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EXPERIMENTS ON CHEMICAL AND CULTURAL CONTROL OF THE RASPBERRY CANE MIDGE (*RESSELIELLA THEOBALDI*) AND MIDGE BLIGHT

PIRJO DALMAN and SIRKKA MALKKI

DALMAN, P. & MALKKI, S. 1986. **Experiments on chemical and cultural control of the raspberry cane midge** *(Resseliella theobaldi)* **and midge blight.** Ann. Agric. Fenn. 25: 233—241. (Agric. Res. Centre, South Savo Res. Sta., SF-50600 Mikkeli, Karila, Finland.)

The effects of cultural and chemical control measures on the number of raspberry cane midge larvae and fungal lesions in first-year canes, the wilting of second-year canes caused by midge blight and the yield of the red raspberry cv. Ottawa were studied in 1980—82. Azinphos-methyl, trichlorfon and tolylfluanid did not reduce midge blight incidence. When the second-year cane density was reduced from 10—12 canes/m to 5—6 canes/m and first-year canes were thinned respectively, the yield decreased from 52 kg/100 m^2 to 25 kg/100 m^2 but midge blight was not reduced. The mechanical removal of young canes at the height of 10—20 cm reduced the incidence of midge blight significantly. When the first and the second flush of young canes were removed the effect on cane midge larvae was better than after one removal but the growth of replacement canes was so weakened that yield did not increase.

Index words: red raspberry, *Resseliella theobaldi,* midge blight, chemical control, cultural control, cane density, young cane removal, azinphos-methyl, trichlorfon, tolylfluanid.

INTRODUCTION

The raspberry cane midge, *Resseliella theobaldi* (Barnes), lays eggs in the splits which develop in the bottom 40 cm of first-year red raspberry canes (PITCHER 1952). The larvae feed between the outer cortex and the periderm and degrade cell wall components (SEEMÜLLER and GRÜNWALD 1980). This damage is of little direct importance, but when the feeding sites are invaded by pathogenic fungi, lesions which block part of the vascular cylinder may develop. The name midge blight describes the death, bud failure and lateral wilt of fruiting canes which follow midge injury to first-year canes. In the first year the symptoms are discrete, lobate, sunken areas concentrated towards the base of the cane (PITCHER and WEBB 1952). According to WILLIAMSON and HARGREAVES (1979a), the irregular patch lesions caused by midge blight can best be seen by scraping the cane in winter to remove all of the rind and

cork. The principal fungal species from the larval feeding areas have been isolated (PITCHER and WEBB 1952, NIJVELDT et al. 1963, WILLIAMSON and HARGREAVES 1979b, SEEMÜLLER and GRÜNWALD 1980, RUOKOLA 1982).

Midge blight has been prevented more succesfully by controlling the cane midge than by application of fungicides. However, the cultural measures which are employed to control fungal cane diseases are recommended to be applied against midge blight. These include the thinning of canes, which promotes an open type of growth (NIJVELDT et al. 1963, SEEMÜLLER and KRCZAL 1980). Growers are currently advised to control cane midge by avoiding cultivation of susceptible varieties; by biennial cropping; by the removal of the first flush of young canes or by application of insecticides (SEEMÜLLER and KRCZAL 1980, GORDON and WILLIAMSON 1984). Removal of the first canes at the height of 10—20 cm can be done either by cutting or spraying with the desiccant herbicide dinoseb in oil. Replacement canes growing after the removal thus avoid serious midge infestation because their splits develop late (NIJVELDT et al. 1963, SEEMÜLLER 1976, WILLIAMSON et al. 1979).

Insecticidal control involves spraying before harvesting, to kill first-generation midges and eggs, and after harvest, to control the third generation. Direct control of the most damaging second generation is not allowed because emergence coincides with harvest. The timing of spraying is difficult because the emergence period varies considerably from year to year and from site to site, and it is not easy to observe adult midges or eggs in the field. It is more simple to spray when a certain level of natural splitting has been reached. In England, growers can contact advisers who operate a warning system in some midgeprone areas (GUNN and FOSTER 1978, WOODFORD et al. 1979, GORDON and WILLIAMSON 1984). Chlorpyrifos, gamma-HCH, fenitrothion, dimethoate or parathion, applied at high volume to the basal part of the cane and reapplied once or twice at 10—14 day intervals, should provide adequate control (WOODFORD et al. 1979, SEEMÜLLER and KRCZAL 1980, GORDON and WILLIAMSON 1984).

The importance of midge blight and the susceptibility of the most widely cultivated varieties Ottawa and Muskoka in Finland have been discussed by RUOKOLA (1982) and DALMAN (1986). The aim of this preliminary trial was to experiment with cultural and chemical treatments to control cane midge and midge blight in the susceptible variety Ottawa.

MATERIAL AND METHODS

The control trial was carried out in 1980—82 at the South Savo Research Station where the severe cane midge infestation of a five-year-old raspberry plantation of cv. Ottawa was observed in autumn 1979. The thinning of canes and tolylfluanid were applied to decrease fungal cane diseases, and the removal of young canes, azinphos-methyl and trichlorfon were employed against cane midge. The split plot design with four replicates was used, the cane densities being whole-unit treatments. Each sub-unit plot was 3 m long with 2,5 m intervals between the rows.

Eighteen first-year canes/meter were left in the high cane density plots and nine canes/meter in the low cane density plots at the end of June. In September the first-year cane densities were sixteen and eight/meter, respectively. The aim was to leave twelve second-year canes/meter in the high density plots and six/meter in the low density plots at the start of growing season. However, the canes died frequently during the

winter, so that the number of living second-year canes was as follows in the middle of May:

	low cane density	high cane density
1980	5,9 canes/meter	10,2 canes/meter
1981	4,5 —"—	9,4 —"—
1982	5,6 —"—	11,4 —"—

Tolylfluanid at 0,125 % active ingredient (as Euparen M) was sprayed when first-year canes were 5—10 cm high at the end of May and again two weeks later.

The removal of young canes was done mechanically by hand cutting when the canes were 10—20 cm high. In 1980 the first flush and the second flush of canes were removed at the beginning and in mid-June. In 1981 and 1982 the first flush of canes was removed only.

The artificial splits in first-year canes were used, as by STENSETH (1977) and GUNN and FOSTER (1978), to determine the beginning of the oviposition of the cane midge in early summer 1980. The method was not useful because the previous year's splits in second-year canes were preferred by females to artificial splits. Therefore, about ten second-year canes and ten first-year canes were examined weekly until eggs or larvae were found in 1981 and 1982. Trichlorfon at 0,16 % a. i. (as Dipterex) and azinphos-methyl at 0,05 % a. i. (as Gusation) were sprayed at the basal 80 cm of the canes on June 26th, 1980 and on June 29th, 1981, when the first eggs and larvae were found, and again after harvest on August 28th, 1980 and September 3rd, 1981, when there were numerous larvae in the canes. Raspberry flowered in late June. In 1982 insecticides were not applied against the midge because the first eggs were not found until July 6th. The whole trial was sprayed with azinphos-methyl to control the raspberry beetle (*Byturus tomentosus*) every year at the beginning of June and just before the onset of flowering in the middle of June.

Three first-year canes/plot, totalling 120 canes yearly, were sampled systematically after harvesting but before the application of trichlorfon and azinphos-methyl. The basal parts of the canes, 0—30 cm, were examined to estimate the incidence of larvae and fungal lesions. At this time third-instar larvae were abundant on the canes and fungal lesions were easy to asses before cane maturation. The number of all fungal lesions on the outer cortex was estimated. The area of skin covered by lesions in the scoring classes 1, 2, 3, 4 and 5 corresponded approximately to: 0—2,5; 2,5—10; 10—20; 20—40 and >40 %, respectively. The number of midge larvae under the outer cortex was estimated on a scale of 0—3, where 0 = no larvae, 1 = one to three larvae, 2 = four to ten larvae and 3 = more than ten larvae per cane. The dead, wilted second-year canes were counted at the start of harvesting to asses midge blight. Berries were picked twice a week.

Fungal species in the first-year canes were investigated at the Department of Plant Pathology of the University of Helsinki in autumn 1980 and 1981. These results have been published by RUOKOLA (1982).

Statistical comparison of the incidence of larvae and fungal lesions was not possible. The significance of other differences between the treatments was tested with analysis of variance. Pearson correlation coefficients were used.

RESULTS

The incidence of cane midge larvae in first-year raspberry canes in autumn 1981 was almost as frequent as that in 1980 (Tables 1 and 2). In high cane density there were less canes attacked by larvae than in low cane density, and in 1980 the number of larvae was also lower in high cane density. The removal of young canes reduced the number of larvae clearly. In 1980 canes were removed twice and the effect was better than that after one removal in 1981. Trichlorfon and azinphos-methyl tended to increase the incidence of larvae compared to untreated canes.

The incidence of fungal lesions in first-year canes was much the same in autumn 1981 as that in 1980, and it was not affected by cane density (Tables 3 and 4). Fungal lesions were decreased by the removal of young canes. After two removals there were less lesions than after one removal. Tolylfluanid tended to reduce the number of lesions. In 1980—81 there was a significant positive correlation, $r = 0{,}52$ ($P < 0{,}001$, $n = 240$), between the numbers of midge larvae and fungal lesions on first-year canes.

Thirty-five percent of second-year canes were destroyed by midge blight before har-

Table 1. Effect of cultural and chemical control on the number of cane midge larvae in first-year raspberry canes in autumn 1980 and 1981. Larvae on the scale 0—3, with 0 = no larvae, 1 = one to three larvae, 2 = four to ten larvae and 3 = more than ten larvae.

	Larvae (0—3)				
	Low cane density		High cane density		
Treatment	1980	1981	1980	1981	Mean
Untreated	1,7	1,1	1,0	1,1	1,2
Young canes removed	0,3	0,5	0,2	0,7	0,4
Trichlorfon	2,3	1,5	1,7	1,0	1,6
Azinphos-methyl	1,6	1,3	1,4	1,4	1,4
Azinphos-methyl and tolylfluanid	2,2	1,4	1,7	1,7	1,7
Mean	1,6	1,1	1,2	1,2	

Table 2. Effect of cultural and chemical control on the incidence of cane midge larvae in first-year raspberry canes in autumn 1980 and 1981. % of canes examined.

	Canes attacked (%)				
	Low cane density		High cane density		
Treatment	1980	1981	1980	1981	Mean
Untreated	83	84	59	75	75
Young canes removed	17	50	8	50	31
Trichlorfon	92	100	75	67	84
Azinphos-methyl	75	100	75	84	84
Azinphos-methyl and tolylfluanid	83	84	84	100	88
Mean	70	84	60	75	

Table 3. Effect of cultural and chemical control on the number of fungal lesions on first-year raspberry canes in autumn 1980 and 1981. Lesions on the scale 0—5, classes 1, 2, 3, 4 and 5 correspond to 0—2,5, 2,5—10, 10—20, 20—40 and >40 % of the stem area, respectively.

	Fungal lesions (0—5)				
	Low cane density		High cane density		
Treatment	1980	1981	1980	1981	Mean
Untreated	2,8	3,0	2,9	3,2	3,0
Young canes removed	0,9	1,5	0,9	1,5	1,2
Trichlorfon	4,2	3,0	3,2	2,3	3,2
Azinphos-methyl	3,0	2,9	2,7	2,8	2,8
Azinphos-methyl and tolylfluanid	2,9	2,4	2,4	2,9	2,6
Mean	2,8	2,6	2,4	2,6	

Table 4. Effect of cultural and chemical control on the incidence of fungal lesions on first-year raspberry canes in autumn 1980 and 1981. % of canes examined.

	Canes attacked (%)				
	Low cane density		High cane density		
Treatment	1980	1981	1980	1981	Mean
Untreated	100	100	100	100	100
Young canes removed	67	100	84	92	86
Trichlorfon	100	100	100	92	98
Azinphos-methyl	100	100	100	100	100
Azinphos-methyl and tolylfluanid	92	92	100	100	96
Mean	92	98	97	97	

vesting in 1981 and 26 % in 1982 (Table 5). Cane density did not affect the wilting of canes significantly ($P > 0,05$). Removal of young canes decreased cane death significantly in low cane density in 1981 ($P < 0,05$) and in both cane densities in 1982 ($P<0,05$). Twenty-three percent of the second-year canes were destroyed by midge blight in 1981 after two cane removals in 1980, and 10 % in 1982 after one removal in 1981. Pesticide treatments did not reduce the incidence of midge blight; in low cane density they tended to increase it.

The mean yield was 45 kg/100 m^2 in 1981 and 32 kg/100 m^2 in 1982 (Table 6). The yield was affected by cane density significantly in both years ($P < 0,01$). For 1981—82 the average yield in high cane density was 52 kg/100 m^2 which is twice that in low cane density, 25 kg/100 m^2. The removal of young canes and the pesticide treatments did not affect the yield significantly ($P > 0,05$). The yield and the number of canes at the start of harvesting were correlated positively, $r = 0,68$ ($P < 0,001$, $n = 77$).

After the removal of young canes the replacement canes grew shorter than the canes grown normally from the beginning of season, especially after two removals in 1980 (Table 7).

Table 5. Effect of cultural and chemical control on the infestation of second-year raspberry canes by midge blight. Dead canes before harvesting in 1981 and 1982.

	Dead canes (%)				
	Low cane density		High cane density		
Treatment	1981	1982	1981	1982	Mean
Untreated	29	27	45	22	31
Young canes removed	14	9	32	11	17
Trichlorfon	42	36	37	23	35
Azinphos-methyl	45	37	34	26	36
Azinphos-methyl and tolylfluanid	40	38	32	26	34
Mean	33	30	36	21	

Component of variation	in 1981	in 1982
between cane densities	F = 0,35 ns	F = 2,53 ns
between control treatments	F = 2,66 ns	F = 3,99 x
interaction	F = 4,86 x	F = 0,23 ns

Table 6. Effect of the cultural and chemical control of raspberry cane midge and midge blight on the saleable yield in 1981 and 1982.

	Yield (kg/100 m^2)				
	Low cane density		High cane density		
Treatment	1981	1982	1981	1982	Mean
Untreated	26	25	53	42	37
Young canes removed	32	25	58	45	40
Trichlorfon	25	22	68	37	38
Azinphos-methyl	22	25	63	40	38
Azinphos-methyl and tolylfluanid	28	17	72	37	39
Mean	26	23	63	40	

Component of variation	in 1981	in 1982
between cane densities	F = 39,44 xx	F = 60,79 xx
between control treatments	F = 2,01 ns	F = 0,59 ns
interaction	F = 2,45 ns	F = 0,11 ns

Table 7. Effect of the cultural and chemical control of raspberry cane midge and midge blight on the first-year cane height in autumn 1980 and 1981.

	Cane height (cm)				
	Low cane density		High cane density		
Treatment	1980	1981	1980	1981	Mean
Untreated	175	170	185	180	180
Young canes removed	125	145	125	165	140
Trichlorfon	185	165	185	180	180
Azinphos-methyl	185	170	185	180	180
Azinphos-methyl and tolylfluanid	180	170	185	185	180
Mean	170	165	175	180	

DISCUSSION

The life cycle of the raspberry cane midge has not been investigated in Finland but according to the observations made during the control trial two generations occurred in 1980 and 1981. Larvae were first found in the last week of June, so the emergence of first-generation midges had obviously begun during the second week of June. The second-generation adults had emerged at about the start of harvesting at the end of July and during harvest as there were third-instar larvae in the canes after harvesting. The first natural splits in the first-year canes of cv. Ottawa can be observed in late June but larvae may be found in the previous year's splits of second-year canes as well (DALMAN 1986).

The correlation between the midge larvae and fungal lesions in the first-year canes of cv. Ottawa has also been observed earlier (DALMAN 1986). Cv. Ottawa is not susceptible to spur blight (*Didymella applanata*) (RUOKOLA 1982) but midge larvae can cause severe fungal infestation. The symptoms of midge blight in first-year canes described by PITCHER and WEBB (1952) can be used to asses the extent of infested plantations of cv. Ottawa in late summer.

The number of the most damaging second-generation larvae tended to increase when azinphos-methyl and trichlorfon were applied against the first generation. This might have resulted from the damage caused by spraying to the natural enemies of the midge (BOLDYREV 1971). Applications of azinphos-methyl against the raspberry beetle had no affect on the cane midge, although they were obviously performed during the emergence of the first midges. On the other hand, spraying against the cane midge might have increased the 1981 yield because insecticides do reduce the damage caused by the raspberry beetle. Tolylfluanid tended to reduce fungal lesions estimated on the cane rind, but the wilting of second-year canes was not affected by the treatment. Fungicides do not control the fungi penetrating into the cane vascular cylinder from larval feeding areas (NIJVELDT et al. 1963, SEEMÜLLER 1976, GORDON and WILLIAMSON 1984).

Fenitrothion is the most interesting of the insecticides recommended against the cane midge elsewhere (STENSETH 1977, WOODFORD et al. 1979, SEEMÜLLER and KRCZAL 1980, GORDON and WILLIAMSON 1984). The application of fenitrothion against the raspberry beetle is permitted in Finland but that of gamma-HCH, diazinon and chlorpyrifos is prohibited. Dimethoate and parathion were applied against the beetle at the South Savo Research Station prior to 1980 yet the cane midge still invaded the raspberries. In addition to the testing of insecticides, both the timing of spraying in early summer and autumn, as well as the volume of spray required should be investigated.

The thinning of canes recommended by NIJVELDT et al. (1963) did not decrease fungal cane diseases when the cane midge occurred. On the contrary, thinning may increase fungal lesions because there are more larvae/cane in lower cane density as reported by MASON (1981). The effect of cane number on yield has been reported in many papers but only MASON (1981) has discussed the results in relation to midge blight incidence. Cv. Ottawa produces canes sparingly and in the trial it was difficult to obtain more than ten fruiting canes per meter. Therefore, whenever a plantation is infested by the cane midge, all the canes long enough to be supported by wires should be allowed to grow.

The removal of young canes resulted in good control over midge larvae, cane diseases and midge blight, although reinfestation by midge from neighbouring rows reduced efficiency. Following two removals the control of larvae was better than after one removal but the control of midge blight worsened. Cane growth

was excessively weakened by two removals and weak canes were destroyed by midge blight. Two removals of young canes were performed in the first year of the trial and because of weakened growth the yield was not increased although the control of midge blight was good. Removal is recommended for vigorous cultivars only (NIJVELDT et al. 1963, SEEMÜLLER 1976, WILLIAMSON et al. 1979). Cv. Ottawa is not classified as a vigorous variety, but for a plantation infested heavily by midge blight removal can be done in two years. Young canes must be removed only once when they are 15—20 cm high. Removal has other advantages, too, because the competition between first-year canes and fruiting canes is reduced. Moreover, yield and berry size increase and access to the fruit at harvest as well as overall health status improve (WILLIAMSON et al. 1979). Removal is economical only when done chemically, but application of dinoseb onto raspberry is prohibited in Finland.

In addition to the removal of young canes the control of midge blight is possible in Finland by cultivating cv. Muskoka which is less susceptible to the cane midge than is cv. Ottawa and equally winterhardy (DALMAN 1986).

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SELOSTUS

Vatunvarsisääsken ja midge blight -taudin torjunta

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Maatalouden tutkimuskeskus

Vatunvarsisääski munii vadelman versojen alaosiin kuoren luonnollisiin halkeamiin. Toukat elävät versoissa kuoren alla ja koteloituvat maahan. Kesässä kehittyy yleensä kaksi sukupolvea. Eniten vahinkoa aiheuttaa toinen sukupolvi, joka munii versoihin sadonkorjuun aikaan. Toukat imevät ravintoa ensimmäisen vuoden versoista mutta eivät juuri haittaa vadelman kasvua. Varsinaisen tuhon aiheuttavat toukkien syöntialueelle iskeytyvät sienet, jotka tunkeutuvat versojen keskustaan. Seuraavana vuonna versojen kasvu on hidasta, silmuja ja sivuversoja kuihtuu ja pahoin saastuneet versot kuolevat ennen kuin niistä saadaan satoa. Taudin nimi on englanniksi midge blight. Ensimmäisen vuoden versoihin tauti aiheuttaa lähes samanlaisia laikkuja kuin versotaudit spur blight ja cane blight.

Midge blight -taudin torjuntaan ei ole tehokkaita fungisideja, joten torjunta suunnataan varsisääskeä vastaan. Pääasialliset torjuntakeinot ovat lajikevalinta, vuorovuosiviljely, uusien versojen poisto ja ruiskutukset sääsken ensimmäistä sukupolvea vastaan. Keväällä ensimmäisinä kehittyvät uudet versot poistetaan kokonaan 10—20 cm:n pituisina, jolloin tilalle kasvavien versojen halkeilu viivästyy eikä ensimmäisen sukupolven naaraille ole munintapaikkoja. Myös lajikkeiden kestävyys riippuu kuoren halkeilun ajankohdasta ja määrästä. Torjuntaruiskutukset aloitetaan munien löydyttyä tai versojen halkeilun alettua. Yleensä ruiskutetaan 2—3 kertaa parin viikon välein.

Vatunvarsisääsken ja midge blight -taudin torjuntamahdollisuuksia sekä sääsken elintapoja torjunnan ajoittamiseksi selvitettiin vuosina 1980—82 Etelä-Savon tutkimusasemalla, missä 5 vuotta vanha 'Ottawa'-kasvusto oli pahoin saastunut midge blight -tautiin. Varsisääskeä yritettiin torjua poistamalla uudet versot tai ruiskuttamalla atsinfossimetyyliä (Gusation) ja triklorfonia (Dipterex) ensimmäisten toukkien löydyttyä ja sadonkorjuun jälkeen. Sienitautien torjumiseksi versot ruiskutettiin kahdesti tolyylifluanidilla (Euparen M) keväällä kahden viikon välein sekä harvennettiin versoja niin, että tiheään kasvustoon jäi 10—12 satoversoa/m ja harvaan kasvustoon 5—6 versoa/m.

Vuosina 1980 ja 1981 vatunvarsisääskellä oli ilmeisesti kaksi sukupolvea. Ensimmäiset toukat löydettiin versoista kesäkuun viimeisellä viikolla, ja sadonkorjuun jälkeen versoissa oli paljon täysikasvuisia toisen polven toukkia. Toukkien ja sienilaikkujen määrät olivat ensimmäisen vuoden versoissa syksyllä selvästi korreloituneita. 'Ottawa' ei ole altis versotaudille mutta varsisääski aiheuttaa voimakkaan sienisaastunnan.

Torjunta-ainekäsittelyt eivät vähentäneet midge blight -taudin aiheuttamaa satoversojen kuihtumista. Tolyylifluanidi ei vaikuttanut versojen sisäosiin tunkeutuviin sieniin, joille toukat raivasivat tietä. Atsinfossi-metyyli ja triklorfoni eivät tehonneet sääsken toukkiin ja muniin, jotka ovat suojassa kuoren alla. Vattukuoriaista vastaan tehdyt kaksi atsinfossi-metyyliruiskutusta eivät myöskään tehonneet sääskeen, vaikka sattuivat sääsken aikuistumisen aikoihin. Viime vuosina on sääsken torjunnassa saatu muualla hyviä tuloksia fenitrotionilla, jonka käyttö myös Suomessa voisi tulla kysymykseen. Ruiskutusten ajoitus ja tekniikka, esim. nestemäärä, kaipaavat lisätutkimusta.

Versomäärän vähentyessä puoleen sato aleni lähes vastaavasti eikä harventaminen vähentänyt midge blight -tautia. 'Ottawa' on niukasti versova lajike ja kokeessa oli vaikeuksia saada kehittymään 10 satoversoa metrille, joten vatunvarsisääsken esiintyessä Ottawa-lajiketta ei tarvitse harventaa.

Ensimmäisten uusien versojen poisto kokonaan oli tehokas torjuntakeino varsisääskeä ja midge blight -tautia vastaan. Kun versot poistettiin kahdesti, oli teho varsisääskeen parempi, mutta versojen pituuskasvu heikkeni liikaa.

Yleensä käsittelyä suositellaan vain voimakaskasvuisille lajikkeille. Jos varsisääskeä esiintyy, poisto voidaan tehdä myös Ottawa-lajikkeelle kahtena vuonna peräkkäin. Versot poistetaan viimeistään 20 cm pitkinä touko-kesäkuun vaihteessa. Suurilla viljelmillä poisto on kannattavaa vain, jos se voidaan tehdä kemiallisesti. Esim. Englannissa versot tuhotaan dinosebilla, mutta sitä tuskin sallitaan Suomessa. Parakvatti ja dikvatti eivät ole olleet tehokkaita; eräitä uusia herbisidejä on kokeissa.

Midge blight -tautia voidaan Suomessa estää tehokkaasti viljelemällä Muskoka-lajiketta, joka ei ole yhtä altis sääskelle kuin 'Ottawa'. Siellä, missä sääskeä ei vielä esiinny, on varottava alkusaastuntaa taimien mukana, sillä munia, vastakuoriutuneita toukkia ja mullassa kulkeutuvia koteloita on vaikea huomata.

ANNALES AGRICULTURAE FENNIAE, VOL. 25: 243—247 (1986)
Seria AGRICULTURA N. 80 — Sarja PELTOVILJELY n:o 80

Research note

ORTHOPHOSPHORIC ACID AS A DESICCANT IN GRASS-SEED HARVEST

OIVA NIEMELÄINEN

NIEMELÄINEN, O. 1986. **Orthophosphoric acid as a desiccant in grass-seed harvest.** Ann. Agric. Fenn. 25: 243—247. (Agric. Res. Centre, Dept. Crop Sci., SF-31600 Jokioinen, Finland.)

Orthophosphoric acid was tested as a potential desiccant in grass-seed crops of perennial ryegrass, meadow fescue and timothy. The desiccation treatments had a visually masked effect on meadow fescue and timothy stands. Green leaves turned to grey and yellow within 3—4 d. The treatments lowered seed moisture content at harvesting.

In timothy and meadow fescue, the highest seed yield was obtained from the untreated plots. In perennial ryegrass the treatments with orthophosphoric acid gave a slightly higher seed yields than the control. The orthophosphoric acid treatments did not impair the seed quality measured by germination percentage in any crop. Further research is needed to evaluate the potential of orthophosphoric acid in crops of different maturity and lodging.

Index words: desiccants, seed production, orthophosphoric acid.

INTRODUCTION

Lodging causes problems in herbage-seed harvesting. Lodged stands do not mature evenly and stands stay wet for a long time after rain has fallen. When a lodged crop is harvested by direct combining it must be cut very short. The succulent bottom grass then also enters the combine, making harvesting slow and impairing the threshing result. When it comes to harvesting, heavy late tillering causes similar problems to those encountered in lodging. Attempts have been made to avoid the problems. Cutting the stand on swath and combining after the swath has dried is a possible method in areas where the weather is dry during the harvesting period, but this method is not good for crops which shed their seed easily.

Pre-harvest desiccation of legume seed crop is used, for example, in clover seed production. Diquat desiccates the clover crop and enables direct combining. Pre-harvest desiccation has also been studied in grass seed harvesting, especially in perennial ryegrass. Unfortunately it was noticed that the studied desiccants diquat (ROBERTS and GRIFFITH 1973), paraquat (GRIFFITH et al. 1978) and glyphosate

(HAMPTON and HEBBLETWAITE 1982) impair the quality of seeds by depressing their ability to germinate.

In the present study, orthophosphoric acid (H_3PO_4) was tested as a potential desiccant in grass-seed crops. Perennial ryegrass and meadow fescue, which usually lodge heavily and in which bottom grass grows through the lodged crop, were chosen as test crops. Timothy was included in the study to find out if it is possible to make maturing more even with orthophosphoric acid spraying and thus increase the yield in single direct combining.

MATERIAL AND METHODS

The trial was carried out on heavy clay soil at the Agricultural Research Centre in Jokioinen in 1985. Test crops were first-year crops of perennial ryegrass cv. Riikka, meadow fescue cv. Kalevi and timothy cv. Tarmo. The crops were sown on 1 August, 1984 at a row width of 12,5 cm in plots 2,0 m wide × 10 m long. The seed rate was 17 kg ha^{-1} for perennial ryegrass and meadow fescue and 5 kg ha^{-1} for timothy. All treatments were replicated four times in a randomized block design. A dressing of compound fertilizer equivalent to 80, 35 and 65 kg ha^{-1} N, P and K, respectively, was applied at the beginning of the growing period in May 1985.

The spraying treatments were carried out a few days before the normal direct combining date. Orthophosphoric acid was applied as commercial 'Kefo' (Kemira Company) desiccant containing orthophosphoric acid 1,666 kg l^{-1} as the active ingredient and with the wetting agent as an additive. The treatments were:

1. Control — no spraying
2. Kefo 50 l ha^{-1}
3. Kefo 40 l + sulphuric acid 20 l ha^{-1}
4. diquat 0,4 kg a.i. ha^{-1} only in ryegrass
5. Kefo 25 l ha^{-1}

The total liquid amount (active ingredient + water) in all spraying treatments was 400 litres ha^{-1}.

95 % sulphuric acid was used in treatment 3. Diquat was applied as commercial 'Reglone' (ICI). The orthophosphoric acid amount in treatments 2, 3 and 5 was 83,3, 66,6 and 41,7 kg ha^{-1}, respectively.

Spraying was done with an experimental small-scale sprayer. The plots were harvested by using a Wintersteiger small-plot combine. All plots of the same crop were harvested by direct combining at the same date. The germination tests were conducted according to the rules of I.S.T.A. (ANON. 1976) in October 1985 for ryegrass and in January 1986 for meadow fescue and timothy.

Both meadow fescue and timothy stands were poorly established in autumn 1984; the stands were sparse and did not lodge during the experiment year. Ryegrass stand was well established and was dense, lodging completely before the crop was treated. Because of the dry mid summer only a little late tillering occurred in all stands.

RESULTS

The sprays were applied at different stages of maturity in different crops. The seed moisture content (SMC) at spraying time varied from 45 % in meadow fescue to 40 % in timothy and 28 % in perennial ryegrass:

	Spraying date	Seed moisture (%)	Harvest date
Perennial ryegrass	15.8.	28,4	19.8.
Meadow fescue	31.7.	45,5	8.8.
Timothy	15.8.	39,6	24.8.

Weather conditions between spraying treatment and harvesting varied greatly in different crops. In ryegrass, the weather between treatment and harvesting was warm (average mean daily temperature 17,0 °C) and dry (rainfall 1 mm) during the 5 d period. However, in meadow fescue the whole 9 d period between treatment and harvesting was calm (average mean daily temperature 15,2 °C) and rainy. It rained on eight out of nine days and the total rainfall was 24 mm. In timothy the weather was warm and dry except for one thunderstorm on 21 August. On that single day, 61 mm of rain fell, causing serious seed shedding losses. The losses due to seed shedding were considerably higher in treated than in untreated timothy plots.

The desiccation treatments had a visually masked effect on meadow fescue and timothy stands. Green leaves turned to grey and yellow within 3—4 d. Adding sulphuric acid to orthophosphoric acid accelerated the rate of desiccation. Ryegrass was totally lodged and the head bearing stems formed a uniform level above the bottom grass. The visual effect of spraying treatments was not so great on ryegrass as it was on meadow fescue and timothy. This may be due to the later maturity stage of ryegrass at spraying and the different structure of ryegrass stands, which have more stems.

In timothy and meadow fescue, the highest seed yield was obtained from the untreated plots (Table 1). In perennial ryegrass the treatments with orthophosphoric acid gave a slightly higher seed yields than the control but the yield increase was not statistically significant.

The treatments lowered SMC at harvesting (Table 2). The difference in SMC at harvest between untreated plot and plot sprayed with orthophosphoric acid plus sulphuric acid was statistically significant in perennial ryegrass and in meadow fescue. The orthophosphoric acid treatments did not impair the seed quality measured by germination percentage in any crop (Table 2). Treatment with diquat decreased the germination percentage to some extent.

Table 1. Seed yield (kg ha^{-1} at 12 % moisture content) with different desiccation treatments.

	Perennial ryegrass	Meadow fescue	Timothy
1. Control	1533 ab	638 a	392 a
2. 50 l Kefo ha^{-1}	1567 a	583 a	314 a
3. 40 l Kefo + 20 l H_2SO_4 ha^{-1}	1597 a	627 a	302 a
4. 0,4 kg diquat ha^{-1}	1529 ab		
5. 25 l Kefo ha^{-1}	1656 a		
(Combining at spraying time	1380 b)		

a—b: Means not having the same superscript letter within a column are significantly different ($P<0,05$)

Table 2. Seed moisture content (SMC) at harvest and germination percentage of seeds (G) with different desiccation treatments.

Crop	Perennial ryegrass		Meadow fescue		Timothy	
Treatment	SMC	G	SMC	G	SMC	G
1. Direct combining	21,3 a	94 ab	29,3 a	81 a	31,0 a	90 a
2. 50 l Kefo/ha	19,7 ab	96 ab	27,3 b	85 a	30,2 a	92 a
3. 40 l Kefo + 20 l H_2SO_4 ha^{-1}	18,9 b	95 ab	26,8 b	84 a	28,9 a	93 a
4. 0,4 kg diquat ha^{-1}	18,2 b	88 b				
5. 25 l Kefo ha^{-1}	19,9 ab	97 a				

a—b: Means not having the same superscript letter within a column are significantly different ($P<0,05$)

DISCUSSION

Drying rate of cut herbage sward has been increased by spraying the sward with organic or inorganic acid (TETLOW 1983, JOHNSON et al. 1984). In the present study, treatment with orthophosphoric acid had an obvious desiccation effect. In the treated plot, SMC at harvest was one to three percentage units lower than in the untreated plot.

In erect meadow fescue and timothy crops, treatments resulted in a smaller yield. Yield reductions probably resulted from shedding losses which were greater in treated plots than in untreated plots. In perennial ryegrass desiccation with orthophosphoric acid had a favourable effect on the seed yield obtained in single direct combining. This may be due to low shedding losses in heavily lodged stands in warm and dry weather, and to better threshing results in dry crop.

In timothy, late combine harvesting gives higher seed yields than double-combining (TIME and HILLESTAD 1975). Delaying the harvest can, on the other hand cause high seed shedding losses from wind and rain. Spraying the timothy crop with orthophosphoric acid could force the crop to mature evenly. In this trial, orthophosphoric treatment seems to have increased the shedding losses from rain in both timothy and meadow fescue. This indicates a desiccation risk for the erect stand. In lodged stands, the effect could be more complicated and in some cases favourable. It therefore needs further investigation.

In perennial ryegrass, new growth retardants, e.g. paclobutrazol may reduce lodging considerably. Paclobutrazol also alters the harvesting methods of perennial ryegrass. Single direct combining of a pacloputrazol-treated crop does not harvest all the seed available (HAMPTON and HEBBLETHWAITE 1985). Treatment of the crop with orthophosphoric acid could made the crop to mature more evenly and possibly increase the yields as the result of more efficient threshing.

Preharvest desiccation trials in grass-seed crops with diquat, paraquat and glyphosate have had an adverse effect on germination of seeds of treated grass crop (ROBERT and GRIFFITH 1973, GRIFFITH et al. 1978, HAMPTON and HEBBLETHWAITE 1982).

In this preliminary trial spraying grass seed crops with orthophosphoric acid had a desiccation effect without impairing seed quality. Further research is needed to evaluate the potential of orthophosphoric acid in crops of different maturity and lodging, and under different weather conditions.

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SELOSTUS

Ortofosforihappo lehdistöhävitteenä heinänsiemennurmien korjuussa

OIVA NIEMELÄINEN

Maatalouden tutkimuskeskus

Ortofosforihapon vaikutusta lehdistöhävitteenä englanninraiheinän, nurminadan ja timotein siemennurmen korjuussa tutkittiin kasvinviljelyosastolla Jokioisissa v. 1985. Ortofosforihappona käytettiin Kefo -varsistohävitettä, jossa tehoaineena on fosforihappo ja lisäaineena on kostuteaine.

Ortofosforihapolla oli selvästi näkyvä kasvustoa vaalentava ja kuivattava vaikutus. Käsitellyissä kasvustoissa lehdet kellastuivat 3—4 päivän kuluessa ruiskutuksesta. Ruiskutus alensi siementen puintikosteutta. Timoteilla ja nurminadalla käsitellyistä kasvustoista saatiin pienemmät siemensadot hehtaaria kohti kuin käsittelemättömästä kasvustosta. Sateet ja tuuli aiheuttivat pystyissä nurminata- ja timoteikasvustoissa suuremmat varisemistappiot käsitellyissä kuin käsittelemättömissä koejäsenissä. Englanninraiheinällä käsitellyistä koejäsenistä saatiin hieman suuremmat sadot kuin käsittelemättömästä.

Ortofosforihapporuiskutus ei alentanut siementen itävyyttä. Englanninraiheinäkokeessa mukana ollut ruiskutus dikvatilla alensi siementen itävyyttä.

Tässä alustavassa tutkimuksessa ei ortofosforihapporuiskutuksilla havaittu olevan haitallista vaikutusta siementen laatuun. On syytä tarkemmin selvittää, onko ortofosforihapporuiskutuksilla mahdollista helpottaa pahasti lakoutuneiden siemenheinänurmien korjuuta.

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Seria AGRICULTURA N. 81 — Sarja PELTOKASVIT n:o 81

COMPARISON OF ANTHER CULTURES OF BARLEY CULTIVARS IN BARLEY-STARCH AND AGAR GELATINIZED MEDIA

SEPPO SORVARI

SORVARI, S. 1986. **Comparison of anther cultures of barley cultivars in barley-starch and agar gelatinized media.** Ann. Agric. Fenn. 25: 249—254. (Agric. Res. Centre, Dept. Pl. Breed., SF-31600 Jokioinen, Finland.)

The response of anthers of 2- and 6-rowed barley varieties and lines were compared in agar- and barley-starch gelatinized media.

All varieties and lines produced more embryoids/calli and green plantlets in barley-starch than in agar media. The mean quantity of green plantlets was five times higher in starch and the amount of androgenetic anthers was about three times higher than that in agar media.

Usually the 6-rowed varieties were androgenetically more productive but the single variety Ingrid showed exceptionally high androgenetic capacity. Consequently 2-rowed barleys produced more green plantlets on average than did the 6-rowed.

Among the 6-rowed barleys the early type cultivar Arra, the line Jo 1389 and Dissa responded best in the formation of embryoids/calli and green plantlets in barley-starch.

Index words: *Hordeum vulgare*, 2-rowed barley, 6-rowed barley, anther culture, androgenesis, haploids, gelatine agent, barley-starch, agar.

INTRODUCTION

In the anther cultures of 2-rowed Ingrid and 6-rowed Dissa it was shown that agar can be completely replaced by starch (SORVARI 1986). Both in embryoid formation and differentiation of green plantlets are barley starch media superior to agar. The low response of anthers in agar-based media may due to the inhibitors in agar frequently reported (WILSON 1977, KOHLENBACH and WERNICKE 1978, SUNDERLAND et al. 1979, KAO 1981).

There are, however, indications that genotype also influences the response of cultured anthers in rye (WENZEL et al. 1977), barley (FOROUGHI-WEHR et al. 1982) and in turnip rape (SORVARI 1985). This paper reports on how anthers of commonly cultivated 2- and 6-rowed barley varieties and lines from official variety tests responded to agar and barley-starch gelatinized media.

MATERIAL AND METHODS

Donor plant material consisted of 2- and 6-rowed barley varieties cultivated in Finland, and lines from official trial tests (Table 1). The only exception was Dissa which is not cultivated in Finland but has proven to be a type that responds well in anther culture. Dissa plant material was kindly supplied by Dr Bärbel Foroughi-Wehr.

The barley plants were cultivated in growth chambers in which the conditions consisted of an 18 h day at 18 °C by day and 12 °C by night. The plants were artificially illuminated by Osram "Power Star" HQJ-T 1000 W/D lightbulbs with a light intensity of 50 klux above the plants. Once a week the plants were fertilized with N-P-K-fertilizer (6-7-17).

Anthers were removed aseptically at the uninucleate stage. In order to avoid the effect of genotype between the treatments, the anthers of every spike were always divided in two equal parts, one part for agar and the other for barley-starch.

The basic media with modifications were based on that of MURASHIGE and SKOOG (1962), LINSMAIER and SKOOG (1965), CLAPHAM (1973) and FOROUGHI-WEHR et al. (1976). For the induction of anthers LSH-AI- and LSH-BI -media were used for differenti-

Table 1. Response of anthers of 2-rowed and 6-rowed barley varieties and lines in agar and barley-starch gelatinized nutrient media.

Barley type	Variety or line	Numbers of anthers inoculated		Numbers of anthers producing calli/embryoids				Numbers of green plantlets regenerated				Numbers of albino plantlets regenerated			
				agar (LSH-AI)		starch (LSH-BI)		agar (LSH-AII)		starch (LSH-BII)		agar (LSH-AII)		starch (LSH-BII)	
		agar	starch	total	‰[a]	total	‰[a]	total	‰[a]	total	‰[a]	total	‰[a]	total	‰[a]
2-rowed	Kustaa	1215	1231	4	3,3	7	5,7	1	0,8	—	—	—	—	2	1,6
	Jo 1369	1469	1126	5	3,4	12	10,7	—	—	3	2,7	1	0,7	6	5,3
	Jo 1378	1221	1084	7	5,7	13	12,0	—	—	—	—	1	0,8	2	1,8
	Jo 1382	1003	1078	2	2,0	6	5,6	1	1,0	—	—	—	—	8	7,8
	Jo 1413	974	1086	9	9,2	20	18,4	—	—	3	2,8	2	2,1	10	9,2
	Jo 1358	1112	1120	12	10,8	33	29,5	—	—	—	—	7	6,3	28	25,0
	Ingrid	1072	1070	9	8,4	67	62,6	1	0,9	30	28,0	1	0,9	43	40,2
	Ida	1083	1160	11	10,2	20	17,2	—	—	2	1,7	3	2,8	24	20,7
	Aapo	1222	1218	4	3,3	11	9,0	—	—	—	—	1	0,8	7	5,7
	Patty	1087	1185	5	4,6	23	19,4	—	—	3	2,5	1	0,9	20	16,9
6-rowed	Arra	1130	503	2	1,8	25	49,7	1	0,9	5	9,9	7	6,2	19	37,8
	Dissa	1239	1347	6	4,8	44	32,7	—	—	7	5,2	—	—	53	39,3
	Agneta	1039	1028	15	14,4	49	47,7	—	—	—	—	5	4,8	39	37,9
	Pokko	1105	1123	1	0,9	5	4,5	—	—	—	—	—	—	1	0,9
	Potra	1123	1122	4	3,6	18	16,0	—	—	3	2,7	1	0,9	12	10,7
	Kilta	1179	1176	8	6,8	32	27,2	—	—	3	2,6	3	2,5	19	16,2
	Kalle	1055	1064	6	5,7	14	13,2	1	0,9	1	0,9	6	5,7	14	13,2
	Jo 1330	989	997	15	15,2	24	24,1	—	—	1	1,0	15	15,2	30	30,1
	Jo 1374	1099	1099	12	10,9	35	31,8	—	—	—	—	2	1,8	29	26,4
	Jo 1389	1074	1070	30	27,9	38	35,5	8	7,4	9	8,4	10	9,3	20	18,7
	Pomo	1108	1105	2	2,7	10	9,0	—	—	—	—	1	0,9	5	4,5
2-rowed	total	11458	11358	68	5,9	212	18,7***	3	0,3	41	3,6	17	1,5	150	13,2
6-rowed	"	12140	11534	101	8,3	294	25,3***	10	0,8	29	2,5	50	4,1	241	20,7
2-r.+6-r.		23598	22992	169	7,2	506	22,0	13	0,6	70	3,0	67	2,8	391	17,0

a = amount per 1000 isolated anthers

*** = indicates that numbers of anthers producing calli/embryoids is significantly higher in starch than in agar ($P < 0{,}001$)

ation LSH-AII- and LSH-BII -media, respectively (SORVARI 1986). The preparation of media and the culture of anthers was according to method previously described (SORVARI 1986).

The influence of main and branch tiller was studied by selecting donor plants randomly and studying the response of anthers dissected from them.

Cytological analysis was performed from root tips fixed in (1:3) glacial acetic acid: alcohol and then stained by acetic orcein.

RESULTS

One of the most notable features of the barley-starch gelatinized media was the direct embryoid formation from microspores. In the early stages had the embryoids emerging through tapetum dense structures (Fig. 1). They either remained dormant, or rapidly developed single or multiple meristematic zones with leaf primordia clearly visible under the microscope (Fig. 2).

On average the number of anthers producing calli/embryoids and green plantlets was higher in barley-starch than in the agar media. The quantity of androgenetic anthers of 2-rowed barleys in agar media was 5,9/1000 and in the barley-starch media 18,7/1000. In the 6-rowed barleys the number of androgenetic anthers in agar media was 8,3/1000 and in the barley-starch media 25,3/1000. Both in the 2-and 6-rowed barley plants the quantity of androgenetic anthers was significantly ($P<0,001$) higher in barley-starch than in agar media.

Although there were significantly more androgenetic anthers in the 6-rowed barleys ($P<0,001$) than in the 2-rowed barleys, the 2-rowed barleys produced more green plantlets (3,6/1000) than did the 6-rowed barleys (2,5/1000). This was due to the exceptionally high androgenetic response of the Ingrid variety in barley-starch. The amount of green plantlets produced by Ingrid comprised 3/4 of the total amount of green plantlets.

The line Jo 1389 was the only variety with high amounts of androgenetic anthers and green plantlets both in the agar- (27,9/7,4) and starch-media (35,5/8,4). The other 6-rowed and 2-rowed barleys produced a maximum of 1,0/1000 green plantlet in the agar media.

Though all the varieties and lines had

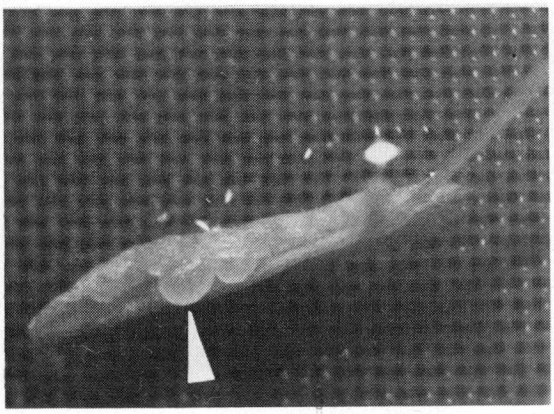

Fig. 1. Barley anther with embryoids after three weeks culture in high sucrose starch-medium.

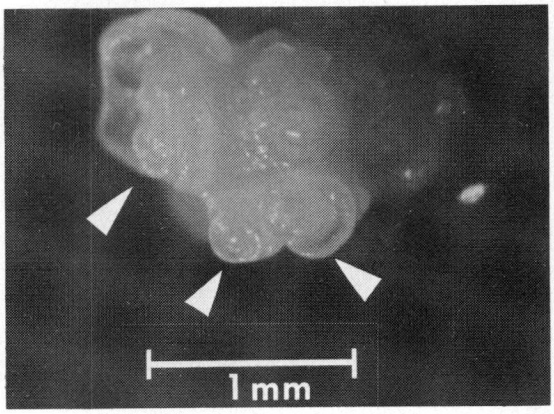

Fig. 2. Differentiating multimeristematic barley embryoid after one week culture in low sucrose starch-medium. Three of the meristems are shown by arrows.

callus/embryoid formation both in the agar and barley-starch gelatinized media some were unable to produce green plantlets in neither agar nor in barley-starch gelatinized media. The 6-rowed variety Agneta had a very high number of androgenetic anthers (47,7/1000) but regeneration of green plantlets was not successfull in any media employed here. Another variety that was extremely recalcitrant was the malting barley variety Pokko. The number of androgenetic anthers in agar was 0,9/1000 and in starch media 4,5/1000, respectively with Pokko only one albino in the barley-starch gelatinized media could be regenerated.

The ratio of green diploids to green haploids (Fig. 3) was for the 2-rowed barleys in starch 1/1 and in agar 3/0, respectively. For the 6-rowed barleys the corresponding rations were 2,5/1 and 1,9/1.

The androgenetic response of anthers dissected from main and branch tiller was equal (Table 2). The quantity of anthers that produced embryoids/calli was 15,5/1000 for main tiller and for branch tiller 13,3/1000. 3,2/1000 green plantlets were produced by main tiller anthers and 3,4/1000 by branch tiller anthers. The differences between main and branch tiller in embryoid/callus production and in the regeneration of green plantlets were not significant (P = 0,001).

Fig. 3. Root tip squash of haploid microspore originated plant showing n = 7 chromosomes.

Table 2. The androgenetic response of anthers dissected from main and branch tillers of randomly selected barley varieties and lines cultured in agar and starch gelatinized media.

Numbers of anthers cultured from		Numbers of anthers producing embryoids/calli		Numbers of green plantlets regenerated		Numbers of albino plantlets regenerated	
main tiller	branch tiller	main tiller	branch tiller	main tiller	branch tiller	main tiller	branch tiller
8301	8211	129	109	27	28	75	58
per 1000 anthers		15,5[a)]	13,3	3,2[a)]	3,4	9,0[a)]	7,1

a) difference not significant to the branch tiller (P = 0,001)

DISCUSSION

Previously various types of starch and agar have been tested in the androgenesis of 2-rowed Ingrid and 6-rowed Dissa (SORVARI 1986). In that study barley starch proved superior compared to the other types of starch or agar.

When using any culture system every genotype reacts in its own way and is thus very difficult to regulate. This is confirmed by numerous earlier studies, for example in rye (WENZEL et al. 1977) in barley (FOROUGHI-WEHR et al. 1982, HUANG et al. 1984) in wheat (BULLOCK et al. 1982, LAZAR et al. 1984) in potato (WENZEL and FOROUGHI-WEHR 1984) and in summer turnip rape (SORVARI 1985). Variation due to genotype should be taken in consideration as much as possible when modifying the nutrient media in order to obtain a uniform response.

The results obtained previously with Ingrid and Dissa are also valid for this study. The superiority of the starch medium to agar in androgenesis can be also confirmed when using different lines and varieties. Despite the great variation between the lines and varieties in both types of media the mean amount of anthers that produced embryoids/calli was in all cases higher in starch than in agar. For the differentiation of green plantlets the starch media were more productive as well. In 2-rowed barleys the quantity of green plantlets in starch was twelve times higher and in 6-rowed three times higher than in agar. However, in 2-rowed barleys the variety Ingrid produced 3/4 of the green plantlets, accounting for the disproportionate results to 6-rowed barleys. Excluding such exceptions, 6-rowed barleys produced more green plantlets than 2-rowed. In the 6-rowed lines and varieties, 7 out of 11 (63 %) and in the 2-rowed, 5 out of 10 (50 %) produced green plantlets.

There are some indications that in dicot *B. campestris* anthers respond differently when dissected from main or side inflorescence (SORVARI 1985). FOROUGHI-WEHR and FRIEDT (1981) did not find in the anther response of the barley cultivar Dissa any difference between anthers dissected from main and branch tiller. The results obtained with Dissa are similar to the results of the present study.

In the randomly selected varieties and lines no significant difference ($P = 0{,}001$) was found in anther response between main and branch tillers. This is important because, for example, there are then more anthers available from a single genotype.

Succesful results in anther culture are the syntheses of several factors: growth conditions of donor plants, genotype, dissecting season and cultural conditions of anthers and even the skillfulness of technical personnel. Because genotype has an important role in succesful anther culture, it is tempting to concentrate more on the anther culture responsive genotypes suggested by FOROUGHI-WEHR et al. (1982).

However, there are situations where the selection of cell and tissue culture-fitting genotypes is not possible, or the creation of cell and tissue culture adapted lines takes too long. Therefore it is best to study in addition to genotypes other factors as well especially one of the most basic factor: the nutrient medium. This study has shown that the agar-omitted starch media promoted the response in anther culture not only in Dissa and Ingrid, but also in all of the twenty-one lines and varieties used in this experiment.

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SELOSTUS

Agar- ja ohratärkkelyspohjaisten ravintoalustojen vertailu ohralajikkeiden ponsiviljelmissä

SEPPO SORVARI

Maatalouden tutkimuskeskus

Haploidien ohrien tuottaminen epäkypsistä siitepölyhiukkasista mikrospooreista on riippuvainen hyvin monista tekijöistä. Kaksi hyvin keskeistä seikkaa ovat ravintoalusta ja kasvin genotyyppi.

Aikaisemmassa tutkimuksessa voitiin osoittaa, että kaksitahoisen Ingridin ja monitahoisen Dissan ponsiviljelmissä tärkkelyspohjainen alusta oli merkittävästi parempi kuin agar-alusta. Koska genotyypillä on merkittävä osuus ponsiviljelmän onnistumisessa tutkittiin eri lajikkeiden ja linjojen suhtautumista näihin kahteen ravintoalustatyyppiin.

Sekä kaksi- että monitahoisilla esiintyi huomattavaa vaihtelua molemmilla alustatyypeillä, mutta kuitenkin niin, että androgeenisten ponsien lukumäärä oli tärkkelysalustalla merkittävästi korkeampi. Tärkkelyspohjainen alusta, josta puuttuvat agarille ominaiset haitta-aineet voi täysin korvata agarin myös erilaisilla genotyypeillä.

ANNALES AGRICULTURAE FENNIAE, VOL. 25: 255—263 (1986)
Seria AGROGEOLOGIA ET -CHIMICA N. 138 — Sarja MAA JA LANNOITUS n:o 138

CADMIUM IN CULTIVATED FINNISH SOILS

JOUKO SIPPOLA and RITVA MÄKELÄ-KURTTO

SIPPOLA, J. & MÄKELÄ-KURTTO, R. 1986. **Cadmium in cultivated Finnish soils.** Ann. Agric. Fenn. 25: 255—263. (Agric. Res. Centre, Dept. Soil Sci. SF-31600 Jokioinen, Finland.)

The mean cadmium content of cultivated Finnish soils extracted with aqua regia was 0,21 mg/kg, or on a w/v basis 0,15 mg/l soil. 0,5 N HNO_3 and AAAc-EDTA extractable cadmium were 0,10 and 0,06 mg/l, respectively. The mean cadmium content of timothy was 16 μg/kg. Soils in Southern Finland contained more cadmium than those in Northern Finland. Regional differences in the cadmium content of timothy were less distinct. Soil cadmium was positively correlated to soil calcium, while the cadmium content of timothy was negatively correlated to soil zinc.

Index words: cadmium, soil, aqua regia, 0,5 N HNO_3, acid ammonium acetate-EDTA, timothy, pollution.

INTRODUCTION

Cadmium contents in the soil, water and air have increased from their natural background levels due to industrial and agricultural practices. Cadmium is transferred from the soil into plants, and via food chains finally to humans. The accumulation of cadmium in the liver and kidneys is a serious health risk. Cadmium is therefore considered to be one of the most harmful substances in the environment.

Phosphorus fertilizers, atmospheric deposits and sewage sludge are the main sources of cadmium in cultivated soils. Phosphorus fertilizers, containing cadmium as an impurity consist of about one half of total cadmium input to soil and atmospheric fallout one third, respectively. Sewage sludge may contain various levels of cadmium and its use on cultivated soils has to be well-regulated. Cadmium supplies in the soil and the availability of Cd to plants, as well as the cadmium contents of grain have increased during this century (ANDERSSON 1984). It has been estimated that the cadmium content of cultivated soils will further increase by 0,3—0,4 % annually (ANDERSSON 1982), and that the cadmium content of the environment will be double by the year 2000 (HÄSÄNEN 1983).

The aim of this work was to collect information on the cadmium content of cultivated soils in Finland. Three extractants were used to compare the results obtained here with those of other studies. The cadmium content of timothy growing on soil sampling sites was also determined to evaluate the availability of soil cadmium to plants.

MATERIAL AND METHODS

The soil samples were part of larger sample material collected from cultivated fields throughout Finland in 1974 (SIPPOLA and TARES 1978). Timothy was sampled as an indicator crop from soil sampling sites at the heading stage just before flowering in the same year. All samples were stored dry at room temperature until 1984 when they were analyzed.

The soil samples were prepared for cadmium determination and their physical and chemical properties determined as described by BAGHDADY and SIPPOLA (1983). The determination of soil cadmium was done by three different extractants: aqua regia (AR), HCl:HNO_3 3,5 : 1 (KICK et al. 1980); 0,5 N HNO_3 (COTTENIE et al. 1982) and 0,5 N NH_4-acetate-acetic-acid-EDTA (AAAc-EDTA), pH 4,65 (LAKANEN and ERVIÖ 1971). Forty-six soil samples were the same for these three extractants, but the rest were different. However, all of the soil samples studied were nationally representative. Cadmium concentration was measured in the extractants by an atomic absorption spectrometer with an air-acetylene flame.

The cadmium content of timothy was determined by flameless atomic absorption after ashing the sample at 450 °C and dissolving the residue in HCl.

RESULTS

Cadmium in soil

The mean AR extractable cadmium content of cultivated Finnish soils was 0,21 mg/kg, or on a soil volume basis, 0,15 mg/l (Table 1, Fig. 1). 0,5 N HNO_3 extracted more than one half of the amounts extracted by AR, and the mean Cd content was 0,10 mg/l soil, with a range of 0,01 to 0,32 mg/l. AAAc-EDTA appeared to be a rather weak extractant, and the mean Cd

Table 1. Mean cadmium contents of cultivated Finnish soils and timothy by soil type group. Soil cadmium extracted with AR, 0,5 N HNO_3 and AAAc-EDTA ($\bar{x}$ = mean; s = standard deviation; n = number of samples).

Soil type group		Soil Cd				Timothy Cd
		AR		0,5 N HNO_3	AAAc-EDTA	
		(mg/kg)	(mg/l)	(mg/l)	(mg/l)	(µg/kg DM)
Coarse mineral soils	$\bar{x}$	0,15	0,14	0,09	0,05	16
	s	0,08	0,07	0,04	0,03	8
	n	29	29	210	118	215
Clays	$\bar{x}$	0,20	0,19	0,14	0,08	20
	s	0,08	0,06	0,04	0,03	6
	n	28	28	48	29	48
Organic soils	$\bar{x}$	0,28	0,13	0,10	0,06	16
	s	0,14	0,09	0,05	0,03	9
	n	29	29	98	60	98
All soils	$\bar{x}$	0,25	0,15	0,10	0,06	16
	s	0,12	0,08	0,05	0,03	8
	n	86	86	356	207	361
range		0,04—0,76	0,02—0,47	0,01—0,32	0,01—0,20	2—64

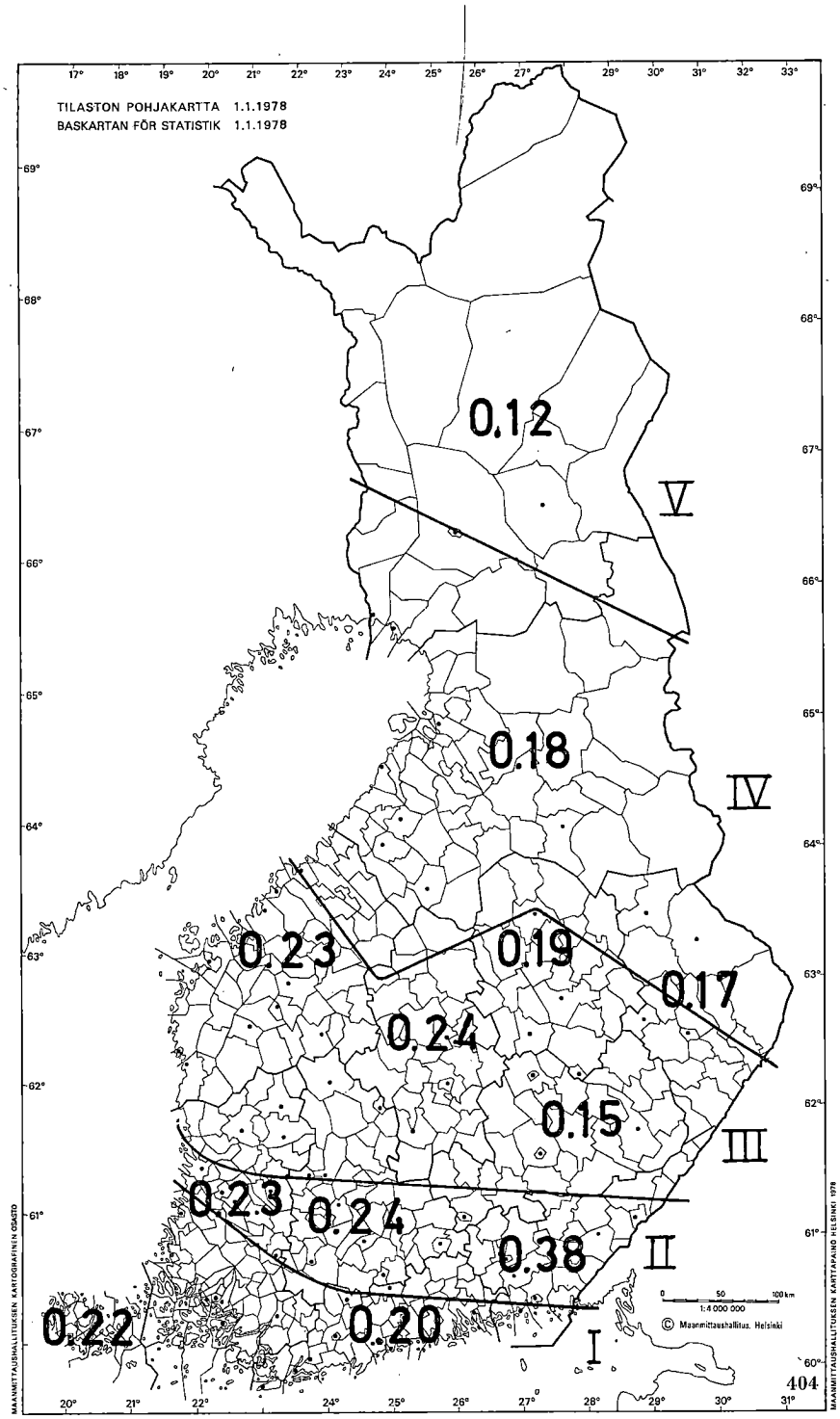

Fig. 1. Total cadmium contents (mg/kg) of cultivated Finnish soils by locality. Cultivation zones from I to V are indicated by dividing lines.

content was 0,06 mg/l, ranging from 0,01 to 0,20 mg/l. On a w/w basis, organic soils appeared to be rich in Cd. On a soil volume basis, clay soils were abundant in Cd and coarse mineral and organic soils were rather similar with respect to their cadmium content.

Regional differences in soil Cd content were evident (Table 2). The soils of the southern and western parts of Finland contained more than 0,15 mg/l AR extractable Cd, while the soils of other areas, comprising about two thirds of Finland, contained less than 0,15 mg/l. The

Table 2. Mean cadmium contents of cultivated Finnish soils and timothy by locality. Soil cadmium extracted with AR, 0,5 N HNO_3 and AAAc-EDTA. ($\bar{x}$ = mean; s = standard deviation; n = number of samples).

Province		Soil Cd			Timothy Cd
		AR (mg/l)	0,5 N HNO_3 (mg/l)	AAAc-EDTA (mg/l)	(µg/kg DM)
Ahvenanmaa Islands	$\bar{x}$	0,23	0,25	0,17	15
	s	0	0,07	0,03	1
	n	1	3	3	3
Turku and Pori province	$\bar{x}$	0,19	0,13	0,08	20
	s	0,04	0,03	0,02	10
	n	12	34	24	34
Uusimaa province	$\bar{x}$	0,18	0,13	0,06	20
	s	0,04	0,02	0,02	5
	n	12	14	6	14
Häme province	$\bar{x}$	0,18	0,13	0,07	19
	s	0,08	0,04	0,03	5
	n	11	31	19	31
Kymi province	$\bar{x}$	0,24	0,12	0,07	17
	s	0,16	0,04	0,02	7
	n	4	16	4	16
Vaasa province	$\bar{x}$	0,15	0,10	0,06	15
	s	0,07	0,05	0,03	7
	n	11	33	18	33
Prov. of Central Finland	$\bar{x}$	0,16	0,11	0,06	15
	s	0,07	0,04	0,03	8
	n	4	31	25	32
Mikkeli province	$\bar{x}$	0,15	0,12	0,07	17
	s	0,04	0,04	0,02	10
	n	2	28	10	28
Kuopio province	$\bar{x}$	0,08	0,08	0,05	13
	s	0	0,02	0,02	7
	n	2	22	16	22
Prov. of North Karelia	$\bar{x}$	0,11	0,10	0,07	17
	s	0,04	0,05	0,04	8
	n	6	52	21	53
Oulu province	$\bar{x}$	0,13	0,07	0,04	10
	s	0,08	0,03	0,02	6
	n	13	49	31	52
Lapland province	$\bar{x}$	0,06	0,06	0,03	20
	s	0,04	0,02	0,02	7
	n	8	43	30	43

lowest mean value, 0,06 mg/l, was observed in Lapland province and the highest, 0,24 mg/l, in Kymi province. In addition, 0,5 N HNO_3 and AAAc-EDTA extractable Cd indicated a similar regional distribution. On average, the Cd contents found in Northern Finland were less than half those of the southern and western regions. The very low soil Cd content in Northern Finland was even more evident when 0,5 N HNO_3 extractable cadmium results were grouped according to cultivation zones (Tables 3 and 4).

The relationship of soil Cd content to the contents of other extractable soil mineral elements was also investigated. The most significant correlation was between soil Cd and soil Ca. The correlations of AR, 0,5 N HNO_3 and AAAc-EDTA extractable Cd to soil Ca were 0,27**, 0,40*** and 0,50***, respectively. Other correlations were low or not significant.

Table 3. Means of the 0,5 N HNO_3 extractable soil cadmium by cultivation zones (I—V). Tested by rows with Tukey HSD procedure at 95 % level.

Soil type group		Soil cadmium (mg/l)				
		I	II	III	IV	V
Coarse mineral soils	$\bar{x}$	0,16[a]	0,11[a]	0,10[a]	0,08[b]	0,04[c]
	s	0,09	0,03	0,04	0,03	0,02
	n	3	22	97	74	14
Clay soils	$\bar{x}$	0,15[a]	0,13[a]	0,17[a]	0,10[a]	—
	s	0,05	0,04	0,05	0,01	—
	n	20	19	7	2	—
Organic soils	$\bar{x}$	0,14[ab]	0,15[a]	0,11[a]	0,08[b]	0,03[b]
	s	—	0,04	0,04	0,04	0,02
	n	1	11	38	44	4
All soils	$\bar{x}$	0,15[a]	0,13[a]	0,11[b]	0,08[c]	0,04[d]
	s	0,05	0,04	0,04	0,03	0,02
	n	24	52	142	120	18

Table 4. Mean cadmium contents of timothy by cultivation zones. Tested by rows with Tukey HSD procedure at 95 % level.

Soil type group		Cadmium in timothy µg/kg				
		I	II	III	IV	V
Coarse mineral soils	$\bar{x}$	19[ab]	19[ab]	16[ab]	13[b]	22[a]
	s	9	6	9	7	4
	n	3	22	99	77	14
Clay soils	$\bar{x}$	19[a]	20[a]	21[a]	15[a]	—
	s	7	4	7	7	—
	n	20	19	7	2	—
Organic soils	$\bar{x}$	13[a]	18[a]	16[a]	14[a]	24[a]
	s	—	10	9	8	6
	n	1	11	38	44	4
All soils	$\bar{x}$	19[ab]	19[ab]	17[b]	14[c]	23[a]
	s	7	6	9	7	5
	n	24	52	144	123	18

Cadmium in timothy

The mean Cd content of timothy was 16 μg/kg DM, ranging from 2 to 64 μg/kg (Table 1). The mean Cd content of timothy grown in clay soil was significantly higher than that of timothy grown in organic or coarse mineral soils. Regional differences in the Cd contents of timothy were not significant (Table 2). The lowest mean value, 10 μg/kg DM, was found in Oulu province, while the highest mean value, 20 μg/kg DM, was found in Uusimaa, Turku and Pori as well as Lapland provinces.

The relationship of timothy Cd to other mineral elements was investigated. The most significant correlation found was between timothy Cd and soil Zn. In the AR and 0,5 N HNO_3 groups, the correlations were −0,20* and −0,14**, respectively. Other correlations obtained were very low or not significant.

DISCUSSION

Cadmium in soil

Various methods are used for extracting soil cadmium. Depending on the extraction method employed, a total amount or different fractions, such as exchangeable, easily soluble and plant available fractions, are determined. Analytical results may be expressed in various ways. Generally the total Cd content is expressed on a weight basis, i.e. mg/kg soil. From the point of plant nutrition, results are more comparable when expressed on a volume basis, i.e. mg/l soil, especially in the case of soils having a broad range of organic matter. Therefore both ways are used here to express the AR results.

The Cd contents of cultivated Finnish soils reported here represent soil conditions in 1974. To day these contents would be a few per cent higher due to the use of fertilizers and atmospheric deposition (ANDERSSON 1982).

The total i.e. AR extractable cadmium contents of the cultivated Finnish soils found in this study were at about the same level as those reported earlier for Finnish soils (SOVERI 1977, HÅRDH 1977).

The total Cd contents of cultivated Finnish soils approximated the values reported in other Northern European countries: for Sweden, on average, 0,22 mg/kg HNO_3 extractable Cd (ANDERSSON 1977) and for Denmark about 0,25 ppm concentrated HNO_3 extractable Cd (TJELL and HOVMAND 1978).

Finnish soils contained less total Cd than do soils in highly industrialized and densily populated Central European countries: for example, Germany averages 0,8 mg/kg AR extractable Cd (KICK et al. 1980), and the Netherlands averages 0,4 mg/kg 2 N HCl extractable Cd (van DRIEL et al. 1983) as well as from 0,3 to 0,9 mg/kg concentrated HNO_3 extractable Cd (van DRIEL and SMILDE 1981).

Total Cd concentrations in agricultural soils are normally reported to be less than 1 mg/kg (KLOKE 1977, KORTE 1982). In Germany, it has been proposed that the highest acceptable Cd concentration in agricultural soils should be 3 mg/kg (KLOKE 1980).

The estimation of soil Cd by 0,5 N HNO_3 is not very common. Field or grassland soils in Belgium were reported to contain about 0,6 mg/kg 0,5 N HNO_3 extractable Cd (BOSMANS and PAENHUYS 1980).

The AAAc-EDTA extraction method has been used by other Finnish researchers also. According to FORSS and AHONEN (1982) cultivated soils in Helsinki contained, on average, 0,29 mg/l AAAc-EDTA extractable Cd. This value was significantly higher than that obtained in the present study. Urban soils are obviously more contaminated by cadmium

than Finnish soils on average. HÅRDH (1977) also reported the highest Cd levels from city areas.

The higher total Cd values observed in this study for the southern and western parts of Finland were understandable due to the prevalence of clay soils, industry and population there. Intensive agriculture using high rates of fertilizer is practiced in these parts of the country. The quantity of Cd deposition originating from highly industrialized areas abroad is obviously much higher in Southern Finland than in the north as found in Sweden (ANDERSSON 1981). Differences in soil Cd levels between the northern and southern parts of Finland were also reported by SOVERI (1977).

The high mean Cd content found here in organic soils by AR extraction when expressing the results in mg/kg was due to the low bulk densities of the organic soils. By calculating the results in mg/l soil, the differences between the soil type groups were comparable to those by other extraction methods. The differences between the soil type groups found in this study were similar to those found elsewhere (van DRIEL and SMILDE 1981, MACLEAN 1976). Organic soils and clays have, in general, higher absorption capacities than do coarse mineral soils. Obviously, this is true with cadmium as well. The positive and highly significant correlations obtained between soil Cd and soil Ca were supported by the results published by MARTTINEN and EDGREN (1984) for Finnish soils. These correlations may be due to the dependence of calcium and cadmium on soil adsorption capacity.

Cadmium in timothy

The Cd contents of timothy obtained in this study were low compared with the results obtained for grasses by other researchers. HÅRDH (1977) indicated the Cd content of ley grass grown in Finland to be on the average, 75 µg/kg DM in "clean" soils and 140 µg/kg DM in more contaminated soils. The Cd content of grass grown in Iceland is reported to vary from 25 to 109 µg/kg DM (PORSTEINSSON and PALMASON 1984). According to MACLEAN (1976) Cd content of timothy grown in Canada was about 210 µg/kg DM.

The normal Cd concentration in plants has been reported to usually range from 50 to 200 µg/kg in relatively uncontaminated areas (ANON. 1982). Cd uptake by plants is known to depend on the chemical form of the heavy metal, on many physical and chemical soil properties, as well as on synergistic and antagonistic reactions with nutrients, on plant factors, such as species and cultivars, and on some climatic factors. The low Cd contents found in this study in timothy might be due to its late stage of development during sampling. The significant negative correlation obtained between timothy Cd and soil Zn indicated that Zn obviously inhibits Cd uptake by timothy.

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SELOSTUS

Kadmium viljelymaissamme

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Maatalouden tutkimuskeskus

Tämä tutkimus oli osa suuremmasta kokonaisuudesta, jossa kartoitettiin suomalaisten viljelymaiden kivennäis- ja hivenainetilannetta. Tässä osatutkimuksessa määritettiin kadmium 86 maanäytteestä uuttaen kuningasvedellä, 356 maanäytteestä uuttaen 0,5 N HNO_3:lla sekä 207 maanäytteestä uuttaen happamalla ammoniumasetaatti-EDTA:lla (AAAc-EDTA), pH 4,65. Lisäksi maanäytteiden ottopaikoilta kerätyistä 361 timoteinäytteestä määritettiin kadmium. Kaikki kadmium-määritykset tehtiin atomiabsorptiospektrofotometrisesti.

Kuningasvesiuutolla saatiin selville maan kokonaiskadmiumpitoisuus, joka oli keskimäärin 0,15 mg/l. 0,5 N HNO_3 uutti maan kokonaiskadmiumpitoisuudesta kolme neljäsosaa eli 0,10 mg/l. AAAc-EDTA, pH 4,65, oli heikko uuttoneste, joka uutti kadmiumia keskimäärin 0,06 mg litrasta maata. Etelä- ja Länsi-Suomessa pitoisuudet olivat korkeampia kuin muualla maassa. Savet sisälsivät enemmän kadmiumia kuin eloperäiset maat ja karkeat kivennäismaat. Tämä maalajikohtainen ero osittain selittää havaittuja alueellisia eroja.

Teollistuneisuus ja runsas lannoitteiden käyttö Etelä-Suomessa ovat olleet omiaan lisäämään peltojen kadmiumpitoisuutta. Kadmiumin kulkeutuminen ilman kautta maamme rajojen ulkopuolelta runsaampana Etelä- kuin Pohjois-Suomeen on ilmeistä.

Suomen viljelymaiden kadmiumpitoisuudet olivat suunnilleen samaa tasoa kuin muissa Pohjoismaissa, mutta sen sijaan selvästi alhaisempia kuin Keski-Euroopassa. Lisäksi maan kadmiumpitoisuus oli positiivisessa vuorosuhteessa maan kalsiumpitoisuuteen. Tähkälletulovaiheessa korjatun timotein kadmiumpitoisuudet osoittautuivat hyvin pieniksi, keskiarvon ollessa 16 µg/kg kuiva-ainetta. Savimailla kasvanut timotei sisälsi keskimäärin enemmän kadmiumia kuin eloperäisillä tai karkeilla kivennäismailla kasvanut timotei. Timotein kadmiumpitoisuudella oli negatiivinen vuorosuhde maan sinkkipitoisuuteen.

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Seria AGROGEOLOGIA ET -CHIMICA N. 139 — Sarja MAA JA LANNOITUS n:o 139

SOME EXTRACTION METHODS AS INDICATORS OF NEED FOR PHOSPHORUS FERTILIZATION

JOUKO SIPPOLA and INTO SAARELA

SIPPOLA, J. & SAARELA, I. 1986. **Some extraction methods as indicators of need for phosphorus fertilization.** Ann. Agric. Fenn. 25: 265—271. (Agric. Res. Centre, Dept. Soil Sci., SF-31600 Jokioinen, Finland.)

Ammonium lactate was more efficient in extracting phosphorus than the other methods studied. The amount of phosphorus extracted from a 20 cm soil layer equalled that in ten yields. The phosphorus extracted by carbonate or resin amounted to about half of that extracted by lactate and water or acid ammonium acetate was only one tenth.

The amounts of phosphorus extracted by acid ammonium acetate correlated closely with the amounts extracted by resin and by water. Acid ammonium acetate is thus likely to extract similar soil phosphorus pools as resin and water. Of the variation in the yield increases obtained by phosphorus fertilization the results of the water extraction method explained 68 %, the resin method 61 %, the acid ammonium acetate method 53 %, the sodium bicarbonate method 46 %, the ammonium sulphate + potassiumphosphate method 43 %, the ammoniumsulphate method 40 % and the ammonium lactate method 39 %.

The acid ammonium acetate method used in soil testing in Finland explained a larger portion of the variation in yield increases than did the sodium bicarbonate and ammonium lactate methods extensively used in many countries. Because of long experience with the acid ammonium acetate method its use in soil testing may be continued with good reason. If, however, more precise knowledge of the need for phosphorus fertilization is required, the water extraction method would most likely be the best choice.

Index words: soil testing, phosphorus, extracting methods.

INTRODUCTION

The soil phosphorus test methods in use often rather poorly explain the variation in yield increases obtained by phosphorus fertilization on the field. The variation explained may be less than 10 % (HAHLIN and JOHANSSON 1977). Great variation in soil properties and other growth factors diminishes the significance of one single nutrient element in determining yield. Therefore to improve the value of soil testing new methods are constantly being developed to more precisely characterise soil phosphorus status.

Of the recent innovation the water extraction method, which has an exceptionally

wide extraction ratio, may be mentioned (van der PAAUW 1971). The resin extraction method has been found to be promising as a means to assess soil phosphorus status (AURA 1978, SIBBESEN 1979). Due to the complexity of the anion resin extraction method, it has not been used in routine soil testing. The ammonium lactate method is widely used in soil testing in several countries, and in addition to phosphorus also other major nutrients are determined by this extract (HAHLIN and JOHANSSON 1977). The $NaHCO_3$-extraction method was developed originally for alkaline soils but has been used also on other types of soils and has been widely accepted for routine use (OLSEN et al. 1954).

The aim of this study was to compare the suitability of the above-mentioned phosphorus test methods to indicate the need for phosphorus fertilization based on phosphorus fertilization trials. The acid ammonium acetate extraction method used in Finland was included in the study. Two extraction methods proposed recently by STÅHLBERG (1980, 1982) also were compared.

MATERIAL AND METHODS

The study was based on results obtained in a series of phosphorus fertilization experiments that took place at several of the Research Stations of the Agricultural Research Centre. The dependence of yield increases obtained by 60 kg/ha phosphorus application at 13 sites over three years on phosphorus test values was used as the basis to compare the methods. The soils of the experimental fields differed, ranging from heavy clay to finesand and included organic soils. The test crops were barley, wheat or rye. The phosphorus in soils at the beginning of the experiments was extracted with several methods (Table 1). For extractions by all of the methods the soil was measured by volume and the results reported as mg/l soil despite what was originally proposed for each method. In the case of the resin extraction 5 ml soil and 2,5 g resin was taken. The phosphorus in the extracts was determined by the ascorbic acid method (WATANABE and OLSEN 1965) but in the case of acid ammonium acetate extracts reduction was performed with methol and stannous chloride (VUORINEN and MÄKITIE 1955).

Table 1. The studied extraction methods.

Method	Extraction ratio v/v	Extraction time h	pH	Reference
1. Acid ammonium-acetate	1:10	1	4,65	VUORINEN & MÄKITIE 1955
2. Sodiumbicarbonate	1:20	1	8,50	OLSEN et al. 1954
3. Water	1:60	22+1	—	SISSINGH 1971
4. Anion exchange resin	1:20	24	—	SIBBESEN 1979
5. Ammoniumsulphate	1:20	1	—	STÅHLBERG 1980
6. Ammoniumsulphate + potassiumphosphate	1:20	17	—	STÅHLBERG 1982
7. Ammoniumlactate	1:20	4	3,75	EGNER et al. 1960

RESULTS AND DISCUSSION

1. Phosphorus extracted from soils by different methods.

Of the methods tested ammonium lactate was the most efficient in extracting soils phosphorus (Table 2). Plain water also extracted phosphorus rather effectively. The broad extraction ratio most likely promoted good extraction. The content of phosphorus in water extract is low and hence difficult to determine. However the mean phosphorus content of the present sample material studied now, 11,7 mg/l, is almost the same as the mean 11,5 mg/l of a larger Finnish sample consisting of 104 soils (HARTIKAINEN 1982).

The recently proposed 0,1 M ammonium sulphate solution (STÅHLBERG 1980) extracted less phosphorus than did water, but by the ammoniumsulphate-potassiumphosphate method (STÅHLBERG 1982) the phosphorus concentrations of suspension in equilibrium with soil were similar to those in acid ammonium acetate and water.

The mean quantities of phosphorus extracted by ammonium lactate from soils are equal to about ten times the quantities taken up by a crop of the 20 cm deep plow layer. The phosphorus quantities extracted by acid ammonium acetate and water were on the order of the phosphorus uptake of one crop yield.

Table 2. Soils of the experimental fields, their organic carbon content, pH, with 60 kg/ha P obtained yield increase and phosphorus extracted with methods investigated.

				P mg/l soil						
Soil type	Org. C %	pH (H_2O)	Yield increase kg/ha	Acid amm. acetate	Sodium bicar-bonate	Water	Anion exchange resin	Amm. sul-phate	Amm. sulphate + Potassium phosphate	Amm. lactate
Mull	22,7	5,3	170	9,2	55	8,9	55	2,1	4,5	67
Sandy clay	2,7	6,6	–50	56,6	116	42,9	114	16,5	32,9	285
Heavy clay	1,9	6,5	400	3,9	33	5,8	39	1,0	3,0	55
Finesand	1,7	5,7	370	8,9	45	5,7	39	3,3	7,3	85
Sandy clay	2,2	5,8	130	14,1	81	16,8	71	5,0	13,1	151
Loam	8,1	5,7	140	9,1	86	6,2	48	1,6	2,2	139
Silt	9,9	6,0	540	6,9	42	6,8	49	2,5	4,5	107
Loam	2,3	5,6	360	3,0	25	3,3	23	1,4	4,3	39
Finer finesand	1,6	6,1	110	14,2	49	10,1	52	7,3	19,1	125
Silt	2,7	6,2	190	27,8	65	17,1	72	11,4	26,3	206
Finer finesand	3,0	5,4	850	4,7	39	1,4	19	1,0	1,2	72
Finesandy mull	18,0	4,7	280	14,8	101	23,4	98	15,5	31,5	119
Silty clay	2,4	5,7	570	3,7	26	3,8	29	1,9	6,3	57

2. Relationship between the phosphorus extracted with different methods.

The correlation between the results of different methods is generally high due to the small number of experimental sites and broad range in phosphorus contents of their soils (Table 3). The highest coefficient of correlation ($r = 0,99$) was between the results of the ammonium sulphate and the ammonium sulphate-potassium-phosphate methods. The same ion acts as an extractant in these two methods which may cause the similarity in extraction. Furthermore, the results of water and resin extractions correlated rather closely which may be due to the fact that in the resin extraction water is the actual extractant.

The results of water extraction and acid ammonium acetate correlated quite well. Acid ammonium acetate extracts from soil only a very easily extractable fraction of soil phosphorus which correlates with the NH_4Cl-extractable soil phosphorus (KAILA 1964). In addition the water extractable phosphorus dissolves of the NH_4Cl-extractable fraction (HARTIKAINEN 1982) and thus the similarity of these two results is understandable.

The results obtained with ammonium lactate correlate best with those by resin extraction. Because of its acidity ammonium lactate extracts more calcium phosphate than do iron or aluminium phosphates (MUNK and BÄRMANN 1971). The resin in the bicarbonate form extracts to some extent phosphorus bound by calcium by precipitating calcium as a carbonate. In addition phosphorus bound by aluminium and iron is extracted as by the sodium bicarbonate method.

3. Relationship between yield increases and phosphorus extracted by different methods.

According to the results little phosphorus was extracted from soils which responded well to phosphorus fertilization (Fig. 1). For those soils containing an abundance of phosphorus the response to phosphorus fertilization was small. This general principle holds true for all extraction methods, but in the closeness of correlation there were differences between methods.

According to the logaritmic regression the

Table 3. The correlation between phosphorus amounts extracted with different extractants.

	Ammonium-lactate	Water	Anion exchange resin	Ammonium-sulphate	Ammonium-sulphate + potassium-phosphate	Sodium bicarbonate
Acid. amm. acetate	$0,84^{xxx}$	$0,93^{xxx}$	$0,83^{xxx}$	$0,82^{xxx}$	$0,80^{xxx}$	$0,75^{xx}$
Ammonium-lactate	—	$0,87^{xxx}$	$0,93^{xxx}$	$0,84^{xxx}$	$0,80^{xxx}$	$0,91^{xxx}$
Water	—	—	$0,95^{xxx}$	$0,90^{xxx}$	$0,87^{xxx}$	$0,85^{xxx}$
Anion exchange resin	—	—	—	$0,91^{xxx}$	$0,88^{xxx}$	$0,91^{xxx}$
Ammonium-sulphate	—	—	—	—	$0,99^{xxx}$	$0,78^{xxx}$
Ammoniumsulphate + potassiumphosphate	—	—	—	—	—	$0,73^{xx}$

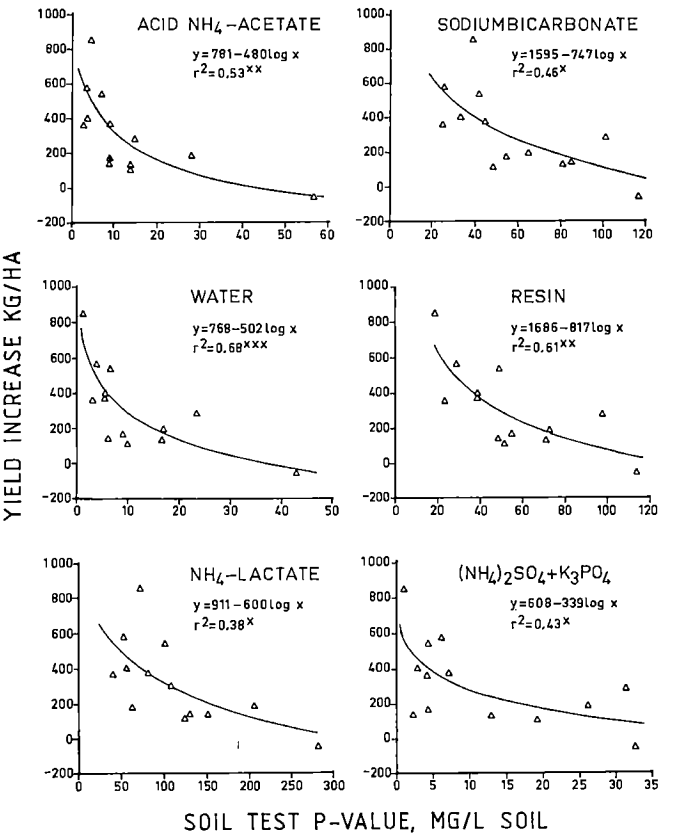

Fig. 1. The dependence of yield increase on the soil test value obtained with the studied extraction methods.

phosphorus extracted by various methods explained from 39 to 68 % of the variation in yield increases. The degree of explained variation was rather high considering that the test material was data from field experiments. For example HAHLIN and JOHANSSON (1977) reported results where the variation explained was 15 % at most. The calculation of a mean yield increase over three years was likely to decrease the variation in the present study as has been the case also elsewhere (VETTER et al. 1978).

Contrary to the results of AURA (1978) and SIBBESEN (1979) the results of the water extraction method better explained variation in yield than did the results of resin extraction method. When the water extraction method was developed the test crop was potato a plant which has high requirements for available phosphorus (van der PAAUW 1971). The resin extraction is likely to dissolve a fraction of more plant unavailable phosphorus than the water extraction. There are also differences between test crops. For example oats is known to be efficient in utilizing soil phosphorus. Therefore results may differ.

Acid ammonium acetate, at pH 4,65, extracts from soils a rather easily soluble fraction (KAILA 1964). The acidity of this solution is not enough for efficient extraction compared for example to ammonium lactate whose hydrogen ion activity is almost tenfold

and extracts phosphorus accordingly. The extraction with acid ammonium acetate appears rather well to indicate the need for phosphorus fertilization and only the water and resin extraction methods were superior. These methods are more expensive, however, because only phosphorus is determined from the extract. As opposed to these methods, by the acid ammonium acetate extract method other nutrient elements are also determined.

In this study ammonium lactate extraction appeared to be rather poor in indicating need for phosphorus fertilization. This is contrary to the results of VETTER et al. (1978) who found ammonium lactate to be almost as good as the water method. In both the above and the present study the sodium bicarbonate method similarly explained the variation in yield increases, 49 and 46 %, respectively.

Based on the results obtained it may be concluded that the use of acid ammonium acetate extraction can be continued in soil testing in Finland with good reason. If, however, more precise knowledge of the need for phosphorus fertilization is required, the water extraction method would most likely be the best choice.

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SELOSTUS

Eräät maa-analyysimenetelmät fosforilannoitustarpeen ilmaisijoina

JOUKO SIPPOLA ja INTO SAARELA

Maatalouden tutkimuskeskus

Tutkimuksessa verrattiin keskenään viljavuustutkimuksessa käytettyjä tai käyttöön esitettyjä fosforiuuttomenetelmiä kenttäkokeiden antamiin tuloksiin nojautuen.

Ammoniumlaktaattimenetelmä osoittautui tehokkaimmaksi fosforin uuttajaksi aineiston keskiarvon vastatessa 20 cm:n muokkauskerrosta kohti laskettuna 10 sadon ottamaa fosforimäärää. Natriumbikarbonaatti- ja hartsimenetelmät uuttivat noin puolet ammoniumlaktaattimenetelmän uuttamista sekä hapan ammoniumasetaatti- ja vesimenetelmät noin kymmenesosan.

Vesimenetelmällä koemaista uuttuneet fosforimäärät olivat verraten kiinteässä vuorosuhteessa anioninvaihtohartsi- ja hapan ammoniumasetaattimenetelmillä uuttuneiden määrien kanssa. Siten ammoniumasetaattimenetelmä ilmeisesti uuttaa ainakin osittain samoja helposti liukenevia maan fosforivarastoja kuin mainitut muut menetelmät.

Eri menetelmien antamat fosforiluvut selittivät saaduista sadonlisäyksistä seuraavan osuuden: vesi 68 %, anioninvaihtohartsi 61 %, hapan ammoniumasetaatti 53 %, natriumbikarbonaatti 46 %, ammoniumsulfaatti + kaliumfosfaatti 43 %, ammoniumsulfaatti 40 %, ammoniumlaktaatti 39 %.

Hapan ammoniumasetaattimenetelmä, jonka antamia tuloksia maassamme käytetään viljavuustutkimuksessa lannoitussuositusten perusteena selitti siten suuremman osuuden saaduista sadonlisistä kuin muissa maissa laajasti käytetyt natriumbikarbonaatti- ja laktaattimenetelmät. Ottaen huomioon happaman ammoniumasetaattimenetelmän käyttöön liittyvän pitkäaikaisen kokemuksen sitä voidaan edelleen suositella käytettäväksi lannoitussuositusten perusteena maassamme. Mikäli kuitenkin fosforilannoitustarpeesta halutaan saada tarkempaa tietoa näyttäisi vesiuutto soveltuvan tähän tarkoitukseen parhaiten.

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Research note

SODIUM CONTENTS OF DIFFERENT PLANT SPECIES GROWN SIDE BY SIDE

HÅKAN JANSSON

JANSSON, H. 1986. **Sodium contents of different plant species grown side by side.** Ann. Agric. Fenn. 25: 273—277. (Agric. Res. Centre, Dept. Soil Sci., SF-31600 Jokioinen, Finland.)

The sodium contents in the dry matter of various parts of 17 crops were compared. The crops were grown side by side during two seasons at nine experimental sites in different parts of Finland.

The sodium contents of crops varied widely among the crops studied. The difference between the highest (sugar beet tops) and the lowest mean content (potato tuber) was over 600-fold. In addition internal variation within most plant species was wide.

Root crops, in general, were rich in sodium, but relatively high sodium levels were also measured in rye grass. Beside the potato tuber, relatively low sodium contents were typical of grain crops. The average Na content of timothy varied from 19 (dry hay) to 48 mg/kg DM (fresh growth) and that of clover was somewhat higher. The greatest differences in the sodium contents of different parts of the same plant species were found in sugar beet, turnip rape and pea.

Index words: sodium content, cereals, timothy, red clover, rape, rye grass, pea, onion, turnip, carrot, potato, beet, swede.

INTRODUCTION

Although the biological importance of sodium to the physiological processes of animals is well-known, there is no definitive knowledge about its quantitative requirements for different farm animals in such varying conditions as pregnancy and lactation. Often the recommendations presented are obviously too high (MICHELL 1985).

Sodium is essential for the growth of C4 and the CAM plants only (BROWNELL 1979) although it can replace potassium to a limited extent. For example, it has been estimated that in Finnish conditions about 40 per cent of the K need of the sugar beet can be met by sodium (HALLANORO and HEIMO 1983). As in case of several other nutrients the uptake of sodium by plants is strongly accelerated by increasing nitrogen fertilization (RINNE et al. 1974). Therefore, differences in fertilization level may be one of the reasons limiting the comparability of the sodium contents of plants grown in various conditions. In the present study this

source of error has been eliminated since all the plants included in this experiment were equally fertilized at all growing sites. The results presented here refer to typical Finnish soils and growing conditions. This paper belongs to series of reports on the chemical contents of Finnish crops.

MATERIAL AND METHODS

The general properties of the experimental soils at the nine research stations located different parts of Finland are given in Table 1. The experimental layout, crops, sampling methods and fertilization have been described in an earlier paper (YLÄRANTA and SILLANPÄÄ 1984). Soil sodium was determined from acid ammonium acetate extract, pH 4,65 (VUORINEN and MÄKITIE 1955) by atomic absorption spectrometry. Preparation and ashing of plant samples were carried out as described by SILLANPÄÄ (1982). Sodium was determined with an atomic absorption spectrophotometer.

Table 1. General soil properties and acid ammonium acetate extractable sodium contents of topsoils at the experimental sites.

Site	Soil type	Org. C %	pH ($CaCl_2$)	Electr. cond. 10^{-4}S cm	Na (extractable) mg/l
1. Häme Res. Station	Sandy loam	1,7	5,3	0,9	15,5
2. Sata-Häme Res. Sta.	Silty clay	3,8	5,1	2,0	16,8
3. S.W. Finland Res. Sta.	Sandy clay	1,7	4,0	1,6	7,0
4. S. Savo Res. Sta.	Finesand	4,4	4,8	1,5	20,0
5. Dept. of Soil Science	Heavy clay	4,7	4,5	1,8	19,1
6. Central Finland Res. Sta.	Finesand	1,5	4,8	0,9	26,3
7. Kainuu Res. Sta.	Carex peat	47	4,1	1,3	23,1
8. N. Savo Res. Sta.	Mould soil	16	4,6	4,2	33,3
9. S. Ostrobothnia Res. Sta.	Mould soil	19	4,9	2,3	3,3
Mean			4,7	1,8	18,3
± s			0,4	1,0	9,2

RESULTS AND DISCUSSION

The mean content of the acid ammonium acetate (AAAc) extractable soil sodium of this study 18,3 ± 9,2 mg/l, corresponds closely to the mean content (17,8 ± 12,3 mg/l) of a much larger soil material (n = 2050) reported by SIPPOLA and TARES (1978). Somewhat higher contents, 20—30 mg/l, were considered to be normal for Finnish conditions (KURKI 1982) but considerably higher contents, 75,4 ± 65,7 mg/l, exist in the acid sulphate soils of the western lowlands of Finland (ERVIÖ and PALKO 1984). In an international study the mean sodium contents of Finnish soils were the seventh lowest among thirty countries (SILLANPÄÄ 1982).

The extractable sodium contents of the experimental soils seem to be poorly reflected in the Na contents of various plants which may

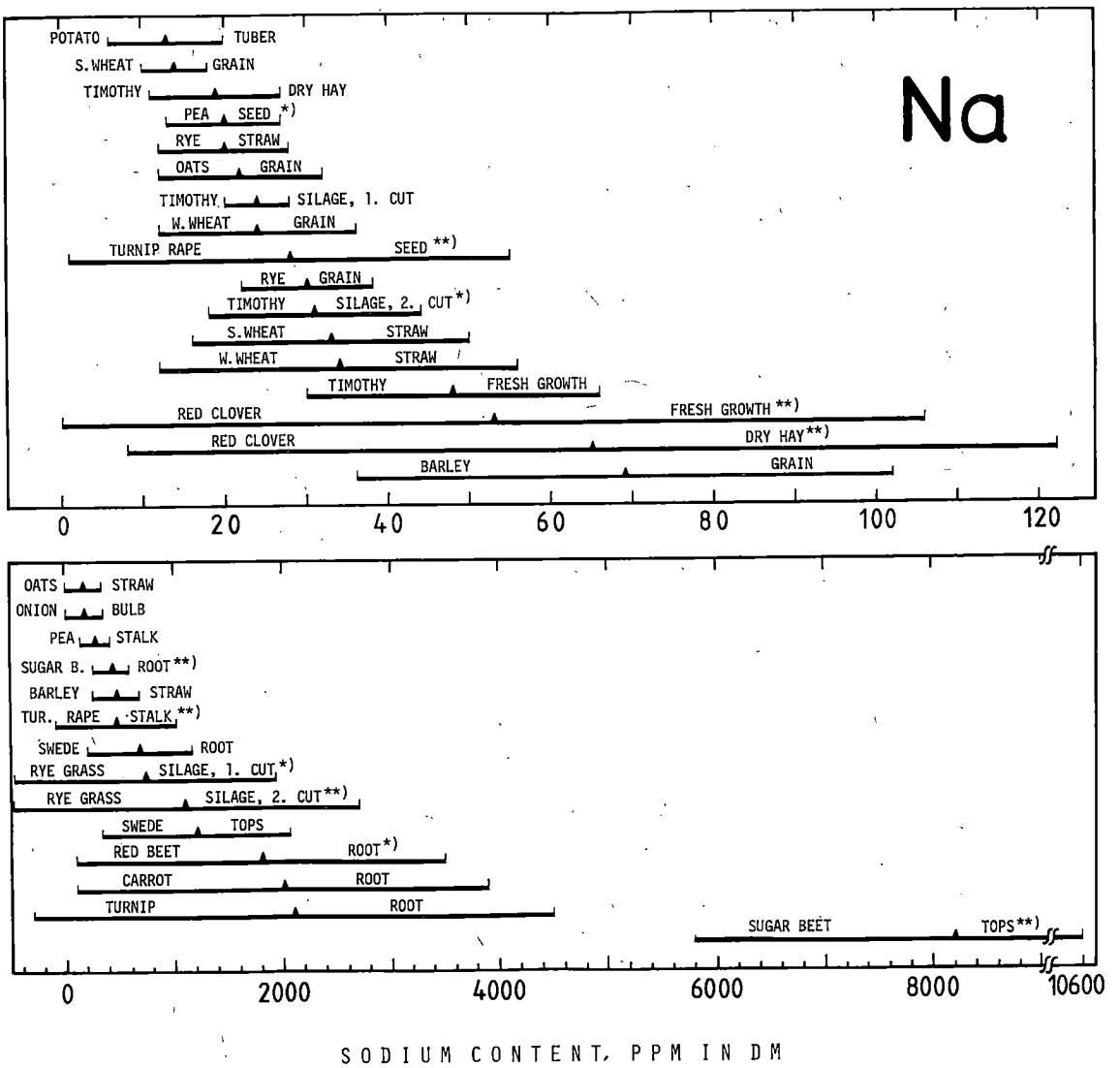

Fig. 1. Two-year averages ($\bar{x} \pm s$) of sodium contents of different parts of 17 crops grown side by side at nine sites. Crops grown succesfully at eight sites*) or at seven sites**) only are indicated.

partly be due to the poor reproducibility of the plant sodium analysis (KÄHÄRI and NISSINEN 1978). This naturally broadens the internal variations of the Na contents within different plant species which, compared to other nutrients in the same plants (YLÄRANTA and SILLANPÄÄ 1984, JANSSON et al. 1985) are exceptionally wide. Moreover the difference between the highest and the lowest mean nutrient contents of different plant species, which in the above studies varied from 4- (Cu) to 60-fold (Ca), was in the case of sodium over 600-fold (Fig. 1).

The highest sodium contents were measured from root crops; especially the tops of sugar beet were high in Na. Na in the tops of swede

also exceeded that of the root. According to McDOWELL et al. (1983) the Na requirement of grazing ruminants is 400—1800 mg/kg (dry basis). The higher level concerns lactating dairy cows. Among the crops studied here these requirements were met mainly by root crops but the Na content of rye grass was also relatively high.

Potato tuber had the lowest Na content of the present plant material, however relatively low, and varying contents were typical also for grain crops. Grains contained less Na than the respective straws with rye being an exception. The Na content of timothy seems to depend on the time of harvesting. It was lowest in dry hay (19 ± 8 mg/kg) somewhat higher in silage cuts and more than double in fresh growth (48 ± 18 mg/kg). An average Na content of timothy (47 ± 37 mg/kg) from the material of over 2 000 samples collected at the full spike stage was reported by KÄHÄRI and NISSINEN (1978). Red clover has a higher Na content than timothy on average but wide internal variation is typical of this crop.

The differences between the Na contents of the different parts of the same crop were greatest in the case of sugar beet. The tops contained 19 times as much Na as the root. Similar differences were found in turnip rape and pea. The Na contents of their stalks exceeded that of the seeds by factors of 17 and 14, respectively. In the other crops included in the study the differences between the plant parts were less marked except for rye, where the Na content of the above-ground vegetative part was higher than that of the respective seed or root.

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SELOSTUS

Viljelykasvien natriumpitoisuuksien vertailu

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Maatalouden tutkimuskeskus

Vertailukelpoisen tiedon saamiseksi eri viljelykasvien ja kasvinosien natriumpitoisuuksista kasvatettiin 17 viljelykasvia rinnakkain yhdeksällä, eri puolilla Suomea sijaitsevalla koepaikalla kahtena kasvukautena. Koemaiden, joihin kuului sekä hienoja ja karkeita kivennäismaita että eloperäisiä maita, yleiset ominaisuudet vastasivat muutamin poikkeuksin suomalaisten viljelymaiden keskimääräistä tasoa. Eri kasveista analysoitiin natriumpitoisuus sellaisista kasvinosista, joilla on merkitystä eläinten tai ihmisten ravinnossa.

Kasvilajien ja kasvinosien natriumpitoisuuksien välillä todettiin suuria eroja korkeimpien niistä (sokerijuurikkaan naatit) ylittäessä alhaisimmat (perunan mukula) yli 600-kertaisesti. Myös laaja sisäinen vaihtelu oli tyypillistä useimmille kasveille.

Juurikasvien natriumpitoisuudet olivat yleensä korkeammat kuin muiden kasvien, mutta melko korkeita pitoisuuksia mitattiin myös raiheinästä. Perunan ohella suhteellisen alhaisia pitoisuuksia löytyi viljakasveista, joiden jyvissä, ruista lukuunottamatta, natriumpitoisuudet olivat alhaisempia kuin oljissa. Timotein odelman keskimääräinen natriumpitoisuus (48 mg/kg) ylitti vastaavan kuivan heinän pitoisuuden (19 mg/kg) yli kaksinkertaisesti. Puna-apilassa natriumia oli keskimäärin jonkinverran enemmän. Suurimmat (14—19 -kertaiset) erot saman kasvin eri kasvinosien natriumpitoisuuksien välillä todettiin sokerijuurikkaassa, rypsissä ja herneessä.

ANNALES AGRICULTURAE FENNIAE, VOL. 25: 279—283 (1986)
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Research note

PESTS OF CULTIVATED PLANTS IN FINLAND IN 1985

MARTTI MARKKULA

MARKKULA, M. 1986. **Pests of cultivated plants in Finland in 1985.** Ann. Agric. Fenn. 25: 279—283. (Agric. Res. Centre, Dept. Pest. Inv., SF-31600 Jokioinen, Finland.)

The damage caused by about fifty animal pests to cereals, forage plants, root crops, vegetables, rape, sugar beet, pea, apple, berries and other cultivated plants in Finland during 1985 is reported from the results of questionnaire surveys.

The weather was variable and cool in the beginning of the growing season throughout the country. The whole season was slightly cooler than normal. The answers to the inquiries showed that the average abundance of all pests was 2,3, i.e. smaller than the average of 2,5 during the twenty-year period from 1965 to 1984.

The index of severity for the damage of *Rhopalosiphum padi*, 1,5, was greater than the average of 1,1, for the twenty-year period, but there was little need for control sprays. *Sitodiplosis mosellana* was found in many localities in southern Finland. The grain yield was reduced by one third in some places and its quality was poorer, too.

Meligethes aeneus continued to occur in large numbers. The severity of the damage was 2,4, i.e. the same as the year before and clearly greater than 1,6 the average during the twenty-year period.

The pests of sugar beet were less abundant than usual. *Lugus rugulipennis* did not continue to occur abundantly as in the previous year.

Vegetable root pests caused more damage than usual. Also the severity of damage by *Trioza apicalis* was also greater on average than during the twenty-year period but not as great as the previous year.

Apple trees and berries suffered no serious pest damages.

Index words: plant pests, severity of damage, *Rhopalosiphum padi, Sitodiplosis mosellana, Meligethes aeneus, Lygus rugulipennis, Trioza apicalis.*

The survey is based on replies to inquiries sent to the advisers at Agricultural Advisory Centres. The network of 200 advisers covers all 461 municipalities. Four inquiries were sent during the growing season, and the replies received were as follows:

	Replies	%	Municipalities	%
Spring inquiry	108	58	145	31
First summer inquiry	87	47	116	25
Second summer inquiry	92	49	123	27
Autumn inquiry	87	47	106	23

Each inquiry requested an estimate of the severity and frequency of damage caused by insects and other pest animals specified in the questionnaire. A ten-point scale was used to estimate the severity of damage and the frequency of damage was estimated as the percentage of cultivations in which damage had occurred in each observation area. In the autumn inquiry the advisers were also asked to give a general estimate of the pest abundance

throughout the growing season. For this purpose a five-point scale was employed with the following ratings: very sparse, sparse, normal, abundant, very abundant. The same inquiry requested an estimate of the percentage of apples damaged by *Argyresthia conjugella* and *Cydia pomonella* and of pea pods damaged by *Cydia nigrigana.*

The beginning of the growing season had variable and cool weather throughout the country. In southern and central Finland there was much rainfall in the beginning of May and only in the latter half of the month two short warm periods occurred.

The beginning of June was cool at times, with warmer weather after 20th of June. The mean temperature and rainfall for the month were normal.

In July there was little rainfall and temperatures were lower than usual in southern and central Finland, but higher than normal in northern Finland. August was characterized by warm and rainy weather.

New comparison period for pest occurrence 1965—1984

The current method of collecting data on the occurrence of pest was begun in 1965. At the beginning each year could only be compared with previous ones. After ten years of data had been accumulated, the means for the period from 1965 to 1974 were calculated as comparison values (MARKKULA 1976).

New comparison values of the severity and frequency of damage have now been calculated for the twenty-year period from 1965 to 1984. They are used in this and future reports.

A summary on the occurrence of pests during in 1965—1984 will be published separately and the processing of data has already begun.

Occurrence of pests in the growing season of 1985

The average abundance of pests, on a five-point scale, during the entire growing season was 2,3, i.e. smaller than the average of 2,5 during the twenty-year period from 1965 to 1984. This, and information on single species, indicates that pests were less abundant than usual.

According to a forecast made in the spring *Rhopalosiphum padi* was expected to occur in large numbers in fields of spring cereals. Accordingly, the severity of damage, 1,5, was clearly greater than the twenty-year average value of 1,1. In spite of this there was little need for control treatments.

The midge *Sitodiplosis mosellana* Geh., which unexpectedly caused damage in summer 1983, was found in many places. Altogether 62 wheat ear samples were collected from different locations in Finland. The midge larvae were common: 82 % of the samples contained larvae. The worst damage occurred, as before, in the eastern parts of Uusimaa province, where the midge decreased yields sometimes by nearly one third, causing the yield to be so poor in quality that it was inadequate for baking purposes.

Meligethes aeneus continued to occur in large numbers. The severity of damage was 2,4, i.e. the same as the previous year and clearly greater than the average of 1,6 during the twenty-year period from 1965 to 1984. The beetles reduced the seed yield of rape, but during the last few years they have also caused new damages to cauliflower.

In field experiments the use of a trap crop system has significantly reduced the damage to cauliflower. The cauliflower cultivations are surrounded by plants with yellow flowers, especially rape, and the beetles that aggregate to the flowers are then destroyed by pesticides.

This trap crop system has produced such good results that it will be developed further for the needs of rape cultivation as well.

Pests of sugar beet were less common than

usual. Especially noteworthy is that *Lygus rugulipennis* was no more so unusually abundant as in the previous year (MARKKULA 1985).

The vegetable root pests, *Delia radicum, D. floralis, D. antiqua* and *Psila rosae* were more abundant than usual. The abundance of the carrot-damaging *Trioza apicalis* exceeded the mean for the twenty-year period from 1965 to 1984 but did not reach the very high value of the previous year. *Phaedon cochleariae* was very scantly on crucifers. According to the replies *Cydia nigricana* damaged 11 % of the pea pods. The average for 1965—84 was 11 %, too.

The worst pests of apple, *Argyresthia conjugella* and *Cydia pomonella* were almost absent. The severity index for *A. conjugella* was only 0,8. In the previous year it was 2,5, and the mean for the last twenty years, 2,7, was even greater. The advisers' estimates of damage to apples indicates the following:

	percentage of apples damaged			replies
	1985	1984	1965—84	1985
Argyresthia conjugella	12	35	28	26
Cydia pomonella	13	32	19	28

In berry plants pest damage was small. Especially *Anthonomus rubi* was low in number. *Thomasiana ribis* (Marikovskij), which earlier has mainly occurred in eastern Finland, caused damage this year also in the southwestern province of Häme.

Table 1. Results of questionnaires. Severity of damage estimated on a scale of 0—10. Frequency of damage calculated as the percentage of crops in which damage was observed.

	Number of observations 1985	Severity of damage 1985	Severity of damage 1965—84	Frequency of damage 1985	Frequency of damage 1965—84
CEREALS					
Rhopalosiphum padi (L.)	62	1,5	1,1	31	22
Oscinella frit (L.)	64	0,6	0,8	8	11
Elateridae	28	0,4	0,8	5	10
Phyllotreta vittula (Redtb.)	66	0,6	0,7	11	14
FORAGE PLANTS					
Nanna spp.	44	1,1	1,3	21	25
Apion spp.	26	0,2	0,8	9	15
RAPE AND TURNIP RAPE					
Meligethes aeneus (F.)	35	2,4	1,6	62	47
Phyllotreta spp.	40	0,7		20	
SUGAR BEET					
Lygus rugulipennis Popp.	25	1,6	1,6	39	44
Chaetocnema concinna (March)	44	1,3	1,4	37	39
Pegomya betae (Curt.)	55	1,3	1,6	33	43
Aclypea opaca (L.)	17	1,2	1,2	23	30
PEA					
Cydia nigricana (F.)	25	1,0	1,7	23	34

ROOT CROPS AND VEGETABLES					
Trioza apicalis (Först.)	40	1,8	1,3	21	23
Phyllotreta spp. on crucifers	66	1,4	1,6	27	33
Delia radicum (L.), *D. floralis* (Fall.)	72	2,0	1,8	27	28
Plutella xylostella (L.)	40	1,6	1,7	7	24
Delia antiqua (Mg.)	35	1,8	1,5	13	18
Psila rosae (F.)	31	1,0	0,8	11	10
Phaedon cochlearie (F.)	21	0,5	0,9	6	17
APPLES					
Lepus europaeus Pallas, *L. timidus* L.	41	2,0	1,8	25	20
Argyresthia conjugella Zell.	26	0,8	2,7	12	39
Cydia pomonella (L.)	28	1,2	2,0	13	34
Panonychus ulmi (Koch.)	32	0,7	1,1	13	17
Aphis pomi (Deg.)	23	1,0	1,2	14	21
Yponomeuta padellus malinellus Zell.	17	1,5	1,2	15	19
Microtus agrestis (L.)	33	0,7	1,2	8	9
Psylla mali (Schmidbg.)	25	0,6	0,8	10	13
Arvicola terrestris (L.)	30	0,4	0,7	2	5
BERRIES					
Cecidophyopsis ribis (Westw.)	64	1,7	2,0	17	27
Lampronia capitella Cl.	51	1,5	1,7	14	21
Nematus ribesii (Scop.), *Pristiphora pallipes* Lep.	30	1,4	1,5	10	17
Tarsonemus pallidus Bks.	36	1,8	1,9	19	28
Byturus tomentosus (Deg.)	36	1,5	1,5	19	27
Anthonomus rubi (Hbst.)	30	0,9	1,4	21	25
Pachynematus pumilio Knw.	39	1,4	1,2	15	19
Aphididae on *Ribes* spp.	37	1,7	1,6	17	24
Zophodia convolutella (Hbn.)	28	1,1	0,8	11	11
PESTS ON SEVERAL PLANTS					
Deroceras agreste (L.) etc.	31	1,1	1,3	18	24
Hydraecia micacea (Esp.)	35	1,5	1,1	17	22

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SELOSTUS

Viljelykasvien tuhoeläimet 1985

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Maatalouden tutkimuskeskus

Maatalouskeskusten piiriagrologien ilmoittamien tietojen perusteella voidaan kasvukautta pitää tuholaisten esiintymisen kannalta melko helppona. Koko kasvukauden tuholaisten runsautta kuvaava luku oli 2,3, kun kaksikymmenvuotiskauden 1965—1984 vastaava keskiarvoluku oli 2,5.

Keväällä laaditun ennusteen mukaan oli odotettavissa, että tuomikirva aiheuttaisi tuhoja kevätviljapelloissa. Tuhojen ankaruusluku 1,5 ylittikin selvästi kaksikymmenvuotiskauden keskiarvon 1,1, mutta torjuntaruiskutusten tarve jäi kuitenkin vähäiseksi.

Tähkäsääskestä tehtiin runsaasti uusia havaintoja. Pahimmat tuhot havaittiin edelleen itäisellä Uudellamaalla, jossa sääski pienensi satoa paikoin kolmanneksella ja heikensi sadon laatua. Joidenkin tilojen sato ei kelvannut leipäviljaksi.

Rapsikuoriaisen runsaan esiintymisen kausi jatkui. Tuhojen ankaruusluku pysyi samansuuruisena kuin edellisvuotena, mutta oli samalla selvästi suurempi kuin 20-vuotiskautena.

Sokerijuurikkaan tuholaiset esiintyivät tavallista vähälukuisempina. Peltoluteen edellisvuotinen runsaan esiintymisen kausi ei jatkunut.

Kasvien juuria vioittavat kärpästoukat olivat vihanneskasveissa tavallista yleisempiä. Myös porkkanakempin runsaus ylitti kahdenkymmenen vuoden keskiarvon, mutta ei yltänyt kuitenkaan edellisvuoden määrään.

Omenan pahimmat tuholaiset, pihlajanmarjakoi ja omenakääriäinen pysyivät miltei näkymättömissä. Marjakasvit säästyivät pahoilta tuholaisvaurioilta.

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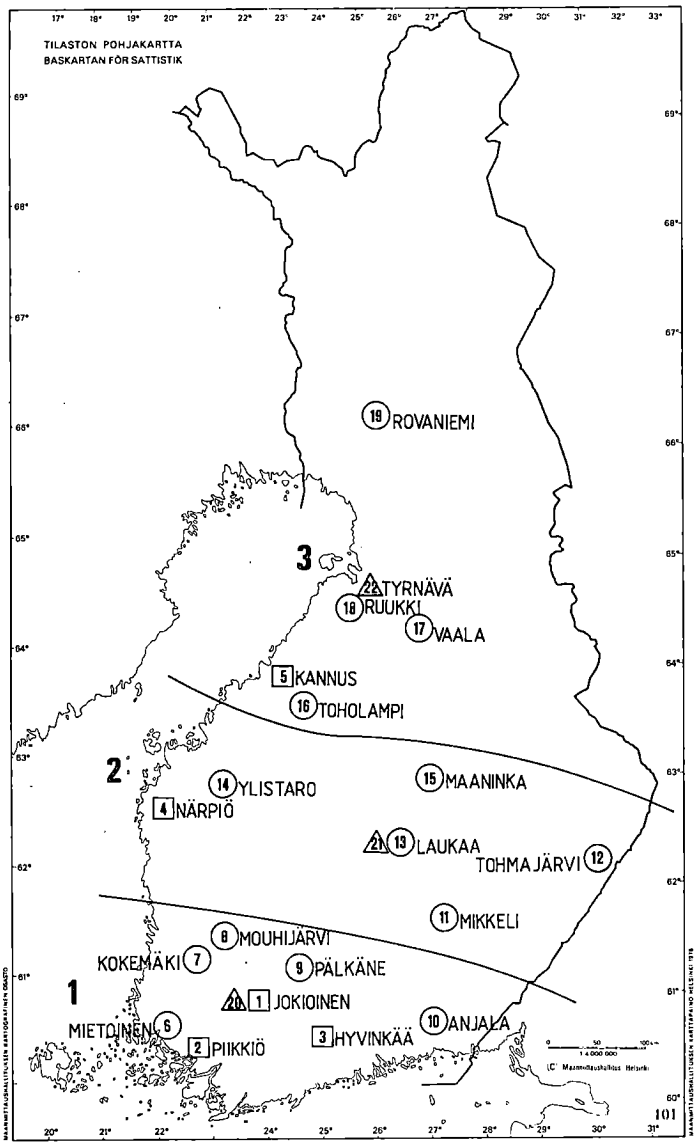

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