Early Weed Succession on an Abandoned Field: Vegetation Composition and Production of Biomass*

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Abstract

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We investigated the early stage (second to fourth year) of weed succession on an experimental fallow field in central Bohemia (western Czech Republic). The experimental ground was ploughed in the autumn, harrowed and rolled in the spring, and divided into 5 × 5 m plots. In the control the weed stands were left intact, the other variants were mowed with or without cultivation of the superficial soil layer in June and July. The position of the plots and the treatments were the same each year. The production of aboveground biomass and proportion of monocotyledonous and dicotyledonous annuals and perennials in different years (1993 to 1995) were recorded. The production of biomass (the aboveground crop of weeds in September) was highest in the controls with no treatment. In mowed or cultivated plots the total biomass production (the sum of biomass at the time of the treatment plus biomass re-grown after the treatment) was greater when the treatment was made in July than in June. In the second year of succession, the biomass of annuals was greater than that of perennials. From the third year on, perennial dicotyledonous species became the dominant weed community, in controls as well as on mowed or superficially cultivated plots. The rate of increase of the proportion of dicotyledonous perennial weeds was greatest in mowed plus superficially cultivated plots, intermediate in the controls, and lowest in plots where the weeds were only mowed.

Key words: fallow field; weeds; monocotyledonous plants; dicotyledonous plants; perennial; annual; succession

Generally it is well known that in the course of a succession of weed vegetation on abandoned fields, annuals are replaced by perennials during the few early years of succession (OSBORNOVÁ *et al.* 1990). However, the rate of change in the composition of weed communities depends on several factors including local climate, available soil seed bank and soil conditions. In extreme cases, perennials may replace annuals even in the second year of succession (BROWN *et al.* 1987). Consequently, several studies have dealt with aspects of the rate of invasion of perennial weeds in abandoned fields or in fallow fields integrated into the crop rotation sequence, while others focused at cultivation technologies that may manipulate the rate and mode of succession of weed species (SCHMIDT 1986; SHASKOV 1981; TSIKOV *et al.* 1980; NAMURA-OCHALSKA 1993; DERKSEN *et al.* 1994; HINTZSCHE & PALLUTT 1995; MOKSHIN 1978).

The change of land ownership and systems of agricultural production in the Czech Republic increased the acreage of abandoned fields. The main problem is growth of weeds that are difficult to eradicate by usual agricultural practices, which would make a later reversion of abandoned fields into cultivated ones difficult and expensive. This situation made a study of the rate of weed succession under local conditions relevant. We, therefore, recorded the rate of succession on an experimental abandoned field established in central Bohemia (western part of the Czech republic); the field had previously grown different agricultural crops. Investigated was the aboveground biomass of weed communities as affected by measures aimed at decreasing weed growth, i.e., mowing or mowing followed by superficial cultivation.

MATERIAL AND METHODS

Experimental ground. The experiment was performed at Prague-Ruzyně (50°06' N, 14°15' E, altitude 350 m above sea level) in a field used for small plot experiments since the 1950's. Before the experiment, the ground had been routinely cultivated each year (medium depth plough-

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ing in the autumn, harrowing and rolling in the spring) and sown with different cover crops (mustard, mixtures of oats and peas, millet) without fertilization. The experiment was established in 1992. The paper reports data of the second to fourth year (1993 to 1995) of the succession; comparable data of the first year are not available. The 25 × 25 m experimental area was situated in the corner of an experimental field and was bordered by cover crops (east and south), an asphalt road (north), and a grass balk (west). The marginal position might facilitate the penetration of perennial weeds from the ridges.

Experimental treatment. The experiment started in 1992 and continued until 1995. Each year the experimental area was ploughed to a medium depth (15–20 cm) in November–December. The next spring (late March–early April) the ground was machine harrowed and manually rolled (to prevent uneven soil compression). Then it was divided into 25 plots of 5 × 5 m whose position was identical each year. The weed stands were then left to develop spontaneously. There were five plots for each of the following treatments: early mowing (June 9, 1993, June 8, 1994 and June 13, 1995) further referred to as M-June, late mowing (July 22, 1993, July 19, 1994 and July 26, 1995) further referred to as M-July, early mowing plus cultivation of the superficial soil layer (on the same dates as early mowing) further referred to as C-June, late mowing plus cultivation (on the same dates as late mowing) further referred to as C-July, and no treatment (control). The mowing consisted of manual cutting of the aboveground parts of weeds taller than 5 cm. Superficial cultivation (which followed mowing and removal of the aboveground biomass) consisted of manual disturbance of the upper 5 cm of the soil which cut the roots and rootstocks to a depth of 5 cm. Plots with different treatments were arranged in a latin square design so that the same treatments were not repeated in rows or columns.

Measuring plant cover characteristics. The production (standing crop) of aboveground biomass of weeds was measured at the time of mowing in June or July, and at the end of the season (between September 15–October 15). After mowing, the weeds were separated into annual and perennial dicotyledonous and annual and perennial monocotyledonous plants. The wet mass of the total samples of weeds of each category from each plot was determined. Of each wet mass sample of each weed category 200–400 g were oven dried and weighed, and the dry mass of the sample was calculated. At the end of the vegetation season the aboveground biomass was established by harvesting two or four 1 m^2 areas from each experimental plot. The harvested weeds were divided into species whose biomass was determined. The total biomass of control plots was calculated as the sum of dry biomasses of each species. Total production on mowed plots was calculated as aboveground dry mass of weeds at the time of mowing plus dry mass harvested at the end of the vegetation season. The biomass of weeds on C-June and C-July plots was not measured at the time of mowing; the values from mowed plots were used instead.

Data elaboration. The statistical significance of differences between treatments and years were tested by LSD test of contrasts included in the one way analysis of variance (ANOVA) of Statistica for Windows (STATSOFT 1994). Botanical nomenclature follows DOSTÁL (1988).

RESULTS

Biomass production. The total biomass produced throughout the season varied from year to year. It was significantly smaller in 1994 than 1993 and 1995 (Table 1). The production of biomass in 1994 was negatively influenced by drought (May to July sum of precipitation 111 mm) combined with high temperature (average May to July temperature 17.9 °C). This contrasted with a more rainy and cooler 1993 (233 mm, 15.9 °C) and 1995 (269 mm, 16.0 °C). The total production varied also with treatment. The highest final biomass was determined in the controls where the weed stands were left intact throughout the season. Mowing or cultivation in July (Table 1) did not sig-

Table 1. The total weed (mean ± SD) aboveground biomass (g/m^2) in the autumn (grown after June and July treatment) and over the whole vegetation period (pooled biomass grown before and after June and July treatments). See Material and Methods for explanation of abreviations of treatments

		C-June	C-July	M-June	M-July	Control
Autumn	1993	267.8 ± 27.5^{abklf}	88.0 ± 3.3^{adg}	322.0 ± 18.5^{dcklh}	139.4 ± 22.3^{bce}	451.2 ± 52.8^{kefgh}
	1994	180.4 ± 15.6^{ake}	113.8 ± 7.1^{ac}	163.8 ± 15.2^{kd}	140.2 ± 12.2^{b}	305.4 ± 21.6^{klbcde}
	1995	194.6 ± 23.7^{ablg}	61.5 ± 5.2^{adh}	215.2 ± 20.7^{cdle}	98.0 ± 11.4^{bcf}	451.0 ± 14.3^{lefgh}
Season total	1993	–	375.8 ± 59.8	–	443.4 ± 54.7^{k}	451.2 ± 52.8^{k}
	1994	243.2 ± 22.3	287.0 ± 19.1^{k}	227.0 ± 11.8	313.6 ± 25.1^{kl}	305.4 ± 21.6^{kl}
	1995	274.8 ± 21.4^{abe}	395.8 ± 40.7^{ak}	296.0 ± 24.3^{cd}	420.0 ± 42.2^{bcl}	451.0 ± 14.3^{del}

The figures followed by the same letters are different at $p < 0.05$. Tested were differences between years within treatments (*k*, *l*) and between treatments within years (*a*–*h*) nificantly decrease total weed biomass produced over the season (i.e., the sum of biomass standing at the time of treatment plus biomass grown from the treatment until the end of the season), on average only by 3–12%. The difference against the control was not significant. Mowing or cultivation in June (Table 1) decreased significantly the total biomass production in 1995 by 35–36% compared to the control. The biomass of the M-June sample was 19% (average of 1993–1995) of the total annual production on the control plots, the biomass of M-July was 65% of the control (Table 2). The growth of weed biomass following treatments varied with years and time of treatments. The low increase of weed biomass following June mowing and cultivation in 1994 was probably caused by low June–July precipitation (62 mm) compared to high precipitation in 1993 (182 mm) and 1995 (174 mm). By contrast, the production of biomass following July mowing and cultivation was highest in 1994, probably due to high August precipitations (79 mm, compared to 40 and 53 mm in 1993 and 1995, resp.). In 1993–1995, the average biomass produced following June and July mowing was 8% and 26% higher than the biomass produced following June and July cultivation. The total biomass production over the season was lowest after June treatments, regardless of whether they were mowed or cultivated. The differences between mowing and cultivation in June or July were not significant (Table 1).

Vegetation succession. The weed community through the second to fourth year of the experiment was represented by more than 60 species. Abundant species were *Alsinula media* (L.) Dost., *Amaranthus retroflexus* L., *Anagallis arvensis* L., *Artemisia vulgaris* L., *Capsella bursa-pastoris* (L.) Medik., *Cirsium arvense* (L.) Scop., *Chenopodium album* L., *Echinochloa crus-galli* (L.)

Table 2. Weed biomass (mean ± SD, g/m^2) harvested from mowed plots in June and July

		Annual		Perennial		
		monocotyledonous	dicotyledonous	monocotyledonous	dicotyledonous	Total
June	1993	–	–	–	–	–
	1994	0.02 ± 0.02	9.2 ± 2.43	2.56 ± 0.87	51.18 ± 9.9^{k}	62.96
	1995	0	1.31 ± 0.41	6.98 ± 3.1	72.42 ± 5.58^{k}	80.72
July	1993	5.76 ± 3.58	228.24 ± 43.93^{kl}	2.54 ± 1.98	68.03 ± 13.2^{km}	304.57
	1994	3.3 ± 2.46	15.58 ± 8.88^{k}	2.8 ± 1.11	151.76 ± 17.42^{kl}	173.44
	1995	1.32 ± 0.6	4.1 ± 0.9^{l}	24.48 ± 7.01	292.5 ± 33.75^{lm}	322.4

The figures followed by the same letters are different at $p < 0.05$. Tested were differences between years within treatments terms of mowing (k–m)

Table 3. The biomass of monocotyledonous (monocot) and dicotyledoneous (dicot) weeds in the autumn (mean ± SD, g/m). See Material and Methods for explanation of abreviations of treatments

			C-June	C-July	M-June	M-July	Control
1993	annual	monocot	54.0 ± 16.5^{kl}	15.2 ± 7.8	65.5 ± 11.8^{k}	47.4 ± 15.2^{k}	46.5 ± 9.8^{kl}
		dicot	89.0 ± 16.5^{abmn}	13.1 ± 3.7^{bc}	182.6 ± 3 0.3^{acdlm}	54.6 ± 15.7^{dl}	332.7 ± 52.3^{mn}
	perennial	monocot	6.4 ± 2.6	1.6 ± 0.7	0.9 ± 0.6	1.6 ± 1.2	6.3 ± 2.6^{o}
		dicot	118.2 ± 35.7^{ab}	58.4 ± 12.8^{a}	73.2 ± 23.5^{n}	36.1 ± 7.6^{b}	65.7 ± 21.5^{qr}
1994	annual	monocot	8.9 ± 3.2^{ak}	2.7 ± 1.4^{b}	48.5 ± 7.0 ^{ab}	26.3 ± 6.4	19.3 ± 3.4^{k}
		dicot	4.9 ± 2.0^{abm}	5.1 ± 1.1^{cd}	33.9 ± 12.0^{bdl}	34.6 ± 9.7^{ac}	35.4 ± 5.0^{m}
	perennial	monocot	0.7 ± 0.3	11.1 ± 4.6	10.1 ± 3.6	14.6 ± 5.3	22.1 ± 11.8^{p}
		dicot	165.8 ± 18.1^{ab}	94.8 ± 5.2^{cd}	71.6 ± 16.8^{bo}	65.2 ± 8.2^{ad}	228.7 ± 19.9^{rs}
1995	annual	monocot	20.4 ± 3.1^{l}	1.7 ± 1.5	27.4 ± 5.8^{k}	11.1 ± 5.9^{k}	2.73 ± 1.3^{l}
		dicot	5.9 ± 2.3^{n}	1.2 ± 0.3	14.4 ± 5.3^{m}	3.8 ± 1.4^{l}	13.6 ± 9.9^{n}
	perennial	monocot	8.3 ± 3.3	6.4 ± 1.3	21.7 ± 6.3	15.7 ± 6.1	54.1 ± 32.8^{op}
		dicot	159.9 ± 21.2^{ad}	52.3 ± 8.4^{ab}	151.9 ± 20.1^{bcno}	67.4 ± 15.6^{cd}	380.8 ± 24.6^{qs}

The figures followed by the same letters are different at $p < 0.05$. Tested were differences between years within plant types (k–s), between M and C treatments within years, term of treatment and plant type (a–d), and between terms of treatment within treatments, years and plant types ()

Beauv., *Elisanthe noctiflora* (L.) Willk, *Elytrigia repens* (L.) Desv., *Fallopia convolvulus* (L.) Á. Löve, *Galinsoga parviflora* Cav., *Galium aparine* L., *Lactuca serriola* L., *Lamium amplexicaule* L., *Matricaria maritima* L., *Medicago lupulina* L., *Persicaria lapathifolia* (L.) S. F. Gray, *Plantago major* L., *Polygonum aviculare* L., *Rumex crispus* L., *Solanum nigrum* L., *Sonchus arvensis* L., *Sonchus asper* (L.) Hill, *Sonchus oleraceus* L., *Thlaspi arvense* L., *Tithymalus helioscopia* (L.) Scop., *Tussilago farfara* L., *Urtica urens* L., *Veronica agrestis* L., *Veronica persica* Poir. in Lam. The abundant species did not change during the three years of the experiment. The effect of treatments on species composition was not significant, and the species composition in the spring (before mowing or cultivation) was similar in controls and treated plots. However, there were significant changes in the proportion of annual and perennial dicotyledonous and monocotyledonous plants. Annuals dominated the stands in 1993 (the second year of the experiment). In dicotyledonous plants, *Th. arvense*, *A. retroflexus*, *L. amplexicaule* and *E. noctiflora* were most abundant at the time following spring germination, while *A. retroflexus*, *G. parviflora* and *L. serriola* represented the greatest proportion of biomass at the end of the season. The most abundant monocotyledonous annual was *E. crus-galli*. In the third and fourth years the biomass was dominated by dicotyledonous perennials, *C. arvense* and *T. farfara*, and among monocotyledonous plants *E. repens*. The shift of dominant position from annuals to perennials between 1993 and 1994 was the combined effect of a decreasing abundance of *A. retroflexus* and the very small size of plants of this species in 1994.

The composition of the weed biomass in the autumn was influenced both by mowing and cultivation. The autumn biomass of annuals and their proportion in the total biomass was greater on mowed than on cultivated plots (Table 3, Fig. 1). The biomass of perennial dicotyledonous plants and their proportion in the total biomass was significantly greater on cultivated than on mowed plots in 1993 and 1994. However, on mowed plots the biomass of perennial dicotyledonous plants continously increased from 1993 to 1995 so that in 1995 their biomass was similar in cultivated and mowed plots. At the same time, the proportion of perennial dicotyledonous plants on mowed plots was significantly lower than on cultivated plots. The biomass of monocotyledonous perennials and their proportion in the total biomass increased till 1995. It was greater on mowed than on cultivated plots, but the differences were not significant. The time of mowing or cultivation, June or July, did not affect the proportion of perennial dicotyledonous and monocotyledonous plants in the total weed biomass. The total biomass of dicotyledonous perennials (produced before and after mowing) and their proportion in the total biomass were similar in control plots (average 77% of 1994 and 1995) and plots mowed in July (78%), but smaller in plots mowed in June

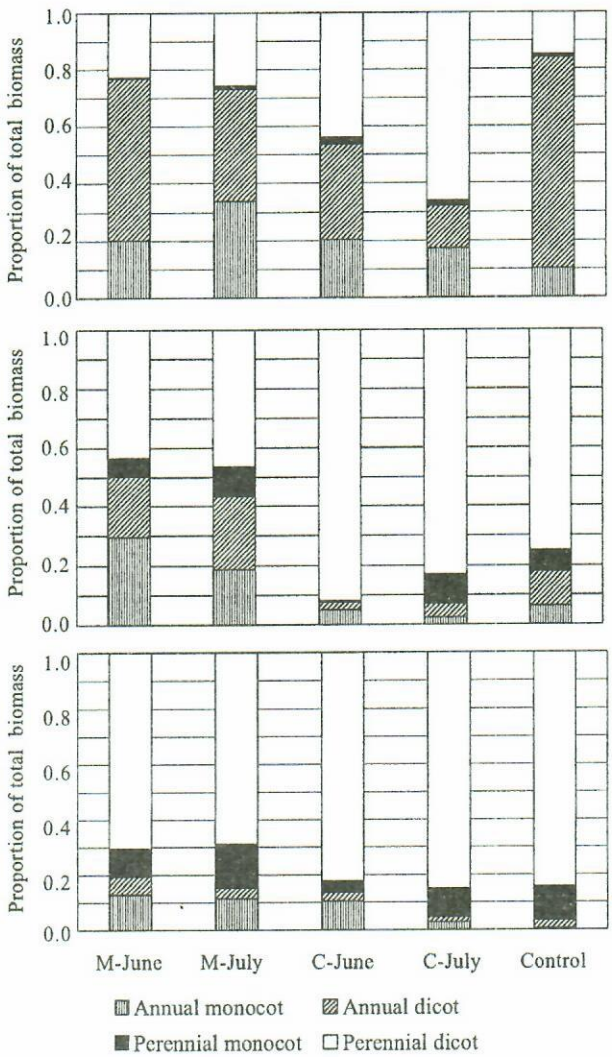

Fig. 1. The proportion of biomass of annual and perennial monocotyledonous (monocot) and dicotyledonous (dicot) plants in plots with different treatments (see Material and Methods for explanation of abbreviations) in 1993 (top), 1994 (middle), and 1995 (bottom)

(65%). The proportion of monocotyledonous perennials was similar in control plots (average 9% of 1994 and 1995) and plots mowed in June (8%) or July (8%)

In general, cultivation promoted an increase of the biomass of dicotyledonous perennials, while mowing promoted slightly but not significantly the development of monocotyledonous perennials. However, although the spread of dicotyledonous perennials in mowed and control plots was slower than in cultivated plots, dicotyledonous perennials dominated all plots in the fourth year of the experiment.

DISCUSSION

Perennial weeds regularly replace annual weeds during succession on abandoned fields. In our experiment, annual weeds dominated only the first two years, and from the third year of the experiment the weed stand was dominated by perennials. The speedy spread of perennial weeds could be promoted by regular autumn ploughing. Similar rates of succession were observed also by other authors (KRUMBIEGEL *et al.* 1995; REDONDO *et al.* 1974; BROWN *et al.* 1987).

The spread of dicotyledonous perennials was favoured by the sudden decrease of annual dicotyledonous plant biomass between the second and third years of the experiment, which is an effect of the decreased abundance and individual mass of *A. retroflexus*. This was perhaps due to the spread of *C. arvense* whose allelopathic effect on *A. retroflexus* was demonstrated by HUME (1982). The allelopathic effects of *E. repens* (MIKULKA 1995) may also favour the spread of this species and contribute to a suppression of annual weeds. Generally, allelopathic effects may have an important role in determining the rate of succession of different species (JACKSON & WILLEMSEN 1976; NUMATA 1977). A superior capacity for below-ground competition for water in *C. arvense* (COLLECTIVE 1995) probably further contributed to dominance of this species in the third and fourth year of the experiment.

The greater increase in biomass of dicotyledonous perennials weeds on cultivated plots confirmed that their spread is promoted by sporadic or careless cultivation. The population of *Cirsium* may be decreased only by frequent and thorough cultivation (TSIKOV *et al.* 1980; SHASKOV 1981). The effect of poor cultivation on *C. arvense* may consist not only in fragmentation of rootstocks and their spread, but also in loosening the soil. MOKSHIN (1978) demonstrated that lateral rhizomes of *C. arvense* grew well in a loose soil (specific mass 0.9 g/cm^3) but their growth ceased in a compact soil (1.3 g/cm^3). The loosening of soil by cultivation might contribute to spread of *C. arvense* although, in our experiment, the differences in soil compactness between cultivated and other plots were probably small since the experimental field was ploughed every year. On the other hand, the spread of *C. arvense* was negatively influenced by mowing whose effect is greatest when the shoots are about 1/2 m tall (COLLECTIVE 1995). In our experiment the total annual and final autumn biomass of *C. arvense* was small in plots mowed in June, when the plants had approximately this height. The high abundance of *T. farfara* on mowed plots contrasts with results from Poland where NAMURA-OCHALSKA (1993) ascertained that intensive cultivation was a pre-requisite for survival of this species in fallow fields. In our experiment, *T. farfara* spread even though ploughing was done only in autumn, probably due to the spread of rootstock parts from ridges partly surrounding the experimental area. The somewhat higher biomass of *E. repens* on mowed and control plots demonstrated that decreased cultivation had a positive effect on the spread of this species.

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Souhrn

ŠTOLCOVÁ J., HONĚK A. (1999): **Rané stadium sukcese na úhoru: změny složení vegetace a produkce biomasy**. Pl. Protect. Sci., **35**: 71–76.

Bylo zkoumáno rané stadium (2.–4. rok trvání pokusu) sukcese plevelů na experimentálním úhoru v Praze-Ruzyni. Pokusný pozemek byl každoročně orán na podzim a vláčen a válen na jaře. Poté byl rozdělen na pokusné plošky o rozměrech 5 × 5 m, na nichž byly spontánně vzešlé plevele po celou vegetační sezonu nedotčeny (kontrola), nebo byly sekány, anebo sekány s následnou kultivací povrchové vrstvy půdy v červnu nebo v červenci. V jednotlivých letech (1993–1995) byla zjišťována produkce sušiny nadzemní biomasy a podíl sušiny biomasy jednoděložných a dvouděložných jednoletých a vytrvalých plevelů na celkové biomase. Produkce sušiny biomasy (nadzemní biomasa plevelů sklizená v září) byla nejvyšší na kontrolních plochách. Na parcelkách, na nichž bylo uplatněno sekání nebo povrchová kultivace, byla celková produkce sušiny biomasy (součet biomasy vyprodukované v době příslušného zásahu + biomasa vyprodukovaná po něm) vyšší, pokud byl příslušný zásah proveden v červenci než při jeho provedení v červnu. Ve druhém roce sekundární sukcese byl podíl sušiny biomasy jednoletých plevelů na celkové biomase vyšší než plevelů vytrvalých. Od 3. roku pokusu začala v porostu dominovat biomasa vytrvalých dvouděložných plevelů jak na kontrolních, tak sekaných i plečkovaných parcelkách. Rychlost přírůstku podílu sušiny biomasy vytrvalých plevelů byla nejvyšší na plečkovaných parcelkách, nižší na kontrolních a nejmenší na parcelkách, na nichž plevele byly pouze sekány.

Klíčová slova: úhor; plevele; jednoděložné; dvouděložné; vytrvalé; jednoleté; sukcese

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