Ingrid Marie	—	59
Muut lajikkeet — *Other varieties*		
Alice	+ + +	300
Cellini	+ +	256
Filippa	+ +	226
Gravenstein	—	0
James Grieve	—	68
Linda	+ +	256
Rupert	+ + +	288
Signe Tillisch	+	177
Stenkyrke	+	210
Wealthy	+ + +	283

Huom. Pisteet on laskettu kertomalla terveiden puiden %-luku 3:lla, lievästi vaurioituneiden 2:lla, voimakkaasti vaurioituneiden 1:llä, ja laskettu tulojen summa.

Note. The points are counted by multiplying the per cent figure of sound trees by 3, that of slightly injured by 2 and seriously injured by 1, and put together.

Tällöin 300—275 = + + +
Then 274—225 = + +
224—125 = +
124— 0 = —

sin I-hedelmänviljelyvyöhykkeeltä. Huvitus, Kaneli, Antonovka, Lavia ja Melba selviytyivät talvesta erittäin hyvin, kun taas Lobo, Bergius, Åkerö ja Wealthy kärsivät melko suuria vaurioita. Lobo-puista 30 % vaurioitui voimakkaasti tai kuoli. Vastaava prosenttiluku oli kaikkien vakiolajikkeiden osalta keskim. 22 ja koko omenapuuaineistosta 21. Luumupuista, joita koskeva aineisto käsitti pääasiallisesti Victoria-lajiketta, vaurioitui voimakkaasti tai kuoli yhteensä 59 %.

Omenapuiden suhteen pyrittiin selvittämään erikseen alle 5-vuotiaiden ja sitä vanhempien puiden talvehtimista (taul. 5). I-hedelmänviljelyvyöhykkeeltä saaduista tiedoista ilmeni, että Valkea kuulas- ja Kaneli -lajikkeiden alle 5-vuotiaat ja sitä vanhemmat puut talvehtivat yhtä hyvin. Bergius-, Lavia-, Melba- ja Åkerö -lajikkeiden nuoret puut talvehtivat jonkin verran paremmin kuin vanhemmat. Sitä vastoin Lobon suhteen tilanne oli päinvastainen. Nuorista Lobo-puista nimittäin vaurioitui voimakkaasti ja kuoli neljä kertaa suurempi määrä kuin vanhemmista puista. Nuorien Lobo-puiden onkin yleisesti todettu olevan alttiimpia pakkasvaurioille kuin vanhempien erityisesti silloin, jos kovia pakkasia esiintyy jo marraskuussa.

Ahvenanmaalla omenapuiden vakiolajikkeet talvehtivat suhteellisen pienin vaurioin lukuunottamatta Ingrid Marieta, jonka puista säilyi terveinä vain 9 %. Eniten viljelty lajike Lobo selviytyi Ahvenanmaalla paljon pienemmin vaurioin kuin mannermaalla. Muista lajikkeista Signe Tillisch, Filippa, Stenkyrke, James Grieve ja Gravenstein talvehtivat heikosti. Viimeksi mainittu lajike koki ilmeisesti täydellisen tuhon. Uudesta ruotsalaisesta Alice-lajikkeesta oli kasvamassa vain aivan nuoria puita, jotka talvehtivat lumen suojassa. Puutarhantutkimuslaitoksella Piikkiössä oli vanhempien Alice-puiden talvehtiminen suunnilleen samanlaista kuin Lobo-puiden.

Taulukossa 6 esitetään omenapuulajikkeet jaettuina talvehtimisensa perusteella neljään ryhmään erikseen manner-Suomessa ja Ahvenanmaalla.

Tulosten tarkastelu

Tehtäessä vertailuja muihin hedelmänviljelylle tuhoisiin talviin voidaan todeta, että talven 1965—1966 aiheuttamat vauriot hedelmätarhoissa jäivät huomattavasti pienemmiksi kuin talvella 1939—1940, jolloin hedelmänviljelyn menetykset olivat erittäin suuret (Meurman 1943). Mainittu talvi aiheutti melkoisia vaurioita myös muiden Pohjoismaiden sekä Keski-Euroopan hedelmätarhoissa. Tosin nytkin esiintyi mm. Itä-Norjan hedelmänviljelyksillä huomattavan suuria vaurioita. Kysymyksessä oleva talvi ei myöskään näytä aiheuttaneen Suomessa niin suuria menetyksiä kuin talvi 1955—56 (Säkö 1957). Vaurioiden lopullinen määrä ei tätä kirjoitettaessa ollut kuitenkaan vielä tiedossa, koska puiden runkoviat tulevat selville vasta kasvukaudella 1967 ja pahentavat jonkin verran tilannetta. Pakkasvioitusta esiintyi etenkin niissä osissa runkoa ja niissä oksanhangoissa, jotka olivat keskitalvella juuri lumirajan yläpuolella. Tämä johtui luonnollisesti siitä, että lämpötila on pakkassäällä alimmillaan lähellä lumirajaa. Erityisesti Wealthy- ja Valkea kuulas -puiden rungot ovat olleet alttiita pakkasvioituksille.

Useimpien omenapuulajikkeiden kukkasilmut vioittuivat lukuunottamatta lumen alla olleita oksia. Monissa tarhoissa saatiinkin satoa kasvukaudella 1966 vain tällaisista oksista. Muutamissa parhaiten säilyneissä tarhoissa kehittyi lähes normaali sato, mutta keskimäärin koko maamme omenanviljelyalueella sato lienee jäänyt noin kolmannekseen normaalista. Kukkasilmujen vioittumisen seurauksena on nyt uusien kukkasilmujen runsas kehittyminen sekä jaksoittaissatoisuus, ts. sadon muodostuminen joka toinen vuosi. Tätä haitallista ilmiötä voidaan kuitenkin lieventää ja estää kemiallisella raakileenharvennuksella.

Kasvukaudella 1966 esiintyi omenissa verrattain runsaasti epämuotoisuutta. Sitä ilmeni varsinkin Ahvenanmaan hedelmätarhoissa ja erityisesti Åkerö-omenissa. Hedelmät olivat uurteisia ja harjuisia sekä toispuolisia. On ilmeistä, että tämäkin johtui kukkasilmujen pakkasvaurioista, sillä siemenien määrä ja niiden kehittyminen oli tällaisissa hedelmissä normaali, mikä oli osoituksena siitä, että kukat pölyttyivät normaalisti. Vastaavaa todettiin mm. Norjassa talven 1955—56 jälkeen (Thorsrud 1957).

Tuhojen syitä tarkasteltaessa kiintyi huomio erityisesti marraskuun pakkasiin. Lämpötilan äkillinen ja voimakas aleneminen marraskuussa aiheuttaa yleensä maamme oloissa vaurioita hedelmäpuissa (Säkö 1957). Tässä vaiheessa versot eivät ole ennättäneet vielä riittävästi tuleentua eivätkä puut ole asettuneet lepotilaan. Monet omenapuulajikkeet ja erityisesti tärkein lajikkeemme Lobo ovat erityisen alttiita vioittumaan myöhäissyksyn tai alkutalven pakkasissa. Sen sijaan esim. Huvitus ja Kaneli, joille on ominaista nopea tuleentuminen ja lepotilaan asettuminen syksyllä, kestävät varsin hyvin jo myöhäissyksynkin pakkasia (Säkö 1967). Toisaalta on todettu, että Lobon lepotila jatkuu melko myöhään keväällä, jonka vuoksi se on verrattain kestävä kevättalven pakkasissa. Tämä on käynyt ilmi mm. Puutarhantutkimuslaitoksella laboratorio-olosuhteissa suoritetuissa pakkaskäsittelyissä. Vaikka omenapuut tammi—helmikuussa niiden lepotilan ollessa syvimmillään kestävät melko koviakin pakkasia, saattavat ne tässäkin vaiheessa vioittua varsinkin, jos pakkaskausi on pitkä. Helmikuun alkupuolella 1966 esiintynyt varsin kylmä periodi, jolloin lämpötila useina päivinä laski alle —30°

C:n, aiheutti hedelmäpuissa runkovikoja sekä vioitti kukkasilmuja lumirajan yläpuolella. Sen sijaan lumen alla olleet rungon osat ja oksat säilyivät useimmiten vaurioitta.

Hedelmäpuiden talvehtimisen onnistuminen riippuu ensisijassa viljeltävän kasviaineiston, ts. lajikkeiden ja perusrunkojen kestävyydestä. Käytännössä lajiketta ei luonnollisestikaan voida valita viljelyyn pelkästään sen ilmastonkestävyyden perusteella, vaan valintaan vaikuttavat ratkaisevasti satoisuus sekä hedelmien laatuominaisuudet. Tällaisista omenapuulajikkeista, jotka hyvän talvenkestävyyden lisäksi täyttävät korkeat laatuvaatimukset, on maassamme suuri puute. Se voidaan ilmeisesti poistaa vain oman jalostustoimintamme tuloksilla. Omenapuiden perusrunkoina käytetäänkin maamme hedelmätarhoissa jo yleisesti verrattain ilmastonkestävää aineistoa, kuten suvuttomasti lisättävää A_2 -perusrunkoa sekä kotimaisia siemenperusrunkoja, jotka ovat syrjäyttäneet oloissamme heikosti kestävät Malling-tyypit. Käytetyn kasviaineiston lisäksi myös kasvupaikan olosuhteet sekä viljelyteknilliset toimenpiteet voivat huomattavasti vaikuttaa siihen, miten puut selviytyvät talvista. Käsiteltävänä oleva tiedusteluaineisto sekä aikaisempien tuhotalvien kokemukset osoittavat, että talvehtimisvaurioiden välttämiseksi olisi kiinnitettävä tähänastista paljon suurempaa huomiota hedelmätarhojen paikan valintaan. Hyvin monet maamme hedelmätarhoista on perustettu alaviin maastokohtiin, minne kylmän ilman virtaukset pysähtyvät. Varsinkin tyynellä säällä saattaa lämpötila olla tällaisissa maastokohdissa paljon alhaisempi kuin rinnemailla ja ylävillä paikoilla. Esim. Puutarhantutkimuslaitoksella Piikkiössä mitattiin talvella 1965—66 lähes 10°C:n lämpötilojen eroja lähellä meren pintaa olevan alavan maastokohdan ja n. 10—11 m korkeamman kohdan välillä. Samat omenapuulajikkeet, jotka selviytyivät korkeammalla kasvupaikalla vaurioitta, paleltuivat pahoin mainitussa alavassa maastokohdassa. Myös hedelmätarhan tuulensuojauksen vaikutus puiden talvehtimiseen kävi talven 1965—66 jälkeen monissa tapauksissa erittäin selvästi esille. Tiedusteluaineistosta saatujen tietojen perusteella, jotka koskivat yli 50 000 omenapuuta, keskimäärin 31 % puista vaurioitui pahoin tai kuoli olosuhteissa, joissa tuulensuoja oli heikko. Tuulensuojan ollessa kohtalainen oli vastaava prosenttiluku 20. Sen sijaan hyvin tuulelta suojatuissa hedelmätarhoissa vain 13 % puista vaurioitui pahoin tai kuoli.

Yhteenveto

Ankara talvi 1965—66 aiheutti melkoisia vaurioita maamme hedelmätarhoissa. Puutarhantutkimuslaitos ja Hedelmänviljelijäin yhdistys lähettivät yhteisesti tiedustelun hedelmänviljelijöille vaurioiden laajuuden selvittämiseksi. Tiedot saatiin 80 690 omenapuun ja 1 027 luumupuun talvehtimisesta. Valtaosa tiedoista on peräisin Lounais-Suomen hedelmätarhoista I-hedelmänviljelyvyöhykkeeltä.

Vaurioiden määrä osoittautui erilaiseksi eri hedelmätarhoissa (taul. 2). Tämä johtunee hedelmätarhojen toisistaan poikkeavista kasvuolosuhteista, pääasiallisesti kasvupaikan lämpöoloista. Alavissa maastokohdissa ja maaston painumissa puut talvehtivat heikommin kuin rinteillä ja ylävillä mailla. Myös tuulensuoja vähensi vaurioitumisen vaaraa.

Kyseisen aineiston mukaan manner-Suomessa vaurioitui voimakkaasti tai kuoli vakiolajikkeisiin kuuluvista omenapuista keskimäärin 22 % sekä kaikkien lajikkeiden puista vastaavasti 21 %. Luumupuiden, lähinnä Victoria-lajikkeen vastaavat vauriot olivat 59 %. Eniten viljellyistä omenalajikkeista Huvitus, Kaneli, Antonovka, Lavia ja Melba talvehtivat hyvin. Bergius, Valkea kuulas, Wealthy ja Åkerö menestyivät niitä heikommin. Tärkein omenapuulajikkeemme Lobo kärsi erittäin pahoja vaurioita. Lobo-puista vaurioitui voimakkaasti tai kuoli keskimäärin 30 %. Erityisesti nuoret Lobo-puut olivat alttiita pakkasvaurioille.

Ahvenanmaalla omenapuiden vakiolajikkeet selviytyivät talvesta verrattain pienin vaurioin lukuunottamatta Ingrid Marie -lajiketta. Muita heikosti talvehtivia lajikkeita olivat siellä Filippa, Gravenstein, James Grieve, Signe Tillisch ja Stenkyrke.

Talvenkestävyyden mukaan on omenapuulajikkeet jaettu neljään ryhmään (taul. 6).

KIRJALLISUUTTA

MEURMAN, O. 1943. Omenapuiden ilmastollisesta kestävyydestä. Puutarhavilj. Liiton Julk. 27: 1—8

SÄKÖ, J. 1957. Hedelmänviljelyä kohdanneesta tuhosta v. 1955—56. Maatal.tiet. Aikak. 29: 1—26.

SÄKÖ, J. 1967. Vinterhärdighetsproblem vid fruktodling. Frukt og Baer 1. (Painossa).

THORSRUD, J. 1957. Vinterskaden på epletrea 1955—56. Frukt og Baer 10: 29—35.

SUMMARY

Injuries in Finnish orchards caused by winter 1965—66

JAAKKO SÄKÖ and TAPANI PESSALA

Agricultural Research Centre, Department of Horticulture, Piikkiö, Finland

The exceptionally cold winter 1965—66 caused severe injuries in Finnish orchards. A questionnaire was distributed to fruit farms in oder to obtain an idea of the extent of damage and for getting data of the winter hardiness of different fruit tree varieties. The data was collected from 80 690 apple trees and 1 027 plum trees. These data chiefly originates from South-West Finlands orchards and the Aland islands. This part of the country is climatically most favourable for fruit growing in Finland.

A very great variation was found in the extent of frost injuries between various orchards, even with those situated close by (Table 2). This was mostly due to the micro climatical conditions and the location of the orchards. More injuries were found in orchards on low-lying terrain compared with those on sloping and elevated terrain. The windbrakes were found to effectively reduce the risk of frost injuries.

According to the material mentioned above about 22 per cent of the apple trees of the Finnish standard varieties were badly damaged or killed by the winter on the mainland. If all the commonly grown apple varieties were taken into account the corresponding per cent was 21. The plum trees, as expected, suffered more than apple trees; 59 per cent were seriously damaged or killed. The plums consisted mostly of the variety of Victoria. The commonly grown apple varieties Huvitus, Kaneli, Antonovka, Lavia and Melba hibernated well. On the other hand, Bergius, Transparente Blanche, Wealthy and Åkerö were less hardy. Lobo, the most important apple variety in Finland suffered very serious injuries. About 30 per cent of Lobo trees were badly damaged or killed (Table 3). The young Lobo trees, especially, were susceptible to frost injuries (Table 5).

The apple crop on the Finnish mainland was estimated in 1966 about only one third of the normal. In many cases fruits only developed on the branches covered with snow in winter.

In the Aland islands the standard apple varieties came through the winter with less damage than in the mainlands conditions. Ingrid Marie, however, suffered badly (Table 4). Other varieties with a poor winter hardiness were Filippa, Gravenstein, James Grieve, Signe Tillisch and Stenkyrke.

Table 6 shows the points given the apple varieties relating to the hibernation. The varieties are divided into four hardiness croups.

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THE EFFECT OF RATE OF LEYS AND INTENSITY OF NITROGEN DRESSING IN DIFFERENT CROP ROTATIONS

Results obtained in the years 1958—65 from a rotation trial established at Tikkurila in 1952

MARTTI SALONEN

Agricultural Research Centre, Department of Agricultural Chemistry and Physics, Tikkurila, Finland

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Long-term experience has shown that the cropping system used up to the present in Finland, with its rotation of ley and cereals, is a very suitable method, since when this system is followed no deterioration in the productivity of the soil need occur. In this method of farming, domestic animals play an essential role. If they are eliminated, grass cultivation generally has to be abandoned. Farming then becomes virtually restricted to cereal-growing, and there is reason to doubt whether such a cropping system is any longer of value. This problem is very important in our farming to-day, and thus it was considered necessary to study the factors required for the success of such a ley-free cropping system.

Despite the importance of this matter, relatively few investigations have been carried out on the effect of various cropping methods on the condition and productivity of the soil. It has mostly been necessary to base conclusions on various experiences and deductions. They may, of course, be correct, but there is no quarantee of this.

The need for experimentally determining the influence of different cropping systems on the productivity of the soil was apparently first recognized in the United States. At the end of the last century a number of field experiments on this subject were performed there. The importance of the crop sequence and particularly the inclusion of ley in the sequence became very evident. In recent times the experiments have been complemented by using different levels of nitrogen application, and it has been found that liberal use of fertilizers may eliminate, at least to a great extent, the disadvantages of continuous cropping (e.g. ALLAWAY 1957). However, it was soon noticed that the situation cannot be regulated exclusively by fertilization (LANG 1960).

In recent decades a considerable number of rotation trials have been set up in England, and these trials are up-to-date both from the theoretical standpoint and from the viewpoint of their practical application. As yet the experiments have been in progress for too short a time to provide final information, but it has become evident that the level at which fertilizers are applied is of considerable importance in eliminating the drawbacks of ley-free cultivation (e.g. MANN and BOYD 1958, BOYD, COOKE et al. 1961, BOYD 1966).

AGERBERG (1966) has published a review of the studies pertaining to crop rotation now being carried out in Scandinavia. As for the trials in progress in Norway, UHLEN (1963) has discussed the most important of them. The results obtained indicate that cereals give higher yields in rotations containing leys than in those without leys. The effect of fertilizers in reducing the difference between the two systems will probably become confirmed as the trials are continued.

In Finnish plant husbandry research very little attention has been paid to the question of crop rotation. The trial carried out in the years 1913—26 and described by SIMOLA (1936) does not provide any information on the present problem. It was not until the beginning of the 1950's that a few trials concerned with the effect of rate of ley in the rotation were established. The trial described here is the oldest of them. A preliminary report of the results has already been published (SALONEN 1963).

Design of the rotation trial

Crops. The aim in designing the present trial was to obtain as complete a picture as possible of the effect of including ley in the rotation on the yield level in general and especially on the success of cereals. The inclusion of spring wheat goes without saying under conditions in southern Finland. Rye was selected because winter cereals are desirable crops in the region of dry spring and early summer conditions, in which Tikkurila is also located and winter wheat was considered too uncertain for long-term trials. Rye and spring wheat occur in all the rotations, being the so-called test crops, and they are therefore most suitable for comparison in assessing the trial. In addition, there are the so-called treatment crops, which comprise the differences between the different rotations. Ley is naturally the most important of these, and in the three rotations tested it made up 0 %, 25 % and 50 % of the area (or of the years, which is essentially the same). The latter rate of ley is close to the level generally used in Finland up to now. Replacing ley in the first two rotations was barley, while in the ley-free rotation peas-oats was further included (peas alone was regarded as too uncertain).

By their very nature, rotation trials not only take a long time but also demand much labour. Therefore the sequences chosen were as simple as possible, and consequently of short duration. They are shown below:

	A = no ley	B = 25 % ley	C = 50 % ley
Test crops:	1. rye	rye	rye
	2. spring wheat	spring wheat, undersown with ley	spring wheat, undersown with ley
Treatment crops:	3. peats-oats	1st-years ley	1st-years ley
	4. barley	barley	2nd-year ley

In sowing the various crops, varieties were used which were considered to be the most suitable in the region.

Fertilizer dressings. The design of the trial did not include the application of farmyard manure. Phosphorus and potassium were applied identically to all the rotations. Potassium was given to all the crops at a rate of 200 kg/ha of 50 % potash salt annually. Phosphorus was applied preferentially to rye and spring wheat; these crops received 400 kg/ha annually 19 % superphosphate, while the others were given 200 kg/ha, so that the average annual rate was 300 kg/ha.

The only fertilizer for which the rate of application was varied was nitrogen, since in the case of phosphorus and potassium there was scarcely any justification for trying to economize on them and on the other hand increasing their amounts in excess of the rates required could not be expected to give any appreciable results, at least on soil such as that of the trial field. Nitrogen was applied during all the years of the trial as ammoniumnitrate-limestone mixture containing 25 % nitrogen (finnish Oulu-saltpetre). The rates given since 1958 were as follows (kg/ha):

Rotation				Level 1	Level 2
A	B	C		N_1	N_2
rye	rye	rye	autumn	50	100
»	»	»	spring	100	200
spring wheat	spring wheat	spring wheat		0	100
peas-oats	1st-yr ley	1st-yr ley		0	100
barley	barley	2nd-yr ley		100	200
Total for each rotation, 4 years, 25 % Oulu-salpetre				250	700
» » »	»	» »	pure N	62.5	175
Average per year			» »	15.6	43.8
Difference » »			» »		28.2

In determining the amounts of nitrogen to use in the trial, several different limitations had to be taken into consideration. In order to achieve the aim of the trial, it was necessary to obtain a considerable difference between the two nitrogen levels. But for many reasons the level N_2 could not be raised too high. For instance, owing to the risk of lodging, rye and barley were not given more than 200 kg/ha 25 % nitrogen fertilizer, and secondly, it was essential not to endanger the success of clover by excessive nitrogen applications to the nurse crop and the first-year ley. In order to obtain an adequately large difference, therefore, the level N_1 had to be placed quite low. It may be mentioned that serious lodging in rye and barley occurred only in 1962. No differences which could have arisen from the different rates of nitrogen dressings were seen in the emergence and growth of the ley crops.

S o i l o f t h e t r i a l f i e l d. The experimental field is located on field A VII at the farm of the Agricultural Research Centre at Tikkurila. The soil type is clay loam. The area is uniform, as regards both its topography and its physical and chemical qualities. According to three mechanical soil analyses, which were in good agreement with one another, the fractional composition of the mineral portion of the soil is:

clay	less than 0.002 mm	41 %
silt	0.002—0.02 »	24 %
finesand	0.02 —0.2 »	30 %
coarser material		5 %

Twenty-four soil samples were taken from the plots on the field in the autumns of 1952 and 1965 and analysed. Humus was determined according to BARKOFF (1954), while calcium, potassium and phophorus were analysed according to the ammonium acetate method (VUORINEN and MÄKITIE 1955, KURKI et al. 1965). After careful examination and comparison of the analysis results, it was found that the differences between the different rotations were so small and inconsistent that the tabulation below presents only the averages and standard deviations of all the soil analyses:

		1952	1965
humus	%	9.2 ± 0.68	8.7 ± 0.74
pH in water		5.6 ± 0.07	5.7 ± 0.10
exchangeable calcium	Ca mg/l	2 180 ± 135	2 044 ± 138
exchangeable potassium ...	K »	197 ± 20	238 ± 32
readily soluble phosphorus	P »	8.6 ± 1.2	8.6 ± 1.4

The humus content may be regarded as satisfactory, while all the other values must be considered as only just sufficient. The differences between the two times of analysis are significant in the case of potassium and almost significant for humus and calcium. These differences may possibly be due to differences in the methods of sampling and analysis, which were performed by different persons in 1952 and 1965. It should also be mentioned that, especially in 1965, the humus determinations caused difficulties, owing to the fact that different plant species were growing on the different plots at the time of sampling. It proved extremely difficult to eliminate the influence of the plant remains, which ranged from living parts through all stages of decomposition to completely humified remnants. — It is intended to make a separate study on the soil of the experimental field, with particular reference to the effect of different cropping methods on its physical properties.

Layout of trial field. The trial field comprises 36 ares. There are 6 main plots, consisting of two replicates of each of the three rotations. These 6 main plots are further divided into four 1.5-are subplots which correspond to the four crops which rotate every year. In 1958, these plots were divided into two parts for the nitrogen application tests. Consequently, there are a total of 48 such 75 m² plots. The harvest plots from which the yields are weighed have always been 25 m² in area, so that the total amount of shelter belts comprises 2/3 of the entire area of the field.

Management of trial field. Since the topography of the whole trial field is level and the soil quite impervious, it is very important to ensure rapid run-off of surface water. Although the field is properly underdrained, further measures were taken before the establishment of the trial to construct convex strips of land separated by water furrows. Moreover, care has always been taken to maintain sufficient inclination of the ground surface. Consequently the field has been spared from the formation of ice layers in winter, which would be injurious to the overwintering crops, rye and ley.

The cultural practices used for the different crops were mostly those generally employed in Finland. The trial plots were located on the field so that ordinary tractors and other cultivating implements could be used. Ploughing has always been done to a depth of 20 cm. Phophorus and potassium fertilizers were harrowed into the soil where the arable crops were to be grown, while top dressings were made on the leys. Nitrogen was applied to all the crops as a top dressing.

Special measures to eliminate weeds were taken only in exceptional circumstances, since one of the purposes of the trial was to ascertain the effect of the cropping method on the weeds. The most noxious weed was milk thistle; other weeds were present as well, but not couch grass. No attempts were made to control plant diseases by special means. The most serious disease since 1962 was take-all (*Ophiobolus*) of spring wheat, particularly in rotations A and B. Pest control proved to be indispensable on peas, where the pea weevil (*Sitona*) was controlled by dusting in spring and the pea moth (*Laspeyresia*) by spraying in summer.

Weather conditions during the years of the trial. Detailed information about the weather conditions at the trial location (observation post ca. 200 m from the experimental field) during the years investigated has been published by Valle (1962, 1966). A brief summary of the weather conditions in the different years is given below (figures according to Valle):

Year	General weather conditions	May—September deviations from the 1921—50 normal temp. C°	day-degree summation	precipitation, mm
1958	Better than indicated by the figures	—0.7	—103	— 58
1959	Warm and very dry	0.7	112	—147
1960	Best growing season during the entire period	1.0	150	120
1961	Owing to dryness, slightly poorer season than the previous	0.3	50	— 10
1962	Poorest growing season, due to continual cloudiness and low temperatures	—1.7	—252	115
1963	Warm and dry	1.7	260	— 45
1964	Harmful shortage of rain for more than a year	0.0	8	—121
1965	Cloudy and cool, early summer dry	—0.4	— 66	18

It can be seen that during the first four years the weather conditions were clearly more favourable than during the second four-year period.

Yield results obtained in the years 1958—65

The trial was established in 1952, but not until 1954 were all the desired crops growing, since two years were required to obtain 2nd-year ley. Another essential was that the crops previous to each of the crops, especially to the so-called test crops, which are common to all the rotations, were in accordance with the experimental design. This stage was not attained with the important spring wheat until 1956. Division of the plots for the different nitrogen levels was made in 1958, and only after that date can the results be considered worth description. The previous years can be regarded as a preparatory phase. During this period, the yield level of the different crops was slightly above the average in southern Finland, and the differences between the three rotations were small.

Since it is scarcely justifiable to give the numerical values of the yields of the different crops in each individual year, the results are presented graphically in Figures 1—5. Table 1 shows the average yields of the crops and their standard deviations for the whole 8-year trial period (only 7 years for rye, since in 1958 rye was replaced by oats, because excessive rainfall the previous autumn prevented sowing of rye). The grain yields of the cereals and peas are given as kg/ha with 15 % moisture content. The yields of ley are shown as kg/ha dry matter and comprise hay (1st cut) and aftermath (2nd cut). Botanical analyses of the ley yields were always made, and the yields include only the amounts of the actual cultivated crops (clover and timothy).

Figure 5 shows, in diagram form, the annual mean yields of the different rotations in fodder units per hectare (1 fodder unit = 1 kg rye, wheat, barley, peas; 1.2 kg oats; 1.87 kg dry matter of clover, 2.04 kg dry matter of timothy). The average yield of the rotation has been calculated by converting the individual yields of the separate crops to fodder units and dividing by four. These values are then added together and the sum represents a sort of average hectare yield. In 1958 rye was replaced by oats, as mentioned above. These overall averages of the annual mean yields are given at the bottom of Table 1.

Statistical tests were applied to the yields of each crop separately and also to the average yield of all the crops in the rotations; conventional analysis of variance was used in these tests (e.g. Bonnier and Tedin 1957). The results of the statistical tests are given in Table 2.

The significance of the trial results will be discussed later in connexion with the respective aspects, but attention can be drawn here to the difference between replicates. This difference was significant only in the case of barley. It was indeed noticed nearly every year that in replicate 2 barley grew slightly less well than in replicate 1. In the other crops, the difference was virtually undetectable, but nevertheless it was consistent to such a degree that the average for all the crops in the rotation was significant. It appears from all indications that the difference in yield between the replicates was brought about by differences in the moisture conditions of the soil, since on the basis of the mechanical composition and the chemical properties analysed, such a difference was not to be expected.

Discussion of results

The proportions of the different crops in the average yields of the various rotations for each year are shown in Fig. 5; the yields are given as fodder

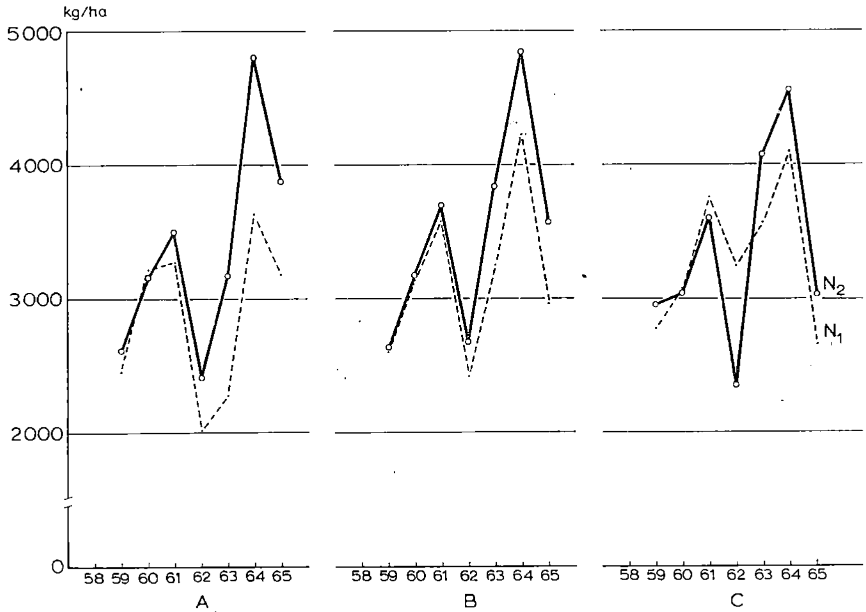


Fig. 1. Annual grain yields of rye (kg/ha) on nitrogen levels N_1 and N_2 during the period 1959—65.

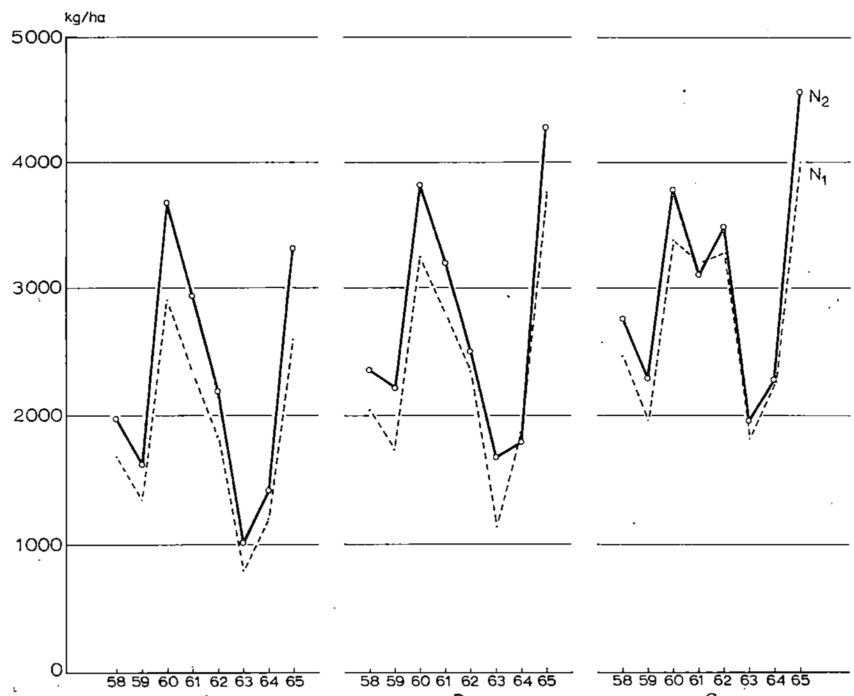


Fig. 2. Annual grain yields of spring wheat (kg/ha) on nitrogen levels N_1 and N_2 during the period 1958—65.

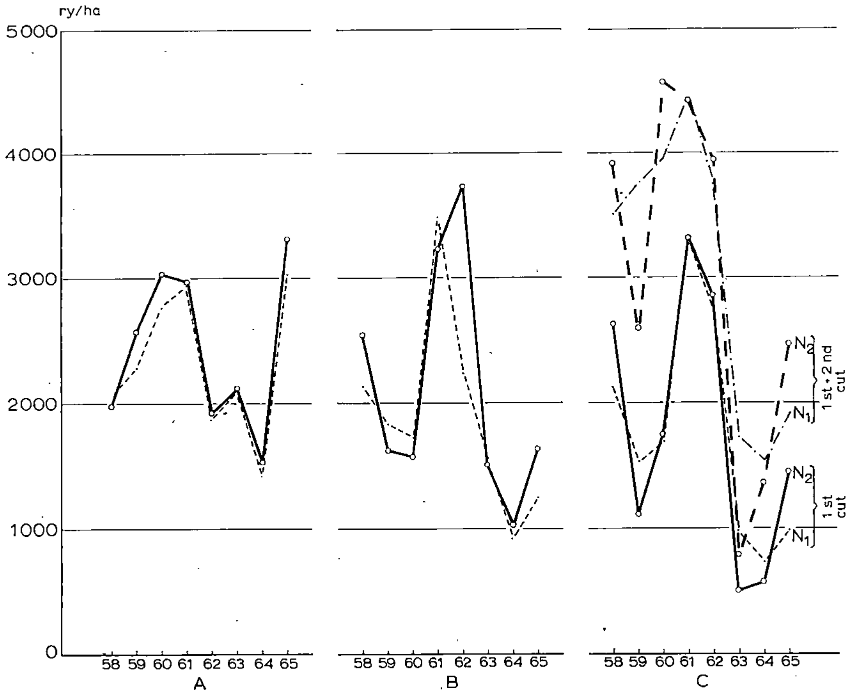


Fig. 3. Annual yields (f.u./ha) of peas-oats (rotation A) and 1st-year ley (rotations B and C) on nitrogen levels N_1 and N_2. In rotation C separate yields are shown for the 1st cut (solid line) and the combined 1st + 2nd cuts (broken line).

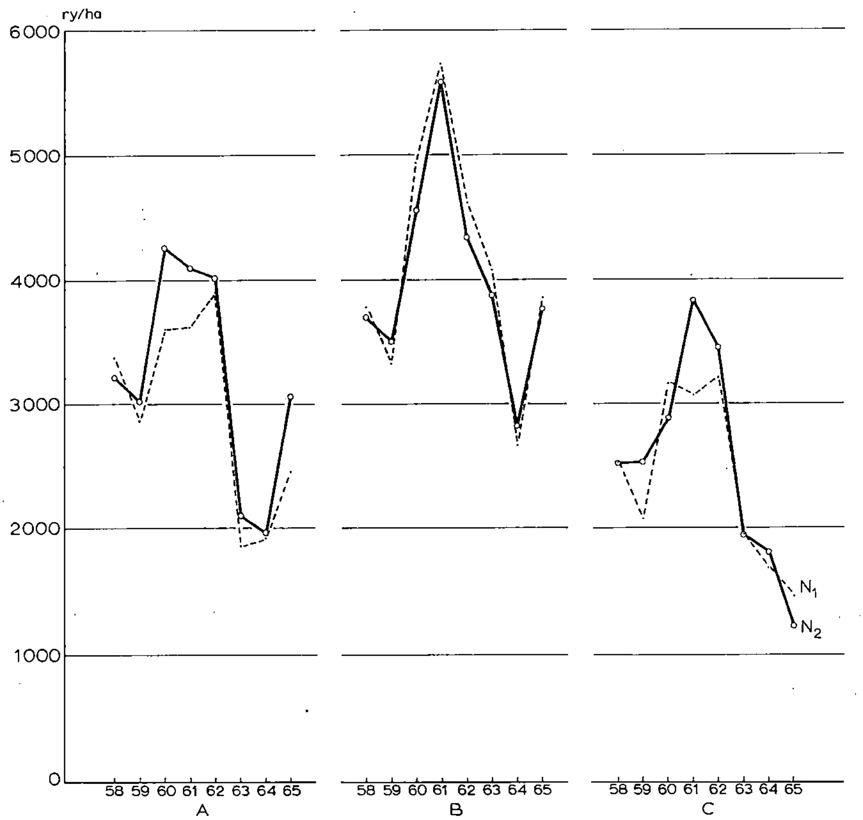


Fig. 4. Grain yields of barley (rotations A and B) and hay yields of 2nd-year ley (rotation C) on nitrogen levels N_1 and N_2, shown as fodder units per hectare.

Table 1. Average yields and standard deviations during the 8-year period 1958—65 (7 years for rye 1959—65).

	Rotation A no ley		Rotation B 25 % ley		Rotation C 50 % ley	
	N_1	N_2	N_1	N_2	N_1	N_2
Test crops						
1. Rye, kg/ha grain 15 % moist.	2 869 ± 608	3 366 ± 830	3 171 ± 613	3 494 ± 761	3 311 ± 524	3 377 ± 750
2. Spring wheat, kg/ha grain 15 % moist.	1 835 ± 727	2 273 ± 951	2 363 ± 857	2 733 ± 943	2 795 ± 778	3 028 ± 880
Treatment crops						
3. Peas-oats, kg/ha 15 % moist., peas	1 188 ± 335	1 193 ± 421	—	—	—	—
oats	1 345 ± 463	1 482 ± 525	—	—	—	—
peas + oats	2 533 ± 567	2 675 ± 525	—	—	—	—
1st-year ley, kg/ha dry matter, clover	—	—	1 764 ± 948	1 230 ± 809	1 391 ± 837	1 240 ± 950
timothy	—	—	1 944 ± 1 556	2 969 ± 1 461	2 083 ± 1 644	2 271 ± 1 359
aftermath	—	—	—	—	2 495 ± 1 145	2 338 ± 1 379
clover + timothy (+ aftermath)	—	—	3 708 ± 1 520	4 199 ± 1 890	5 969 ± 2 250	5 849 ± 2 770
4. Barley, kg/ha 15 % moist.	2 950 ± 798	3 218 ± 879	4 125 ± 964	4 018 ± 822	—	—
2nd-year ley, kg/ha dry matter, clover	—	—	—	—	2 007 ± 1 273	1 363 ± 659
timothy	—	—	—	—	2 724 ± 1 395	3 677 ± 1 601
clover + timothy	—	—	—	—	4 731 ± 1 370	5 040 ± 1 710
Average of all crops f.u./ha	2 502 ± 482	2 843 ± 530	2 909 ± 507	3 113 ± 472	2 899 ± 519	3 006 ± 555

units per hectare. The test crops are placed lowest in the columns so that they may be compared more easily, since comparisons between these are especially important. By comparing the different columns with one another, a picture can be obtained of the fluctuations from year to year in the proportions of the different crops, expressed both as fodder units and as percentages.

Table 2. F-values and their significance for different factors as determined by analysis of variance.

	Replications	Rotations	Years	Interaction rotations-years	Nitrogen dressings	Interactions		
						Rotations-nitrogen dressings	Years-nitrogen dressings	Rotations-years-nitrogen dressings
Test crops								
1. Rye	0.4	3.4 (*)	33.1***	2.5*	39.9***	7.2**	7.9***	1.5
2. Spring wheat	0.5	35.1***	49.5***	1.1	78.0***	2.4	2.6	0.7
Treatment crops								
3. Peas-oats (peas+oats)	0.7	—	33.7***	—	2.7	—	0.5	—
1st-year ley (clover + timothy)	1.7	5.8*	71.4***	1.6	7.3*	3.7	4.6**	2.7*
4. Barley	5.3*	208.6***	69.2***	9.7***	2.7	14.8**	0.9	2.3
2nd-year ley (clover+timothy)	1.2	—	38.7***	—	3.3	—	1.8	—
Average all crops	6.0*	44.5***	114.2***	8.3**	102.6***	10.2**	2.4*	1.6

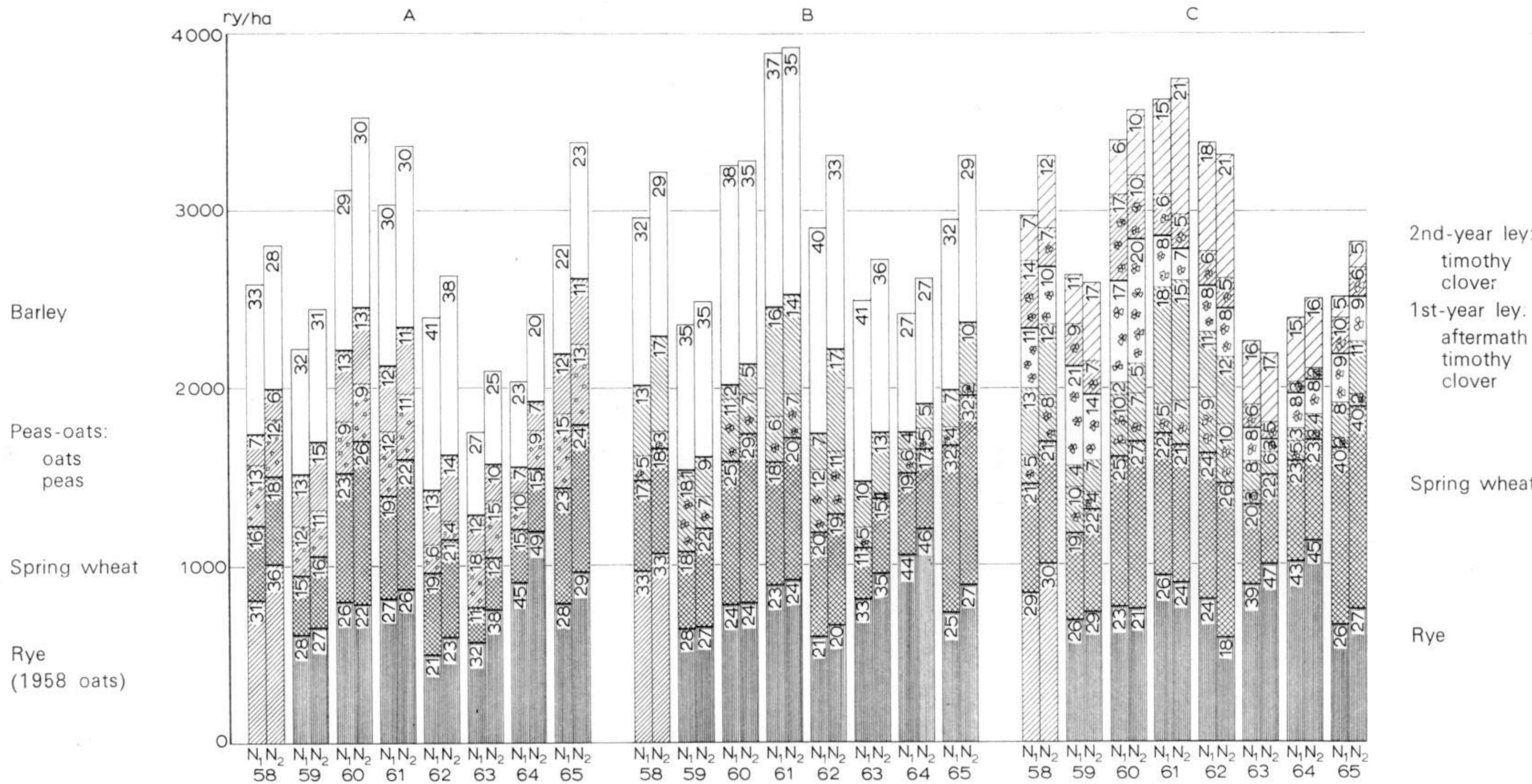


Fig. 5. Average annual yields (f.u./ha) of the different rotations and the proportion of each crop in the total yield. The numbers in the different parts of the columns denote the percentages of each crop.

Table 3. Percentages of total yields of rotations (f.u./ha) contributed by each crop; averages for entire period.

	A		B		C	
	N_1	N_2	N_1	N_2	N_1	N_2
1. Rye (oats in 1958)	29	31	28	31	29	29
2. Spring wheat	18	20	20	21	24	25
3. Peas-oats, peas	12	10	—	—	—	—
oats	11	11	—	—	—	—
total	23	21	—	—	—	—
1st-year ley, clover	—	—	8	5	6	6
timothy	—	—	8	12	9	9
aftermath	—	—	—	—	11	10
total	—	—	16	17	26	25
4. Barley	30	28	36	31	—	—
2nd-year ley, clover	—	—	—	—	9	6
timothy	—	—	—	—	12	15
total	—	—	—	—	21	21

Table 3 gives the average percentages of the different crops out of the whole yield of the rotation. In all the rotations the proportion of rye was much greater than it should theoretically have been on the basis of the area devoted to it (25 %). In certain years, for example 1964 (Fig.5), rye made up nearly half the total yield of the rotations. The percentage of spring wheat, on the contrary, was clearly lower than it should have been according to its area on the field. Only in rotation C on nitrogen level N_2 did it attain a yield corresponding to the area covered, 25 %. Comparisons reveal, however, that ley gave the poorest results of all the crops when the aftermath was not included; this was the case for the 1st-year ley of rotation B and the 2nd-year ley of rotation C. The proportion of barley exceeded theoretical expectation in rotation A, but it was even greater in rotation B, a result which can justifiably be attributed to ploughing under of the ley aftermath the previous autumn. As regards ley, the wide variations from year to year (Fig. 5) are especially noteworthy, for example between 1961 and 1964.

Annual fluctuations depend to a major extent on factors which cannot be influenced by man, namely weather conditions. Such fluctuations, as is well known, have an adverse effect in all spheres of agriculture. They also impede plant husbandry studies, since they make it difficult to obtain reliable data and to interpret the results of trials. Thus it would be an extremely important achievement to find ways to decrease annual fluctuations and reduce their detrimental effects. The present trial provides valuable data for assessing this problem.

The annual results depicted in Figures 1—5 also give an indication of the extent of annual fluctuations. A more concise indication is given by the standard deviations of the average yields in Table 1. It is furthermore seen from Table 2 that the variations due to years are highly significant for all the crops. A clearer picture of the annual variations for the various crops can be obtained from Table 4, where the so-called coefficients of variation are shown. This coefficient is the standard deviation in percent of the average value.

The highest coefficients of variation, and thus the greatest annual fluctuations, occur in the case of 1st-year ley. This is obvious in cases where the yields depends not only on the weather conditions of the year in question but also on the conditions during the previous year, when the ley was established. Second place as regards annual fluctuations is taken by spring wheat, followed by 2nd-year ley and then by barley and peas-oats, which are approximately equal. Rye is seen to have given the most uniform yields from year to year, but it should be pointed out that during the years of this trial there were never any appreciable over-wintering damages. The least annual fluctuation occurred in the average for all crops.

Table 4. Standard deviation as percent of the mean value or coefficient of variation.

	A		B		C	
	N_1	N_2	N_1	N_2	N_1	N_2
1. Rye (7 years)	21	24	19	22	16	22
2. Spring wheat	40	42	36	36	28	29
3. Peas-oats, peas	28	35	—	—	—	—
oats	34	35	—	—	—	—
total	25	26	—	—	—	—
1st-year ley, clover	—	—	54	66	60	77
timothy	—	—	80	49	79	60
total	—	—	41	45	52	60
4. Barley	27	27	23	20	—	—
2nd-year ley, clover	—	—	—	—	63	48
timothy	—	—	—	—	51	44
total	—	—	—	—	29	34
Average of all crops	19	19	17	15	18	18

The effect of the different rotations on the annual fluctuations is most clearly evident for spring wheat, where the presence of ley decreased such fluctuations. In the case of rye and particularly barley, as well as in the average of all crops, the interaction between rotation and years is significant, which probably means that the influence of the rotation may have been different in the different years.

The interaction between years and nitrogen dressing is significant for rye and 1st-year ley as well as for the average of all crops. It is well known that the effect of nitrogen dressing varies in different years. According to Table 4, however, nitrogen did not reduce the annual fluctuations.

The effect of nitrogen dressing in the different rotations. From the trial results only the effect of increasing nitrogen dressing can be calculated (cf. p. 65); this is indicated in Table 5 as N_2—N_1. Figures 1—5 give a picture of the influence of additional nitrogen in the individual years. According to the F-values in Table 2, the effect of addition of nitrogen itself as well as in many cases the interaction of nitrogen and years or nitrogen and

Table 5. Average annual yield increases (kg/ha) obtained with additional nitrogen; averages of all crops are expressed as fodder units per hectare.

	Nitrogen kg/ha per year			Average annual yield increase from additional nitrogen (N_2—N_1)		
	N_1	N_2	diff. N_2—N_1	A	B	C
1. Rye	37.5	75.0	37.5	497	323	66
2. Spring wheat	0	25.0	25.0	438	370	233
3. Peas-oats, peas	0	25.0	25.0	5	—	—
oats	—	—	—	137	—	—
total	—	—	—	142	—	—
1st-year ley, clover	0	25.0	25.0	—	—534	—151
timothy	—	—	—	—	1 027	188
aftermath	—	—	—	—	—	—157
total	—	—	—	—	491	—120
4. Barley	25.0	50.0	25.0	268	—107	—
2nd-year ley, clover	—	—	—	—	—	—644
timothy	—	—	—	—	—	953
total	—	—	—	—	—	309
Average of all crops	15.6	43.8	28.2	341	204	107

rotation is significant. In the case of barley, nitrogen application caused quite different responses in the different rotations, a fact which is also seen in the significance shown by the interaction rotation-nitrogen.

The effect of nitrogen and/or additional nitrogen is very different in the different rotations. One consistent trend is obvious, namely that the beneficial effect of nitrogen decreases when the amount of ley in the rotation increases. The yield increase afforded by nitrogen was very high in the ley-free rotation A, but with one-fourth of the area under ley the yield increase is only about 60 % of that of rotation A, and when one-half is under ley the increase is only about 30 %

Of all the crops included spring wheat gave the best response to added nitrogen, while rye took second place. Barley in rotation A with no ley also responded well to addition of nitrogen, but in rotation B containing ley the result was a reduction in yield. In the case of peas-oats, the beneficial influence of nitrogen was limited exclusively to oats. The most irregular results with nitrogen occurred in the leys, a phenomenon which was naturally due to the negative response of clover to increased nitrogen level.

Does addition of nitrogen reduce the drawbacks of ley-free cropping? One of the most important aims of the present trial was to obtain data on the relation between cropping system (= rotation) and intensity of nitrogen application. Above all, it is essential to find out to what extent the disadvantages of ley-free cropping can be counteracted by increasing nitrogen applications.

In making such evaluations, the results of this trial can be used so that comparisons are made between the two nitrogen levels of the different rotations. In this respect, the most essential and important comparison is that between the nitrogen level N_1 of the high-ley rotation C, which resembles the system generally practised today in Finland, and the nitrogen level N_2 of the other rotations with less or no ley.

Figures 6—8 present this comparison annually for rye and spring wheat, the tests crops, as well as for the average yields of all the crops. In Ta-

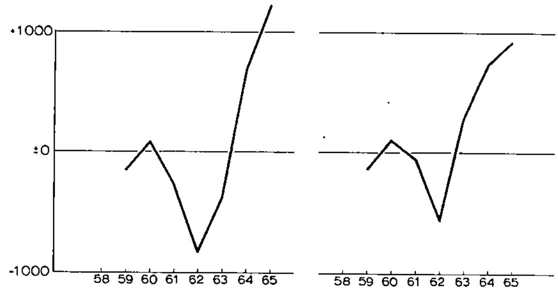


Fig. 6. Annual grain yields of rye (kg/ha) in response to cropping method and nitrogen intensity. At the left, the yield obtained on nitrogen level N_1 in rotation C (50 % ley) has been subtracted from the yield on level N_2 of rotation A (no ley; in Table 6, AN_2—CN_1). At the right, the yield obtained on nitrogen level N_1 in rotation C has been subtracted from the yield on level N_2 of rotation B (25 % ley) (in Table 6, BN_2—CN_1).

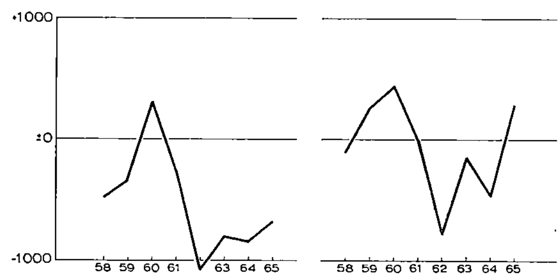


Fig. 7. Annual grain yields of spring wheat (kg/ha) in response to cropping method and nitrogen intensity. Same explanations as in Fig. 6.

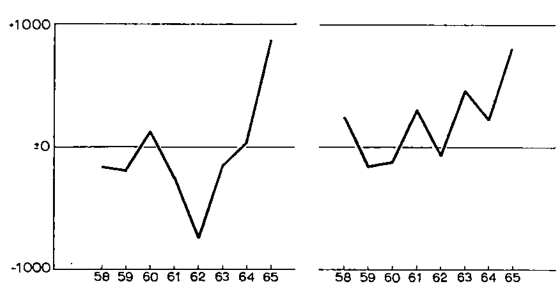


Fig. 8. Average annual yields (f.u./ha) of all crops in the rotations in response to cropping method and rate of nitrogen application. Same explanations as in Fig. 6.

Table 6. Comparison between yields obtained on nitrogen level N_2 of rotations A and B with yields on nitrogen level N_1 of rotation C.

	A N_2—C N_1	B N_2—C N_1
Rye, kg	55	183
Spring wheat, kg	—522***	—62
Average of all crops, fodder units	— 56	214**

ble 6 the average values for the whole 8-year trial period are compared.

When the higher rate of nitrogen was given to rye in the rotations with no ley and with little ley (A and B), the yields were at least as high as in the rotation with 50 % ley (C) at the low rate of nitrogen (Fig. 6, Table 6). Spring wheat showed a different response. This is most clearly seen in the comparison AN_2—CN_1, in which the negative difference is highly significant. On the other hand, the difference in the comparison BN_2—CN_1 is small and not significant.

Similarly, as regards the averages of all the crops, it is useful to examine these relationships in order to gain an overall picture, even though it is not certain to what extent the fodder unit can be accepted as a unit of measuring. The best comparison in this case is with nitrogen level 2 of the rotation containing 25 % ley, or BN_2, and here the difference is highly significant.

One of the aims of long-term rotation trials is *to determine whether the yield level is maintained or changed by a certain cropping system.* As will be seen from the diagrams showing the annual yield results, the present trial has been in progress for too short a time to furnish an answer to this question. Above all, the large annual fluctuations due to wheather conditions make such comparisons difficult.

Summary

In 1952 a long-term rotation trial was established on clay loam soil in order to study the effects of rate of ley and intensity of nitrogen dressing on different crops. The present paper discusses the results obtained in the years 1958—1965.

The results may also be used to compare the differences in yield between the different crops which may be regarded as due to annual fluctuations in the weather conditions, since throughout the years of the trial all the crops were grown on the same soil and were managed according to the same practices. The widest annual variations occurred in the yields of first-year ley, followed by spring wheat and then by barley, peas-oats and second-year ley, all approximately equal in this respect. The smallest annual variations occurred in the yields of rye. Nitrogen dressing did not diminish such yearly yield variations.

The percentage of ley yield, calculated as fodder units, tended to be quite small in relation to the total output. The presence of ley in the rotation improved the yield of spring wheat but scarcely affected that of rye.

The less ley in the rotation, the larger were the yield increases brought about by nitrogen fertilizers. It appears possible that by increasing nitrogen applications, rye at least may be induced to give yields in a ley-free rotation which are as high as in a rotation containing ley. In the case of spring wheat, on the other hand, additional nitrogen was not able to compensate for the adverse effect of ley-free culture.

The trial has so far been of such short duration that the influence of different cropping systems on the productivity of the soil has not yet become evident.

LITERATURE

AGERBERG, L. S. 1966. Växtföljdsproblem i nordisk försöksverksamhet. Nord. Jordbr.forskn. 48: 153—180.

ALLAWAY, W. H. 1957. Cropping systems and soil. Yearb. Agric. 1957: 386—395.

BARKOFF, E. 1954. Beiträge zur kolorimetrischen Humusbestimmung im Boden. Maatal.tiet. Aikak. 26: 198—210.

BONNIER, G. & TEDIN, O. 1957. Biologisk variationsanalys. 2. uppl. Stockholm.

BOYD, D. A., COOKE, G. W., DYKE, G. V., MOFFATT, J. R. & WARREN, R. G. 1961. The Rothamsted ley-arable rotation experiment. Rep. Roth. Exp. Sta 1961: 173—180.

BOYD, D. A. 1966. Rothamsted ley-arable rotation experiment. Ibid. 1965: 216—221.

KURKI, M., LAKANEN, E., MÄKITIE, O., SILLANPÄÄ, M. & VUORINEN, J. 1965. Viljavuusanalyysien tulosten ilmoitustapa ja tulkinta. Summary: Interpretation of soil testing results. Ann. Agric. Fenn. 4: 145—153.

LANG, A. L. 1960. Crop rotation: Practical or passé? Plant Food Rev. Winter 1960: 13—15.

MANN, H. H. & BOYD, D. A. 1958. Some results of an experiment to compare ley and arable rotations at Woburn. J. Agric. Sci. 50: 297—306.

SALONEN, M. 1963. Nurmen määrän merkitys ja typpilannoituksen vaikutus erilaisissa viljelykierroissa. Summary: The effect of rate of leys and nitrogen fertilization in different rotations. Maatal. ja Koetoim. 17: 60—72.

SIMOLA, E. F. 1936. Peltoviljelyskiertokokeiden tuloksista maatalouskoelaitoksen kasvinviljelysosastolla vv. 1914—1926. Referat: Über die Ergebnisse der an der Abteilung für Pflanzenbau der Landwirtschaftlichen Versuchsanstalt i.d. J. 1914—1926 ausgeführten Zirkulationsversuche. Valt. Maatal. koetoim. Julk. 78.

UHLEN, G. 1963. Noen virkninger av ulike vekst-omløp. Summary: Some effects of different crop rotations. Forskn. og forsøk i Landbr. 14: 421—442.

VALLE, O. 1962. Sääolot ja niiden vaikutus kasvintuotantoon Etelä-Suomessa 1958—61. Summary: Weather conditions and their influence on plant production in southern Finland in the years 1958—61. Maatal. ja Koetoim. 16: 38—50.

— 1966. Sääolot ja niiden vaikutus kasvintuotantoon Etelä-Suomessa 1962—65. Summary: Weather conditions and their influence on plant production in southern Finland in the years 1962—65. Ibid. 20: 29—39.

VUORINEN, J. & MÄKITIE. O, 1955. The method of soil testing in use in Finland. Agrogeol. Publ. 63.

SELOSTUS

Nurmen määrän ja typpilannoitustason vaikutus erilaisissa viljelykierroissa

Tuloksia 1952 alkuun pannusta viljelykiertokokeesta

MARTTI SALONEN

Maatalouden tutkimuskeskus, Maanviljelyskemian ja -fysiikan laitos, Tikkurila

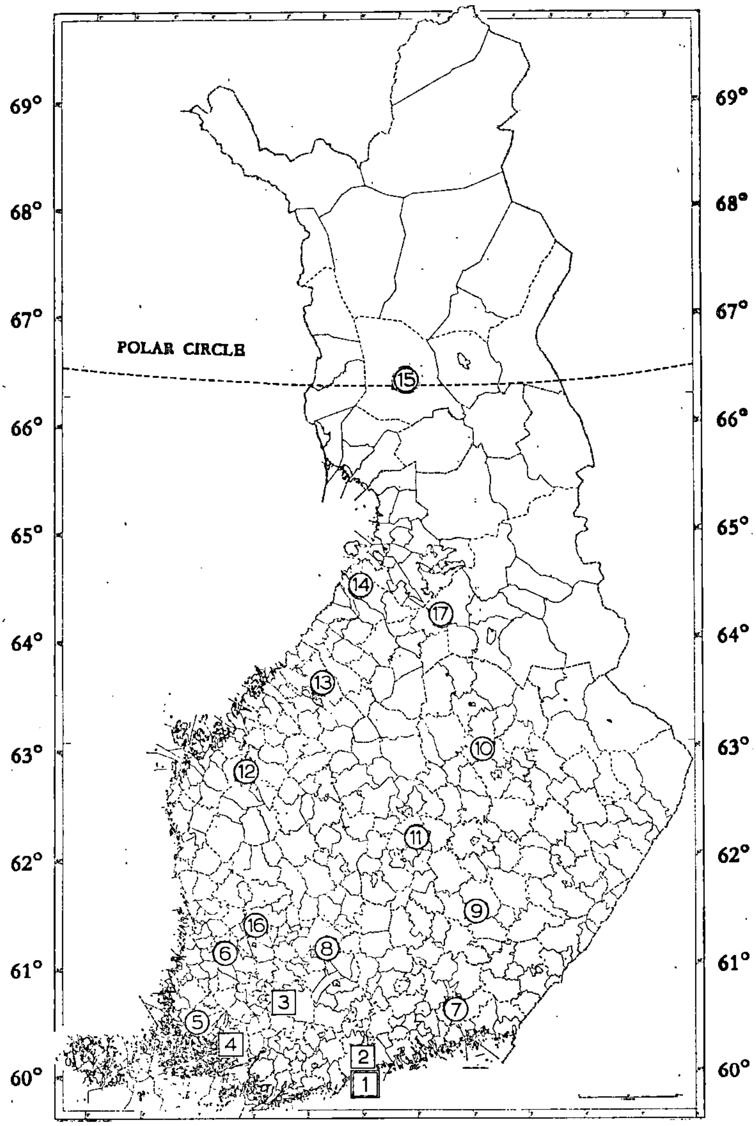
Vuodesta 1952 on hiesuisella hietasavimaalla käynnissä nurmen määrän ja typpilannoitusintensiteetin vaikutuksia selvittelevä viljelykiertokoe. Kokeen 1958—65 antamina tärkeimpinä tuloksina voidaan lyhyesti mainita seuraavaa:

Säätekijät ovat aiheuttaneet kaikkien kokeessa mukana olleiden kasvien sadoissa huomattavaa vaihtelua siitä huolimatta, että viljelysmaa on ollut sama ja kaiken aikaa on sovellettu samaa viljelytekniikkaa. Kaikkein suurinta vuotuisvaihtelu on ollut ensimmäisen vuoden nurmessa, sitten seuraa järjestyksessä kevätvehnä, sen jälkeen tulevat keskenään suunnilleen samanarvoisina ohra, hernekaura ja toisen vuoden nurmi; pienintä vuotuisvaihtelu on ollut rukiissa. Typpilannoitus ei ole vähentänyt vuotuisvaihtelua.

Jos kaikkien kasvien sadot muunnetaan rehuyksiköiksi, voidaan vertailla keskenään hyvin erilaatuisia kasveja. Tässä vertailussa selviytyvät ensimmäisen vuoden nurmet huonoimmin. Nurmen mukana olo viljelykierrossa on kuitenkin parantanut kevätvehnän menestymistä.

Typpilannoituksen vaikutus on ollut sitä suurempi, mitä vähemmän nurmea viljelykiertoon on kuulunut. Runsaalla typpilannoituksella on rukiista saatu hyviä tuloksia täysin nurmettomassakin viljelyssä. Kevätvehnän suhtautuminen on ollut päinvastaista sikäli, että runsas typpilannoituskaan ei ole korjannut viljelytavan yksipuolisuuden haittoja.

Koeaika on vielä liian lyhyt, jotta eri viljelytapojen vaikutukset maan kasvukuntoon voisivat tulla esille.



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SISÄLLYS—CONTENTS

Helsinki 1967. Valtion painatuskeskus