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Seria AGROGEOLOGIA ET -CHIMICA N. 84 — Sarja MAA JA LANNOITUS n:o 84

SOIL NUTRIENT STATUS AS RELATED TO SOIL TEXTURAL CLASSIFICATION

Leila Urvas, Raimo Erviö and Seppo Hyvärinen

Urvas, L., Erviö, R. & Hyvärinen, S. 1978. **Soil nutrient status as related to soil textural classification.** Ann. Agric. Fenn. 17: 75—82. (Agric. Res. Centre, Inst. Soil Sci., SF-01300 Vantaa 30, Finland).

Soil pH and contents of acid ammonium acetate (pH 4,65) extractable calcium and potassium were in positive, but phosphorus in negative correlation with the clay content in subsurface (20—40 cm) and in subsoils (40—60 cm). At equal clay levels, the contents of Ca and K decreased with increasing content of fine silt.

The pH of subsoils exceeded that of subsurface soils by 0,2 pH-unit, on the average. Also, the Ca contents were higher but K and P contents generally lower in subsoils than in the subsurface. At a low clay level (5—9 % $<2\mu$ clay), the average potassium content was 38, and at a high clay level (85—89 % clay) 294 mg K/l soil. The Ca contents were about tenfold, 400 and 2 700 mg Ca/l, respectively.

The present textural classification of soils seems to be justified as far as the clay content is concerned, as well as from the soil nutritional point of view. However, for the separation of sandy and silty clays, no real support for this classification was obtained from the results of the chemical soil analyses.

Index words: Soil texture, soil types, macronutrients.

Soil classification in Finland is mainly based on texture and humus content of soils (Aaltonen et al. 1949). The contents of exchangeable calcium and potassium have been found to be positively correlated, and that of readily soluble phosphorus negatively correlated to the contents of the finest particle fractions, especially to that of clay (Salminen 1931, Kurki 1963, Kaila and Rytı 1968, Lakanen and Hyvärinen 1971). In samples collected from various parts of the country, the mineral composition of equal textural fractions seems to be independent of the geographical origin of the samples (Sippola 1974).

The present paper deals with the relations of soil pH, and Ca, K, and P contents to soil texture. Further, concerning the nutrient status of soils, the fitness of certain textural borderlines between the soil types have been taken into consideration.

The soil material consists of 1 079 surface soil (0—20 cm), 1 310 subsurface (20—40 cm), and 1 560 subsoil (40—60 cm) samples representing cultivated fields in 15 soil survey areas (Table 1). The samples from areas 1, 2, and 4 are mainly clays; from areas 9, 10, 12, 13, and 14 mainly silt soils; and from areas 7 and 15 finesands. Clay, silt, and finesand soils were more equally represented in samples from areas 3, 5, 6, 8, and 11. The humus content of surface soils was 6,3 per cent (Org. C = 3,64 %) on the average, while that of lower soil levels was generally below 1 per cent.

Particle size distribution was determined by the dry and wet sieving method from coarse soils, and by the pipette method (HEINONEN 1953) from fine soils. The textural soil classification used is given in Fig. 1 (VUORINEN 1961). According to this classification, soils with a silt (2—20 μ) fraction of 50 per cent or more are classified as silt soils, regardless of their clay content.

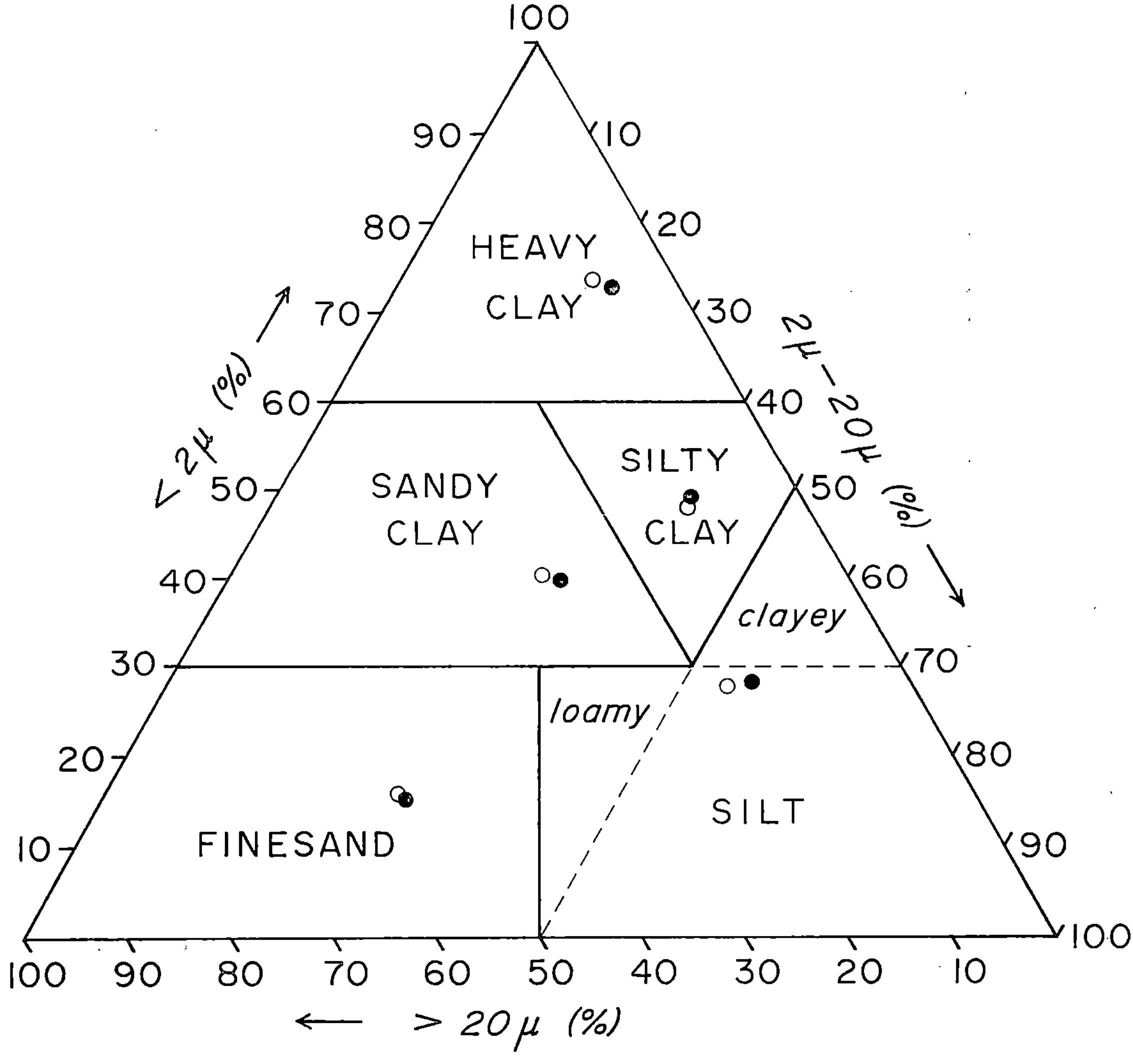

Fig. 1. Textural classification of sorted mineral soils used in soil survey and textural average within soil types (○ = subsurface soils, ● = subsoils).

Table 1. The number of soil samples collected from different soil survey areas.

Soil survey area	Surface 0—20 cm	Subsurface 20—40 cm	Subsoil 40—60 cm	Total
1. Turku	51	42	47	140
2. Lohja	134	209	209	552
3. Kerava	2	12	12	26
4. Porvoo	50	75	34	159
5. Riihimäki	180	148	191	519
6. Lahti	177	181	126	484
7. Pori	80	111	108	299
8. Vammala	139	158	212	507
9. Tampere	71	140	206	417
10. Kangasala	63	57	102	222
11. Valkeakoski	41	73	72	186
12. Teisko	18	34	67	119
13. Orivesi	—	1	77	78
14. Jyväskylä	63	52	78	193
15. Rovaniemi	10	17	19	46
Total	1 079	1 310	1 560	3 947

Calcium, potassium, and phosphorus were extracted with acid ammonium acetate (0,5 N CH_3COONH_4, 0,5 N CH_3COOH), pH 4,65 (Vuorinen and Mäkitie 1955). Calcium and potassium were determined from the extract with a flame photometer, and phosphorus with a colorimeter. The results are expressed in mg/litre of soil (Kurki et al. 1965). Soil pH was determined from soil : water (1 : 2,5) suspension, and humus content was obtained by multiplying the organic carbon, determined by the bichromate method, by a coefficient of 1,727.

RESULTS AND DISCUSSION

Soil nutrient status as related to texture

Cultivation practice, especially liming and fertilization have changed the original chemical properties of the surface (0—20 cm) soils to such a degree that the influence of soil texture on them may be less clear than in the deeper soil levels.

Therefore, in this study, special attention is paid to results obtained from samples representing subsurface (20—40 cm) and subsoils (40—60 cm).

The average soil pH was 5,63 in the surface soils; it then rose in the scale toward the subsurface (5,82), and still further in the subsoils (6,06). At all clay levels the pH of subsoils exceeded that of subsurface soils by 0,1—0,3 pH unit. An increase in clay content from 5—9 to 85—89 per cent caused a rise in pH from 5,63 to 6,07 in subsurface soils, and from 5,69 to 6,36 in subsoils (Tables 2—3, Fig. 2 A).

The clay—pH correlation is obviously based on mineralogical differences between clay and coarser fractions, i.e. on higher contents of basic cations and the higher BS-values in clay than in coarser fractions. E.g. Lakanen et al. (1970) reported an almost linear relation between extractable calcium and pH in a material of 80 000 samples.

The correlation of extractable **calcium** with the clay content was linear and highly significant both in subsurface ($r = 0{,}713^{***}$) and in subsoil ($r = 0{,}732^{***}$) material (Fig. 2 B). With increasing clay content, the calcium content increased about tenfold, from approximately 300 in the lowest to about 3 000 mg/l in the highest clay classes (Table 2). In general, the calcium contents of subsoils were slightly higher than those at the respective clay levels of subsurface soils.

Silt fraction seems to have a decreasing effect on calcium content. An increasing fine silt (2—

Table 2. Acid ammonium acetate extractable nutrients and pH at different clay levels of the subsurface (1) and subsoil (2) samples.

Clay fraction in per cent	Number of samples		pH (H_2O)		Acid ammonium acetate (pH 4,65) extractable nutrients, mg/l soil					
					Calcium		Potassium		Phosphorus	
	Sub-surface 20—40 cm 1	Subsoils 40—60 cm 2	1	2	1	2	1	2	1	2
≤ 4	9	8	5,68	5,70	340	285	50	32	2,63	2,12
5— 9	33	43	5,63	5,69	395	420	45	32	2,58	2,32
10—14	52	52	5,63	5,83	555	580	58	43	2,42	2,39
15—19	57	61	5,77	5,92	635	785	51	64	1,87	2,50
20—24	82	95	5,66	5,93	820	975	76	61	1,75	1,73
25—29	129	115	5,78	5,96	945	1 065	84	72	1,73	1,84
30—34	147	147	5,77	5,96	1 160	1 175	86	79	1,28	1,35
35—39	144	161	5,77	6,06	1 220	1 410	102	91	1,59	1,14
40—44	124	146	5,84	6,10	1 420	1 550	106	107	1,48	1,12
45—49	130	170	5,81	6,06	1 515	1 690	120	112	1,36	1,08
50—54	110	140	5,92	6,12	1 680	1 965	135	137	1,36	0,81
55—59	79	122	5,88	6,10	1 825	2 045	146	147	1,25	0,86
60—64	51	83	5,86	6,22	2 100	2 140	185	172	1,32	0,87
65—69	43	58	5,94	6,26	2 015	2 230	195	205	1,50	0,83
70—74	29	49	5,95	6,26	2 265	2 560	226	237	0,95	1,11
75—79	25	38	6,17	6,36	2 455	2 475	268	260	1,08	0,87
80—84	37	36	6,09	6,21	2 460	2 490	269	277	0,83	0,88
85—89	24	29	6,07	6,36	2 625	2 745	284	302	0,85	0,88
≥90	4	6	5,80	6,22	3 200	2 400	262	324	0,67	0,67

Table 3. Average pH and macronutrient contents in three horizons of five soil types.

Soil type	pH (H_2O)			Acid ammonium acetate (pH 4,65) extractable mg/l soil								
				Calcium			Potassium			Phosphorus		
	Surface 0—20 cm 1.	Sub-surface 20—40 cm 2.	Subsoil 40—60 cm 3.	1.	2.	3.	1.	2.	3.	1.	2.	3.
Finesand	5,67	5,63	5,76	1 036	650	765	105	66	52	6,4	2,1	1,8
Silt	5,60	5,77	5,98	1 152	919	1 008	114	77	70	5,1	1,7	1,8
Sandy clay	5,66	5,77	6,00	1 701	1 406	1 634	181	122	116	6,2	1,6	1,1
Silty clay	5,61	5,86	6,10	1 658	1 588	1 818	162	118	124	4,2	1,2	0,9
Heavy clay	5,67	5,99	6,28	2 329	2 290	2 406	233	230	231	3,4	1,1	0,9

6 μ) content, from about 15 per cent level upwards, was accompanied by a substantial decline in extractable calcium. This decrease was more marked in soils of high clay content (Fig. 3 A).

Contents of extractable **potassium** increased markedly with increasing clay content. E.g. in subsoils, the increase from the lowest clay class to the highest one was tenfold (Table 2). The parabolic regressions given in Fig. 2 C are highly significant for both soil groups, R = 0,723*** for subsurface soils and 0,814*** for subsoils.

The effect of the fine silt fraction on potassium within various clay content classes is given in Fig. 3 B. The effect is slight at the lowest clay levels, but at medium and high clay levels its diminishing effect on potassium is substantial.

The dependence of extractable calcium and potassium contents on clay content is obviously due to the higher cation exchange capacity of clay compared with that of coarser fractions (e.g. Heinonen 1960, Kaila and Rytti 1968). The diminishing effect of silt on calcium and potassium may not be due to the silt fraction alone.

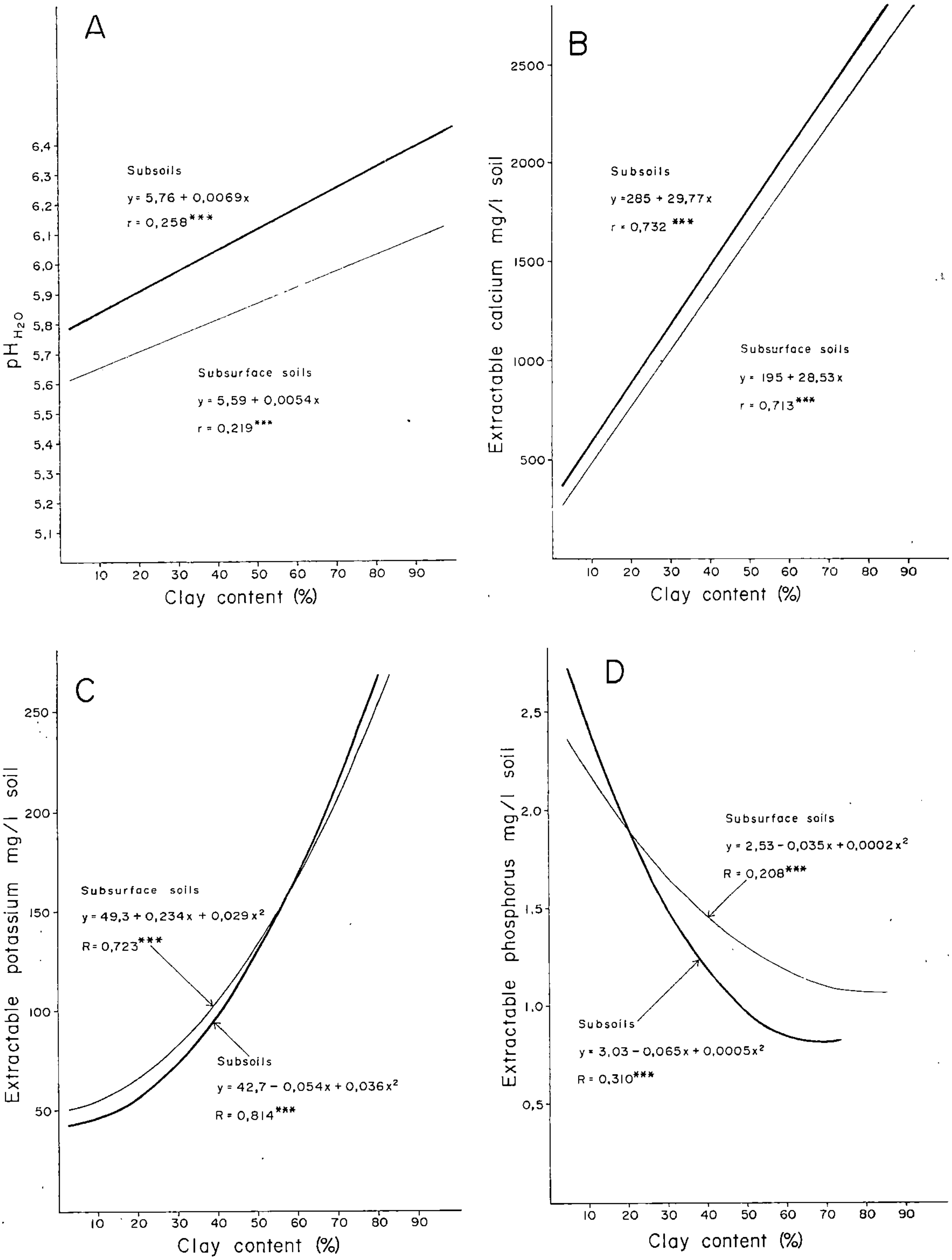

Fig. 2. Regressions of pH, and acid ammonium acetate extractable calcium, potassium, and phosphorus on clay content in subsurface and subsoils.

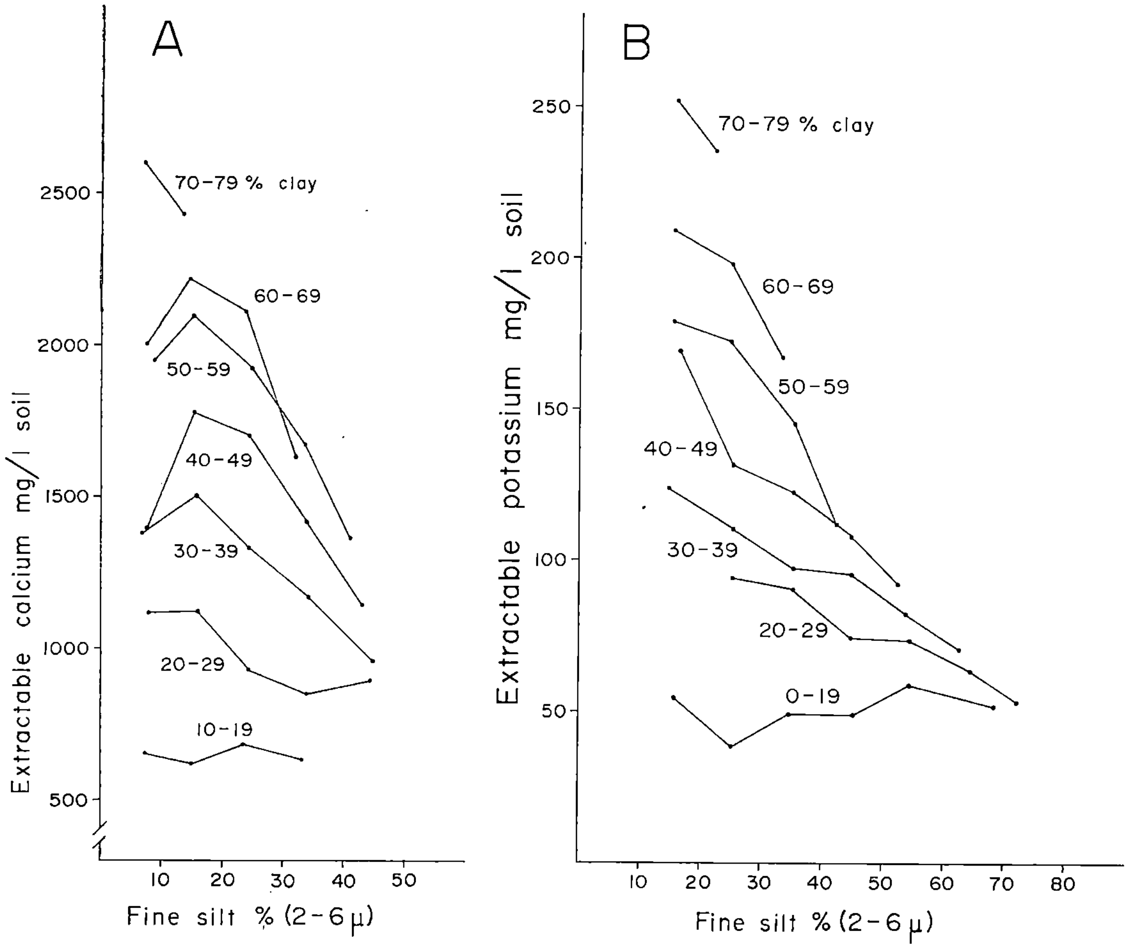

Fig. 3. Effects of fine silt content on extractable calcium and potassium at different levels of clay content both in subsurface and subsoils together.

In soils of high silt content, the clay fraction is generally coarser than in soils where there is less silt. The effect of coarse clay on calcium and potassium is obviously less pronounced than that of fine clay. When studying the cation exchange capacity of Finnish soils, HEINONEN (1960) also found an increasing effect of clay and a decreasing effect of silt on the exchange capacity.

In contrast to calcium and potassium, the contents of soluble **phosphorus** decreased with increasing clay content (Table 2 and Fig. 2 D). The clearest regressions were curvilinear and highly significant both for subsurface soils (R = 0,208***) and subsoils (R = 0,310***). This is apparently due to the stronger fixation of phosphorus to clay than to coarser fractions (LAKANEN and HYVÄRINEN 1971).

Textural classification as related to soil fertility

Textural averages for various soil types are given in Fig. 1, and respective mean nutrient contents and pH in Table 3. In general, the least differences between the soil types were found in the surface layer and the most substantial differences in the subsoil. This is obviously due to cultivation practices.

The average **pH** in the surface soil was almost the same for all soil types, while in deeper layers the rise of pH toward finer textured soils was clear, in subsoil from 5,8 to 6,3.

The contents of extractable **calcium** and **potassium** in all three levels increased substantially from finesand soils towards the finest textured clays. For both these nutrients, the rise was over two-fold in surface soils, and 3—4-fold in the two deeper levels. There was also a substantial decrease downwards from the surface layers of the two coarser textured soil types, finesand, and silt. This decrease was milder in sandy and silty clays and finally levelled off in heavy clays.

The ratio Ca/K was about 10 in surface soil and somewhat higher in deeper levels.

The contents of readily soluble **phosphorus** were highest in the coarse textured soil types, being about twice as high in all three levels of the finesand as in those of the heavy clay. The average phosphorus contents in the surface of all soil types were 3—5-fold compared to those in deeper levels, indicating the effect of long time fertilization practices.

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SELOSTUS

Maan ravinteisuuden riippuvuus lajittuneiden maiden lajitekoostumuksesta ja tämän arvo käytössä olevan maalajiluokituksen tukena

Leila Urvas, Raimo Erviö ja Seppo Hyvärinen

Maatalouden tutkimuskeskus

Maataloudellisen maaperäkartoituksen yhteydessä, taul. 1 osoittamilta alueilta, otetuista 3 947 maanäytteestä tehtiin lajitekoostumusmääritykset, joiden pohjalta maiden pH-arvoja, kalsium-, kalium- ja fosforipitoisuuksia on tarkasteltu. Tuloksia on käsitelty erikseen muokkauskerroksen, jankon ja pohjamaan näytteiden osalta.

Jankon ja pohjamaan näytteiden pH (H_2O) sekä happaman ammoniumasetaatin vaihtaman kalsiumin ja kaliumin pitoisuudet kohosivat savilajitteen osuuden kasvaessa, kun taas liukoisen fosforin pitoisuus aleni (kuva 2 A, B, C ja D, taulukko 2). Kalsiumin ja pH:n riippuvuus savipitoisuudesta oli suoraviivainen, mutta kalium- ja fosforipitoisuuden riippuvuutta kuvasi paremmin paraboolinen käyrä.

Samalla savestasolla maan kalsium- ja kaliumpitoisuudet laskivat hienomman hiesulajitteen osuuden kasvaessa (kuva 3 A ja B). Selvimmin tämä ilmeni savimaissa, joiden hienohiesuprosentti oli yli 20.

Eri savestasoilla oli pohjamaan pH keskimäärin 0,2 pH-yksikköä korkeampi kuin jankon ja sen kalsiumpitoisuus kaikilla savestasoilla jankon arvoja suurempi. Sen sijaan jankon kaliumpitoisuudet olivat noin 50 saviprosenttiin saakka pohjamaan arvoja suurempia. Fosforia uuttui jankosta yleensä enemmän kuin pohjamaasta, ja näin tapahtui varsinkin savestasolla 35—70 %. Jankon kalsiumarvot olivat noin kymmenkertaisia ja pohjamaan 9—15-kertaisia kaliumarvoihin verrattuina kaikilla savestasoilla. Ca-pitoisuus oli alhaisella savestasolla (5—9 % savilajitetta) jankossa ja pohjamaassa keskimäärin vain noin 400 mg Ca/l maata, kun se korkealla savestasolla (85—89 %) oli lähes 2 700 mg. Vastaavilla savestasoilla K-arvot olivat 38 ja 294 mg K/l maata.

Maalajien keskimääräiset pH-arvot, kalsium- ja kaliumpitoisuudet kasvoivat yleensä maalajin muuttuessa karkeammasta hienompaan suuntaan, sarjana: hieta, hiesu, hietasavi, hiesusavi ja aitosavi (taulukko 3). Muokkauskerroksen pH-arvossa ei kuitenkaan tällaista johdonmukaisuutta ilmennyt. Fosforipitoisuus sen sijaan laski kaikissa kerroksissa maalajin hienousasteen kasvaessa.

Tutkittujen maan kemiallisten ominaisuuksien perusteella näytteen saveksen määrään pohjautuva maalajien luokitus näyttää oikealta. Myös hienohiesuaineksen määrää voitanee käyttää luokituspohjana, sen saviaineksen karkeusastetta ilmentävän ja siten ravinteisuuteen vaikuttavan luonteen vuoksi.

ANNALES AGRICULTURAE FENNIAE, VOL. 17: 83—88 (1978)
Seria AGROGEOLOGIA ET -CHIMICA N. 85 — Sarja MAA JA LANNOITUS n:o 85

THE EFFECT OF NITROGEN FERTILIZATION ON K/(Ca + Mg) RATIO IN GRASS

SIRKKA-LIISA RINNE, MIKKO SILLANPÄÄ, ERKKI HUOKUNA and SIRKKA-LIISA HIIVOLA

RINNE, S-L., SILLANPÄÄ, M., HUOKUNA, E. & HIIVOLA, S-L. 1978. **The effect of nitrogen fertilization on K/(Ca+Mg) ratio in grass.** Ann. Agric. Fenn. 17: 83—88. (Agric. Res. Centre, Inst. Soil Sci., SF-01300 Vantaa 30, Finland.)

The effect of nitrogen fertilization (0, 150, 300, 450, and 600 kg N/ha/yr) on the K/(Ca+Mg) ratio in yields of meadow fescue and cocksfoot harvested for silage three times during the growing seasons was studied at 18 experimental locations.

The average K/(Ca+Mg) ratio, $1{,}94 \pm 0{,}89$ ($n = 1\,573$), was only slightly affected by nitrogen fertilization. The ratio increased with increasing nitrogen application during the first experimental year but decreased during the second and third years.

The ratio was more affected by season, plant species, age of the ley, and soil type than by nitrogen fertilization and level of yield. Al together, 55,3 per cent of the variation was explained by the above variables.

The K/(Ca+Mg) ratio in cocksfoot yields (avg. 2,24) was significantly higher than that in meadow fescue (1,64). The ratio was at its highest (avg. $3{,}83 \pm 0{,}58$) in the spring (1st cut) yield of cocksfoot grown on fine mineral soils.

Index words: K (Ca+Mg) ratio, nitrogen fertilization, meadow fescue, cocksfoot.

INTRODUCTION

Studies on the effects of heavy nitrogen fertilization on the quantity and quality of grass harvested for silage, as well as the effects on chemical properties of soils, have been carried out by the Agricultural Research Centre. Increasing nitrogen application significantly increased both Ca and Mg contents of the grass. In addition, the K content increased considerably during the first growing season but began to decrease during the following seasons (RINNE et al. 1974). This was because the potassium fertilization (100 kg K/ha/yr) was inadequate to meet the increasing K uptake by yields, causing a decrease in soil exchangeable K (SILLANPÄÄ and RINNE 1975). As a consequence, the uptake of K become more restricted: this was manifested in decreasing K contents of plants with increasing age of the ley and with increasing N fertilization and yields. On the contrary, the Ca and Mg contents increased with increasing age of the ley.

Due to the diverging effects of fertilization on the contents of different elements in plants, there are considerable changes in ratios between the various elements. Faulty K/(Ca+Mg) (>2,2) ratio in pasture grasses and silages may promote occurence of tetany in cattle (KEMP and t'HART 1957, METSON et al. 1966).

Factors affecting the K/(Ca+Mg) ratio of grass have been the subject for a relatively small number of studies. According to MÄNTYLAHTI (1975), this ratio is most dependent on the respective ratio in the soil. This paper deals with the effects of nitrogen fertilization, plant species, seasonal variation, age of the ley, and soil types on the K/(Ca+Mg) ratio; as well as with the conditions where the ratio is likely exceed the risk limit.

MATERIAL AND METHODS

Three year nitrogen fertilization experiments were carried out by the Agricultural Research Centre at 18 sites in Southern and Central Finland (lat. 60—64°) on grass leys for silage. The plant species used were meadow fescue and cocksfoot (Tammisto varieties). Five nitrogen treatments were used: 0, 150, 300, 450, and 600 kg N/ha/year. PK fertilizer at the rate of 100 kg K/year, as well as 44 kg P/year were given in one dressing at the beginning of each growing season. The soils ranged from coarse mineral soil (seven trials), to fine mineral soil (nine), and organogenic soil (two). The crop was harvested three times during the growing season, and a sample was taken from each cut for chemical analysis (2 species × 5 N treatments × 3 cuts × 3 year × 18 sites = 1 620 [1]) samples). Full details of the plan of the treatment, quantity and quality of the yields, and results of the mineral analysis were given in the preceding number of this series (HUOKUNA and HIIVOLA 1974, HIIVOLA et al. 1974, RINNE et al. 1974). The ratio K/(Ca+Mg) was calculated on an equivalent basis.

[1]) Due to winter damages the actual number of samples was 1 573.

RESULTS AND DISCUSSION

The average mineral contents of grass in the whole experimental material were: Mg 0,25±0,09, Ca 0,55±0,17, and K 3,20±0,83 per cent. The effect of nitrogen fertilization varied from one cut to another, as well as from one year to another. The decreases in plant available soil potassium and in potassium uptake during the experimental period are reflected in the regressions given in Fig. 1 and 2. At the beginning of the experiments, when the soil potassium supply was still ample, the K/(Ca+Mg) ratio increased with increasing nitrogen fertilization. The changes in soil, a decrease of exchangeable K, and increase of exchangeable Mg (SILLANPÄÄ and RINNE 1975), caused a decrease in the ratio. On the average, increasing N fertilization fourfold, from 150 to 600 kg N/ha, decreased the ratio from 2,09 to 1,83. MÄNTYLAHTI (1975) also found that nitrogen had a relatively small effect on the K/(Ca+Mg) ratio, because an increase in K was accompanied with a simultaneous increase in Mg.

The average K/(Ca+Mg) ratio in cocksfoot (2,24) slightly exceeded the ratio of 2,2, considered the risk limit (KEMP and t'HART 1957), and was significantly higher than that (1,64) for meadow fescue (Table 1). The ratio in the first cut yields, as well as in yields of the first year, exceeded the risk limit. At its highest (avg. 3,83±0,58), the ratio in the first cut yields of

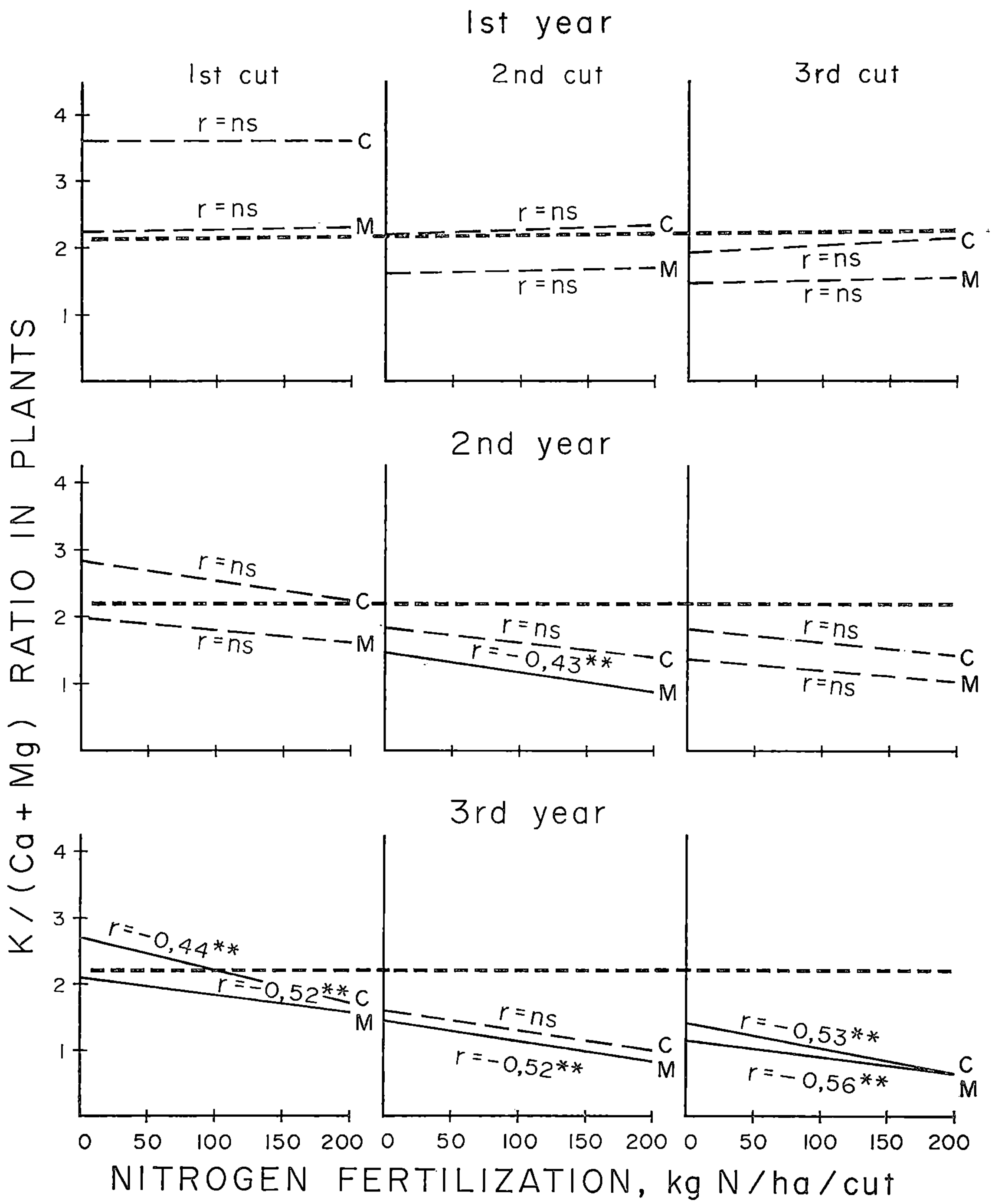

Fig. 1. Regressions of the K/(Ca+Mg) ratio (eqv. basis) on nitrogen fertilization for coarse mineral soils (seven experimental sites). C = Cocksfoot, M = Meadow fescue. The dotted horizontal line indicates the critical value of the ratio according to KEMP and t'HART (1957).

Table 1. Relationships between nitrogen fertilization, cutting time (season), age of the ley, soil type, and plant species, and the K/(Ca+Mg) ratio of the grass. Values followed by the same letter do not differ significantly (P < 0,05) from each other. The Tukey test.

N fertilization	kg N/ha/cut K/(Ca+Mg) ±s	0 1,88[a] ±0,78	50 2,09[b] ±0,83	100 1,99[ab] ±0,93	150 1,89[a] ±0,95	200 1,83[a] ±0,93
Cut no.	K/(Ca+Mg)	1. 2,58[b]		2. 1,66[a]		3. 1,56[a]
Age of the ley, years	K/(Ca+Mg)	1 2,30[c]		2 1,88[b]		3 1,62[a]
Soils	K/(Ca+Mg)	Coarse mineral 1,76[a]		Fine mineral 2,13[b]		Organogenic 1,67[a]
Species	K/(Ca+Mg)	Meadow fescue 1,64[a]		Cocksfoot 2,24[b]		
Whole material	K/(Ca+Mg) ±s	1,94 ±0,89				

cocksfoot grown on fine mineral soils exceeded the risk limit by a factor of 1,7, and was almost independent of applied nitrogen (Fig. 2).

The following variables (in order of magnitude): season, plant species, age of the ley, soil type, nitrogen fertilization, and level of yield; explained 55,3 per cent of the variation in the K/(Ca+Mg) ratio. The respective nutrient ratio in the soil, which according to Mäntylahti (1975) is a decisive factor affecting the ratio in the plant, was not included in the statistical analyses because of insufficient data.

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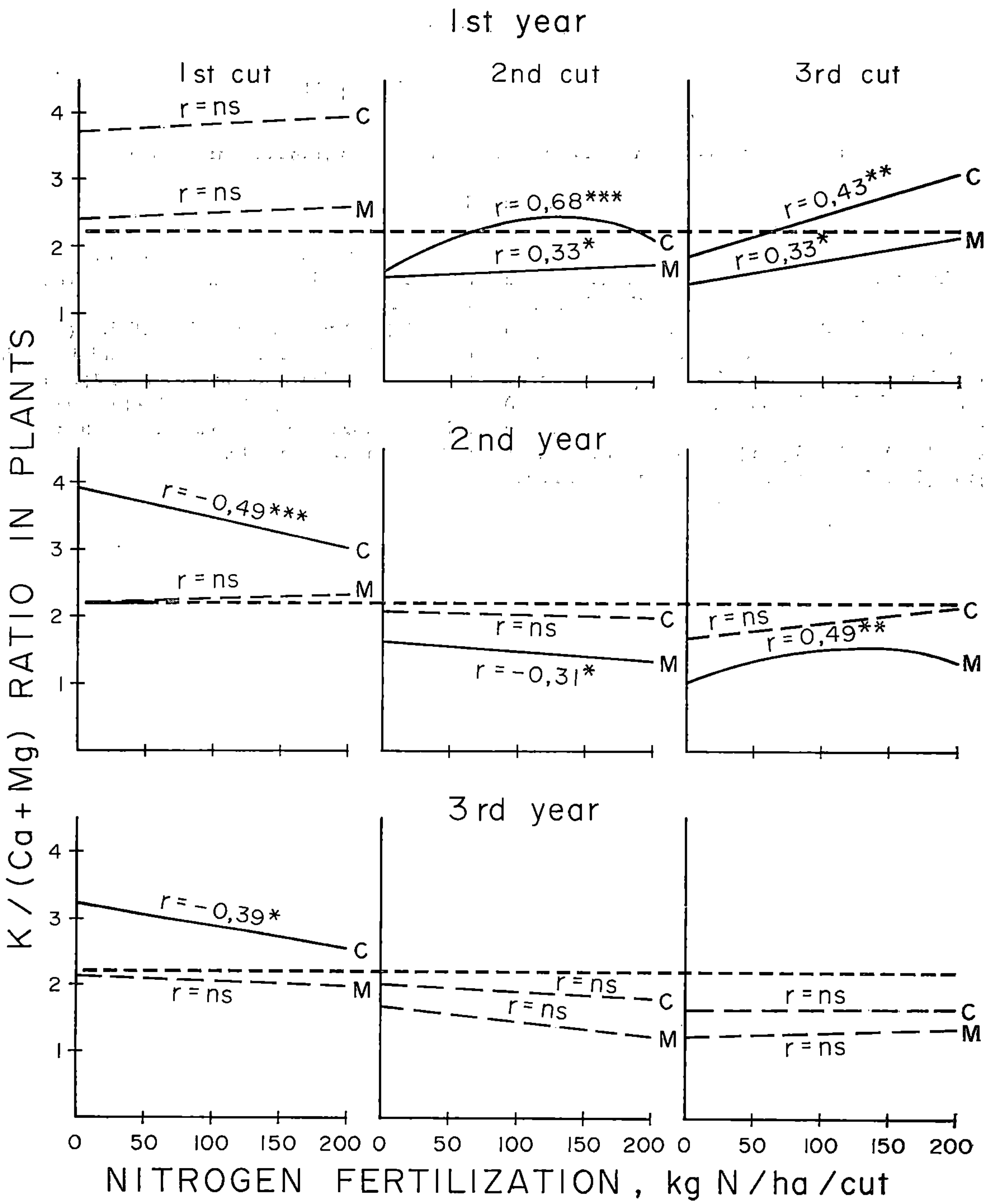

Fig. 2. Regressions of the K/(Ca+Mg) ratio (eqv. basis) on nitrogen fertilization for fine mineral soils (nine experimental sites). C = Cocksfoot, M = Meadow fescue. The dotted horizontal line indicates the critical value of the ratio according to KEMP and t'HART (1957).

SELOSTUS

Typpilannoituksen vaikutus ruohon K/(Ca + Mg) -suhteeseen

Sirkka-Liisa Rinne, Mikko Sillanpää, Erkki Huokuna ja Sirkka-Liisa Hiivola

Maatalouden tutkimuskeskus

Maatalouden tutkimuskeskuksen järjestämissä kokeissa selvitettiin runsaan typpilannoituksen, 0, 150, 300, 450 ja 600 kg N/ha/v, vaikutusta nurminadan ja koiranheinän K/(Ca+Mg) (ekv.) -suhteeseen säilörehunurmilla, joiden sato korjattiin kolme kertaa kasvukaudella kolmen vuoden ajan 18 koepaikalla. Typpi annettiin kolmena eränä kasvukaudella ja PK-lannoitus (44 kg P ja 100 kg K/ha) yhtenä eränä keväisin. Keskimäärin koko aineistossa (n = 1 573) ruohon K/(Ca+Mg)-suhde oli 1,94±0,89, ja typpilannoituksen vaikutus siihen muuttui kasvukauden ja nurmen iän mukaan: kokeen alussa typpeä lisättäessä suhde kohosi, myöhemmin typen vaikutus oli päinvastainen.

K/(Ca+Mg)-suhteen vaihteluista selittivät (suuruusjärjestyksessä) niittokerta, kasvilaji, nurmen ikä, maalaji, typpimäärä ja sadon suuruus yhteensä 55,3 %. Suurimmillaan (keskimäärin 3,83±0,58) K/(Ca+Mg)-suhde oli koiranheinän 1. vuoden kevätsadoissa, jotka olivat kasvaneet hienolla kivennäismaalla.

ANNALES AGRICULTURAE FENNIAE, VOL. 17: 89—102 (1978)
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SELECTION OF FATTY ACID COMPOSTION IN TWO OPEN-POLLINATED VARIETIES OF SUMMER TURNIP RAPE (BRASSICA CAMPESTRIS L. VAR. ANNUA L.)

SAIJA RAVANTTI

RAVANTTI, S. 1978. **Selection of fatty acid composition in two open-pollinated varieties of summer turnip rape** (*Brassica campestris* L. var. *annua* L.). Ann. Agric. Fenn. 17: 89—102. (Agric. Res. Centre, Inst. Pl. Breed., SF-31600 Jokioinen, Finland.)

A cross between cultivars of summer turnip rape (*Brassica campestris* L. var. *annua* L.) Torpe ♀ × Span ♂ and Fenno ♀ × Span ♂, whose F 1 generation was open pollinated, resulted in an F 2 generation whose seeds were subjected to gas and paper chromatography by the half-seed method and grown in isolation groups of 2—3 vigorous plants in each bag. Seeds from the F 3 generation of this cross were almost free from erucic acid, C 22 : 1. There was a lower C 22 : 1 content in the F 3 generation in the Fenno × Span cross than in the Torpe × Span. The original Fenno C 22 : 1 content was 15,6 % higher than Torpe. The C 22 : 1 content of individual plants in the F 2 generation was distributed in a ratio of 1 : 3 or 1 : 2 : 1. When the C 22 : 1 content was 0, the C 20 : 1 content was no higher than 2 %. The C 18 : 2 content of Torpe × Span was evidently originally higher than Fenno × Span.

Torpe is a higher yielding cultivar than Fenno. The yield from the Torpe × Span cross was better than from the Fenno × Span in each F generation. A choice of individuals with good agronomic properties in F 1 and F 2 did not, however, result in a line with a sufficiently high yield. Therefore, in future crossings, a backcross should be done to higher yielding cultivars, or a cross made to different C 22 : 1 free lines.

Index words: the selection of fatty acid composition, *Brassica campestris* L. var. *annua* L.

INTRODUCTION

As a result of the experiments done on animals, health authorities have restricted the use of fats containing erucic acid in many countries during this decade. In Finland, the State Board of Public Health presented its recommendations on the matter in 1976. In the same year, cultivation of rape was transferred entirely to those varieties which do not contain erucic acid (ROINE et al.

1960, ABDELLATIF and VLES 1970, WALKER et al. 1970, BEARE-ROGERS and NERA 1972, BORG 1975, ENGFELDT and BRUNIUS 1975, KORPELA and KUMPULAINEN 1977).

Rapeseed oil contains an average of 24 to 40 % erucic acid (C 22 : 1), 10 to 12 % eicosenoic acid (C 20 : 1), 17 to 34 % oleic acid (18 : 1), 14 to 18 % linolenic acid (C 18 : 2), 9 to 11 % linoleic acid (C 18 : 3), and 2 to 3 % palmitic acid (C 16 : 0) (APPELQVIST and OHLSON 1972). Rapeseed which did not contain erucic acid was found by Canadian scientists in 1961 in individuals of Liho summer rape and in 1964 in Polish domestic summer turnip rape. These findings initiated research into the crossbreeding of rape and summer turnip rape: fatty acid content was determined by simultaneously developed gas and paper chromatographic half-seed methods (STEFANSSON et al. 1961, DOWNEY and HARVEY 1963, DOWNEY 1964, THIES 1971). The first aim was to eliminate C 22 : 1 and C 20 : 1; and then to reduce the C 18 : 3 content and increase the C 18 : 2, C 18 : 1 and C 16 : 0 contents. The object was to develop varieties which would be easy to cultivate and have advantageous fatty acid compositions (see, among others, STEFANSSON et al. 1961, LÖÖF and APPELQVIST 1964, STEFANSSON and HOUGEN 1964, KRYZMANSKI 1967, 1970, RÖBBELEN and RAKOW 1970, SCHUSTER 1970, JÖNSSON 1973, 1974, 1975 b, 1977 b).

Knowledge of heredity is the prerequisite for successful breeding work. Research into heredity with summer turnip rape is more difficult than with rape, as summer turnip rape is an almost absolute cross-breeder. According to the research done by DORELL and DOWNEY in 1964, the C 22 : 1 content of summer turnip rape is regulated by one gene. JÖNSSON (1973, 1977 a and b) found in his research that the C 22 : 1 content of summer turnip rape was regulated by a series of multiple alleles at the same locus. There being at least four alleles, probably more. The effect of an allele is greater in summer turnip rape than in rape.

The same allele controls the synthesis of both C 20 : 1 and C 22 : 1. The alleles exhibit an additive effect for erucic acid at levels below 30 %, while partial dominance is common at higher levels. Those alleles incapable of C 22 : 1 synthesis produce C 20 : 1 at a maximum of 3 %. In rape, C 22 : 1 and C 20 : 1 have been found at several homozygosity levels. The same homozygosity levels are present in summer turnip rape, although their identification is more difficult than with rape. Homozygosity levels create the risk of erroneous selection. The C 22 : 1 content may be low, but the homozygosity of the allele prevents the total elimination of C 22 : 1 in further selection (STEFANSSON and HOUGEN 1964, KONDRA and STEFANSSON 1965, KRYZYMANSKI and DOWNEY 1969, LEE et al. 1974, MORICE 1974, JÖNSSON 1977 a).

According to several studies, C 18 : 2 and C 18 : 3 are bound positively with each other. However, it has been demonstrated that the C 18 : 2 content can be increased and the C 18 : 3 content decreased in the mutation and crossbreeding materials. The two enzymes, working independently of each other, probably guide the syntheses of C 18 : 2 and C 18 : 3 in summer turnip rape (THIES 1968, SCHUSTER 1970, RAKOW 1972, RÖBBELEN and THIES 1973, NITSCH 1975, KONDRA and THOMAS 1975, JÖNSSON 1975 b, KONDRA and WILSON 1976).

Environmental factors play a minor rôle in the synthesis of C 22 : 1 and C 20 : 1, but have a very strong influence on the C 18 : 2 and C 18 : 3 contents (APPELQVIST 1968, 1971, RÖBBELEN 1973, JÖNSSON 1975 a).

The Span and Torch cultivars of summer turnip rape, presently under cultivation in Finland, and which are free from C 22 : 1, have poorer yields and are more sensitive to flattening than the earlier cultivated Torpe and Bele varieties (RAVANTTI and WESTMAN 1977). It would be important, in a country like Finland where small farms predominate, to have a variety of summer turnip rape which have at least the same level of cultivation security as had the old varieties which contained C 22 : 1. In theory, when attemting to combine a favourable fatty acid composition with good agronomic properties, it is necessary to make four backcrosses to parent varieties with better agronomi properties or other corresponding varieties. In practice, however, the same result has been obtained in some instances with a single backcross (Röbbelen and Leitzke 1970, Jönsson 1977 b).

Breeding work in the conversion of fatty acid composition requires many chemical analyses, cross-breedings and isolations. Plant breeding institutes with modest economic means are forced to use simpler methods of breeding than wealthier institutes, although this increases the risk of making an erroneous selection due to, e.g., the homozygosity levels of C 22 : 1. The quickest way to achieve a favorable fatty acid composition is to use in the selection process only selfpollinated seeds. Breeding of summer turnip rape is made more difficult by an inferior ability to selfpollinat, as a result of which the plant declines in vitality (Röbbelen and Leitzke 1974, Jönsson 1977 b, Uppström 1977).

The purpose of this study was to investigate the influence of the selection of fatty acid composition on two cross-breedings of summer turnip rape. An attempt was made to prevent declining vitality in the plants by allowing the pollination of the material to take place internally and openly as much as possible, and by selecting for further breeding out of each generation only the most vigorous and high yielding individuals.

MATERIALS AND METHODS

The study was carried out at the Plant Breeding Department of the Agricultural Research Centre of Finland at Jokioinen during the period 1974—1977. The cross-breedings of Torpe ♀×Span ♂ and Fenno ♀×Span ♂ cultivars of summer turnip rape were made in the late winter of 1974 in the green house. Torpe is a Swedish, high yielding cultivar, rather late maturing, but resistant to flattening, and has a high erucic acid content (Lööf 1973). Fenno is a variety selected from Argentinian material in Finland (Valle 1951). It has a high erucic acid content, and is not as high yielding as Torpe (Anon. 1975). Span is the world's first summer turnip rape cultivar with a low erucic acid content. It came on the market in Canada in 1971 (Anon. 1971).

The F 1 generation was raised in the greenhouse in 6″ clay pots, in each of which 10 seeds were sown. Bag isolations were done on individuals; but they did not yield seeds and a frequent result was that the whole individual became barren. Openly pollinated seeds were obtained in 78 cases of Torpe×Span cross-breedings and in 64 cases of Fenno×Span. The analysis of the fatty acid composition of the material was possible, due to technical reasons, only in the yields from the F 2 generation.

In the growing season of 1975, the seeds of high yielding F 1 individuals were sown in the experimental trial fields. Sixteen individuals from each cross-breeding were grown in the sandy soil of the Plant Breeding Institute in Jokioinen; and fifteen individuals, again from each cross-breeding, in the clay soil of Kymenlaakso Experimental Station at Anjala. The crossbreeds formed isolated populations of their own. The seeds of individuals were sown one after the other in rows at a distance of 40 centimeters. Early and vigorous individuals were isolated in bags or the shoots of 2 or 3 individuals were enclosed in the same bag. The bags were removed after flowering. The isolation of one individual gave a very poor seed yield; the isolations of 2 or 3 individuals were much better.

The fully developed seeds (18 seeds) resulting from the isolations of several individuals together were tested by the half-seed paper chromatography method (Thies 1971). Those individuals whose cotyledons tested out at less than 3 % C 22 : 1 were added into the F 3 generation in the greenhouse in 2″ plastic pots and allowed to freely cross-breed. This was referred to as the A-material. Those isolated plants which were found by paper chromatography to have most seeds with less than 3 % C 22 : 1 were also tested by gas chromatography using the half-seed method. Those individuals whose C 22 : 1 content was less than 3 % of the total fatty acid content were added into the F 3 generation in the greenhouse in 2" plastic pots. This was referred to as the B-material.

Two generations a year could be raised in the greenhouse, although additional light was available only in limited amounts. The development of the plants was slow during the darkest season between November and January, due to lack of light. Leaf mould in the cross-breeds occurred mostly during the late autumn and winter. It was arrested with a sulphuric fumigation. Occurrence of aphids in the plant material was highest during the late winter and summer. The aphids were controlled with a subcarbide powder (Temik 10 G) and dimethoate and bromophoss sprays. The yield from individuals raised in the greenhouse was most often smaller than that of those which had grown in the field.

The oil from the cotyledons was extracted and esterized using the APPELQVIST (1968 b) method. The oil from the seeds was extracted by grinding them with petroleumether and esterizing by the A.O.C.S. Ce. 2-66 method. The esterized fatty acids were pipetted into a Perkin Elmer F 30 gas chromatograph.

	half-seed method	seed samples
column length	6 feet × 2 mm inside diam. glass/metal tubes	6 feet × 2 mm inside diam. glass/metal tubes
column temperature	190 °	programmed 180—210 °C
nitrogen flow rate	25 ml/min	42 ml/min
duration of analysis	15 min	55 min
column filled with	3 % BDS/ CHROMOSORB W	10 % BDS/ CHROMOSORB W

Fourteen fatty acids were analyzed from the seed lots, and six of the most important fatty acids were more accurately checked by the half-seed method. This is the usually accepted degree of accuracy in these analyses (see, *inter alia*, STEFANSSON and HOUGEN 1969, JÖNSSON 1973).

During the cool and rainy growing season of 1977, a comparison was made between Torpe × Span = Jo 1 072 and Fenno × Span = Jo 1 073 trials with Span control and line Jo 1 074 [(Torpe × S.71) × (Torpe × S.72)] and Jo 1 075 [(Maleksberger × S.71) × (Maleksberger × S.72)], in the following locations: the Plant Breeding Department at Jokioinen, the South Ostrobotnia Experimental Station at Ylistaro, and the Central Finland Experimental Station at Vatia. The size of the trial squares 10 square meters and the 4 replicates were used. Nitrogen fertilization was 100 kg/hectare. Jo 1 074 and Jo 1 075 derived their origins from the cross-breeds whose F 1 generation in the greenhouse and F 2 generation in the field were allowed to pollinate openly within the cross-breed. The seed yield from the plants with good agronomic properties in the F 2 generation was harvested by the individual plant. The yields were analyzed by paper chromatography, using the half-seed method. Those individuals having less than 3 % C 22 : 1 in the cotyledon were added into the greenhouse population. The yields from high-yielding individuals were mixed in accordance with the cross-breeding scheme and were added into the field isolation population.

RESULTS

Fatty acid composition of the parent cross-breeds

Fenno's erucic acid content was 15,6 % higher than Torpe's (Table 1). Span was not entirely free of C 22 : 1. The analysis of individual seeds showed that a few of them contained C 22 : 1. The variation of the C 22 : 1 content was 0 to 15,8 % with Span, 25,8 to 46,6 % with Torpe, and 27,4 to 59,1 % with Fenno.

Torpe's C 18 : 1, C 18 : 2 and C 20 : 1 contents were higher than those of Fenno. Span's

Table 1. Fatty acid composition in the seed lots of the crossing parents

Fatty acid		Torpe	Fenno	Span
		Fatty acid composition in percent		
		Variety		
		Torpe	Fenno	Span
Palmitic acid	C 16 : 0	2,9	2,8	3,6
Palmitoleic acid	C 16 : 1	0,1	0,1	0,3
Stearic acid	C 18 : 0	1,1	1,1	1,3
Oleic acid	C 18 : 1	24,4	11,9	61,8
Linoleic acid	C 18 : 2	18,1	14,8	19,8
Linolenic acid	C 18 : 3	9,1	10,3	8,1
Arachidic acid	C 20 : 0	0,6	0,8	1,2
Eicosenoic acid	C 20 : 1	10,3	8,7	2,0
Eicosadienoic acid	C 20 : 2	0,5	0,7	0,9
Behenic acid	C 22 : 0	0,4	+	0,3
Erucic acid	C 22 : 1	31,4	47,0	1,0
Docosadienoic acid	C 22 : 2	+	0,6	—
Lignoceric acid	C 24 : 0	—	0,2	+
Nervonic acid	C 24 : 1	1,1	1,0	+
C 18 : 3 / C 18 : 2		0,58	0,70	0,41

erucic acid composition was typical for a variety with a low erucic acid content; its C 18 : 1 and C 18 : 2 contents were higher, and its C 18 : 3 and C 20 : 1 contents lower than in the varieties high erucic acid contents.

F 1 and F 2 growth heights

F 1 individuals from the cross-breed Torpe × Span were on the average slightly taller and had higher yields than those of Fenno × Span (Table 2). The thousand seed weight was slightly less in the Torpe cross-breed than in the Fenno cross-breed. The deviation was nonetheless larger than expected.

Temperature and moisture conditions were favourable in the 1975 growing season. The F 2 generation of summer turnip rape cross-breeds did very well. The Torpe × Span population at the Kymenlaakso Experimental Station grew in an area slightly contaminated by clubroot.

Table 2. Observations on F 1-plants

Crossing	Plants	Height cm		Pods/plant		Seeds/plant		1 000 seed weight	
		mean	SD ±	mean	SD ±	mean	SD ±	mean	SD ±
Torpe × Span ..	78	108,7	51,61	13,4	11,51	100,5	93,2	2,22	0,62
Fenno × Span ..	64	104,5	21,82	13,7	3,83	98,5	88,8	2,61	0,47

SD = standard deviation

The contamination, which was discovered only during the growing season, caused a slowdown in the plants' growth. Thus, on the average, Torpe × Span individuals were shorter than Fenno × Span individuals grown in Kymenlaakso; at Jokioinen the situation was reversed (Table 3). Fenno × Span individuals branched little more than those of Torpe × Span.

On the average, the size of the seeds of the cross-breeds were the same. Under Jokioinen's conditions of moist, sandy soils the seeds were larger than those from Anjala's clayish soils.

Table. 3. Observations on F 2-plants

Locality Crossing	Plants	Height cm		Branches		1 000 seed weight		
		mean	SD ±	mean	SD ±	Samples	mean	SD ±
Kymenlaakso								
Torpe × Span	488	70,8	±6,7	4,8	±1,4	71	2,43	1,29
Fenno × Span	674	76,2	±4,4	8,0	±1,1	64	2,46	0,53
Jokioinen								
Torpe × Span	100	84,3	±8,1	12,3	±5,1	64	2,75	0,41
Fenno × Span	110	78,6	±11,6	13,1	±4,3	72	2,77	0,45

SD = standard deviation

Fatty acid composition of F 2 generation seed yield

On the average, there were no great differences between the fatty acid compositions of Torpe × Span and Fenno × Span in the F 2 generation (Figure 1). With both cross-breeds, change was directed more towards Span than towards either of the other parents. The standard deviation was greater with Fenno × Span than with Torpe × Span, except in the deviations of C 16 : 0 and C 18 : 2.

The C 22 : 1 content was smaller in Torpe × Span than in Fenno × Span. The C 22 : 1-free individuals were distributed in the cross-breeds in a ratio of approximately 1 : 3. The distributions obtained, however, did not agree well with those that had been expected. Torpe × Span x^2 = 5,03 P = 0,025—0,01** and Fenno × Span x^2 = 6,68** P = 0,01**—0,001***. When the C 22 : 1 content was 0, the C 20 : 1 content was below 2 % in all cases. On the average, the C 20 : 1 content was higher with Torpe × Span, although the number of individuals with the highest content were less than in Fenno × Span. The average C 18 : 2 content of Torpe × Span and the number of individuals of high content was greater than in Fenno × Span, which in turn had higher corresponding values of C 18 : 1 content than Torpe × Span. The C 18 : 3 content was, on the average, the same with both the cross-breeds.

In the graphical analysis of the distribution of C 22 : 1 and C 20 : 1 contents of individual seed sample lots, a monohybrid distribution of 1 : 3 or 1 : 2 : 1 can be observed in the 2 or 3 individuals grouped together in isolation and the in the free pollinated seeds (Figure 2). The distributions obtained agree well with those expected, although the number of observations was small. When the C 22 : 1 content was 0, C 20 : 1 remained below 3 %. When the C 20 : 1 level increased to 15 %, C 22 : 1 increased, in plants 1 to 7 and 9 to 25, to 30 %, and in plant 8 to 35 %; when the C 22 : 1 content was further increased, the C 20 : 1 content decreased.

Fatty acid composition of the F 3 generation's seed yield

Those isolated sample seed lots of the F 2 generation which were found to contain the most seed with a C 22 : 1 content of below 3 % using paper chromatography, were also found to contain the most seeds free from erucic acid, when verified by gas chromatography (Figure 3). The correlation coefficient was slightly smaller in the Torpe × Span cross-breeds than in the Fenno × Span cross-breeds.

The differences in fatty acid compositions between the seeds of the F 3 generation's A and B sample lots were not great. The deviations of the fatty acids' average composition were greater with A than B, with the exception of the C 22 : 1 deviation of Fenno × Span (Figure 4).

The Fenno × Span cross-breed had a lower C 22 : 1 content than the Torpe × Span. The result was reversed in F 2. Both cross-breeds'

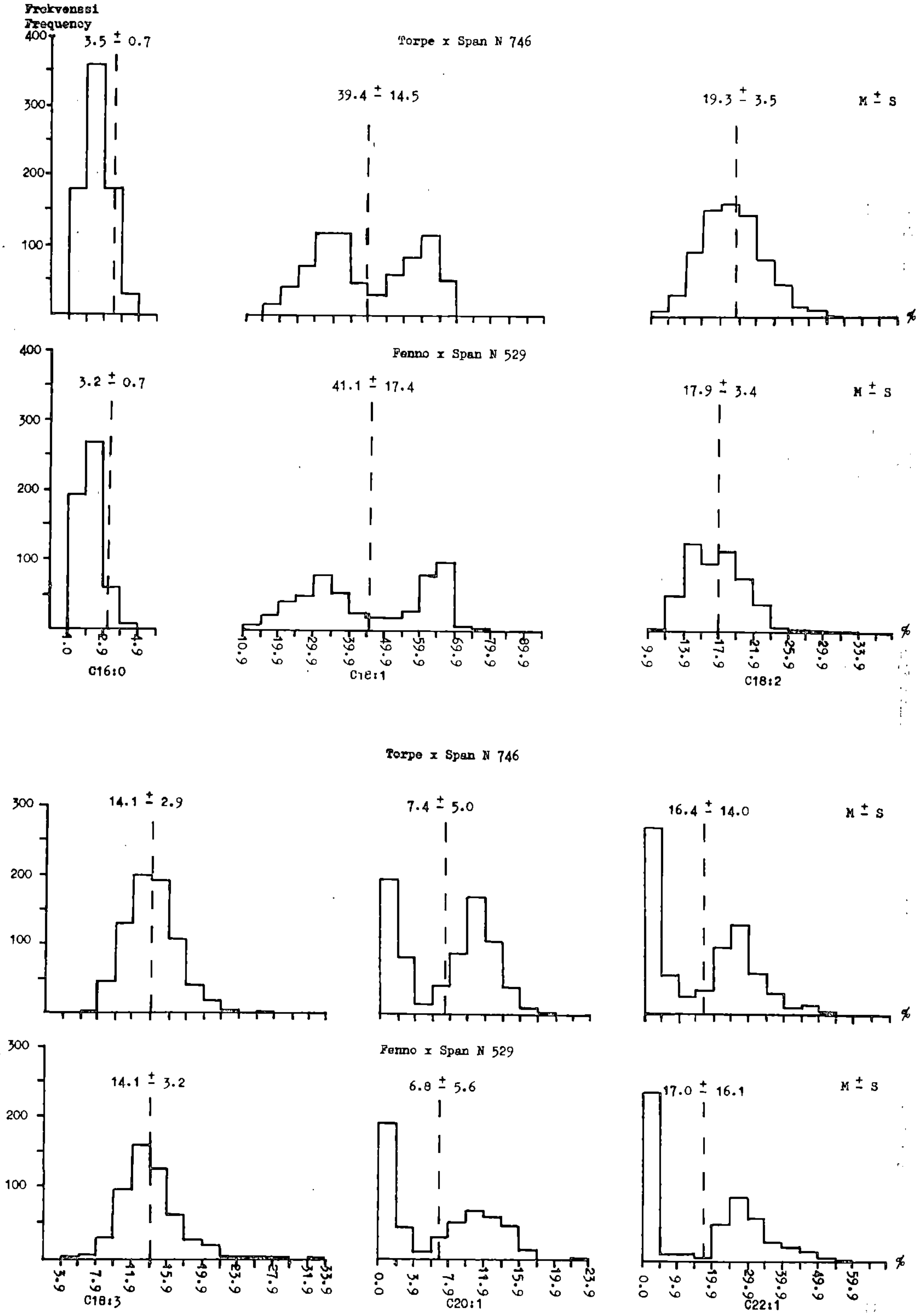
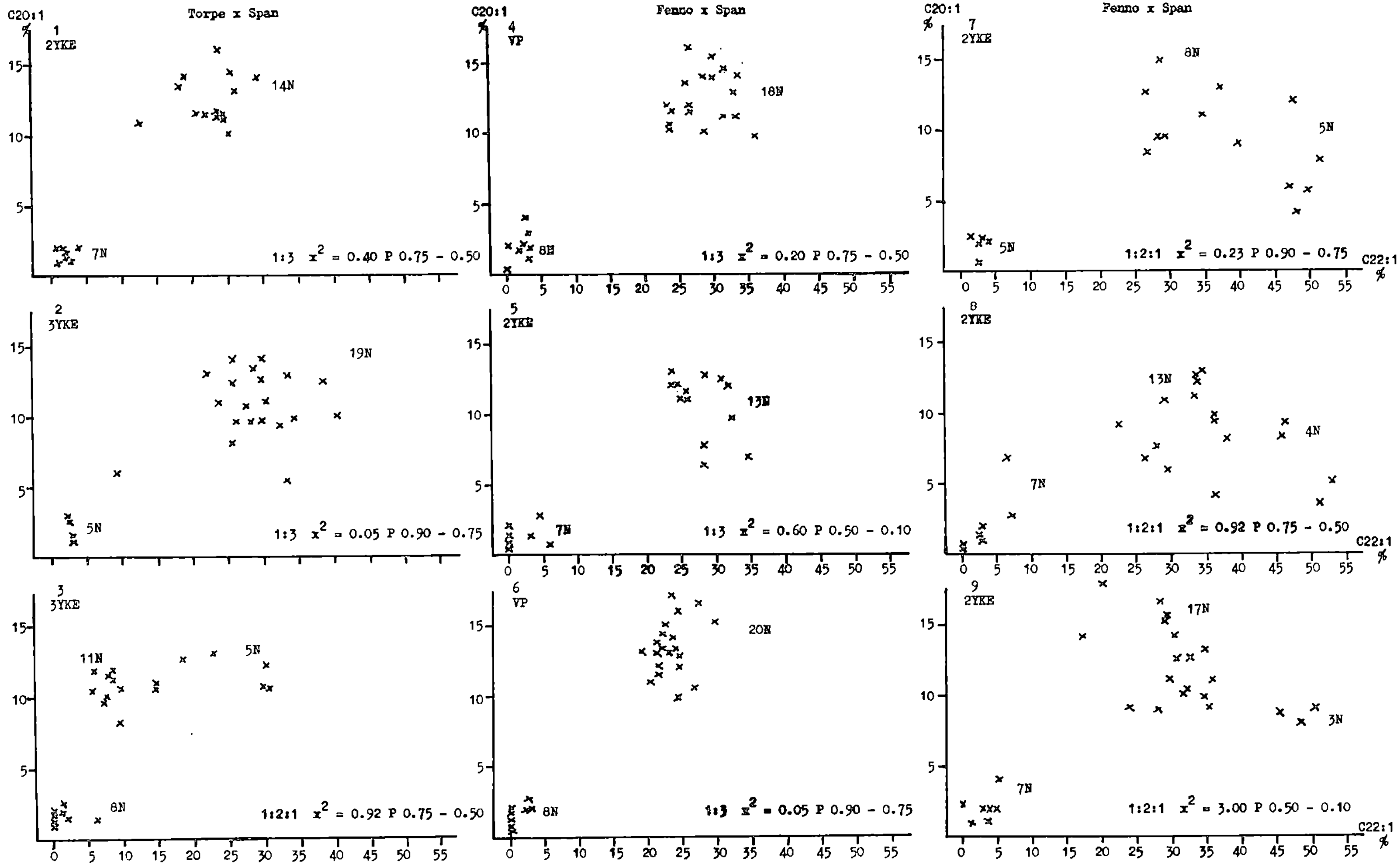


Figure 1. Distribution of fatty acid content in a single seed of the F-2 generation



2YKE = plants, bag-isolated

VP = open pollinated plant

Figure 2. Some examples of erucic fatty acid and eicosenoic fatty acid contents of the seeds of F 2-plants.

A lots had a lower C 22 : 1 content than B lots. Torpe × Span had a higher C 18 : 2 content than Fenno × Span, which in turn had a higher C 18 : 1 content than Torpe × Span. The result was the same as in F 2.

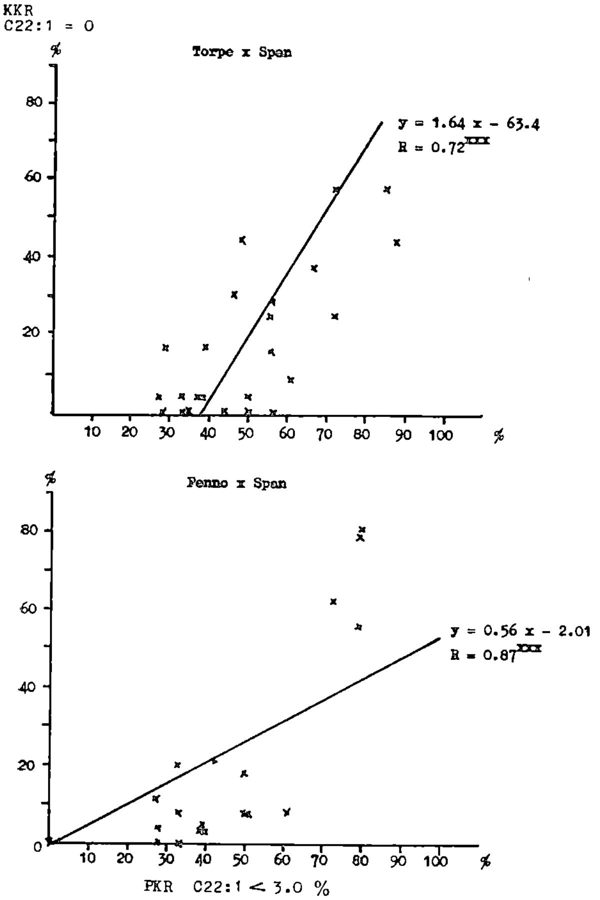


Figure 3. Relations between the paper chromatography selection (PKR) and the gas chromatography selection (KKR) in the seeds of 2—3 plants, bagisolated, in the F 2 generation.

Agronomic properties of the cross-breeds

Jo 1 072 gave higher yields in trials than Jo 1 073 in the cool and rainy growing season of 1 977 (Table 4). Better yields than those of Jo 1 072 were obtained from lines Jo 1 074 and Jo 1 075. Due to the limited material, the differences in yields were not statistically significant. The Jo-lines' resistence to flattening was better than that of Span, despite the fact that their height, with the exception of Jo 1 073, was slightly greater than that of Span. The oil content of the seeds, except that of Jo 1 074, was higher than in Span. The highest oil but lowest protein was in the Jo 1 073 seeds. Jo 1 072 and Jo 1 073 were one day later than Span and their oil clorophyll content was slightly higher.

Table 4. Results of trials with the summer turnip rape in the year 1977

Variety	Seed yield kg/ha Rel. fig.	Oil yield		Crude protein %	Lodging % ±	Plant height cm ±	Growing period days ±	Chlorophyll-content mg/kg oil
		%	kg/ha Rel. fig.					
Span	1 240	43,2	500	23,6	56	95	123	19,0
Jo 1074 1)	108	—0,1	114	—0,4	—13	+4	±0	—5,0
Jo 1075 2)	102	+1,3	110	—0,5	—8	+4	±0	—7,7
Jo 1072 3)	101	+1,2	104	—0,6	—11	+6	+1	+3,8
Jo 1073 4)	83	+1,7	88	—0,8	—11	—2	+1	+6,6

Crossing 1) [(Torpe × S.71) × (Torpe × S.72)]
2) [(Maleksberger × S.71) × (Maleksberger × S.72)]
3) Torpe × Span
4) Fenno × Span

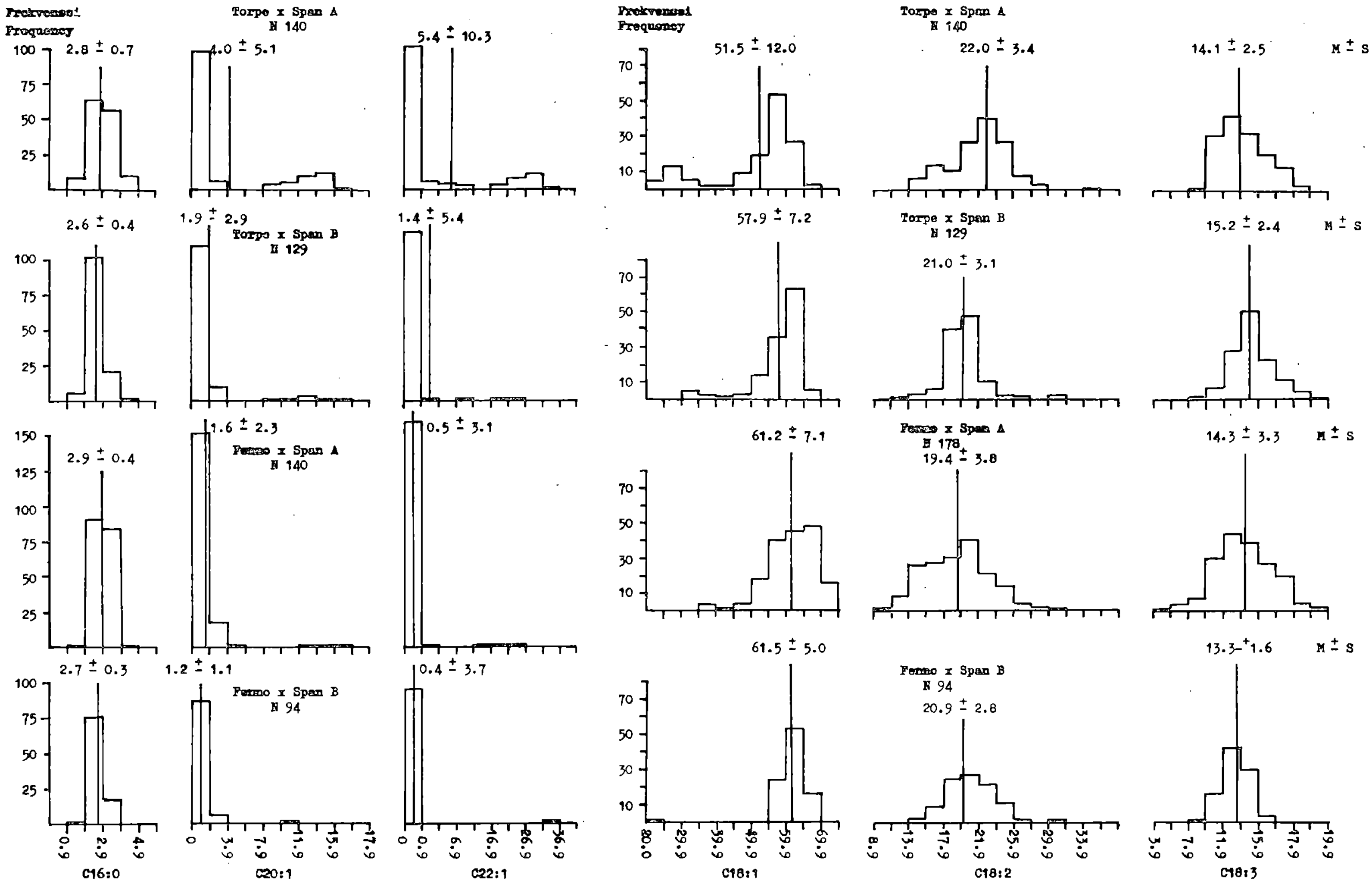


Figure 4. Distribution of fatty acid content in a single seed of the F 3 generation

DISCUSSION

The selection of both cross-breeding parents is important when attempting to combine summer turnip rape's good agronomic properties with a favourable fatty acid composition. It is particularly important to choose those varieties containing good agronomic properties, as emphasized by i.e. Jönsson (1977 b). Torpe's better yield over Fenno is obviously inherited in the cross-breeds. This feature was in evidence in all of the F generations and in the 1977 field trials.

As concerns the vigour of the summer turnip rape, it is definitely advantageous to have open cross pollination (Andersson and Olsson 1961). As far as possible, self-pollination should be avoided in breeding work, although it would be advantageous in mapping the C 22 : 1 homozygosity levels. In this study, the bag isolations of 2 or 3 vigorous and early individuals limited the number of deviations in the F 2 generation. This deviation was caused by open pollination. The distribution of C 22 : 1 in the deviants was found to be primarily in the same direction as in the studies made Dorell and Downey (1969) and Jönsson (1973, 1977 a and b). The elimination of isolated and open pollinated individuals by the half-seed paper chromatography method was successful. As the sole method of selection in F 2, it did not result in as low a C 22 : 1 content in F 3 as it would have if selection had been done by gas chromatography. It seems that considerable savings can be made in practical plant breeding of summer turnip rape by first screening by paper chromatography those plants with the lowest C 22 : 1 contents, followed by refining the results by gas chromatography.

In some investigations, a lower C 22 : 1 content has been observed in F 1 in those crossbreeds whose mother plant has had a high erucic acid content, and not one free from erucic acid (Downey and Harvey 1963, Jönsson 1972). An analysis of the F 1 material in the present study was not technically possible. The result in the F 3 generation was, however, such that there were more C 22 : 1 free individuals in crossbreeds where the mother plant had a high C 22 : 1 content (Fenno × Span). The question arises, is this an accident or the consequence of the above phenomenon observed in F 1?.

The variation in growing conditions during the study period, both in the greenhouse as well in the field, was rather pronounced, thus, it is likely that there were more variations in values for the C 18 group of fatty acids due to outside conditions than to heredity. The higher C 18 : 2 content in the Torpe × Span cross than in the Fenno × Span is nonetheless most likely due to heredity. Jönsson (1975 b) has found in his study precisely the fact that the C 18 : 2 content of Torpe is high and well inherited.

As favourable a population as possible, in terms of agronomic properties, is assured by choosing only the most vigorous plants from among the low C 22 : 1 content individuals. Nevertheless, this method did not guarantee sufficiently high yields with this study material. Evidently, future crosses should be made between the higher yielding varieties of different C 22 : 1 free lines, such as the Jo 1 074 and Jo 1 075 in this study.

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SELOSTUS

Rasvahappokoostumusvalinnasta kahdessa mahdollisimman vapaasti pölyyntyneessä kevätrypsiaineistossa

Saija Ravantti

Maatalouden tutkimuskeskus

Kasvinjalostuslaitoksella v. 1974 kasvihuoneessa suoritetuissa risteytyksissä Torpe×Span ja Fenno×Span pyrittiin yhdistämään Spanin niukkaerukahappoisuus (C 22: 1) runsaserukahappoisten Torpen ja Fennon hyviin viljelyominaisuuksiin. Kevätrypsille luonteenomaisen itsesiitoksen aiheuttaman elinvoiman heikkenemisen estämiseksi annettiin F 1 polven risteytyä vapaasti ja F 2 polvessa 2—3 elinvoimaisen yksilön keskenään sekä valittiin jatkoon vain elinvoimaisimmat, satoisimmat yksilöt.

F 2 polven 2—3 yksilön eristyssiemen analysoitiin paperikromatografisella 1/2 siemenmenetelmällä. <3 % C 22 : 1 omaavat yksilöt lisättiin kasvihuoneessa F 3:ksi. Aineisto nimitettiin A-aineistoksi. Ne eristyssiemenet, joissa oli eniten <3 % C 22 : 1 sisältäviä siemeniä testattiin lisäksi kaasukromatografisella 1/2 siemenmenetelmällä. <3 % C 22 : 1 omaavat yksilöt lisättiin kasvihuoneessa F 3:ksi. Aineisto nimettiin B-aineistoksi.

Fennon C 22 : 1 pitoisuus oli 15,6 %-yksikköä korkeampi kuin Torpen. F 2-polvessa oli Fenno×Spanin keskimääräinen C 22 : 1 pitoisuus $17{,}0 \pm 16{,}1$ ja Torpe× Spanin $16{,}4 \pm 14{,}0$. Kokonaisuutena näytti C 22 : 1 vapaus noudattavan monohybriidi jakautumaa 1 : 3, mutta x^2-testin P arvot eivät ilmaisseet yhteensopivuutta. Sen sijaan todettiin monissa 2 tai 3 yksilön eristyksissä ja vapaapölytyssiemenissä C 22 : 1 vapaiden yksilöiden noudattavan hyvää yhteensopivuutta odotettujen jakautumien

1 : 3 tai 1 : 2 : 1 kanssa. C 22 : 1 ollessa nolla jäi C 20 : 1 alle 2 %:iin eli kyseessä oli varma C 22 : 1 alleelin puuttuminen.

F 3 polven rasvahappojen keskiarvojen hajonnat olivat suuremmat A aineistossa kuin B aineistossa. A aineistojen C 22 : 1 pitoisuus oli korkeampi kuin B aineistojen ja Torpe × Spanin korkeampi kuin Fenno × Spanin. Saatujen tulosten mukaan käytännön kasvinjalostustyössä voidaan säästää kustannuksia analysoimalla F 2:ssa ensin paperikromatografisella menetelmällä ja tarkentaa tulos sen mukaan parhaissa erissä kaasukromatografisella 1/2 siemenmenetelmällä.

Torpe × Spanin F 2 ja F 3 polvissa oli linoleenihappopitoisuus (C 18 : 2) korkeampi kuin Fenno × Spanin. Torpe oli periyttänyt sen.

Torpe on Fennoa satoisampi. Torpen satoisuus periytyi risteytyksessä ilmeten kaikissa F polvissa ja myös vertailevassa kenttäkokeessa v. 1977. Torpe × Spanin sadon sl Spaniin oli 101 ja Fenno × Spanin 83. Torpe × Spanin satoisuus ei kuitenkaan ollut riittävä. Toivottiin saatavan linja, joka olisi 10—15 %-yksikköä satoisampi Spania. Tutkimuksen puitteissa ei siis pelkkä elinvoimaisempien C 22 : 1 niukkojen yksilöiden valinta riittänyt satoisuuden saavuttamiseksi. Jatkossa on suoritettava takaisinristeytyksiä Torpeen tai muihin satoisaksi tunnettuihin lajikkeisiin tai erilaisten C 22 : 1 vapaitten linjojen keskeisiä risteytyksiä.

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Serie ANIMALIA NOCENTIA N. 101 — Sarja TUHOELÄIMET n:o 101

MANGOLD FLY: PREDICTING DAMAGE AND THE ECONOMICS OF CONTROL

ANNA-LIISA VARIS and JORMA RAUTAPÄÄ

VARIS, A-L. & RAUTAPÄÄ, J. 1978. **Mangold fly: predicting damage and the economics of control.** Ann. Agric. Fenn. 17: 103—107. (Univ. Helsinki, Dept. Agric. For. Zool., SF-00710 Helsinki 71, Finland.)

Experiments carried out in 1958—1969 were used to estimate the economic return and threshold value for chemical control of *Pegomya hyoscyami* in Finland. According to the highly significant correlations between the number of eggs on plants, damaged leaf area and root yield losses, the economic threshold justifying chemical control was at least ten living eggs per plant at the five-leaf stage. Based on prices and costs in 1977, the costs of two dimethoate sprayings were repaid when the root yield per hectare was increased by about 500 kg.

Index words: *Pegomya hyoscyami*, chemical control, prognosis, economic return.

Data on the level of infestation of mangold fly (*Pegomya hyoscyami* (Panz.)) justifying its control have been dealt with by several authors (see REHAK & SKUHRAVY 1967). In general, the number of mangold fly eggs in relation to the developmental stage of the plant has been accepted as a basis for predicting the damage and estimating the necessity of control. There is, however, a considerable variation in the critical number of eggs given by different authors. According to REHAK & SKUHRAVY (1967) this varies e.g. for plants at the 4-leaf stage from 6—8 to 25 per plant. Artificial defoliation of the beet has been used to show that the recuperation of beet plants is rather high (e.g. JONES et al. 1955, LÜDECKE and NEEB 1959, MÖLLERSTRÖM 1963), but there has been some doubt whether artificial defoliation corresponds to the damage done by the mangold fly larvae (e.g. DUNNING 1961).

In Finland farmers have been advised to control the mangold fly when there are at least 20 eggs on a plant consisting of an average of five rough leaves. The purpose of this study was to check and possibly change this threshold value, and estimate the economic return of mangold fly control on the basis of experiments carried out in 1958—1969. Damage by *Pegomya hyoscyami* was quite serious in the late '50s and early '60s but since then it has been considerably less.

MATERIAL AND METHODS

The experiments compiled in this study were partly the same as those presented previously by VARIS and RAUTAPÄÄ (1976) when the efficiency and economic return of the chemical control of sugar beet pests were calculated. Here was a total of 28 experiments, all made in 1958—1969 (Table 1).

Generally approved cultivation methods were used. The seeds were sown mainly by dense drilling. The standing crop was thinned before the egglaying period of *P. hyoscyami*.

Plots were usually 20—60 sq.m. each and three to six replicates were arranged. The insecticides used were dimethoate spray (6 experiments), parathion spray and wettable powder (4), trichlorphon wp (10), granulated phorate (4), and granulated thionazin (4) (Table 1).

Only the first-generation larvae of *P. hyoscyami* were controlled in this treatment. The insecticides were spread onto the crop in the middle of June or at the end of June when the first damage done by larvae was observed.

The number of new, unhatched mangold-fly eggs plus living larvae was counted in nine experiments (Table 1) just before treatment. At that time the plants were on average at the five-leaf stage. The damage done by larvae was registered in the middle of July, i.e. some weeks after the plants were treated with insecticides. The leaf area damaged by larvae was estimated

Table 1. Effect of chemical control of *Pegomya hyoscyami* on the root and top yield of sugar beet. + = yield was higher, — = yield was lower than in untreated. Relative yield value = 100 × yield in treated/yield in untreated.

Insecticide	Leaf area (%) damaged by *P. hyoscyami*-larvae in untreated	Change in root yield		Change in top yield	
		tons/hectare	relative root yield value	tons/hectare	relative root yield value
Dimethoate spray	14	—0,35	99	+8,34	114
	21	+3,11	111	+1,34	102
	21	+1,42	105	+8,05	112
	42	+9,92	120	+10,06	121
	23	+4,73	114	—4,78	89
	11	—0,94	97	—0,95	97
Parathion spray or wettable powder	46	+3,36	118	+5,83	112
	21	+0,28	101	—2,68	96
	42	+4,46	109	+5,75	112
	21	—1,42	95	0	100
Trichlorphon wettable powder	36	+2,75	112	—	—
	46	+3,37	118	+4,86	110
	14	+1,06	103	+8,34	114
	14	+1,41	104	+6,56	111
	36	+3,02	112	—	—
	21	+1,13	104	+9,39	114
	74	+1,35	106	—0,41	99
	42	+4,96	110	+8,14	117
	23	—3,38	90	—4,35	90
	23	—1,69	95	—1,69	95
Phorate granulated	46	+5,85	115	+11,89	121
	18	—0,59	98	+0,39	101
	20	—0,44	99	—0,77	99
	28	+2,30	107	+2,50	104
Thionazin granulated	14	+0,35	101	+2,98	105
	21	+0,28	101	+2,68	104
	42	+6,45	113	+7,66	116
	28	+2,92	109	+1,92	103

on the scale 0—5 (0 = completely healthy, 5 = totally destroyed). Actually the scale used also indicated the leaf area destroyed as a percentage. The number 1 on the scale 0—5 corresponds to 20 %, the number 2 corresponds to 40 %, etc. When the number of eggs per plant in this study was correlated with the amount of leaf area damaged, percentage points were used instead of the numbers 0—5.

RESULTS

The leaf area damaged by larvae varied from 11 to 74 % in 28 experiments (Table 1). In most tests both the root yield and the leaf yield were greater in plots treated with insecticides than in those left untreated. The highest increase in root yield was 9,9 tons per hectare and the highest increase in top yield 11,9 tons per hectare.

The correlation between the numbers of eggs per plant and the leaf area destroyed was positive and highly significant (Y = 4,2+1,6 X, r = +0,88, P < 0,01, Fig. 1). When there were 10 eggs at the five-leaf stage, the larvae on average destroyed 20 % of the leaf area, and when the number of eggs was 20, the larvae damaged about 36 % of the leaf area. When the number of eggs at the five-leaf stage increased by 10, the leaf area damaged by larvae increased by 16 percentage points (Fig. 1).

The correlation between the damaged leaf area in percentage and the change of root yield caused by insecticide treatments was positive and highly significant (Y = —1,17 + 0,11 X, r = +0,5, P < 0,01, Fig. 2). On average, the root yield of one hectare was 1,0 ton greater in the treated than in the untreated plots when the larvae destroyed 20 % on the leaf area of un-

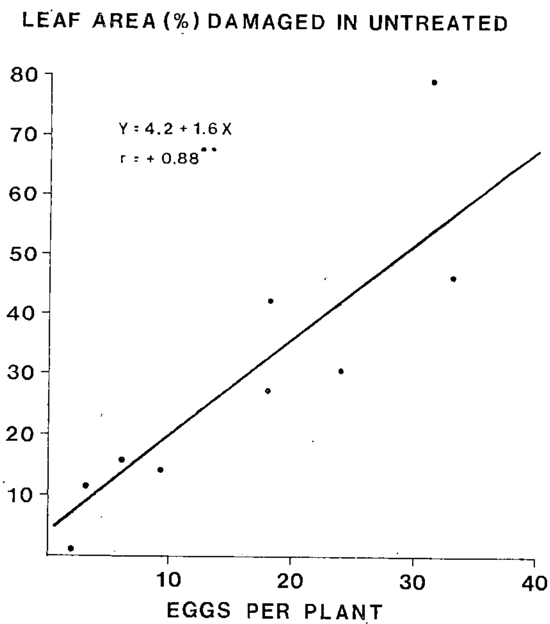

Fig. 1. Correlation between the number of eggs per plant at the five-leaf stage and leaf area (%) damaged by *P. hyoscyami* larvae in untreated plots. xxP < 0,01.

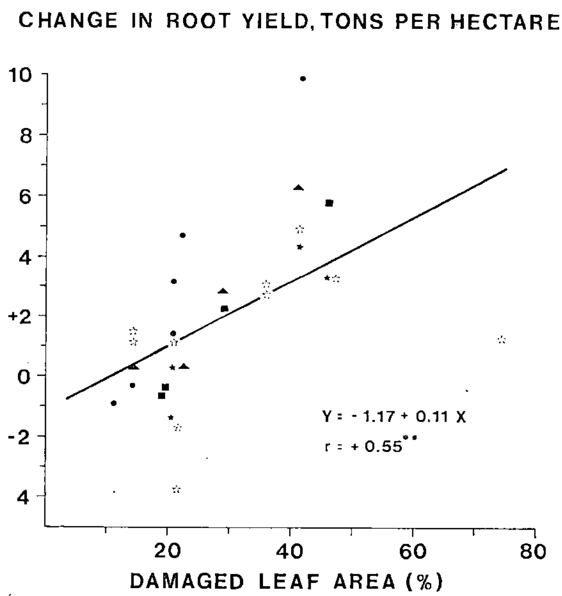

Fig. 2. Correlation between the leaf area (%) damaged by *P. hyoscyami* larvae in untreated plots and the change in root yield of plots treated with insecticides. An increase (+) or decrease (—) in the yield indicates the difference between treated and untreated (zero level) plots. The forms of treatment were as follows: dimethoate (●), parathion spray and wp (★), trichlorphon wp (☆), granulated phorate (■), granulated thionazin (▲). xxP < 0,01.

treated plants. When the damaged leaf area was 40 %, the difference in root yield between treated and untreated plots was about 3,2 tons per hectare. When the damaged leaf area of untreated plants increased by 10 percentage units, the root yield of treated plants increased by 1,1 tons per hectare.

The number of experiments is too small if possible differences between insecticides are taken into consideration.

The correlation between the damaged leaf area and top yield was not significant ($r = +0{,}22$, $P > 0{,}55$).

The loss of root yield corresponding to a certain number of eggs per plant at the five-leaf stage was calculated on the basis of both regression equations in Figs. 1 and 2. The figures are as follows (Fig. 3):

Eggs per plant at the five-leaf stage	Damaged leaf area in untreated plant %	Loss of root yield tons per hectare
4	10,6	0
10	20,2	1,0
20	36,2	2,8
30	52,2	4,5
40	68,2	6,3

When the number of eggs increased by 10, the damaged leaf area of untreated plants increased by 16 percentage points, and the loss of root yield increased by 1,8 tons per hectare.

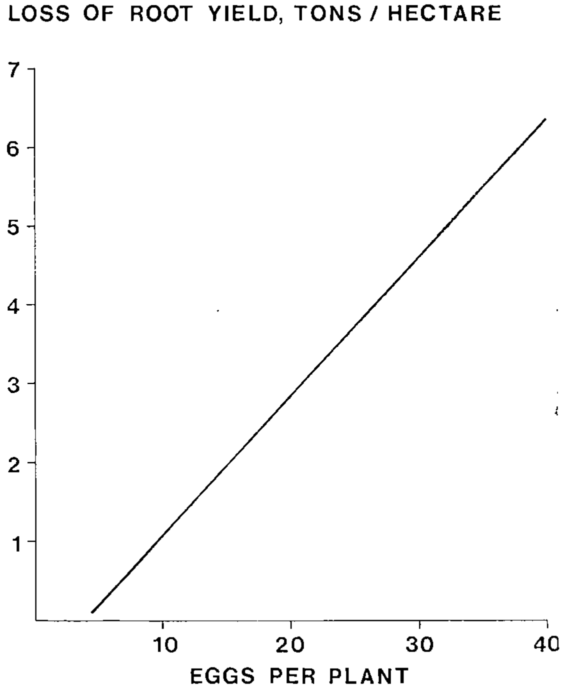

Fig. 3. Relationship between the number of living eggs per plant at the five-leaf stage and loss of root yield. The straight line in Fig. 3 was calculated on the basis of regression equations in Figs. 1 and 2.

CONCLUSIONS

The correlation between the number of eggs per plant at the five-leaf stage and root yield loss could be used as a simple method for predicting the effect of larvae on sugar beet yield. The price paid to farmers in 1977 for sugar beet was 230 marks per ton. The costs of two insecticide sprayings by a tractor sprayer are estimated to be about 100 marks (costs of one spraying: machines and labour 30 marks, 1 litre dimethoate 20 marks). On increase of about 500 kg per hectare in root yield repays the costs of the chemical control of *P. hyoscyami* larvae. According to the results of this study the root yield can be expected to increase by 500 kg per hectare when there are less than 10 eggs per plant at the five-leaf stage. It seems evident that the threshold value of at least 20 eggs per plant at the five-leaf stage, which has been recommended heretofore, is too high. Chemical control using two insecticide sprayings seems to be economically justified when the number of living eggs is greater than 10 per plant. Because exceptionally hot and dry weather can have a detrimental effect on egg hatching, the plants should be inspected very carefully while counting the eggs and only new, unhatched eggs and living larvae should be taken into consideration.

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SELOSTUS

Juurikaskärpäsen torjunnan kannattavuus

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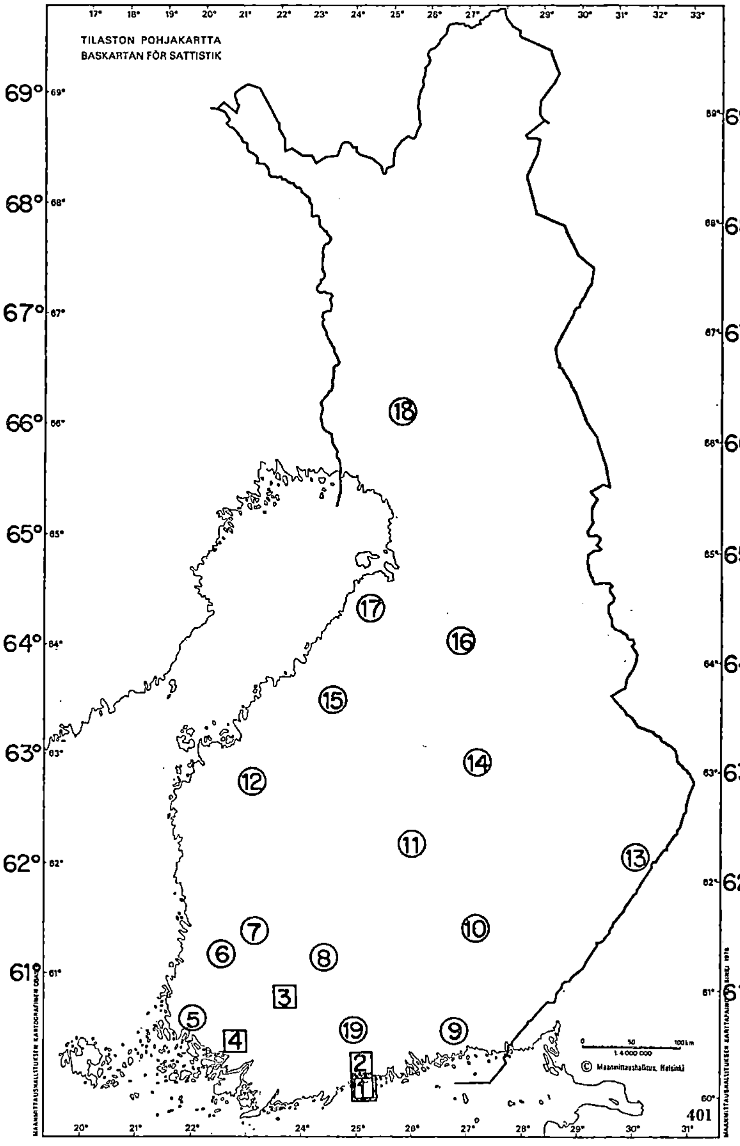
Juurikaskärpäsen torjuntaa on suositeltu silloin kun viisilehtisissä taimissa on keskimäärin vähintään 20 munaa. Tässä selvityksessä tarkistettiin aikaisemmin tehtyjen kokeiden perusteella juurikaskärpäsen torjunnan kannattavuus.

Kun viisilehtisissä taimissa oli keskimäärin 10 hyväkuntoista, elävää munaa tai vastakuoriutunutta toukkaa, tuhosivat toukat myöhemmin kesällä noin 20 % juurikkaiden lehtipinta-alasta. Kun munia oli 20, turmelivat toukat noin 36 % lehtien pinta-alasta. Munien määrän suuretessa kymmenellä lisääntyi toukkien tuhoama pinta-ala 16 prosenttiyksikköä

Mitä enemmän toukat turmelivat juurikkaan lehtiä, sitä pienemmäksi jäi juurisato. Kun lehtien pinta-alasta tuhoutui 20 %, jäi hehtaarin juurisato jokseenkin tasan 1 tonnin verran vioittumattomien kasvien satoa pienemmäksi ja kun toukat tuhosivat 40 % lehtien pinta-alasta, oli sato 3,2 tonnia vioittumattomien kasvien hehtaarisatoa pienempi. Juurikaskärpäsen toukkien vioittaman lehtipinta-alan suuretessa 10 prosenttiyksikköä väheni hehtaarin juurisato keskimäärin 1,1 tonnia.

Vuonna 1977 juurikkaasta maksettujen keskihintojen (230,—/tn) ja kahden traktorilla tehdyn torjunta-ainekäsittelyn kustannusten (yksi ruiskutus: koneet ja työ noin 30,—/ha, dimetoaatti noin 20,—/ha) perusteella arvioiden juurikaskärpäsen torjunta kannattaa, jos hehtaarin juurisato sen seurauksena suurenee vähintään 500 kg. Kokeissa aiheutti tämänsuuruisen lisäyksen juurisatoon torjunta silloin kun viisilehtisissä taimissa oli keskimäärin 7—8 munaa. Tämä munamäärä viisilehtiasteella aiheutti sen, että toukat turmelivat myöhemmin kesällä noin 15 % lehtien pinta-alasta ja se puolestaan johti noin 500 kg:n juurisadon menetykseen.

Aikaisemman suosituksen mukaan juurikaskärpäsen torjunta kannattaa, jos viisilehtisissä taimissa on keskimäärin 20 munaa. Tämän selvityksen perusteella kuitenkin voidaan päätellä, että torjunta kannattaa nykyisen kustannustason vallitessa, jos viisilehtisissä taimissa on keskimäärin vähintään 10 munaa. Kun poikkeuksellisen lämpimät ja kuivat säät voivat vaikuttaa haitallisesti juurikaskärpäsen munien kuoriutumiseen ja lisätä luontaisten vihollisten aktiivisuutta, on torjunnan perustana olevat taimien tarkastukset tehtävä huolellisesti ja laskettava vain tuoreet, täydet munat sekä vastakuoriutuneet elävät toukat.



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