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Weed flora in organically grown spring cereals in Finland

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The weed flora in organically grown spring cereals was investigated in southern and central Finland in 1997–1999 with the primary purpose of determining the species composition and the level of weed infestation. Altogether 165 fields were surveyed in the middle of the growing season. A total of 126 weed species were found, of which 42 exceeded the frequency level of 10%. The most frequent weed species were *Chenopodium album*, *Stellaria media*, *Galeopsis* spp. and *Viola arvensis*. *Elymus repens* was the most frequent grass species. The average density of weeds was 469 plants m^{-2} (median 395), and the air-dry biomass was 678 kg ha^{-1} (median 567) which accounted for 17% of the total biomass of the crop stand. Infestation by *Chenopodium album* and the perennial species *Elymus repens*, *Cirsium arvense* and *Sonchus arvensis* is of major concern. Weed control strategies should include direct control measures to overcome weed problems related to the conversion period from conventional to organic growing.

Key words: weeds, cereals, biodiversity, organic farming

Introduction

The governments of many European countries have launched action plans and environmental programmes to encourage organic farming and sustainable agriculture as a whole. In Finland, organic farming has been an economically feasible alternative for continuing crop production as it has been eligible for substantial subsidies since 1995, the year that Finland became a member of the European Union (Ministry of Agriculture and Forestry 1999). This trend has been promoted by the ongoing debate about the adverse environmental impact of conventional agriculture. The area of arable land under organic management has expanded rapidly, and in 2000 it covered about 148 000 ha, or 6.7% of the cultivated field area (Luomustrategiatyöryhmä 2001). Roughly 5000 farms in Finland are currently engaged in organic production.

Studies on weed flora in organic farming have recently been published in the Nordic countries (Hald 1999, Rydberg and Milberg 2000) and elsewhere in Europe (e.g. Moreby et al. 1994, Albrecht and Mattheis 1998, Becker and Hurle

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1998). A common observation is that organic farming preserves biodiversity since the number of weed species, weed density and the biomass production of weeds are higher than in conventionally cropped fields, which are typically treated with herbicides. Moreover, organic farming could obviously promote populations of rare arable weed species, as it has been demonstrated (Mahn 1984, Wilson et al. 1990) that the use of herbicides and high rates of nitrogen in conventional farming play a key role in the decline of weed flora.

In Finland, Mukula et al. (1969) studied the weed flora of spring cereals in the early 1960s, when the use of herbicides was still minimal. An inventory of weeds in organically cultivated fields was carried out on some 50 farms visited annually in 1984–1986 (Mela 1988). At that time, organic farming accounted for only 0.05% of Finland's total arable field area (Luonnonmukaisen viljelyn toimikunta 1984).

A weed survey of spring cereal fields conducted in 1997–1999 (Salonen et al. 2001) studied the botanical composition of spring cereal fields in both conventional and organic farming. The present follow-up report focuses on weed infestation and particularly on species diversity in organic spring cereal production at a time when organic farming was rapidly expanding in terms of both farm numbers and field area. The objective was to demonstrate the need and target species for weed control. It also provides reference information on species diversity for similar surveys to be conducted in the future. A more detailed analysis of the factors explaining weed occurrence and changes in weed floras will be given separately.

Material and methods

Study regions, farms and fields

The weed survey was carried out in 15 regions in southern and central Finland in 1997–1999. The survey regions were divided into three zones (Table 1), roughly applying the phytogeographical division proposed by Mukula et al. (1969). In practice, the zones can be characterized by a prevalence of spring cereal production in the south and an increasing proportion of grassland in crop rotation towards the north-east. The predominant soil types also differ between the zones, clay soils being typical of southern Finland, sandy soils of eastern Finland and organic soils of more northerly parts of the country.

Seventy-nine farms were visited during a 4-week period starting in mid-July (weeks no. 28/29), by which time the spring cereals had reached the heading stage. The study farms practised either crop husbandry without grassland in crop rotation or animal husbandry with pasture in crop rotation. The information on cropping measures was obtained by interviewing the farmers.

The number of study fields in the two farm types was fairly evenly represented in all three zones, contrary to conventional production in which animal husbandry was mainly concentrated in central Finland (Salonen et al. 2001).

The number of spring cereal fields examined was 165, of which 52% were under oats, 23% barley, 16% wheat and 9% mixed cereals. Grassland was relatively common in crop rotation, 41% of study fields being undersown for grassland. The average area of study fields was 3.8 ha (range 0.3 ha–14.6 ha).

Weed samples

The occurrence of weeds was assessed from 10 sample quadrats randomly located in each field. Two sample quadrats were placed at a distance of 1–3 m from the sown field edge and the other eight in the central area of the field at more than 5 m from the edge. Weed density was determined by counting the number of plants or shoots of grass weeds by species in a rectangular frame measuring 0.1 m^2 (25 cm × 40 cm). In four out of ten sample quadrats, weeds and cereals were cut at the soil surface and their biomass was

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Table 1. Number of fields surveyed, by region and production type.

Region			Number of fields		
				Production type	
Year Municipality	No.	Zone [5]	Total no.	Animal husbandry	Crop husbandry
1997					
Jokioinen [1]	1	S	15	13	2
Lammi [2]	2	S	19	11	8
1998					
Tammela	3	S	9	5	4
Laukaa/Toivakka	4	CE	12	5	7
Kitee	5	CE	9	7	2
Mikkeli [3]	6	CE	16	13	3
Paimio/Tarvasjoki [4]	7	S	16	7	9
1999					
Laihia	8	CW	5	0	5
Nivala	9	CW	10	6	4
Laitila	10	S	13	10	3
Nurmijärvi	11	S	8	5	3
Vieremä	12	CW	9	4	5
Kihniö/Parkano	13	CW	9	4	5
Iitti	14	S	8	0	8
Imatra/Ruokolahti	15	CE	7	1	6
Total			165	91	74

[1] incl. Humppila, Jokioinen, Koski Tl, Loimaa municipality, Somero, Ypäjä
[2] incl. Hämeenkoski, Kärkölä, Lammi, Mäntsälä, Pukkila
[3] incl. Joroinen, Juva, Mikkeli, Mikkeli rural municipality
[4] incl. Lieto
[5] Key of zone abbreviation: S = South, CE = Central-East, CW = Central-West

weighed by species after the samples had been dried in an air-flow dryer at 40°C.

The plant species nomenclature follows that of Hämet-Ahti et al. (1998), and the BAYER codes of weeds were derived from the BAYER AG company (Bayer 1992). Some genera/taxa, e.g. *Galeopsis* spp. (incl. *Galeopsis bifida*, *Galeopsis speciosa*, *Galeopsis tetrahit*), *Lamium* spp. (incl. *Lamium album*, *Lamium amplexicaule*, *Lamium hybridum*, *Lamium purpureum*) and *Trifolium* spp. (incl. *Trifolium hybridum*, *Trifolium pratense*, *Trifolium repens*), had to be pooled since they could not be identified by species at the small seedling stage. As regards grass species, only *Elymus repens* and *Poa annua* were recorded by species if the species had not reached the heading stage. The full scientific names of the 42 most frequent weed species are given in Table 2.

The term frequency refers to the proportion of fields where the species was found. For each field, the total weed density and biomass were summed over the ten sample quadrats, and this figure was used when averages, standard deviations and median values were calculated for the regions, zones and other classifications. The proportion of the ten most abundant species relative to total density and the total biomass were calculated by pooling all the data across all fields by species and then calculating the proportion of each species.

Species diversity was measured by species

Table 2. Frequencies (%) of weed species by region.

Species / Taxon	Year / Region [1]															
	1997		1998					1999								Average
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	1997–99
Achillea millefolium L.	13	11	22	25	33	19	0	0	10	0	13	22	33	25	14	15
Brassica rapa L. ssp. *oleifera* (DC.) METZG.	13	21	0	17	0	13	0	20	0	62	25	0	22	25	14	16
Capsella bursa-pastoris (L.) MEDIK.	27	53	22	25	67	75	13	40	10	31	13	33	56	50	14	36
Cerastium fontanum BAUMG.	0	0	22	42	56	38	13	0	30	0	0	78	44	0	14	21
Chenopodium album L.	100	95	100	100	89	100	94	100	100	100	100	89	89	100	86	96
Cirsium arvense (L.) SCOP.	47	32	56	25	11	19	63	80	10	0	50	11	11	63	71	34
Elymus repens (L.) GOULD	80	89	89	92	89	88	44	60	80	77	75	78	100	75	100	81
Equisetum arvense L.	33	26	22	42	11	31	50	20	20	15	13	56	22	13	0	27
Erysimum cheiranthoides L.	67	74	89	75	89	88	69	100	100	62	88	100	89	100	100	82
Fallopia convolvulus (L.) À. LÖVE	73	63	89	33	44	56	88	80	70	85	88	11	11	63	86	63
Fumaria officinalis L.	47	53	44	42	33	25	44	40	10	31	88	22	0	75	71	41
Galeopsis L. spp.	80	100	89	100	67	94	94	100	100	85	100	100	100	100	100	93
Galium spurium L. [a]	40	26	67	25	22	19	56	60	0	69	38	33	0	75	43	37
Gnaphalium uliginosum L.	13	37	33	92	67	50	44	0	100	31	13	89	78	13	71	48
Juncus bufonius L.	0	5	11	58	33	25	0	0	40	0	0	0	33	0	14	15
Lamium L. spp.	33	32	33	8	11	19	56	40	0	31	25	0	0	25	43	25
Lapsana communis L.	33	74	78	83	44	88	69	0	0	85	38	0	11	88	100	57
Lathyrus pratensis L.	33	5	11	0	0	6	38	20	10	0	13	11	0	13	14	12
Matricaria matricarioides (LESS.) PORT.	33	42	78	67	78	69	19	0	50	46	0	100	33	63	86	50
Myosotis arvensis (L.) HILL	33	63	56	58	44	94	81	60	30	38	13	89	67	63	100	60
Persicaria hydropiper (L.) SPACH	0	0	56	25	33	31	0	0	0	15	0	0	0	50	43	15
Persicaria lapathifolia (L.) GRAY	47	74	33	58	44	56	25	40	70	31	13	78	89	38	100	53
Persicaria maculosa GRAY	0	0	33	0	0	0	50	0	0	38	63	0	0	38	43	16
Plantago major L.	20	16	33	33	78	69	6	0	40	23	0	89	44	38	57	35
Poa annua L.	0	0	11	8	44	25	0	0	0	15	13	22	11	0	14	10
Polygonum aviculare L.	67	84	56	33	56	75	63	60	80	85	88	89	56	75	71	70
Ranunculus acris L.	27	26	11	42	0	19	0	0	20	8	0	33	78	0	0	19
Ranunculus repens L.	0	37	22	33	78	31	6	0	70	8	13	78	33	13	43	30
Rumex acetosa L.	0	5	0	58	0	0	6	0	10	8	0	11	78	0	0	12
Rumex acetosella L.	7	11	33	0	33	19	13	0	20	0	0	33	0	0	14	12
Sagina procumbens L.	0	0	11	42	33	19	0	0	0	0	0	22	67	0	0	12
Sonchus arvensis L.	53	89	44	67	11	63	63	0	50	54	50	33	22	63	71	54
Spergula arvensis L.	67	89	89	100	78	94	63	60	100	77	75	100	78	75	100	83
Stellaria media (L.) VILL.	100	95	100	83	100	94	100	100	100	100	88	89	89	100	86	95
Taraxacum officinale WEBER in WIGGERS	40	16	56	0	56	19	38	0	10	0	38	67	56	13	71	30
Thlaspi arvense L.	20	58	0	8	11	6	6	40	10	23	13	0	11	75	29	21
Trifolium L. spp.	40	58	33	25	67	50	63	20	20	38	38	44	44	63	29	42
Tripleurospermum inodorum (L.) SCH. BIP.	73	63	89	33	22	50	100	80	90	8	50	78	11	63	43	58
Tussilago farfara L.	7	16	11	33	22	31	31	0	20	15	0	56	0	0	29	19
Veronica serpyllifolia L.	0	0	0	17	11	0	6	0	20	0	0	67	56	0	29	12
Vicia cracca L.	40	47	22	0	11	19	19	20	20	23	50	33	22	25	0	25
Viola arvensis MURRAY [b]	87	100	100	83	89	100	100	100	60	92	100	100	89	100	100	93

[a] = incl. *G. aparine*, [b] = incl. *V. tricolor*

[1] Key to region numbers: 1 = Jokioinen, 2 = Lammi, 3 = Tammela, 4 = Laukaa/Toivakka, 5 = Kitee, 6 = Mikkeli, 7 = Paimio/Tarvasjoki, 8 = Laihia, 9 = Nivala, 10 = Laitila, 11 = Nurmijärvi, 12 = Vieremä, 13 = Kihniö/Parkano, 14 = Iitti, 15 = Imatra/Ruokolahti.

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richness, heterogeneity and evenness. Both average and total numbers of species were calculated for each zone. Since the number of species depends on the sample size and since the number of sampled fields varied from one zone to another, total species numbers between zones could not be compared. Therefore, the expected number of species $E(S_n)$ was calculated for each zone by rarefaction:

$$E(S_n) = \sum_{i=1}^{S} \left(1 - \frac{\binom{N-N_i}{n}}{\binom{N}{n}} \right),$$

where $E(S_n)$ = expected number of species in a random sample of n individuals, S = total number of species in the entire collection, N_i = number of individuals in species i, N = total number of individuals in the collection, n = sample size (number of individuals) chosen for standardization (see Heck et al. 1975, Krebs 1995). In rarefaction, the numbers of species of larger samples are scaled down to the given number of individuals which permits the comparison of species numbers between samples differing in size. We scaled sample sizes down to 5000, 7500, 10 000, 12 500 and 15 000 individuals (the lowest number of individuals was 19 152), and calculated 95% confidence limits for each sample size.

Species heterogeneity was measured by the Shannon diversity index H' which was calculated as $-\sum_{i=1}^{S} p_i \ln(p_i)$, where s is the number of species in a field and p_i the proportion of species i individuals of the total population of a field (see Krebs 1995). If two communities have an equal number of species but the relative abundances are more even in the first community it has a higher heterogeneity, i.e., it is more diverse. If two communities have an equal evenness of relative abundances of species but the species number is higher in the first community it has a higher heterogeneity, i.e., it is more diverse (see Krebs 1995).

Species evenness was measured by Hill's evenness index $E_{2,1}$ which was calculated as

$$\frac{N_2}{N_1} = \frac{\left(\sum_i p_i^2\right)^{-1}}{\exp\left[-\sum_i p_i \ln\left(p_i\right)\right]},$$ where p_i is the proportion of species i individuals of the total population of a field (Hill 1973, see also Alatalo 1981). The maximum value (1.0) of evenness index is reached when all species are equally abundant. Data from the ten 0.1 m^2 sample quadrats were pooled before the calculation of heterogeneity and evenness indices.

The material and methods are described in greater detail by Salonen et al. (2001).

Results

Species diversity

Altogether 126 weed species were found in sample quadrats. The occurrence of the 42 most frequent weed species found in more than 10% of surveyed fields is presented by region (Table 2). The average number of weed species per field was 20 when *Galeopsis* and *Lamium* species were pooled as one species (Table 3); without pooling, the number would have been 24 (Salonen et al. 2001). In comparison, the average number of weed species in unsprayed conventional fields was 25.

Seven weed species were found in more than 80% of surveyed fields: *Chenopodium album*, *Stellaria media*, *Galeopsis* spp., *Viola arvensis*, *Spergula arvensis*, *Erysimum cheiranthoides* and *Elymus repens*. Seventeen species were found only in organically cultivated fields. These included *Bidens radiata*, *Festuca ovina*, *Mentha* spp., *Vicia hirsuta* and *V. sativa*. On the other hand, the species pool of conventional fields included 27 species which were found only in conventional fields. These included *Deschampsia caespitosa*, *Alopecurus myosuroides*, *Poa trivialis*, *Euphorbia helioscopia* and *Atriplex patula*.

Table 3. Total and average number of species, average values of Shannon diversity index (H') and Hill's evenness index ($E_{2,1}$) in the whole data and in the three zones (S = South, CE = Central-East, CW = Central-West). Standard deviations are shown in parentheses.

Variable		Total	Zone		
			S	CE	CW
Total no. of species		126	97	95	74
Average	no. of species	19.6 (4.8)	18.5 (4.4)	21.8 (4.6)	19.7 (5.1)
	H'	2.04 (0.34)	1.99 (0.33)	2.2 (0.26)	1.93 (0.4)
	$E_{2,1}$	0.67 (0.1)	0.67 (0.1)	0.68 (0.1)	0.67 (0.1)

Species diversity was highest in the central-eastern (CE) zone (Table 3), where both the average number of species per field and the values of the Shannon diversity index were highest. Furthermore, the total number of species reached almost the same figure as in the southern (S) zone, even though the number of sampled fields was half of that in the southern zone (88 vs. 44). The rarefaction analysis revealed that species richness was significantly lower in the central-western (CW) zone than in other zones (Fig. 1). The central-eastern and southern zones did not, however, differ in species richness (Fig. 1). The proportion of species common to both the southern and the central-eastern zones was 61.3%. The values of the evenness index did not differ between the zones.

Weed density and biomass production

Over all studied fields, the average density of weeds was 469 plants m^{-2} (SD = 340, median = 395). Weed density was lowest in the southern and highest in the central-western zone (Fig. 2). On the animal husbandry farms, the average

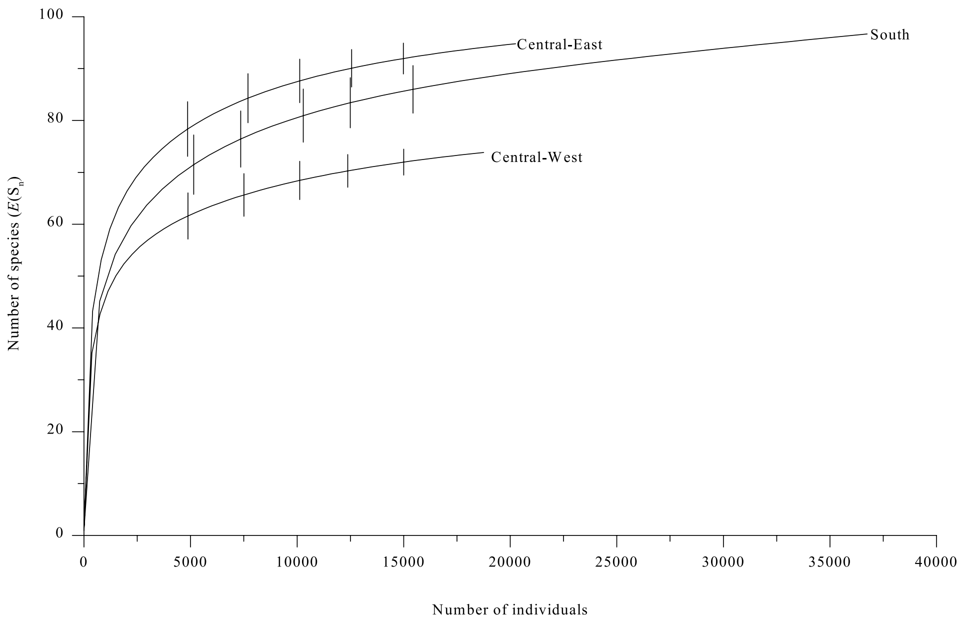

Fig. 1. Rarefied species numbers for each zone. The vertical lines show 95% confidence limits.

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weed density was lower than the grand average, namely 409 plants m^{-2} (SD = 311, median = 345) and on crop husbandry farms it exceeded the grand average, namely 543 plants m^{-2} (SD = 361, median = 466).

The five most abundant weed species were *Chenopodium album* (on average 91 plants m^{-2}; median = 39), *Elymus repens* (49 ; 17), *Spergula arvensis* (49 ; 15), *Stellaria media* (49 ; 24) and *Viola arvensis* (31 ; 14). There were no significant differences in infestation by the most abundant species between the farm types, except that the density and biomass of *S. arvensis* were twice as high on crop husbandry as on animal husbandry farms.

Differences in species composition were detected between the zones (Fig. 3). As regards weed density, *Chenopodium album* and *Spergula arvensis* were among the three most abundant species in every zone. *Stellaria media* was one of the most abundant species in the southern zone whereas *Elymus repens* was the most abundant species in the central-eastern zone and the third most abundant in the central-western zone. *Gnaphalium uliginosum* was another species that was more abundant in eastern and western Finland than in the south. A characteristic species of eastern Finland was *Lapsana communis*.

The average biomass production of weeds was 678 kg ha^{-1} (SD = 547, median = 567). As with weed density, biomass production was lowest in the southern and highest in the central-western zone (Fig. 4). Furthermore, biomass production was highest (median = 955 kg ha^{-1}) in organic soils, intermediate (median = 635) in coarse mineral soils and lowest in clay soils (median = 473).

On animal husbandry farms, the average biomass of weeds was 634 kg ha^{-1} (SD = 558, median = 495) and on crop husbandry farms

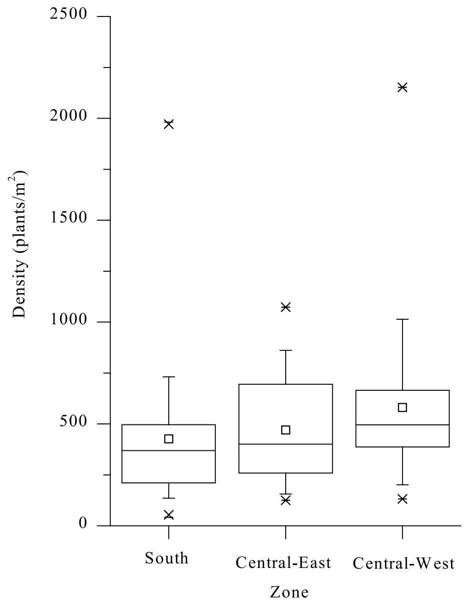

Fig. 2. Density of weeds by zone. The square in the box denotes the mean of the data, and the horizontal lines the 25th, 50th and 75th percentile values. The error bars denote the 5th and 95th, the crosses the 1st and 99th and the dashes the 0th and 100th percentile values.

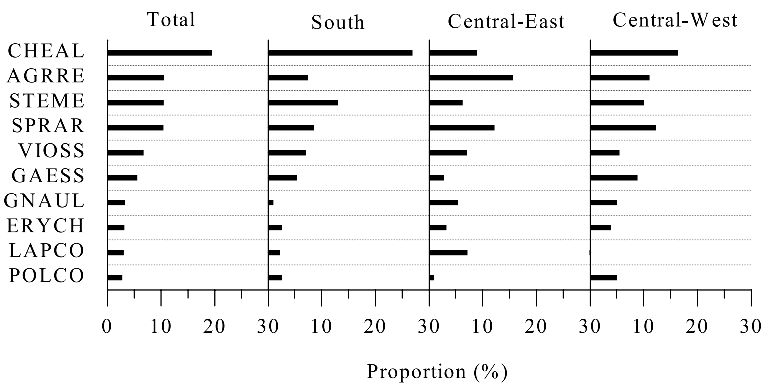

Fig. 3. The ten most abundant species as a proportion of total density in all fields surveyed and in each zone. The Bayer codes for weed species: CHEAL = *Chenopodium album*, AGRRE = *Elymus repens*, STEME = *Stellaria media*, SPRAR = *Spergula arvensis*, VIOSS = *Viola* spp., GAESS = *Galeopsis* spp., GNAUL = *Gnaphalium uliginosum*, ERYCH = *Erysimum cheiranthoides*, LAPCO = *Lapsana communis* and POLCO = *Fallopia convolvulus*.

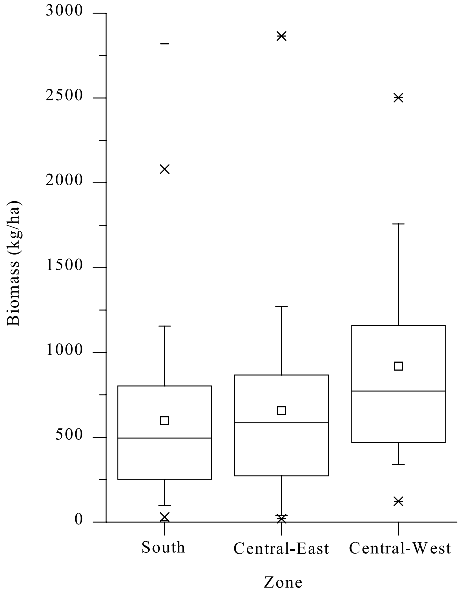

Fig. 4. Biomass of weeds by zone. The square in the box denotes the mean of the data, and the horizontal lines the 25th, 50th and 75th percentile values. The error bars denote the 5th and 95th, the crosses the 1st and 99th and the dashes the 0th and 100th percentile values.

731 kg ha^{-1} (SD = 533, median = 619). The five weed species that produced the highest amounts of biomass were *Elymus repens* (average 178 kg ha^{-1}; median 53), *Chenopodium album* (140 ; 23), *Spergula arvensis* (53 ; 8), *Galeopsis* spp. (47 ; 13) and *Stellaria media* (37 ; 10).

Broad-leaved species accounted for 72% of the average total biomass production of weeds. The most abundant grass species, *Elymus repens*, was the most efficient biomass producer, as it accounted for 26% of the total weed biomass production pooled over all study fields (Fig. 5). *E. repens* was abundant in central Finland, particularly in the central-eastern zone. Its average biomass production in the central-eastern and central-western zones was more than double that in the southern zone. This was clearly due to the dominance of soil types, as in clay soils, which are common in the south, the biomass production of *E. repens* was fairly low (median = 11 kg ha^{-1}) whereas in coarse mineral soils and organic soils, which are more common in central Finland, it was considerably higher (median = 96 kg ha^{-1} and 118 kg ha^{-1}, respectively).

In all, the average proportion of weed biomass relative to total vegetative biomass (crop + weeds) was 17%. The perennial weed species *Sonchus arvensis* and *Cirsium arvense* were highly productive. *S. arvensis* was common in coarse mineral soils in central-eastern Finland (see also Fig. 5), its average biomass in infested fields being 131 kg ha^{-1}. In contrast, *C. arvense* produced the highest average biomass, 106 kg ha^{-1}, in infested clay soils in the southern zone.

To supplement the findings of the most common perennial weed species in sample quadrats, we asked farmers to rank the infestation level of these species in their fields (Table 4). In their opinion, *Elymus repens* was both the most abundant and the most troublesome species.

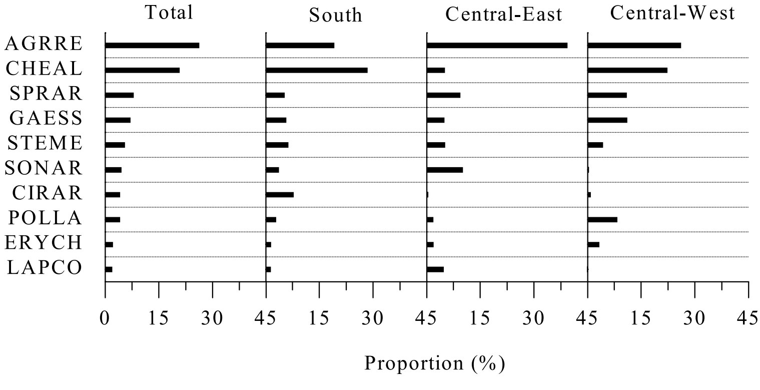

Fig. 5. The ten most abundant species as a proportion of total biomass in all fields surveyed and in each zone. The Bayer codes for weed species: AGRRE = *Elymus repens*, CHEAL = *Chenopodium album*, SPRAR = *Spergula arvensis*, GAESS = *Galeopsis* spp., STEME = *Stellaria media*, SONAR = *Sonchus arvensis*, CIRAR = *Cirsium arvense*, POLLA = *Persicaria lapathifolia*, ERYCH = *Erysimum cheiranthoides* and LAPCO = *Lapsana communis*.

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Table 4. Infestation of survey fields by *Elymus repens* (AGRRE), *Cirsium arvense* (CIRAR) and *Sonchus arvensis* (SONAR) in the opinion of farmers.

Infestation level	Proportion (%) of fields, by species		
	AGRRE	CIRAR	SONAR
Negligible	18	46	42
Moderate	67	49	52
Abundant	15	5	6

Discussion

The total number of weed species (126) found in organically cultivated fields was lower than the number of species (160) found in the whole survey data, which included 525 conventional fields (Salonen et al. 2001). In comparison, in the mid-1980s Mela (1988) found 120 weed species/taxa in organically cultivated cereal fields, and in the early 1960s Mukula et al. (1969) found 304 species in conventional spring cereal fields not treated with herbicides. In all surveys, the lists of most frequent species were very similar to each other.

Only one third, namely 42 weed species/taxa out of 126 observed species, exceeded the overall frequency level of 10%. None of the observed species is classified as endangered in Finland (Rassi et al. 2000). *Chenopodium album*, *Galeopsis* spp. and *Stellaria media* are characteristic species of spring cereal fields in this country since they have been among the most frequent species in all weed surveys (Mukula et al. 1969, Erviö and Salonen 1987, Mela 1988, Salonen et al. 2001). Moreover, they seem to be particularly typical of organic production, as they exceeded the frequency level of 90% in all three zones.

The level of weed infestation was almost identical to that in organic production in the mid-1980s (Mela 1988), when the average weed density was 505 plants m^{-2} and biomass production 575 kg ha^{-1}. The relative importance of weeds has increased slightly, as they currently accounted for 17% of the biomass in crop stands whereas in the mid-1980s their proportion ranged from 10% to 13%, depending on the cereal species (Mela 1988). The median weed density in organic production was only slightly higher (395 plants m^{-2} vs. 374) and the biomass production somewhat higher (567 kg ha^{-1} vs. 413) than in conventional fields not sprayed with herbicides (Salonen et al. 2001).

Most of the fields examined had only a short history of organic farming, the majority of study farms having converted from conventional to organic cropping during the 1990s. A high infestation level such as was observed here is typical of the early stages of conversion to organic growing (Davies et al. 1997, Albrecht and Sommer 1998).

Chenopodium album was the most harmful broad-leaved species in terms of crop-weed competition and weed biomass production. This is in agreement with the findings of a weed survey conducted in Scotland (Davies et al. 1997), where *C. album*, *Polygonum aviculare* and *Spergula arvensis* were amongst the weed species that benefited most from the period of conversion to organic farming. Hallgren (1996) has reported that *C. album* decreased in frequency in the 1960s and 1970s but later, in the 1990s, became more frequent in conventionally farmed fields in Sweden.

Three perennial weed species, *Elymus repens*, *Cirsium arvense* and *Sonchus arvensis*, proved to be highly competitive and are of major concern in terms of yield reductions. In contrast, these perennial species were not particularly common in a recent survey of organic farms in Sweden, where Rydberg and Milberg (2000) suggested that improved soil cultivation technology has reduced the importance of perennial species.

Differences between regions were found in the species diversity, composition and biomass production of some species. While the predominance of certain soil types in different parts of Finland was clearly a key factor affecting species abundance, the higher species diversity in eastern Finland was probably due to the greater diversity of crop rotations and the less intensive use of herbicides before conversion to organic farming in that part of the country than elsewhere. However, the composition of weed floras is a result not of any single factor but of many confounding environmental and management factors (Haas and Streibig 1982, Salonen 1993). Therefore, comparisons of zones, farming types etc. should be interpreted with caution.

Organic crop production aims to maintain weeds at a manageable level by cultural means (Bond and Lennartsson 1999). Weed management strategies should include crop rotation, cultivations, crop density, cultivar selection and mechanical control (Stopes and Millington 1991, Lee 1995, Welsh et al. 1999). Current direct weed control methods alone are often insufficient to control weeds effectively in spring cereal production. In fact, only a few of the survey farms carried out direct weed control measures even though these might provide at least moderate control against some species, e.g. *C. album*. Moreover, perennial weed species such as *Elymus repens*, *Sonchus arvensis* and *Cirsium arvense* will threaten the future of organic cereal production unless their control is given due consideration in crop rotation.

Organic farming appears to promote biodiversity since the number of weed species is often higher than in conventional farming (e.g. Moreby et al. 1994, Hald 1999, Salonen et al. 2001). However, in the present survey the average number of weed species per field and the infestation level of weeds were about the same both in organic fields and in conventional fields not treated with herbicides (Salonen et al. 2001). Thus, the challenge for both cropping systems is to find an acceptable balance between profitable and sustainable crop production and the functional value of a rich weed flora in the arable habitat.

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SELOSTUS

Luomukevätviljapeltojen rikkakasvillisuus 1997–1999

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Luonnonmukaisesti viljeltyjen kevätviljapeltojen rikkakasvillisuutta kartoitettiin Etelä- ja Keski-Suomessa vuosina 1997–1999 yhteensä 15 tutkimusalueella. Aineistoa kerättiin yhteensä 79 tilalta ja 165 pellolta, joista 52 % oli kauraa, 23 % ohraa, 16 % kevätvehnää ja 9 % viljaseosta. Pelloista 41 % oli kylvetty suojaviljaksi. Kasvustonäytteet kerättiin kymmeneltä 0,1 m^2 näytealalta heinäkuun puolivälin ja elokuun alkupuolen välisenä aikana.

Näytealoilta havaittiin yhteensä 126 rikkakasvilajia, joista valtaosa oli leveälehtisiä lajeja. Keskimääräinen lajimäärä oli 20 lajia/sukua peltoa kohti. Yleisimpiä rikkakasveja olivat jauhosavikka, pihatähtimö, pillikkeet ja pelto-orvokki. Juolavehnä oli yleisin rikkaheinä. Kaikkiaan 42 lajia ylitti 10 % yleisyysrajan.

Rikkakasveja kasvoi keskimäärin 469 kpl/m^2, ja niiden tuottama biomassa oli 678 kg/ha. Rikkakasvien osuus kevätviljapellon kasvimassasta (vilja + rikkakasvit) oli 17 %. Juolavehnä oli eniten biomassaa tuottava laji. Jauhosavikka oli runsain leveälehtinen laji.

Luonnonmukaista viljantuotantoa uhkaavat erityisesti kestorikkakasvit juolavehnä, peltovalvatti ja pelto-ohdake. Juolavehnää ja peltovalvattia kasvoi runsaimmin Itä- ja Kaakkois-Suomessa, pelto-ohdaketta puolestaan Etelä-Suomen savialueilla.

Useimmat tutkimustilat olivat siirtyneet luomuviljelyyn vuoden 1994 jälkeen, joten luomutuotannon vaikutus rikkakasvilajistoon ja rikkakasvien runsauteen oli vasta alkuvaiheessa. Rikkakasvien mekaaninen torjunta viljakasvustosta oli varsin harvinaista.