Weed seed banks from neighbouring farms with and without long term use of herbicides

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SUMMARY

Pairs of neighbouring farms on clay and sandy soils in the Netherlands were sampled in wintertime for their weed seed banks. The pairs of farms were selected in such a way that one of them could be considered to represent common agricultural practice (plus farms) whereas the other at least has not used herbicides for a prolonged period (minus farms).

All seedlings that emerged from the soil samples during 3 years were determined. The results indicate, that soils of plus farms contained less plant species and individuals than minus farms; non-graminous weeds and grass weeds (as groups) behaved in the same way. Individual species could be favoured or hampered specifically in either farming system. The minus farms showed higher incidence of relatively uncommon species.

In spite of the quantitive differences in seed populations, weed floras on neighbouring farms with different farming systems were qualitatively more comparable than those on remote farms with comparable systems.

The results indicated above were in accordance with data from the literature, with the exception of those obtained from shortterm seedling surveys.

SAMENVATTING

Zowel op klei- als zandgrond werd op een aantal zgn. gangbare bedrijven, waar herbiciden een belangrijk instrument vormen bij de onkruidbeheersing, de onkruidsituatie vergeleken met die op bedrijven, waar geen herbiciden werden gebruikt. Deze vergelijking werd uitgevoerd op paarsgewijze aan elkaar grenzende bedrijven. Bij de selectie van de bedrijven werd gestreefd naar een redelijke representativiteit voor de betreffende agrarische sector.

Op de geselecteerde bedrijven werden series grondmonsters gestoken waarin vervolgens gedurende drie jaar de opkomende onkruiden werden bepaald.

De resultaten toonden dat de grondmonsters afkomstig van de bedrijven die herbiciden gebruikten, minder individuen en ook minder soorten bevatten dan de bedrijven waar geen herbiciden werden gebruikt. De grasachtige en de breedbladige onkruiden reageerden, als groep gezien, op dezelfde manier. Het aantal zeldzamere soorten was op de alternatieve bedrijven het grootst.

De kwalitatieve overeenkomst in onkruidflora was op de aan elkaar grenzende bedrijven met een verschillend onkruidbeheersingssysteem groter dan verder van elkaar gelegen bedrijven met een overeenkomstig beheersingssysteem.

1. INTRODUCTION

Discussions about weeds, written or oral, often consider so-called "problem weeds". In fact, this qualification is purely technical: it only means that the weeds concerned are difficult to control. It is often interpreted, however, in a quantitative way afterwards: many of these "problem weeds" are regarded as increasing agricultural problems that ask for action to decrease their numbers or to stop their spread. The mere fact that they are left over, however, does not justify such actions at all. In literature, from time to time doubts show up concerning generally accepted increased weed infestations (e.g. Fogelfors, 1979; Fryer and Chancellor, 1970; Koch, 1964), but in most of the literature no relativating remarks can be found. The situation is even more intricate, since citations about "problem species" are often not in accordance. This can be demonstrated from references on Galium aparine, which is reported to have shown in recent times:

- a decreased distribution in sugarbeets (Bachthaler and Dancau, 1970);
- a less common appearance in wintercereals (Gummesson, 1979);
- no clear change in distrubution in cereals (Menck and Behrendt, 1974);
- an increased numerical infestation in eight out of twelve situations, and a decreased one in the remaining four (Petzoldt, 1979).

A similir list of contradictionary claims can be given for other "problem weeds"; for Poa annua it is shown in subsection 4.3 of the present paper. Grasses in general are often mentioned as problems in arable crops nowadays (Cremer, 1976; Cussans, 1976; Fryer and Chancellor, 1970), although such a statement is often limited subsequently towards specific species or situations.

This very unclear picture on changes in (relative) importance of weeds came into existence because of three major reasons.

First, weed situations are described in a number of different ways, like from studies of geographical distributions, coutings of seedlings, estimates of soil cover and seedbank analyses.

Secondly, comparisons of weed populations are based on a variety of periods: one-season surveys from different fields; series of yearly surveys from one or more experimental fields; surveys with time intervals between them ranging from 5-20 years (shortterm comparisons regarding seed viability) to over 20 years (longterm comparisons); seedbanks from fields with a different history.

Thirdly, although all methodologies mentioned above might have their merits for the specific purposes for which they were used, their outcomes are often quoted to support more general statements (sometimes backed up with "own experience" or other untraceable sources). Examples of improper generalizations can be often found in introductions of review articles, e.g. Cussans, 1976; Neururer, 1965; Stryckers, 1979. Sometimes, one years' evidence is loaded with a prophetic value.

In the Netherlands, like in other countries, discussions about weed problems, problem weeds and changes in weed flora suffer form this inconsistency in the data base: more and better data on past weed developments should be needed to improve the quality of predictions for present weed situations and future developments. However, field surveys can not be done backwards in time. Seedbanks analysis, which in principle presents a picture of a fields' history with respect to seed propagating plant species, is accepted as a good alternative. The present paper describes seed bank analysis of various paris of Dutch farms. One of each pair had undergone an agricultural evolution representative for Dutch farming generally, whereas the other maintained more or less the farming concept of 20-30 years ago (conservation, application of Steiners' ideas, or other reasons). We think, that conclusions form this type of studies might be helpful in the weed discussion in the Netherlands, especially as far as effects of long time application of modern agricultural techniques are concerned.

Comparisons of weed populations (in time) commonly have the tendency to relate differences found directly to changes in control measures employed. Weed populations, however, are influenced by the total farm management and by seed influx from the environment. Although the specific significance of these various influences can not be quantified, the authors assume that herbicides, by their mode of action, play at least a very important role.

2. MATERIAL AND METHODS

2.1 Soil origin

For collection of comparable soil samples, pairs of farms were selected on the following criteria:

- one of each pair should use the normal (advised) scala of herbicides, whereas the other should never have used them for at least the last decade;
- the type of agriculture should be more or less the same;
- they should be close to each other (preferably neighbours).

Seven pairs were identified (Table 1) that met the demands well. Those that use herbicides are called 'plus' farms and those that do not 'minus' farms.

2.2 Soil collection

Soil samples were collected on clay soils in the winter of 1978/79 and on sandy soils in the winter of 1979/80.

The samples were drawn with a core sampler (Ø 3.4 cm) to a depth of 25 cm over the whole surface of cultivated land (80 cores/farm). The collected soil from each farm was mixed, weighed and their moist content determined. Rhizomes and other vegetative plant parts were removed. Equal amounts of the subsamples were placed in flat pottery dishes (2.5 l content; 10 dishes/farm) that were subsequently placed in an outdoor set-up to provide protection against rain and birds. The soil was kept moist. During three years, (for clay soils until the end of 1981 and for sandy soils until the end of 1982) all emerging seedlings were determined, either as seedlings or, if doubtful, after raising them up separately. If no new germination took place, the soil in the dishes was stirred thoroughly.

Dishes were sterilized soil were placed between the experimental dishes to check inflow of seeds (wind, insects) from the environment; no seedlings were ever found in them.

3. RESULTS

3.1 Number of species

total number of species encountered is presented in Table 2. More species were found on minus farms (no herbicides) on clay soil and on 2 out of 4 minus farms on sandy soil. From these data can be concluded that:

- a seed-borne weed vegetation on arable land where herbicides have been used tendenced to less species if compared with those where no herbicides have been used.

3.2 Number of seeds

Table 3 summarizes the total number of germinated seeds per kg of dry soil. Although somewhat less explicit in 2 cases from farms on sandy soil, it can be concluded that:

- more viable weed seeds were present in those soils where herbicides have not been used.

3.3 Grasses

In Table 4 the numbers of species and individuals of grasses are given as percentages of the total numbers of species and individuals.

All grass species encountered are listed in Table 5, as well as their absolute numbers/10 kg of dry soil on the different farms.

With regard to grasses, it can be concluded that:

- grasses as a group were not selectively favoured over non-graminous weeds on farms where herbicides have been used, nor on those where no herbicides have been used (Table 4);
- in five out of seven cases less individuals of grasses were found on plus farms than on minus farms (Table 5);
- individual grass species sometimes showed higher incidence on plus farms than on minus farms (Table 5).

3.4 Non-graminous weeds

Table 6 presents the numbers of viable seeds per 10 kg of dry soil of some non-graminous weed species. The species presented (approximately 20% of the total number of non-grass weeds) were selected for this table because they either are species (or represent groups) often mentioned in the literature as to be of concern, or were found in a marked quantity or distribution. All other species that were indentified are listed in Table 7. In general it can be concluded that:

- numbers of most-graminous weed species did not differ much on either plus of minus farms. About 10% of the non-grass species, however, did occur in larger absolute numbers on minus farms.

3.5 Population built-up

Figure 1 averages the weed population built-up for plus and minus farms; it shows what percentages of species represent various numerical groups in the total population. By doing so, the relative abundance of rather uncommon and of rather dominant species is illustrated.

It can be concluded that:

- on minus farms a large percentage of species represented relatively uncommon ones (or: the line in figure 1 representing the plus farms shows the typical picture of a 'disturbed' biological system, in which only few species occur in relatively high numbers).

3.6 Similarity of farms

To compare populations, various similarity indices are available. The association index of Whittaker (1952) is applied here, because it is not only based on numbers of species, but also on their relative numerical importance. A higher index value (closer to 100%) means a higher alikeness of two populations.

The index is used to compare the pairs of farms as well as the minus farms or plus farms mutually. The results are shown in Table 8.

The following conclusions can be drawn:

- the similarity between weed populations on pairs of neighbouring farms with and without the long term use of herbicides was rather low, indicating that the type of farm management strongly influenced its weed flora;
- weed populations on neighbouring farms with and without the long term use of herbicides resembled each other generally more than weed populations from more remote farms with comparable weed control systems; this conclusion means, that the farming system using herbicides did not (yet) lead to a uniform weed flora on all farms representing that system.

4. DISCUSSION

4.1 Number of species

Four publications were found, in which no change in the number of weed species as a result of the use of different weed control practices, including the application of herbicides is reported (Bachthaler & Dancau, 1970; Cremer, 1976; Mahn & Helmecke, 1979; Rademacher & Koch, 1972). Three of these concern short-term studies (5-8 years); one covers a period of 15 years. In two papers (Mittnacht et al., 1979; Petzoldt, 1979) present-day weed populations were compared with those of 20-30 years ago; in both cases the number of species decreased. Less weed species were found by Callauch (1981) on 'conventionally' managed fields as compared with 'biologically' managed fields. His study was set up in a more or less identical manner as the present one. The study at issue confirms the relevant results in the last three papers.

The discrepancy in literature can be attributed to the relative shortness of the study period of the four publications mentioned above first; if circumstances are not suited anymore for a species to survive, it will only disappear from the locality after the seedbank has been exhasuted, which may take many years.

4.2 Number of individuals

In some studies of effects of weed control methods (mostly herbicides) on the weed flora, treated plots are compared with a more or less undisturbed plot. In general, more weeds are found in the latter, and this often did lead to the conclusion that (the) herbicide(s) reduced the weed population (e.g. Stryckers et al., 1976; Zemánek, 1979). Such conclusions are not to be drawn, however, since they suggest that the 'uncontrolled' plot is a more or less fixed situation. Moreover, data from previous periods are generally missing. The only valuable conclusion from such studies is that less weeds are present in the herbicide plots ('actual' situation).

Studies that include weed populations from previous periods (or that are carried out over a number of years), but are based on weed surveys in the field only, are also difficult to interpret, since the results are influenced by strong yearly fluctuations in emergence and growth conditions. This is demonstrated clearly by Rademacher & Koch (1972), who found after 11 years still about the same number of weeds in controlled and uncontrolled plots, whereas in the years in between the weed countings showed considerable decreases and increases. Also Gummesson (1981) showed such fluctuations. Barralis (1972) found that trends in weed populations could not be concluded from short term weed countings (5 years) in the field.

Still more biased are conclusions from field surveys that carried out over a whole season. In such studies, the weed populations from the controlled plots directly reflect the control measures, whereas weeds in untreated plots are counted several times. These studies also present an 'actual' situation and, at the best, they could indicate the direction of changes in the future.
From some publications, the results are even less useful for interpretation by readers, since they do not mention at all how, and especially when their surveys were carried out (e.g. Gummesson, 1981; Rademacher & Koch, 1972).

The only way to get a picture about the 'potential' situation is to sample seedbanks and, if possible to compare them with those from previous periods. This has been done by Roberts (1968) and Roberts & Neilson (1982); they found more individuals in periods longer ago. The present study in which weedbanks were sampled to compare neighbouring fields with a different weed control history, confirms these results; less weed seeds were found on those farms where agriculture had its common evolution, as compared with those where agriculture was more or less kept unchanged. Pulcher & Hurle (1984), comparing seed banks from farm systems with a different intensity of plant protection measures also found after 6-7 years a higher number of weed seeds on the plots without herbicides.

4.3 Grasses

As was demonstrated with Tables 4 and 5, differences in weeds between farming systems can be expressed in a relative or an absolute way. Absolutely, less grass weeds (species and individuals) were present on plus farms. A comparison of relative numbers showed no difference between both farming systems. This result indicates, that the ratio non-graminous weeds/grasses remained the same: grasses behave like other weeds. Bachthaler & Dancau (1972) compared different farming systems with and without use of fertilizers and herbicides and also found hardly any difference in the relation of seed propagating weeds, root propagating weeds and grasses. These findings oppose the assertion that grasses (as a group) increase in herbicide using farming systems. In most papers such a general assertion is immediately restricted again by giving examples of specific species. In others the assertion is kept general (see Introduction). It is conceivable that in weed studies based on field surveys of plants only a higher relative amount of grasses are observed in modern farming systems. Since seed bank studies reveal the opposite these higher amounts must be of a temporary nature (the grass seed bank is still quicker exhausted), unless they are completely caused by vegetative propagation. The same conclusion holds true for non-graminous 'problem weeds': if the seed bank (potential) is small, the emergence (actual) high, and the species propagates mainly by seeds, the 'problem' will solve itself in time.

Therefore, these (so-called) problem weeds do not justify extra research on specialized control systems.

Most reports do not expatiate on ratios of weeds, but only on absolute differences in numbers of individuals and/or on geographic distribution of species. With grasses, findings are not always congruent. This can be demonstrated for Poa annua, that has been reported:

- to have increased its distribution from 1955-1961 to 1962-1969 (Bachthaler & Dancau, 1970);
- to be present in lower numbers (seeds) in the late sixties and early seventies than in the late fifties and early sixties (Roberts, 1968; Roberts & Neilson, 1982);
- to show more individuals in weed controlled plots (Rademacher & Koch, 1972);
- to be present more frequently (seeds) on farms where no herbicides are used (this study).

Here again, remarks about differences in research approach (seed samples vs. surveys) might play an important role: the 'actual' presence of this species, as determined by seedbank analysis, indicates a decrease in modern farming systems. Again, this decrease in 'potential' destinates the 'actual' situation to a temporary one.

With Agrostis stolonifera an equal tendency has been found: the present study indicates smaller numbers on plus farms, and also Mittnacht et al. (1979) found a smaller incidence of this species in the seventies as compared to 1948/1949.

Other data from the present study are in accordance with some other publications on grasses: Alopecurus myosuroides has also been reported to have decreased (or maintained) in occurrence by Bachthaler & Dancau (1970), Mittnacht et al. (1979) and Petzoldt (1979); general statements about this species becoming a problem have not been confirmed yet by any publication found.

Another gnerally mentioned phenomenon - the high amount of individuals of Digitaria ischaemum and Setaria viridis in permanent maize culture- is not contradicted by the present study.

4.4 Non-graminous weeds

Literature on changes in relative or absolute importance of broad leave weed species is extremely numerous and extremely chaotic because of the variety of methodologies used (see Introduction). Comparisons with the results of the present study were difficult to make, since most of the pepers put emphasis on weed distribution more than on weed quantities, or they concerned only short term surveys. One seed bank study was found (Roberts, 1968), concluding that the total weed population was significantly reduced in the course of four years after introduction of herbicides, whereas no firm conclusion could be drawn about relative changes in the importance of separate species. The results of the present study confirm these conclusions.

4.5 Population built-up

The conclusion from the present study that in herbicides-using farms less 'uncommon' species are present is congruent with results of Callauch (1981) and Mittnacht et al. (1979). These authors determined that the species that had disappeared were generally the least common species already before. They include a number of species that have been regarded as indicators for physical of chemical parameters of the environment.

Table 1. Selected pairs of farms for seed (soil) sampling.

Code	Soil	Culture	Size	Herbicides
C1 plus	Clay	arable farming	43 ha	+
C1 minus	"	"	90 ha	-(never)
C2 plus	"	arable farming	44 ha	+
C2 minus	"	"	44 ha	-(since 1968)
C3 plus	"	horticulture	3 ha	+
C3 minus	"	"	5,5 ha	-(since ± 1964)
S1 plus	Sand	horticulture	1 ha	+
S1 minus	"	"	1 ha	-(since ± 1970)
S2 plus	"	arable farming	large*	+
S2 minus	"	"	small	-(never)
S3 plus	"	arable farming	large*	+
S3 minus	"	"	small	-(since ± 1970)
S4 plus	"	arable farming	large*	+
S4 minus	"	"	small	-(never)

* only sampled in a relatively small area close to the sampled neighbouring farm.

Table 2. Total number of weed species determined from seed samples of farms with (plus) and without (minus) longterm use of herbicides.
c = clay, s = sand

	plus	minus
C1	24	31
C2	16	26
C3	20	43
S1	20	26
S2	20	17
S3	29	28
S4	31	39

Table 3. Total number of germinated seeds per kg dry soil from farms with(plus) and without(minus) long term use of herbicides.

	plus	minus
C1	11	50
C2	9	32
C3	7	86
S1	10	43
S2	37	41
S3	24	60
S4	19	23

Table 4. Number of samples and individuals of grasses from farms with(plus) and without(minus) long term use of herbicides, expressed as % of total numbers of species and individuals, respectively.

	species		individuals	
	plus	minus	plus	minus
C1 plus	8	13	9	20
C2 plus	19	8	37	2
C3 plus	10	16	3	23
S1 plus	10	4	47	23
S2 plus	10	24	41	70
S3 plus	14	14	10	9
S4 plus	16	31	54	33

Table 5. Grass weed species and their absolute numbers in 10 kg dry soil from farms with (plus) and without (minus) long term use of herbicides.

	C1		C2		C3		S1		S2		S3		S4	
	plus	minus	plus	minus	plus	minus	plus	minus	plus	minus	plus	minus	plus	minus
Agrostis stolonifera	1	5				5						1	2	27
Alopecurus myosuroides		1				0.5								
A. geniculatus												1		0.5
Apera spica-venti									145	1	2	2	3	0.5
Deschampsia flexuosa														1
Digitaria ischaemum													49	13
Holcus lanatus						2								9
H. mollis														2
Hordeum cultivar					0.5									
Phleum pratense						0.5								1
Poa annua	9	90	16	4	1	171	44	101	6	286	22	50	1	17
P. pratensis			15	1		1				1				1
P. trivialis		3	4			19	0.5			1	0.5			2
Setaria viridis											0.5		47	0.5
Total nr of individuals	10	99	35	5	1,5	199	44,5	101	151	289	25	54	102	74,5

Table 6. Absolute numbers of some non-graminous weed species per 10 kg dry soil from farms with (plus) and without (minus) long term use of herbicides.

	C1		C2		C3		S1		S2		S3		S4	
	plus	minus	plus	minus	plus	minus	plus	minus	plus	minus	plus	minus	plus	minus
Anthemis arvensis												0.5		
Aphanes arvensis													4	0.5
Matricaria discoidea				2	2	6			1		0.5			
M. recutita	9	37		101										
Chenopodium album	6	12		0.5	2	8	2	35	25	22	38	235	8	1
C. ficifolium	3	35		3	1	26		6						
Polygonum aviculare	25	11	27	88		1	0.5	2	10		1	0.5	2	4
P. convolvulus	15	10	1	5		2			11			5	1	1
P. lapathifolium spp. lap.												0.5		
P. lapathifolium spp. pal.	6	2	4	15		0.5						34		
P. persicaria	6	9	9	8		1		1			0.5	3	0.5	
Veronica arvensis								1	1		0.5		7	14
V. hederifolia									4					
V. serpyllifolia														5
V. persica	3	43	1	15		1								
Capsella bursa-pastoris	1	4	2	8	1	12	0.5	3	11		3	18	8	4
Galium aparine	0.5													
Solanum nigrum	1	1	1	13	9	74	4	35		4	0.5	2		0.5
Stellaria media	16	129	5	39	35	336	13	37	29	78	8	77	1	6
Plantago major	2	22		2		12					5	6		1
Thlaspi arvense	2	54		1										
Urtica urens						36	3	154						
Juncus bufonius						1			3	4	130	142	5	1

Table 7. Non-graminous weed species, other than those mentioned in Table 6.

Clay	Sand
Ameranthus lividus	Anagallis arvensis
Anagallis arvensis	Arabidopsis thaliana
Atriplex hastata	Arenaria serpyllifolia
A. patula	Betula spec.
Bellis perennis	Epilobium spec.
Brassica cultivar	Erigeron canadensis
Cerastium holosteoides	Galinsoga ciliata
Chenopodium glaucum	G. parviflora
C. polyspermum	Gnaphalium uliginosum
Coronopus squamatus	Juncus articulatus
Epilobium hirsutum	J. effusus
E. spec.	Lamium amplexicaule
Erigeron canadensis	L. purpureum
Erysimum cheiranthoides	Linaria minor
Euphorbia helioscopia	Myosotis arvensis
Galinsoga parviflora	Ornithopus perpusillus
Juncus articulatus	Oxalis europaea
Lamium purpureum	Papaver spec.
Lycopsis arvensis	Ranunculus repens
Medicago spec.	R. sceleratus
Oxalis spec.	Rorippa islandica
Papaver rhoeas	Rumex acetosella
Ranunculus repens	Sagina procumbens
R. sceleratus	Sceleranthus annuus
Rorippa islandica	Senecio vulgaris
Rumex crispus	Sinapis arvensis
Satureja hortensis	Sisymbrium officinale
Senecio vulgaris	Solanum tuberosum
Sinapis arvensis	Sonchus arvensis
Sonchus arvensis	S. asper
S. asper	S. oleraceus
Taraxacum officinale	Spergula arvensis
Trifolium pratense	Spergularia rubra
T. repens	Taraxacum officinale
Triglochin maritima	Trifolium pratense
Typha angustifolia	T. repens
Urtica dioica	Urtica dioica
	Vicia sativa angustifolia
	Viola arvensis

Table 8. Similarity of weed populations on farms, expressed through the association index of Whittaker (1952).
I. Similarity of neighbouring farms with (plus) and without (minus) long term use of herbicides.
II. Idem, of farms without (minus) long term use of herbicides.
III. Idem, of farms with (plus) long term use of herbicides.

I.	II.	III.
C1 plus / C1 minus: 50	C1 minus / C2 minus: 36	C1 plus / C2 plus: 51
C2 plus / C2 minus: 49	C1 minus / C3 minus: 53	C1 plus / C3 plus: 25
C3 plus / C3 minus: 65	C2 minus / C3 minus: 24	C2 plus / C3 plus: 15
S1 plus / S1 minus: 51	S1 minus / S2 minus: 39	S1 plus / S2 plus: 16
S2 plus / S2 minus: 17	S1 minus / S3 minus: 27	S1 plus / S3 plus: 18
S3 plus / S3 minus: 56	S1 minus / S4 minus: 18	S1 plus / S4 plus: 7
S4 plus / S4 minus: 28	S2 minus / S3 minus: 29	S2 plus / S3 plus: 17
	S2 minus / S4 minus: 14	S2 plus / S4 plus: 16
	S3 minus / S4 minus: 15	S3 plus / S4 plus: 13

percentage of species

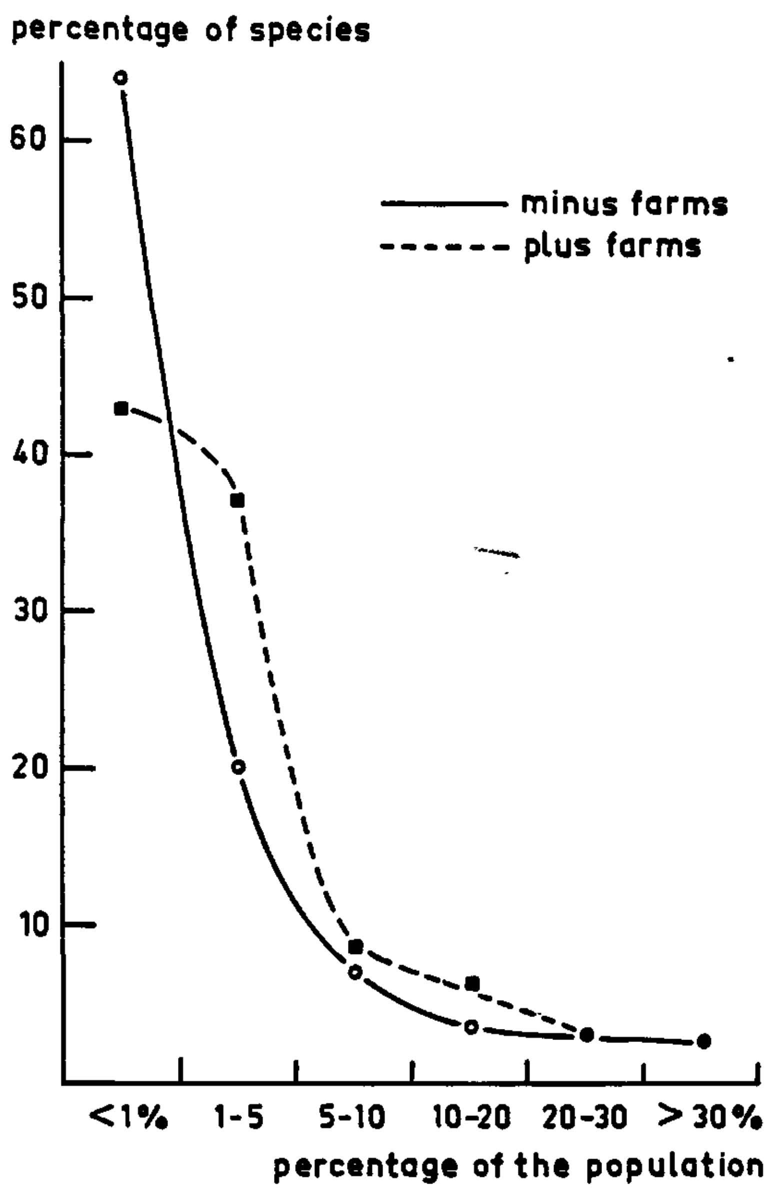

Fig. 1. Weed population built-up on farms with (plus) and without (minus) long term use of herbicides.

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