Soil properties affecting weed distribution in spring cereal and vegetable fields

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The incidence of weed species in 482 cereal and 224 vegetable field plots in southern and central Finland was investigated. The occurrence of the 16 most common weed species was related to soil properties. *Chenopodium album* L., *Lamium* spp. L. and *Fallopia convolvulus* (L.) Löve were more abundant in clay than in coarse mineral or organic soils. *Elymus repens* (L.) Gould, *Erysimum cheiranthoides* L., *Lapsana communis* L., *Myosotis arvensis* (L.) Hill and *Poa annua* L. thrived better in coarse than in clay soils. *Polygonum lapathifolium* L. and *Rumex* spp. L. were more abundant in organic than in mineral soils, and *Lamium* spp. was not found at all in organic soils.

Rumex spp., *Poa annua* and *Polygonum lapathifolium* had higher densities at the lowest pH level, < 5.2. *Lamium* spp. and *Myosotis* spp. thrived at the highest pH levels. *Poa annua* and *Spergula arvensis* were most common in soils where the extractable calcium concentration was below 1000 mg l^{-1} soil.

Key words: Finnish fields, soil type, soil pH, soil organic matter content, soil extractable calcium

Introduction

A study was carried out in 1982 – 1984 to determine the occurrence of weeds in Finnish spring cereals (ERVIÖ and SALONEN 1987) and vegetable fields. Of special interest was the importance of farming management and field factors on weed infestation. As part of this study, the present paper discusses the influence of soil types and soil properties on the occurrence of weed species in cereal and vegetable fields of southern and central Finland.

Diverse conclusions have been drawn about the effect of soil factors on the incidence of weed species. The role of soil pH in the abundance of some species has been reported by some workers (FERDINANDSEN 1918, de VRIES 1934, TRAUTMANN 1954). Low pH may be a restrictive factor in the success of many pretentious weed species, some of which are considered to be calciphiles.

The importance of available nutrients for weed abundance has also been investigated. It would seem however, that physical soil properties such as porosity, aeration, waterholding capacity and humus content have a more marked effect on the abundance of weeds than do chemical soil properties (ELLENBERG 1951, REHDER 1959).

Table 1. Distribution of soil types in different localities.

Localities	Number of plots in soil-type groups					
	Cereal fields			Vegetable fields		
	Coarse mineral soils	Clay soils	Organic soils	Coarse mineral soils	Clay soils	Organic soils
Archipelago	4	18	2	8	2	2
Southwestern Finland	100	200	23	20	7	74
Southern Finland	1	22	–	17	48	4
Eastern Finland	38	–	5	19	1	1
Western Finland	6	14	4	3	3	1
Central Finland	20	3	2	6	–	3
Ostrobothnia	12	1	7	4	1	–
Total	181	258	43	77	62	85

Material and methods

A weed survey was conducted in spring cereal and vegetable fields in ten localities in southern and central Finland in 1982–1984. A detailed description of the localities and data on spring cereals were given in previous publications (Erviö and Salonen 1987, Salonen and Erviö 1988, Salonen 1993). In those papers the occurrence of weeds was analysed from 3–5 plots in every field but here weed numbers have been used only for the plots from which the soil samples were taken. The material has been divided into seven locality groups (Table 1). Weed data on vegetable fields were gathered in the same localities as the spring cereal data. The spring cereals were wheat, oats and barley and the most common vegetable crops were carrot, onion, cabbage and swede.

The number of weeds was counted from a total of 482 cereal plots in 265 fields and from 224 vegetable plots in 112 fields on 379 farms (Table 1). The weed assessment was made on 0.25 m^2 circular sample plots during the second half of July. The interdependences between weed densities and soil properties were studied. Only the 16 most common weed species were analysed.

Soil samples were taken from the plough layer (0–20 cm) by mixing five separate auger pricks together. They were dried and ground to pass through a 2-mm sieve. Soil pH(H_2O), organic matter content and extractable calcium, potassium, magnesium and phosphorus concentrations were measured on all soil samples. In addition, the particle-size analysis was made on 101 samples to confirm that the soil type was correct.

Soil pH(H_2O) was determined on a soil:water V/V suspension of 1:2.5. The organic carbon content of the soil was determined by the automated dry ashing method. The samples were combusted in an oxygen atmosphere and the CO_2 gas formed was measured with a solid-state infrared detector. A conversion factor of 1.73 was used to convert organic carbon to organic matter (O.M.).

Calcium and other macronutrients were extracted from the soil using a 0.5 N ammonium acetate 0.5 N acetic acid (AAAc) solution (pH 4.65), the extraction ratio being 1:10 V/V (Vuorinen and Mäkitie 1955). Concentrations of Ca, K, Mg and P were measured on the soil extracts employing an inductive coupled plasma emission spectrometer (ICP). The concentrations are given as milligrams per litre of soil.

The occurrence of weeds was compared in the soil-type groups. The material was divided into three soil groups: coarse mineral, clay and organic soils. The first group comprised sand, finesand, silt and glacial till soils, and the last one peat, mould and gyttja soils. A soil sample was classified as peat if the O.M. content was at least 40%, as mould if the O.M. content was 20 – 40% and as gyttja if O.M. was at least 6% in lake sediment soil. The soil types were distributed unequally between localities. Thus, in some localities of southern Finland there were no organic soil plots and in eastern Finland no clay soil plots (Table 1).

Differences in the occurrence of weeds in the various soil type groups were analysed with Tukey's HSD multiple range test ($P = 0.05$). The statistically significant differences in the tables are based on the analysis with log-transformed data. The results given in the tables are back-transformed from the logarithmic mean values. Data transformation was used to achieve normal distribution and homogeneity of variances.

Results and discussion

Soil type

The analysis of weed densities (plants m^{-2}) indicated differences in the occurrence of weed species in the various soil types better than did the analysis of weed biomass. It apparently takes only a single big weed plant to raise the biomass ranges to an unreasonably high level. In a previous paper (SALONEN 1993) examining the total weed density, not the density by species, differences were found between soil types in the total weed biomass but not in the total weed density.

Here, divergent densities of weed species were found in different soil-type groups (Table 2). However, the densities of some weeds differed in the soils of cereal and vegetable fields, indicating the strong influence of crop type on weed incidence (cf. ANDREASEN et al. 1991). The abundance of weeds varied from one species to another. *Chenopodium album* had the highest density of all species, averaging 74 plants m^{-2} in the clay soils of vegetable fields. The densities of seven weed species averaged only 1 plant m^{-2} or less.

Chenopodium album and *Lamium* spp. in both cereal and vegetable fields and *Fallopia convolvulus* in cereal fields were more dense in clay soils than in coarse mineral or organic soils. Similar results have been reported for *Lamium* (REHDER 1959, ANDREASEN et al. 1991), and *Fallopia convolvulus* (GRANSTRÖM 1962). In contrast, KORSMO (1925) reported that *Chenopodium album* and *Lamium purpureum* occured in equal densities in all kinds of soil, and REHDER (1959) considered *Fallopia convolvulus* an indifferent species.

Weed species that thrived better in coarse mineral than clay soils were *Elymus repens, Lapsana communis, Myosotis arvensis* and *Poa annua* and, in addition, *Erysimum cheiranthoides* and *Spergula arvensis* in cereal fields. ANDREASEN and STREIBIG (1990) and ANDREASEN et al. (1991) likewise found a negative correlation between clay content and the density of *Elymus repens, Myosotis arvensis* and *Spergula arvensis*. KORSMO (1925) and, later, REHDER (1959) and GRANSTRÖM (1962) showed that *Spergula arvensis* was particularly prevalent in light soil types. *Elymus repens, Myosotis arvensis* and *Spergula arvensis* were characterized for mineral soil species by RAATIKAINEN and RAATIKAINEN (1983); this was not found in the present data.

Chenopodium album and *Galium* spp. were more abundant in mineral than in organic soils, especially in vegetable fields. *Lapsana communis* and *Viola arvensis* occurred more abundantly in coarse mineral than in organic soils, and *Lamium* spp. was not found at all in organic soils. In the whole material, *Polygonum lapathifolium* was more common in organic than in mineral soils as was *Rumex* spp. in cereal fields. GRANSTRÖM (1962) and RAATIKAINEN and RAATIKAINEN (1983) also reported a greater abundance of *P. lapathifolium* in organic than in mineral soils, and STREIBIG et al. (1984) found a positive correlation between soil organic matter and *Rumex acetosella*. MUKULA et al. (1969) found 30 plants m^{-2} of *P. lapathifolium* in organic soils but only 6 and 12 plants m^{-2} in clay and coarse mineral soils, respectively. In this study the density of *Spergula arvensis* was higher in organic soils than in clay soils.

Table 2. Weed density in different soil types. Arithmetic means and geometric means, with superscripts denoting statistically significant ($P < 0.05$) differences.

	Plants m^{-2}					
	Cereal fields			Vegetable fields		
	Coarse mineral soils	Clay soils	Organic soils	Coarse mineral soils	Clay soils	Org. soils
Chenopodium album L.[1]	18	26	8	56	74	14
	2.3^{b}[2]	6.2^{a}	2.1^{b}	8.4^{a}	4.8^{a}	1.6^{b}
Elymus repens (L.) Gould	18	2	8	23	7	6
	1.6^{a}	0.5^{b}	1.2^{a}	2.5^{a}	0.8^{b}	0.7^{b}
Erysium cheiranthoides L.	16	4	9	9	3	2
	1.1^{a}	0.7^{b}	0.9^{ab}	1.7^{a}	1.0^{ab}	0.9^{b}
Fallopia convolvulus (L.) Löve	3	7	2	4	1	3
	0.9^{b}	1.7^{a}	0.8^{b}	0.6^{b}	0.5^{b}	1.5^{a}
Galeopsis spp. L.	8	17	25	5	4	12
	2.0^{b}	3.6^{a}	3.4^{a}	1.0^{b}	0.9^{b}	2.0^{a}
Galium spp. L.	3	8	0	6	3	<1
	0.5^{b}	0.8^{a}	0.6^{ab}	0.8^{a}	0.7^{a}	0.4^{b}
Lamium spp. L.	3	8	0	2	6	0
	0.6^{b}	0.8^{a}	0.4^{b}	0.5^{b}	0.9^{a}	0.4^{a}
Lapsana communis L.	16	4	9	14	<1	<1
	1.7^{a}	0.9^{b}	0.5^{b}	1.2^{a}	0.4^{b}	0.5^{b}
Myosotis arvensis (L.) Hill	8	2	1	2	<1	<1
	1.2^{a}	0.6^{b}	0.6^{b}	0.6^{a}	0.5^{ab}	0.4^{b}
Poa annua L.	5	1	1	29	1	9
	0.6^{a}	0.4^{b}	0.5^{ab}	1.7^{a}	0.4^{b}	1.1^{a}
Polygonum lapathifolium L.	1	1	9	2	1	7
	0.5^{b}	0.5^{b}	0.9^{a}	0.5^{b}	0.5^{b}	1.4^{a}
Rumex spp. L.	1	<1	7	<1	0	1
	0.5^{b}	0.4^{b}	0.7^{a}	0.5^{a}	0.4^{a}	0.5^{a}
Sonchus spp. L.	2	1	0	8	2	1
	0.6^{a}	0.6^{ab}	0.4^{b}	1.0^{a}	0.6^{ab}	0.5^{b}
Spergula arvensis L.	15	2	5	2	1	6
	1.1^{a}	0.6^{b}	1.1^{a}	0.8^{ab}	0.6^{b}	1.2^{a}
Stellaria media (L.) Vill.	30	27	9	17	14	30
	4.0^{ab}	5.8^{a}	2.0^{b}	2.2^{b}	3.7^{b}	8.6^{a}
Viola arvensis L.	17	12	9	21	18	6
	2.6^{a}	2.2^{ab}	1.2^{b}	3.2^{a}	1.9^{ab}	1.0^{b}

[1] Including *Atriplex patula* L.

[2] Densities marked with different superscripts differ from each other significantly ($P < 0.05$) between the soil classes in cereal or vegetable fields.

Soil pH

The soils were divided into six classes by pH level. The incidence of some weed species was affected by soil pH (Tables 3 and 5). The negative significances of the dependence (F value) of weed density on soil pH were highest for *Polygonum lapathifolium*, *Rumex* spp. and *Spergula arvensis* (Table 5). The abundance of *Rumex* species was most clearly affected by the soil pH.

Table 3. Week density in different soil pH classes in cereal and vegetable fields. Arithmetic means and geometric means, with superscripts denoting statistically significant ($P < 0.05$) differences between classes.

	Plants m^{-2}					
	Soil $pH(H_2O)$					
Weed	< 5.2 n = 79	5.2–5.4 n = 100	5.5–5.7 n = 137	5.8–6.0 n = 161	6.1–6.4 n = 115	> 6.4 n = 114
Chenopodium album	22.7 12.6^{a}[1]	58.5 4.6^{b}	25.1 4.2^{b}	18.8 4.0^{b}	26.3 5.1^{b}	30.4 4.6^{b}
Lamium spp.	0.5 0.4^{b}	0.7 0.5^{b}	2.3 0.6^{ab}	4.2 0.7^{ab}	6.7 0.7^{ab}	10.1 0.9^{ab}
Lapsana communis	4.8 0.5^{c}	4.8 0.6^{bc}	5.3 1.0^{ab}	10.5 1.1^{ab}	9.4 1.2^{a}	8.7 1.0^{ab}
Myosotis arvensis	0.4 0.4^{b}	1.1 0.5^{b}	5.0 0.7^{ab}	4.1 0.8^{a}	4.3 1.0^{a}	1.8 0.7^{ac}
Poa annua	20.5 1.2^{a}	6.8 0.8^{ab}	6.2 0.6^{b}	0.4 0.4^{c}	3.7 0.5^{b}	5.4 0.6^{b}
Polygonum lapathifolium	9.0 1.2^{a}	2.8 0.7^{b}	1.4 0.6^{b}	0.8 0.5^{b}	0.8 0.5^{b}	1.5 0.5^{b}
Rumex spp.	5.4 0.7^{a}	0.4 0.4^{b}	0.2 0.4^{b}	0.2 0.4^{b}	0.1 0.4^{b}	0.1 0.4^{b}
Spergula arvensis	6.2 1.2^{a}	3.2 0.9^{ab}	16.6 1.0^{a}	2.6 0.7^{ab}	2.4 0.6^{b}	3.2 0.6^{b}

[1] Densities marked with different superscripts differ from each other significantly ($P < 0.05$) between pH classes.

Their density was highest at pH values below 5.2, being nearly ten times as high as at pH values at least 5.2. *Rumex acetosella* has also been mentioned as an indicator of soil acidity (Nielsen 1926, Ellenberg 1950, Rehder 1959 and Streibig et al. 1984). This opinion is not held by all authors, however (Kivinen 1931 and Åslander 1941). Another species abundant in acid soil was *Polygonum lapathifolium*, as also mentioned by Ferdinandsen (1918) and Rehder (1959); Ellenberg (1950) in contrast considered it a pH-indifferent species. The density of *Poa annua* was noticeably more abundant at pH < 5.2 than at > 5.5. *Spergula arvensis* weeds were numerous at pH 5.5 – 5.7 but significantly less so at pH > 6.1.

Species thriving at high pH levels were *Lamium* spp., *Lapsana communis* and *Myosotis* spp. *Lamium* species grew most abundantly at pH > 6.4. Nielsen (1926), Ellenberg (1950), Rehder (1959) and Andreasen et al. (1991) also reported *Lamium* spp. thriving at high soil pH levels. The density of *Myosotis* spp. was higher at pH > 5.8 class than at pH < 5.5. However, there was no clear indication of its demand for high pH. Ellenberg (1950) mentioned *Myosotis arvensis* as an indifferent species.

Extractable nutrients

There was no distinct, consistent relationship between extractable potassium and phosphorus and weed density. Soil-extractable calcium seemed to affect the densities of some weed species (Table 4). *Elymus repens, Poa annua, Rumex* spp. and *Spergula arvensis* grew at their highest density

Table 4. Weed density in different extractable calcium classes in cereal and vegetable fields. Arithmetic means, and geometric means, with superscripts denoting statistically significant (P < 0.05) differences.

Weed	Plants m^{-2}				
	Extractable Ca concentration mg l^{-1} soil				
	< 1000 n = 73	1000–1499 n = 162	1500–1999 n = 181	2000–2499 n = 112	≥ 2500 n = 178
Elymus repens	18.4 1.5^{a1}	10.5 1.1^{ab}	8.7 0.9^{ab}	9.8 0.9^{ab}	6.1 0.8^{b}
Myosotis arvensis	1.2 0.8^{ab}	1.2 1.0^{a}	0.6 0.7^{ab}	0.5 0.7^{ab}	0.2 0.5^{b}
Lapsana communis	13.8 1.2^{a}	13.6 1.4^{a}	5.9 0.8^{bc}	3.3 0.8^{bc}	3.9 0.6^{c}
Poa annua	28.9 1.3^{a}	1.1 0.5^{b}	5.3 0.6^{b}	5.5 0.6^{b}	2.0 0.5^{b}
Spergula arvensis	28.7 1.4^{a}	4.3 1.0^{ac}	4.9 0.8^{bc}	1.1 0.6^{b}	1.9 0.7^{bc}
Stellaria media	15.8 2.0^{b}	27.1 3.9^{ab}	23.0 3.2^{a}	31.6 2.8^{a}	24.5 3.1^{a}

[1] Densities marked with different superscripts differ from each other significantly (P < 0.05) between Ca classes.

in the lowest Ca class (< 1000 mg l^{-1} soil). The abundance of *Poa annua* differed most clearly. Negative significances of the dependence (F value) of weed density on the concentration of extractable calcium of soil were found only in *Elymus repens, Lapsana communis* and *Myosotis arvensis* (Table 5). According to de Vries (1934), however, *Spergula arvensis* did not indicate a low calcium concentration of soil as it grew well in soil rich in calcium, too. *Stellaria media* was the only species to occur in a significantly higher density in the highest Ca classes (over 1500 mg) than in the class below 1000 mg Ca.

In conclusion, the occurrence of several weed species differed between soil types. Crop type influenced the incidence of all weeds, and soil pH and the extractable calcium concentration the incidence of some. The density of *Poa annua, Polygonum lapathifolium* and *Rumex* spp. was highest in the lowest pH class but that of *Lamium* spp. in the highest one. The occurrence of some species, e.g. *Poa annua* and *Spergula arvensis*, can apparently be reduced with liming as they had a very high density in the lowest extractable calcium class.

Table 5. Statistical significance of dependence (F value, ANOVA), of soil pH and concentration of extractable calcium of soil on weed density. + = ascending, – = descending.

Weed	F values	
	Soil pH	Extractable calcium
Chenopodium album	15.3***+	10.2**+
Elymus repens	–	8.1**–
Lamium spp.	18.7***+	–
Lapsana communis	15.1***+	21.0***–
Myosotis arvensis	14.5***+	19.2***–
Poa annua	17.9***–	–
Polygonum lapathifolium	28.2***–	–
Rumex spp.	21.4***–	–
Stellaria media	5.4**+	6.6**+

** = P < 0.01 *** = P < 0.001

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SELOSTUS

Maaperäominaisuuksien vaikutus rikkakasvilajien esiintymiseen

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Maatalouden tutkimuskeskus

Rikkakasvilajien esiintymisselvityksessä vuosina 1982–1984 otettiin tutkituilta näytealoilta myös maanäytteet, joiden maalajin ja kemiallisten ominaisuuksien merkitystä rikkakasvilajistoon ja yksilöiden määrään selvitettiin. Yhteensä 379 tilalta kerättiin 482 näytettä kevätvilja- ja 224 näytettä vihanneskasvilohkoilta.

Jauhosavikka ja peipit esiintyivät savimailla runsaampina kuin karkeilla kivennäismailla tai eloperäisillä mailla. Sen sijaan karkeita kivennäismaita suosivia lajeja olivat juolavehnä, ukonnauris, linnunkaali ja nurmikka. Ukontatar ja suolaheinä esiintyivät eloperäisillä mailla runsaampina kuin kivennäismailla, mutta peippejä ei löytynyt eloperäisiltä mailta lainkaan.

Suolaheinien ja ukontattaren lukumäärät olivat suurimmat alimmassa pH-luokassa (pH < 5,2). Peipit ja orvokit menestyivät parhaiten korkealla pH-tasolla. Kylänurmikka oli selvästi runsaampi alle 1000 mg helppoliukoista kalsiumia sisältäneessä kuin vähintään 1000 mg kalsiumia sisältäneissä luokissa, kun sen sijaan pihatähtimön esiintyminen oli juuri vastakkainen. Maan helppoliukoisen kaliumin, magnesiumin tai fosforin määrä ei vaikuttanut rikkakasvilajien esiintymiseen.