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EFFECTS OF METHOD OF SOIL MANAGEMENT ON ORCHARD WEED OCCURRENCE AND DISTRIBUTION

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ABSTRACT

Observations were carried out on the plant composition of apple orchard floors in different soil management methods (herbicide strips under trees vs. herbicide applied to entire orchard floor) in the years 1981-1996 (orchard I) and 1981-1989 (orchard II). *Capsella bursa - pastoris* (L.) Med., *Convolvulus arvensis* L. and *Erigeron canadensis* L. predominated in herbicide strips in the tree rows, *Amaranthus retroflexus* L., *Echinochloa crus - galli* (L.) P.B., *Erigeron canadensis* L., *Polygonum aviculare* L. and *Taraxacum officinale Web*. – in alleyways under over-all herbicides, and *Agropyron repens* (L.) P.B., *Lolium perenne* L., *Poa annua* L. and *Taraxacum officinale* Web. were the most abundant components of sod in interrows. The changes occurring in consecutive years and possible reasons for variable species behavior are discussed.

Key words: apple orchard, weeds, soil management

INTRODUCTION

In orchards and small fruit plantations a clear relationship exists between soil management methods and occurrence of different weed species. For example, long-term use of triazine herbicides encouraged the establishment of species resistant to these chemicals [1, 3, 6, 13, 15, 21]. Similar effects of herbicides were observed in both agricultural crops, e.g., corn, and in areas not used in agriculture, e.g., along railroads [19, 21]. An orchards creates special environmental conditions, resulting from shading, changes in soil properties in and between tree rows, and soil disturbance by mechanical equipment. The effects of these factors on plant populations have been discussed by numerous authors [6, 7, 10].

The purpose of our studies was to evaluate the relationship between orchard soil management systems and changes in weed populations over time. Observations were carried out in an apple orchard at AES Felin near Lublin (eastern Poland), on a light clay grey-brown podzolic soil.

MATERIALS AND METHODS

The orchard was planted in 1970 with 3.5 m between rows and 3.0 m between trees in the rows. Total area of the orchard was about 1.5 ha. Herbicide strips about 1.5 m wide were used in the tree rows in the first section (I) of the orchard (cv. Jonathan/M 4) with sod about 2.0 m wide in the alleyways. Herbicides were applied to the entire orchard floor in the second (II) part (cv. Spartan/M. 4). The same herbicides were used in both parts of the orchard: simazine (2-4 kg ha^{-1} pre every year as Gesatop 50), paraquat (4 l ha^{-1} as Gramoxone) at the beginning of the experiment and diquat (4 l ha^{-1} as Reglone), glufosinate (4 l ha^{-1} as Basta), MCPA (2 l ha^{-1} as Chwastox Extra) or glyphosate (5 l ha^{-1} as Roundup) post, depending on the year. Plant protection treatments and fertilization were the same in both parts, according to recent recommendations. Soil characteristics is given in the table 1.

Table 1. Some soil chemical properties in both parts of the orchard *

Orchard	Location	pH	Content of (mg/100 g of dry soil)		
			K	P	Mg
I	Tree rows	4.48	11.42	2.91	5.83
	Interrows	5.39	15.73	3.64	6.14
II	Tree rows	4.66	13.47	3.91	3.83
	Interrows	4.84	10.84	3.87	3.62

* means for the depth 0-30 cm; samples taken every 30 cm. across the interrows in summer 1983

Observations were made in part I in 1981-1996 and in part II in 1981-1989. The transect method was used, since it allows estimation of differences in plant distribution along the sections of the ground in the studied area [9]. All plant species found in a strip 10 cm wide between two trees growing in two adjacent rows and the length of the transect occupied by them were noted. Sixty analyses were made in part I and thirty in part II of the orchard every year. The same zones were sampled each year at the end of July or beginning of August, about four weeks after the last use of foliar herbicides or the last mowing of sod. The distribution of some weeds is presented as their frequency on a 10 cm long section of the transect, expressed as the means of 16 (Jonathan) or 9 (Spartan) years of study (fig. 1) or in each year (fig. 2) with *Erigeron canadensis* L. as an example. The percentage of the total

length of the transect covered with most frequent species over the years with some other characteristics of their occurrence are given in table 2 and table 3. The same data concerning the same species in the years are presented in table 4 and table 5.

Figure 1. The distribution of weed species across the alleyway (in %, means for 16 years – part I and means for 9 years, part II)

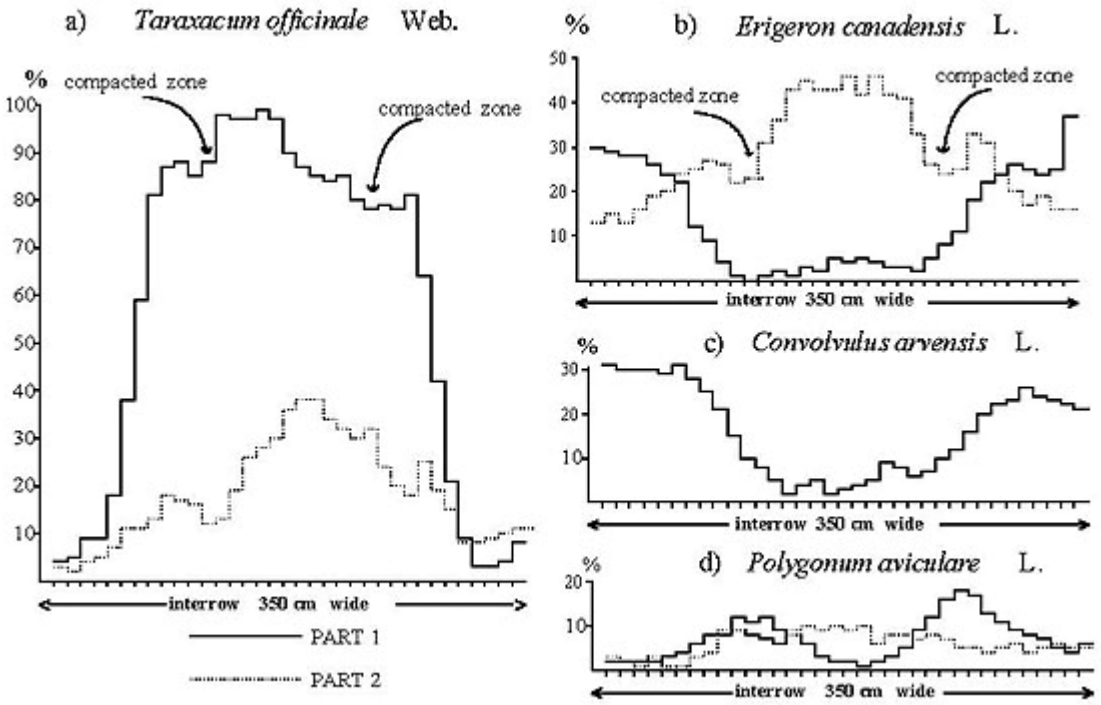
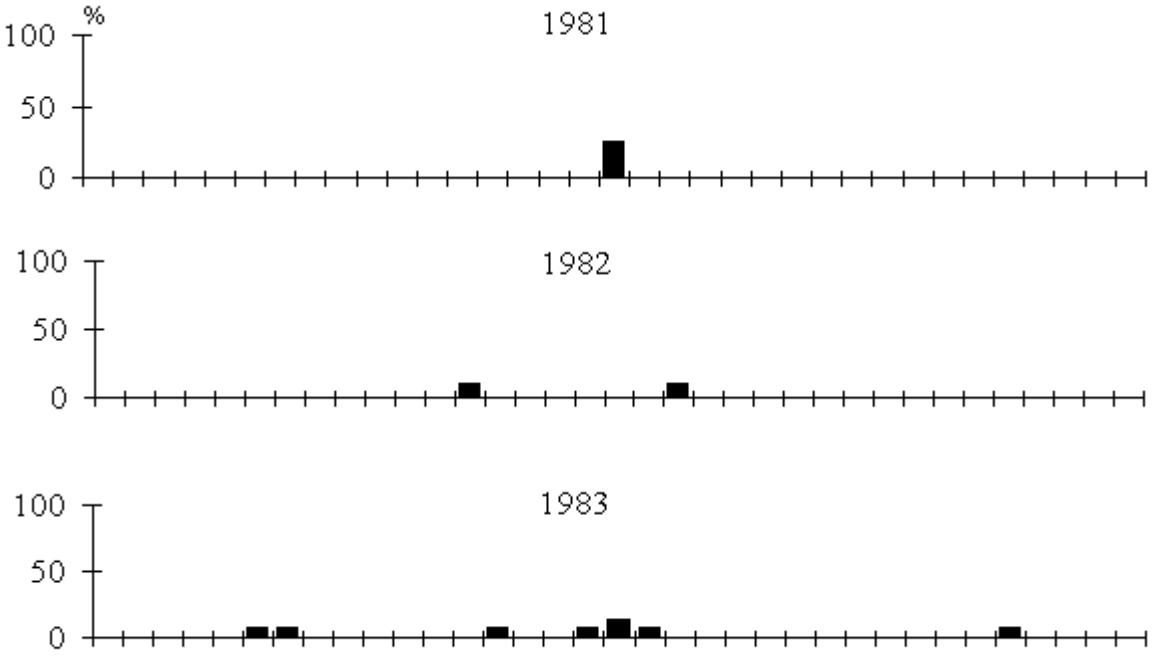
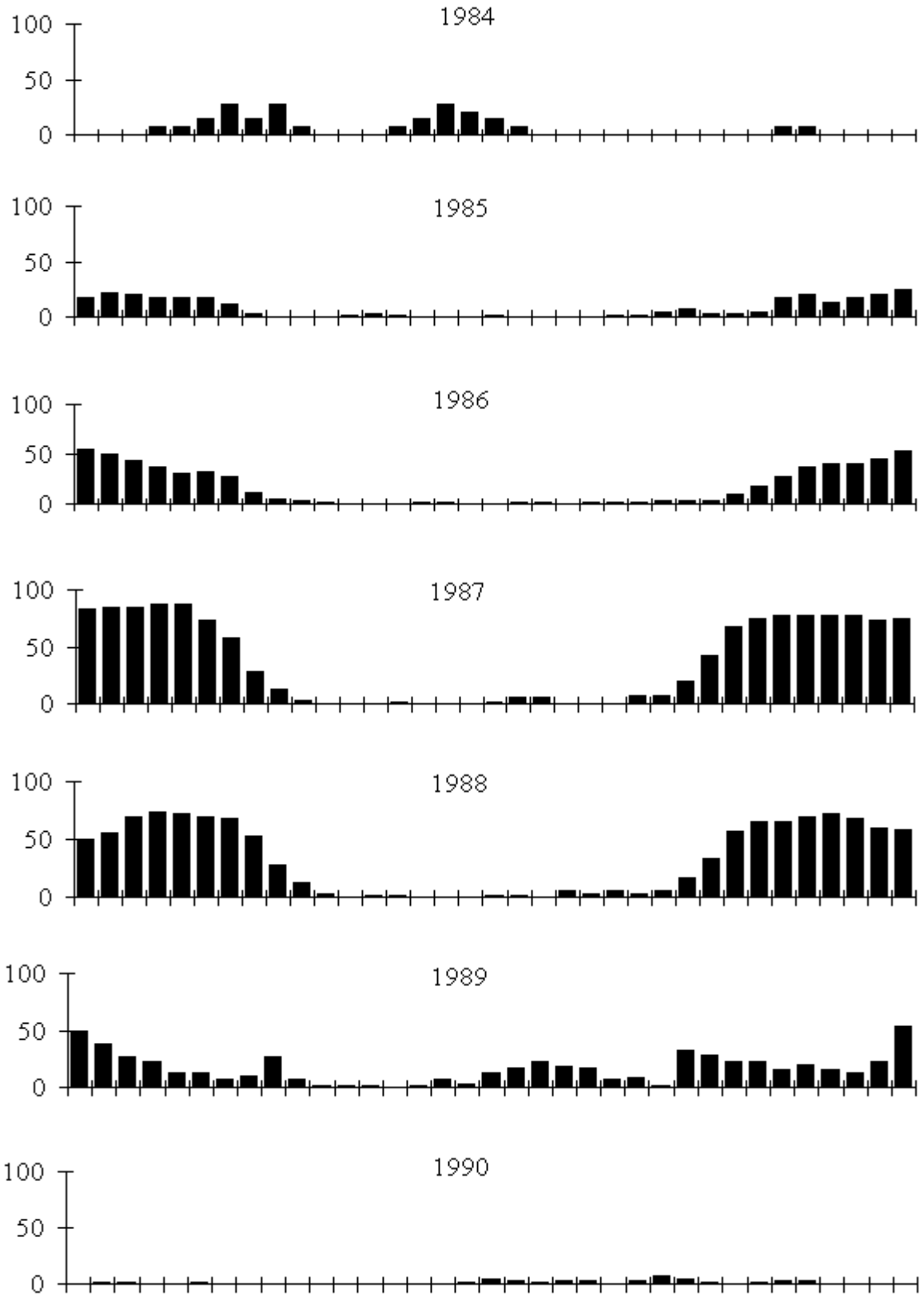


Figure 2. The frequency of *Erigeron canadensis* L. plants in 10 cm long parts of alleyway in the years 1981-1996

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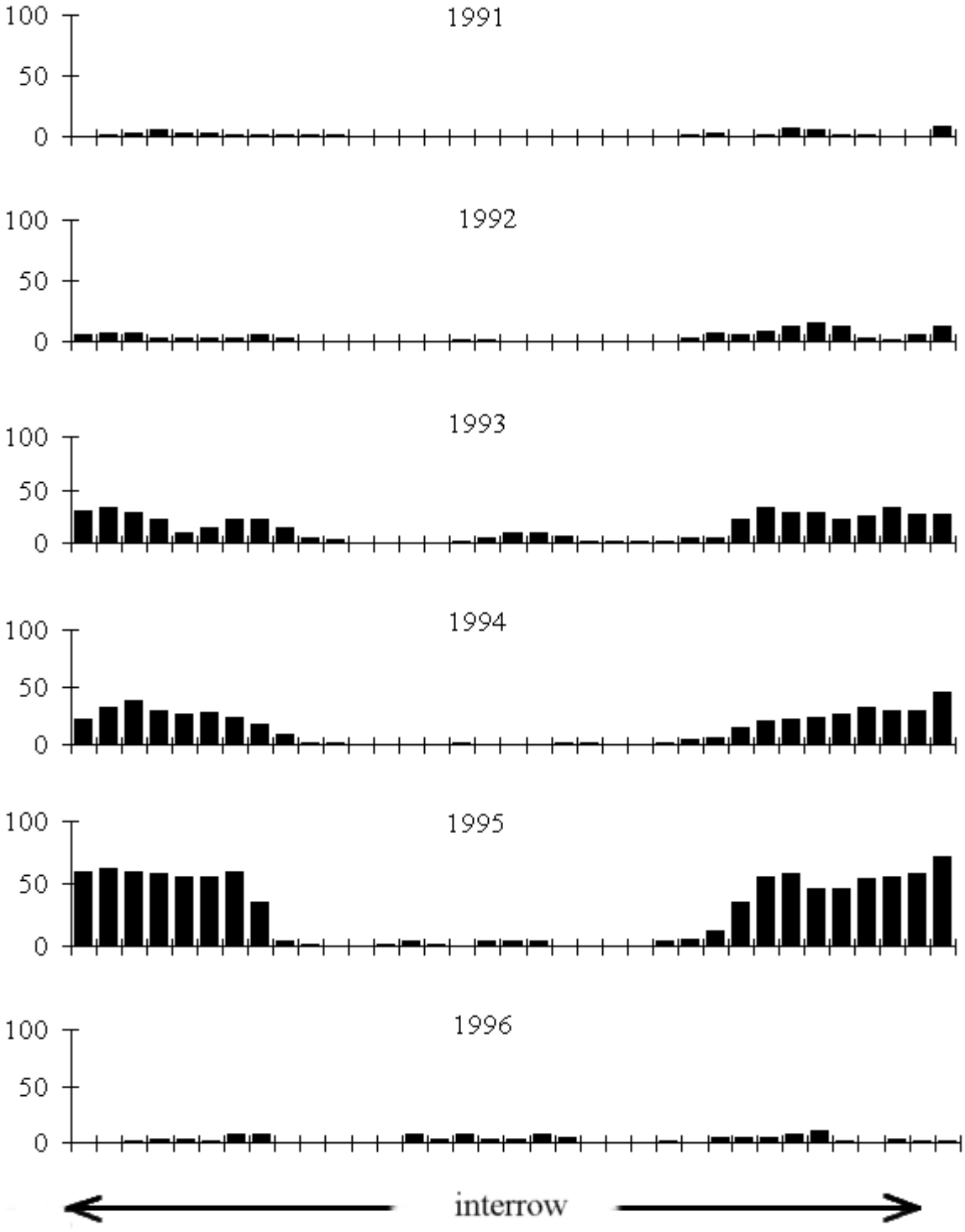

Table 2. Some characteristics of plant species most frequently found in orchard I (in alphabetical order)

Species	Part of interrow in which species was commonly found *	No. of years the species was found	Mean % of transect covered by the species
Achillea millefolium L.	x	16	0.9
Agropyron repens (L.) P.B.	+x	16	20.9

Atriplex patulum L.	o	13	0.6
Bromus mollis L.	x	15	1.1
Capsella bursa-pastoris (L.) Med.	o	16	5.4
Cerastium sp. L.	x	16	1.3
Convolvulus arvensis L.	o	16	11.3
Epilobium adenocaulon Hausskn.	o	8	1.0
Erigeron canadensis L.	o	16	9.7
Lolium perenne L.	+x	16	17.8
Malva neglecta Wallr.	ox	12	1.0
Plantago sp. L.	x	16	3.3
Poa annua L.	+x	16	12.8
Polygonum aviculare L.	++ox	16	6.1
Sonchus sp. L.	ox	16	2.6
Stellaria media Vill.	x	16	0.7
Taraxacum officinale Web.	+ox	16	33.0
Trifolium repens L.	x	16	2.4
Urtica dioica L.	o	16	1.7

* x – plants growing mainly in the middle of alleyway,
o – plants growing mainly in the tree rows,
ox – plants growing in both areas,
+ – plants growing in compacted areas,
++ – plants growing abundantly in compacted areas.

Table 3. Some characteristics of plant species most frequently found in orchard II (in alphabetical order)

Species	Part of interrow in which species was commonly found *	No. of years the species was found	Mean % of transect covered by the species
Agropyron repens (L.) P.B.	ox	8	2.8
Amaranthus retroflexus L.	x	9	5.2
Atriplex patulum L.	o	8	1.9
Capsella bursa-pastoris (L.) Med.	+xo	7	2.1
Chenopodium album L.	o	1	0.2
Cirsium arvense (L.) Scop.	ox	4	0.2
Convolvulus arvensis L.	ox	6	0.4
Echinochloa crus-galli (L.) P.B.	ox	9	5.2
Erigeron canadensis L.	ox	8	23.1
Lolium perenne L.	ox	6	0.6
Poa annua L.	ox	6	0.7
Polygonum aviculare L.	+xo	9	5.2
Polygonum convolvulus L.	x	6	0.6
Stellaria media Vill.	ox	4	0.2
Taraxacum officinale Web.	+xo	9	13.9
Urtica dioica L.	o	7	0.7

* x – plants growing mainly in the middle of alleyway,
o – plants growing mainly in the tree rows,
ox – plants growing in both areas,
+ – plants growing in compacted areas.

Table 4. The percentage of the transect covered by some species plant in the consecutive years (in alphabetical order), orchard I

Plant species	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Achillea millefolium L.	0.7	0	0.2	0.5	0.8	1.8	1.6	1.3	1.2	0.7	0.7	0.6	1.1	1.1	1.1	2.2
Agropyron repens (L.)	30.1	36.2	5.6	30.1	38.8	29.1	24.6	19.3	17.4	15.4	17.3	20.5	15.7	11.1	1.8	2.7
P.B.	0.1	0.1	0	0	0.3	0.5	0.4	0.1	0.2	0	0.2	0.9	1.8	0.7	4.5	1.4
Atriplex patulum L.	0,1	0	0,3	1,7	1,4	0,3	1,2	0,6	0,5	2,7	2,5	1,3	2,0	1,7	0,9	0.3
Bromus mollis L.	1.0	0.9	0.5	2.4	2.9	1.9	3.4	1.1	1.1	4.5	4.2	4.1	18.2	20.2	14.6	6.8
Capsella bursa-pastoris	1.2	0.1	1.1	3.1	2.7	1.0	1.5	0.2	1.0	0.5	1.5	0.3	0.8	0.6	3.3	1.1

(L.) Med.	7.1	7.1	4.1	7.2	11.0	12.1	12.7	17.2	16.8	14.6	14.6	15.6	10.2	8.0	11.0	7.6
Cerastium sp. L.	0	0	0	0	0	0	0	0	0.2	0.1	0.3	0.9	2.5	4.8	6.6	2.8
Convolvulus arvensis L.	0.1	0.1	0.4	1.3	5.9	16.6	33.4	28.8	12.7	0.8	1.0	1.8	10.7	8.1	24.1	1.3
Epilobium adenocaulon Hausskn.	0.5	0.7	2.2	9.6	9.0	7.0	11.6	14.7	15.5	17.1	23.7	28.1	34.0	39.4	53.7	47.7
	0	0	1.3	2.5	3.0	3.0	2.4	0.7	0.5	0.6	0	0.1	0	0	0.3	0.4
Erigeron canadensis L.	5.5	1.5	2.9	1.8	4.0	8.2	8.1	3.7	4.5	4.0	1.1	1.8	1.2	0.7	0.4	1.5
Lolium perenne L.	27.4	6.5	28.3	18.2	13.7	7.9	17.8	12.6	11.2	8.0	15.7	10.2	5.3	2.5	6.0	4.0
Malva neglecta Wallr.	11.3	9.9	15.5	9.5	5.6	12.9	11.9	0.2	1.0	0.7	0.4	1.3	0.3	1.1	10.6	10.3
Plantago sp. L.	2.2	2.7	5.3	4.2	3.5	2.8	3.7	1.9	2.6	2.9	2.7	1.8	1.2	1.4	0.5	0.9
Poa annua L.	1.0	0.1	0.2	1.6	2.4	0.1	0.3	1.0	0.5	0.1	0.9	0.1	1.0	0.2	0.4	4.9
Polygonum aviculare L.	48.0	34.0	46.9	31.4	40.0	45.7	36.8	46.0	34.8	29.4	27.7	36.6	19.7	9.6	8.7	9.1
Sonchus sp. L.	3.5	0.4	3.4	6.1	9.1	1.8	3.1	0.8	0.7	0.5	1.4	0.9	0.9	1.2	2.5	6.1
Stellaria media Vill.	0.6	0.5	0.4	0.8	1.4	0.9	2.0	1.5	1.5	2.9	2.3	1.8	1.5	2.1	0.9	3.3
Taraxacum officinale Web.																
Trifolium repens L.																
Urtica dioica L.																

Table 5. The percentage of the transect covered by some species plant in the consecutive years (in alphabetical order), orchard II

Plant species	1981	1982	1983	1984	1985	1986	1987	1988	1989
Agropyron repens (L.)P.B.	1.3	2.9	6.9	5.0	3.3	0	3.5	1.6	0.4
Amaranthus retroflexus L.	0.2	1.1	6.7	12.1	3.5	0.9	7.4	4.2	10.7
Atriplex patulum L.	0	1.1	0.7	2.0	2.6	0.9	1.6	4.5	3.3
Capsella bursa-pastoris (L.)Med.	1.7	2.2	0.3	3.8	0.2	0	0	2.5	8.0
Chenopodium album L.	1.4	0.5	0.1	0	0	0	0	0	0
Cirsium arvensis (L.) Scop.	0	0.6	0	0.5	0.1	0.3	0	0	0
Convolvulus arvensis L.	1.1	0.2	0	0.7	0	0.4	0.8	0	0.4
Echinochloa crus-galli (L.)P.B.	5.6	7.1	7.6	9.1	0.9	0.4	1.0	2.5	12.2
Erigeron canadensis L.	0	0.5	0.7	7.4	58.6	73.2	36.7	24.7	6.4
Lolium perenne L.	0	0	1.1	0.6	0.2	0.5	0	0.8	2.1
Poa annua L.	1.4	0.4	0	1.3	0	0.1	0	2.1	1.2
Polygonum aviculare L.	8.6	4.9	16.7	5.2	0.4	1.0	3.0	4.9	1.6
Polygonum convolvulus L.	3.9	0.3	0.6	0.1	0	0.1	0	0.3	0
Stellaria media Vill.	1.4	0.2	0.3	0.3	0	0	0	0	0
Taraxacum officinale Web.	0.7	5.4	23.8	22.4	17.7	12.1	2.4	19.2	21.7
Urtica dioica L.	0	0.3	0.5	0	0.7	0.3	1.4	2.2	0.9

RESULTS

Twenty-three species were found in herbicide strips and a total of forty-one species over all in part I of the orchard, whereas a total of thirty-four species occurred in part II. Weed species considered resistant to triazines (or biotypes resistant within susceptible species) predominated in the area treated with herbicides. Nature and frequency of species, however, differed between parts of the orchard and between sod and herbicide-treated areas.

Predominating plants in part I were: common dandelion (*Taraxacum officinale* Web.), couch grass (*Agropyron repens* (L.) P.B.), perennial ryegrass (*Lolium perenne* L.) and annual meadowgrass (*Poa annua* L.) in the alleys, and field binweed (*Convolvulus arvensis* L.), Canadian fleabane (*Erigeron canadensis* L.) and shepherd`s purse (*Capsella bursa – pastoris* (L.) Med.) in the tree rows. Most frequent plants in part II were: Canadian fleabane, common dandelion, redroot pigweed (*Amaranthus retroflexus* L.), barnyard grass (*Echinochloa crus – galli* (L.) P.B.) and, at the end of the observation period, shepherd`s purse. Knotweed (*Polygonum aviculare* L.) was the only plant clearly preferring the wheel tracks (fig. 1d).

The changes in species frequency over time were observed.

Perennial ryegrass, shepherd`s purse and willow herb (*Epilobium adenocaulon* Hausskn.) increased in occurrence in part I in the years 1981-1995, 1993-1995 and 1993-1995, respectively. Decrease was evident in the case of couchgrass and, to a lesser extend, common dandelion (part I). Less evident tendencies were noticed in part II of the orchard, although the occurrence of weeds changed markedly depending on the year. Canadian fleabane grew sporadically across alleyways in both orchards in the years 1981-1983 (or 1984, part I), then increased rapidly in frequency (mainly in tree rows), with the highest values reached in the years 1986-1988 (part I) and 1985-1988 (part II), followed by another very rapid decrease in 1989 (part II) and 1990-1992 (part I). Another peak was noticed in the year 1995 in part I. Shepherd`s purse, which was rarery found in the period 1981-1989, increased slowly in 1990-1992, then rapidly in the years 1993-1995, followed by a reduction (1996) in orchard I. The same plant had two peaks in orchard II, the first in 1984 and a second, much higher one, in 1989. Willow herb appeared first in 1989 in orchard I and its occurrence increased toward the end of the experiment, but only on herbicide treated areas in the tree rows.

DISCUSSION

The species growing in both parts of the orchard were more numerous than those found by other workers. Elmore et al. [6] found more than 20, Merwin [14] between 15 and 50, Rode and Paetzold [17] not more than 36, Stanković et al. [20] an average of 7.8-11.1, depending on herbicide used, and 16.9 without herbicides, Jung et al [8] – 69, but in 27 orchards. The apparent reason for the differences in vegetation in the two parts of the orchard was the use of different soil management methods. The effect of herbicides on the flora in orchards has been reported by numerous authors [1, 2, 3, 6, 14, 20]. In general the use of triazine herbicides favors weed species and/or biotypes resistant to these chemicals. Our results are in agreement with these findings. The opinion [23] that the use of herbicides decreases the number of species relative to those found in sod has also been confirmed in this study.

When herbicides were applied to the entire orchard floor (orchard II), species resistant to them covered larger transect percentages than in orchard I, where herbicides were used in the tree rows only (table 2 and 3). Canadian fleabane is a good example (fig. 1b). However, other plants, such as common dandelion (fig. 1a) and couchgrass were more common in orchard I, since they grew mainly in sod in the alleyways.

Despite close proximity, differences in the occurrence of some weed species in both parts of the orchard could have resulted from differing soil properties, mainly chemical composition. Nutritional requirements of weed species differ [5, 17]. For example, pigweed has high soil fertility requirements and its growth is favored by high light [5], which explains its presence in the middle parts of alleyways in part II and its absence from herbicide strips under trees in part I. Another reason for the absence of pigweed from the tree rows is the presence of bindweed, whose allelopathic action against pigweed is documented [22]. Bindweed requires less light [5], so it can grow freely in shade, forming dense patches (fig. 1c). However, low frequency of bindweed in part II of the orchard is difficult to explain, since this weed is resistant to simazine and should find the proper conditions to grow in this environment. Most of the species found in orchards are considered to be nitrophilous [5], so they can grow in bare soil after treatment with herbicides (usually rich in nitrogen), providing they are resistant or tolerant to these chemicals. Examples include shepherd`s purse, Canadian fleabane, common orache, stinging nettle, goosefoot, and common mallow. Common dandelion did not show clear differences in occurrence in both orchard parts. No correlation was observed between its appearance in the orchard and light intensity, soil humidity, acidity ant nitrogen

content [18]; this plant does not have high requirements for light, water and soil fertility [5]. Lack of competition of other plants in the alleyways could be the reason for the abundance of barnyard grass in orchard II, in comparison with orchard I.

Growth of weeds in the compacted area seemed to be limited by effects of mechanical action *per se* rather that by interaction between compaction and activity of herbicides. Knotweed was the only plant growing abundantly in and/or along the compacted areas. Shepherd`s purse, perennial ryegrass, and annual meadowgrass were more numerous between compacted zones and herbicide strips than in other parts of the interrow. One of possible reasons for this is the formation of depressions in compacted areas and close to them [12], making mowing less effective than in the middle parts of alleyways. Another reason could be higher humidity and fertility of the soil in compacted areas [12], apart from their disturbed structure. Compaction itself favors the development of some plants, such as knotweed [10].

The biggest changes in consecutive years were in the occurrence of Canadian fleabane and, to a lesser extent, shepherd`s purse (in both parts of the orchard), pigweed and barnyard grass (under over-all herbicide) and also willow herb during the last year of the experiment. Rapid changes in the weed populations in consecutive years were also observed by Mahn [13]. They may be connected with some climatic factors [4]. For example annual meadowgrass was found more often in years with high precipitation in June and/or July, whereas its growth was limited by dry weather at this time.

Probably one of the main reasons for all these changes was the behavior of Canadian fleabane. In years when this weed predominated most other plants dissappeared from the orchard or their occurrence was severely limited (table 5). Good examples are shepherd`s purse, pigweed and barnyard grass in 1986 and also common dandelion in 1987. When the frequency of Canadian fleabane declined in 1989, the frequency of these weeds increased. Sudden and massive appearence of Canadian fleabane in numerous orchards in the mid-1980s was undoubtedly connected with selection for resistance to triazines within this species [15]. Similar phenomena occurred in the case of shepherd`s purse [11] and willow herb [2] at the end of the experiment. The rapid disappearance of Canadian fleabane in 1989-1992, as well as its increase in 1993 (part I) could be explained by the data of Regehr and Bazzaz [16]. They pointed out that the reproductive success of *Erigeron canadensis* L. is enhanced by low density of plants (i. e., large rosettes in winter). In the years of its highest density in orchard II the number of individual plants per square meter was so high that rosettes were small and their survival as well as seed production next year were low. Regehr and Bazzaz [16] also stated that the population of Canadian fleabane is never stable in time and space.

Clear replacement of couchgrass by perennial ryegrass observed in this study was probably caused by frequent mowing of sod; various environmental conditions also may have affected this transition.

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