Competitive relationships between sugar beet and weeds in dependence on time of weed control

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ABSTRACT

Small plot trials were carried out in years 2001–2003 with sugar beet. In the treatment without weed control, dry weight of sugar beet top and LAI of sugar beet were very low (approx. 50 g/m^2 and 0.5 m^2/m^2, respectively). Yield loss of sugar beet was 80–93%. Dominant weeds were *Chenopodium album*, *Fumaria officinalis* and *Galium aparine*. In the treatments where weeds were removed (by hand) until 4 leaf stage of sugar beet, dry weight of sugar beet top and LAI of sugar beet at first increased normally, but were markedly decreased from the half of the vegetation period. Yield loss of sugar beet was 54–28%. Dominant weed in this treatment was *Amaranthus retroflexus*. The development of sugar beet top dry weight and LAI of sugar beet was practically identical in the treatments where weeds were removed until 8–10 leaf stage of the crop and in those where weeds were removed during the whole vegetation period (500–900 g/m^2, or 4–7 m^2/m^2, respectively). No yield loss of sugar beet was recorded. Dry weight of weeds did not exceed 30 g/m^2 and LAI 0.1 m^2/m^2. *A. retroflexus* and *Mercurialis annua* were the most frequent weeds in this treatment.

Keywords: sugar beet; weed competition; yield loss; annual weeds; seed production; reproductive ability; time of emergence; competition

Weed control is a decisive and one of the most difficult agricultural arrangements in sugar beet (*Beta vulgaris* ssp. *vulgaris* var. *altissima*) growing. Main reasons include slow early growth of sugar beet, its very low competitive ability at the beginning of vegetation, high sensitivity to herbicides (mainly in early growth stages), and also high cost of special herbicides. Moreover, using herbicides in sugar beet usually induced a decrease of root yield, even in the cases when visual symptoms of injury are not evident (Abdollahi and Ghadiri 2004).

Competition can be defined as a contest of plants under limited supply of environmental factors (light, water, nutrients, etc.). Most of weeds can uptake nutrients and water better than crop (Mesbah 1993). In agrophytocoenosis, competition is strongly affected by the time of single weed emergence in crop canopy and by the duration of weed viability (Keeley and Thullen 1991). Duration of that period is most often related to the sum of effective temperatures of the crop (Dunan et al. 1996, Ferrero et al. 1996, Martinková and Honěk 2001) or to the crop growth stage (Chykoye et al. 1995). For example, Kropff et al. (1992) made an ecophysiologigal model for an effect of competition of *Chenopodum album* on sugar beet – the main factor for reduced yield loss of sugar beet was an emergence timing of weeds compared to crop. The weeds, whose emergence before sprouting of crop is more competitive, can cause higher yield loss in low weed intensity.

To calibrate empirical models of crop yield loss based on relative weed green area to different growing seasons, detailed knowledge of growth characteristics (RGR, NAR, LAR, etc.) of weeds and crops is necessary (Storkey 2004). Sugar beet yield is not influenced by early season competition when weeds are controlled within four to six weeks of planting. This term for controlling weeds may be shortened when weed density is high, or when soil nutrients

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and moisture are limited (Mesbah 1993). Weeds can also lower the quality of sugar beet by reducing sucrose content (Mesbah 1993).

Environmental conditions throughout the growing season may significantly impact the interaction between sugar beet and weeds. Moisture and light are probably the most important factors, but temperature also influences relations between sugar beet and weeds. Sugar beets generally are more sensitive to weeds under condition that favour high yield.

The intensity of competition is closely related to seed production of weeds in single crop. Information about generative production of weeds is so far not available for many weed species under field conditions. If we want to predict weed population dynamics in agroecosystems, we must know the influence of crop on seed production of weeds (Norris 1996).

Understanding the emergence characteristics of weeds can be helpful in determining the optimum time to apply postemergence herbicide. This becomes especially important when using micro herbicide rates. A comparison of the germination temperature of common weed species with those of various crops including sugar beet shows why certain weeds may cause more problems in early sowing than in late sowing. The aim of our work was to determine critical period of sugar beet with regard to weeds, to measure possible competition of single weeds and evidence of influence of weed emergence time on sugar beet root yield and seed production of weeds.

MATERIAL AND METHODS

Small plot trials were carried out in Central Bohemia after winter wheat as fore crop in years 2001–2003. Plot size was 2.25 m (5 rows) × 20 m. The experiment fields were chosen with respect to weed infestation and therefore there were minor agricultural differences among experimental years. Differences in sowing time of sugar beet were caused by weather conditions (soil moisture) in experimental years. General information about experimental sugar beet stands is given in Table 1. The trial had four treatments in four replications. First treatment was without weed control (A). In the second treatment, weeds were removed (by hand) until 4 leaf stage of sugar beet (B). In the third treatment, weeds were removed until 8–10 leaf stage of sugar beet (C). In the fourth treatment, weeds were removed during the whole vegetation time (D).

Information about experimental canopy of sugar beet in individual years is shown in Table 1. Observation and sampling were carried out at 3-week intervals. Number of weeds, dry weight and LAI of the aboveground biomass of weeds and sugar beet were observed. Size of samples was 1 m^2 from each plot. Growth characteristics: relative growth rate (RGR), relative leaves growth rate (RLGR) and net assimilation rate (NAR) were calculated. Main weeds on experimental fields were *Chenopodium album*, *Amaranthus retroflexus* and *Mercurialis annua* (the latter only in years 2001 and 2003). Yield test was carried out before harvest; moreover, 5 plants of weeds were collected from each plot, in order to determine seed production from different treatments. Results were analysed in programme Statgraphic 4.0. by an analysis of variance according to the Tukey HSD ($\alpha = 0.05$). Logistic regression function was used to create the dependence of weed aboveground biomass dry weight (g/m^2) and weed aboveground biomass relative dry weight ($g/g/m^2$) on relative yield loss of sugar beet.

RESULTS AND DISCUSSION

Growth and development of sugar beet top (shoot)

In the treatment A (without weed control), dry weight of sugar beet top (aboveground) and LAI sugar beet increased throughout the vegetation

Table 1. General information about experimental canopy of sugar beet

Years	2001	2002	2003
Date of sowing	24.04	07.04	28.03
Planting space (cm/cm)	45 × 17	45 × 20	45 × 22
Variety	Vegas	Takt	Polaris
Mineral fertilization N (kg/ha)	140	170	120
Weed spectrum	ECHCG, AMARE, CHEAL, POLLA, MERAN	AMARE, CHEAL, GALAP, FUMOF, POLLA	AMARE, CHEAL, MERAN

period only very slowly. In years 2002 and 2003, top of sugar beet dry weight was approx. 50 g/m^2 and LAI of sugar beet was approx. 0.5 m^2/m^2. Only in 2001, top of sugar beet dry weight and LAI were higher (more than 200 g/m^2 and 2.0 m^2/m^2, respectively).

Initial increase of sugar beet top dry weight and LAI in the treatments B, C and D were approximately identical. However, from the half of the vegetation period, the rate of sugar beet top dry weight markedly decreased in the treatment B.

Development of sugar beet top dry weight and LAI of sugar beet were practically identical in the treatments C and D in all years. Sugar beet top dry weight and LAI were increasing throughout all the vegetation period. A slight decline came towards the end of August and in September. Sugar beet top dry weight varied between 500–900 g/m^2 and LAI of sugar beet varied between 4–7 m^2/m^2, depending on the year. Dry weight and LAI of sugar beet top in the treatments C and D were 4–10 times higher than in the treatment A (Figure 1).

Differences between the treatments in the values of RGR, RLGR and NAR of sugar beet top were minimal, nevertheless periodical in every experimental year. Important differences were observed only between the treatments A compared to C and D (Figure 2).

Growth and development of weeds

Chenopodium album dominated in the treatment A, in all experimental years. In this treat-

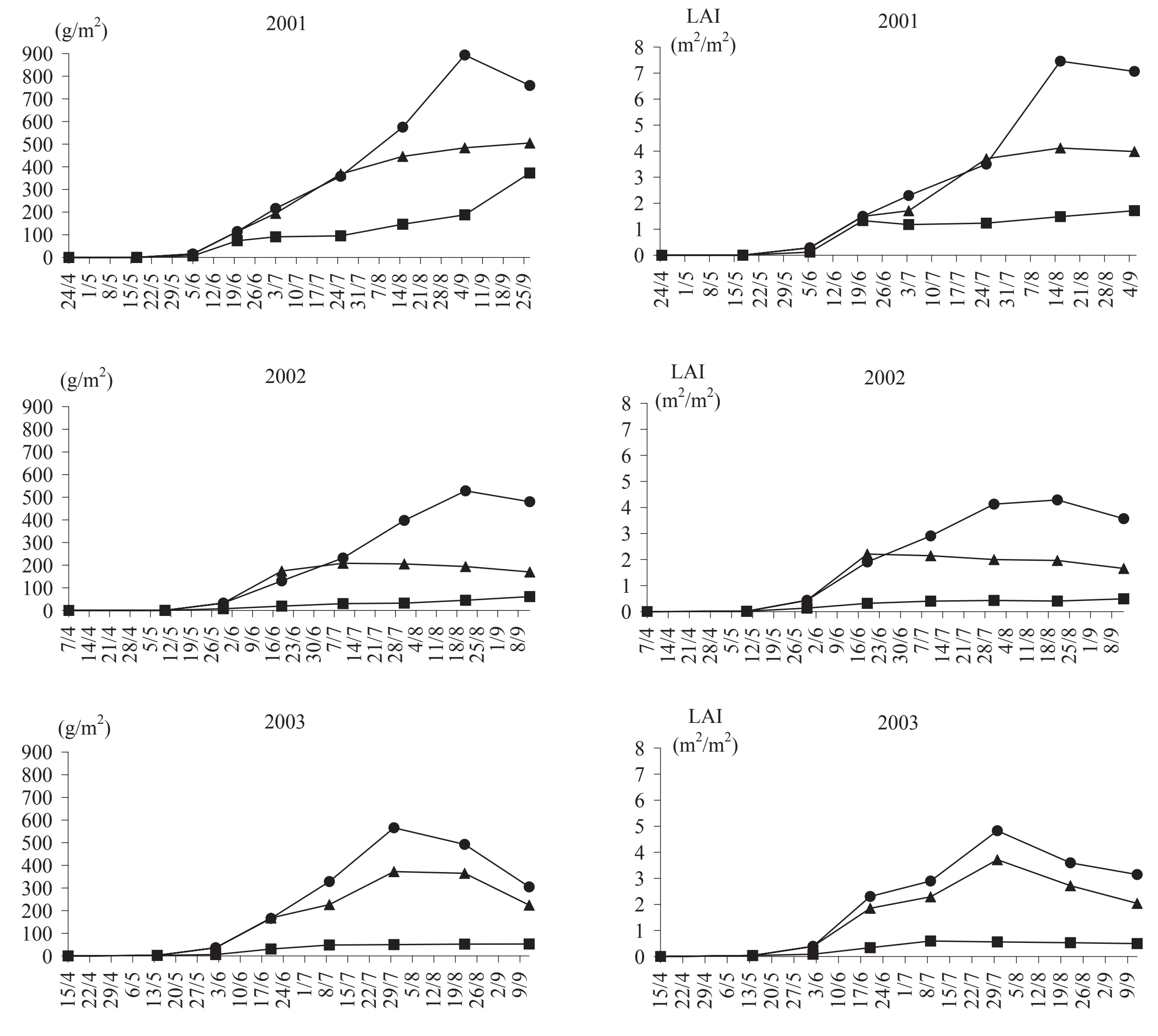
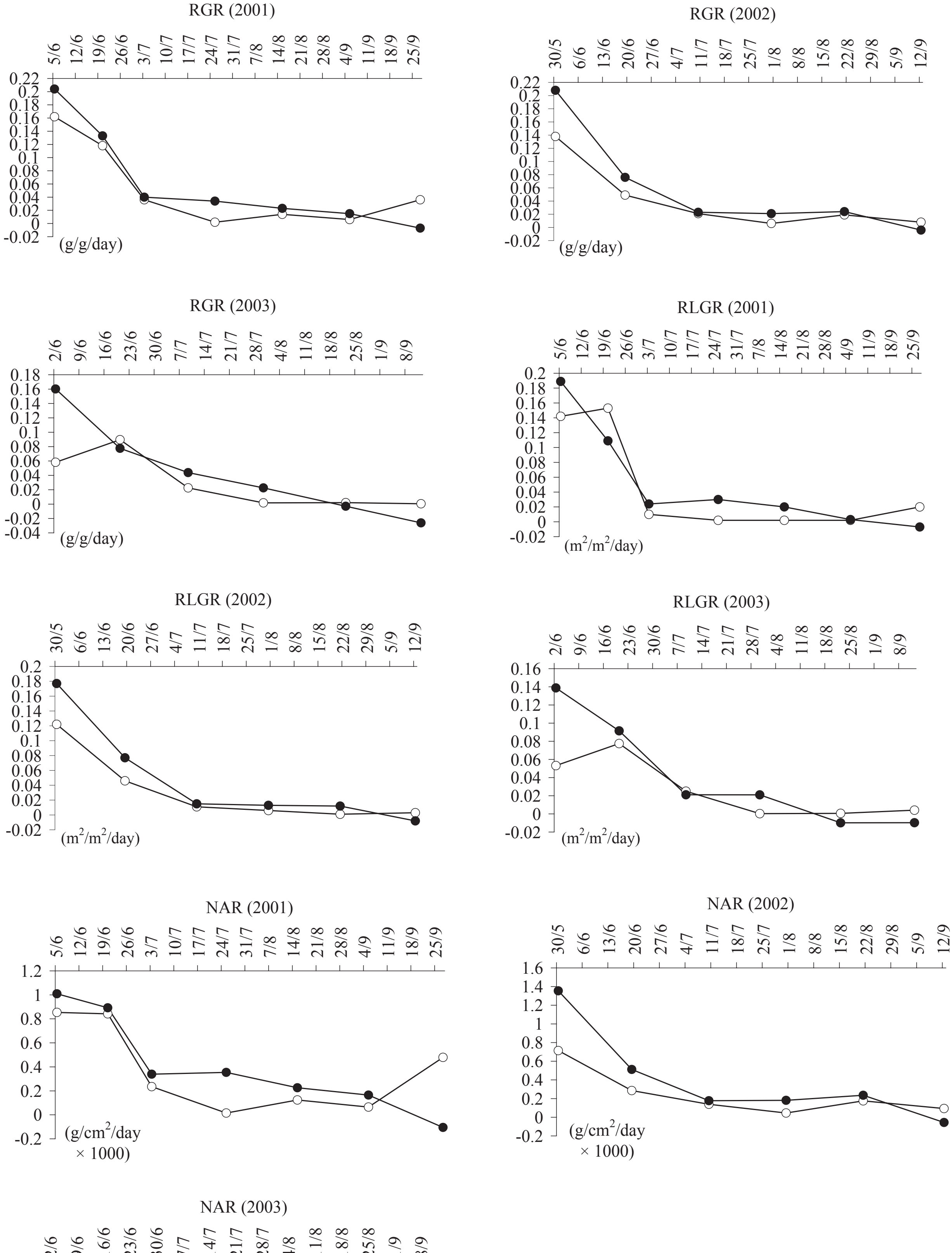


Figure 1. Development of dry weight of sugar beet top from m^2 (on the left) and LAI of sugar beet (on the right) – treatments: ■ A, ▲ B, ● C



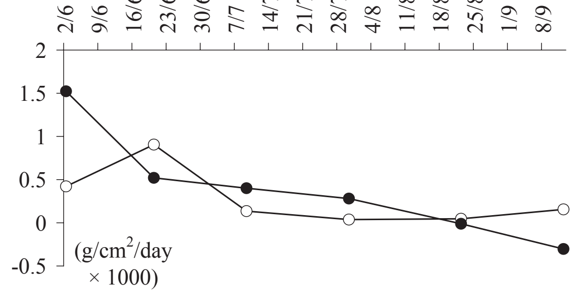


Figure 2. Development of RGR, RLGR and NAR of sugar beet – treatments: ○ A, ● D

ment, *Ch. album* showed the highest dry weight of the aboveground biomass. In 2002, experimental field was highly infested by *Fumaria officinalis* and *Galium aparine* (winter annual weeds), which dominated in the first half of the vegetation period. In the second half of vegetation, *F. officinalis* as well as *G. aparine* were suppressed by summer annual weeds, especially by *Ch. album*. An increase of the aboveground biomass dry weight of *Amaranthus retroflexus* was slightly slower compared to *Ch. album;* only in 2001 (late sowing of sugar beet) *A. retroflexus* prevailed in the treatment A (Figure 3).

Sugar beet dominated in the treatment B till half of June. During July, dry weight of aboveground biomass and LAI of *A. retroflexus* increased rapidly. *Ch. album* occurred minimally (Figure 4).

Sugar beet dominated throughout the vegetation period in the treatment C in every experimental year. At any assessment, dry weight and LAI of weeds did not exceed 30 g/m^2 and 0.1 m^2/m^2, respectively. *A. retroflexus* and *Mercurialis annua* (Figure 5) prevailed in this treatment. *Ch. album* was not successful.

Differences between the treatments in the values of RGR, RLGR and NAR of weeds were minimal and irregular.

Reproduction ability of weeds

Highest generative potential was determined for *A. retroflexus* and *Ch. album*. However, high generative ability of *Ch. album* declined with in-

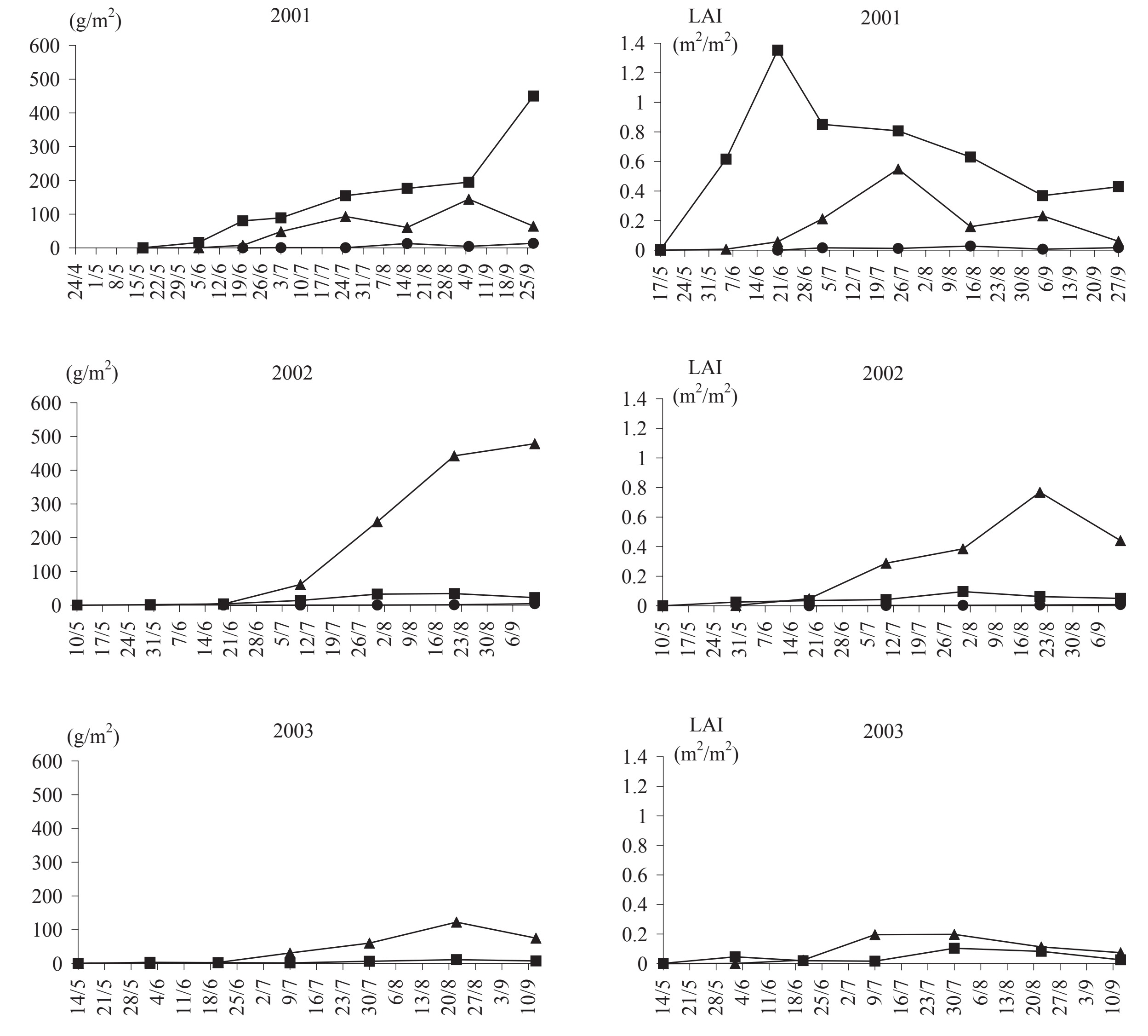


Figure 3. Development of dry weight of aboveground biomass of *Amaranthus retroflexus* from m^2 (on the left) and LAI of *A. retroflexus* (on the right) – treatments: ■ A, ▲ B, ● C

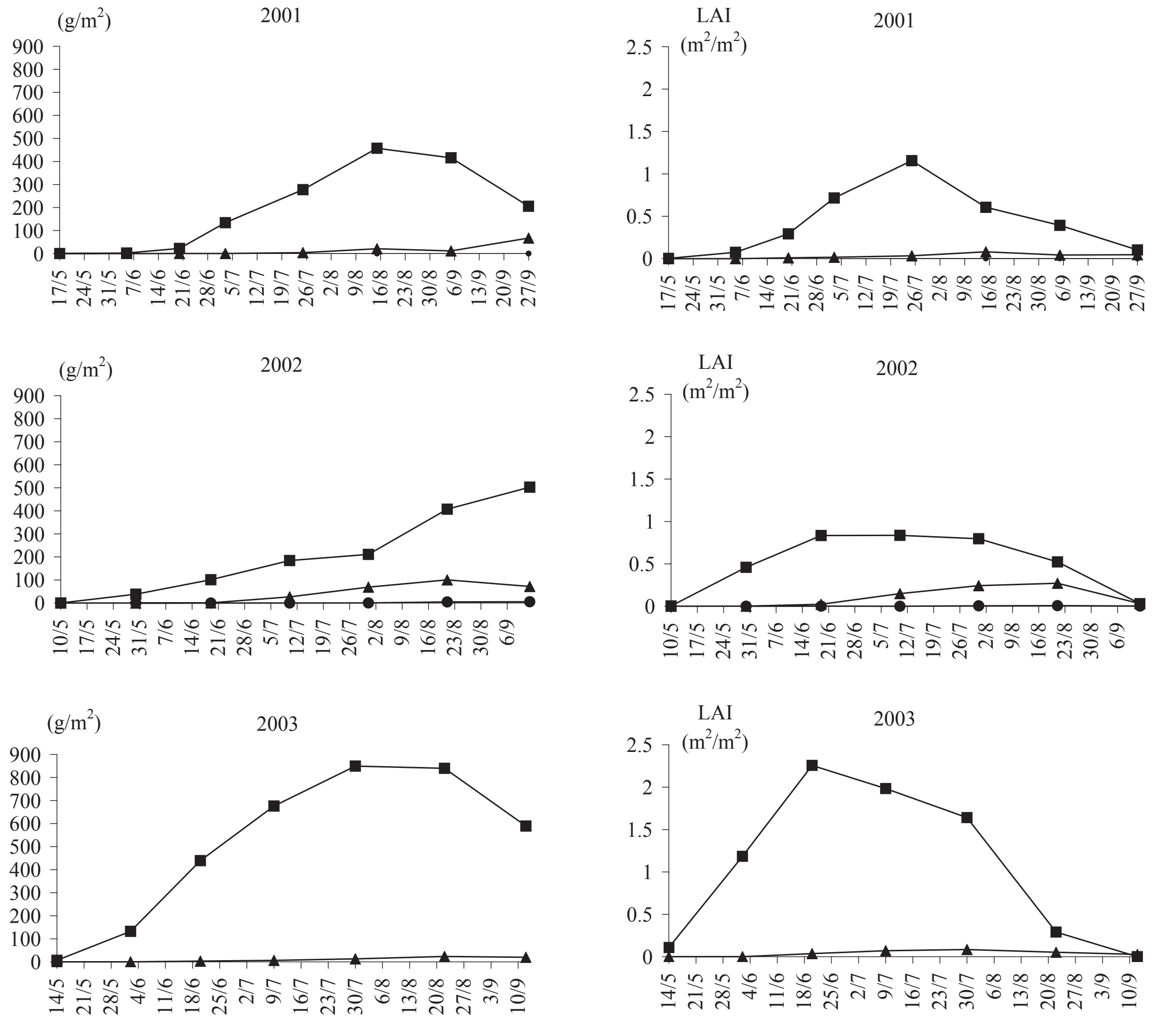


Figure 4. Development of dry weight of aboveground biomass of *Chenopodium album* from m^2 (on the left) and LAI of *Ch. album* (on the right) – treatments: ■ A, ▲ B, ● C

creasing of time between sugar beet emergence and emergence of *Ch. album*. It was due to a very low emergence rate of *Ch. album* in second, third and other emergence waves. On the contrary, *A. retroflexus* was better established in the treatment B. Only in 2001, treatment A showed the highest seed production (late sowing of sugar beet). *A. retroflexus* and *M. annua* showed relatively a high seed production in the treatment C. On the contrary, *Ch. album* showed a low reproductive ability in this treatment (Table 2).

Yield loss of sugar beet and prediction of yield loss

The length of weed-free period affected yield of sugar beet very markedly. In the treatment A, 7–20% yield was reached compared to D (in average 7.99 t/ha). In the treatment B, 46–72% yield was reached compared to D (in average 38.89 t/ha). In the treatment C, 98–102% yield was reached compared to D (in average 62.82 t/ha). Differences between the treatments were significant; only between C and D no significant difference in any year was recorded (Table 3).

Dry weight of weeds in the growth 8–10 true leaf-stage of sugar beet (BBA 25–27) was used to show dependence of dry weight aboveground biomass of weeds (g/m^2) on relative yield loss of sugar beet (R^2 = 89.79). For a closer relationship, dry weight of weeds was recomputed to relative dry weight of weeds (g/g/m^2) – rate between dry weight of weeds and dry weight of sugar beet top (R^2 = 91.6). Used data were taken from every plot with weeds (Figures 6 and 7).

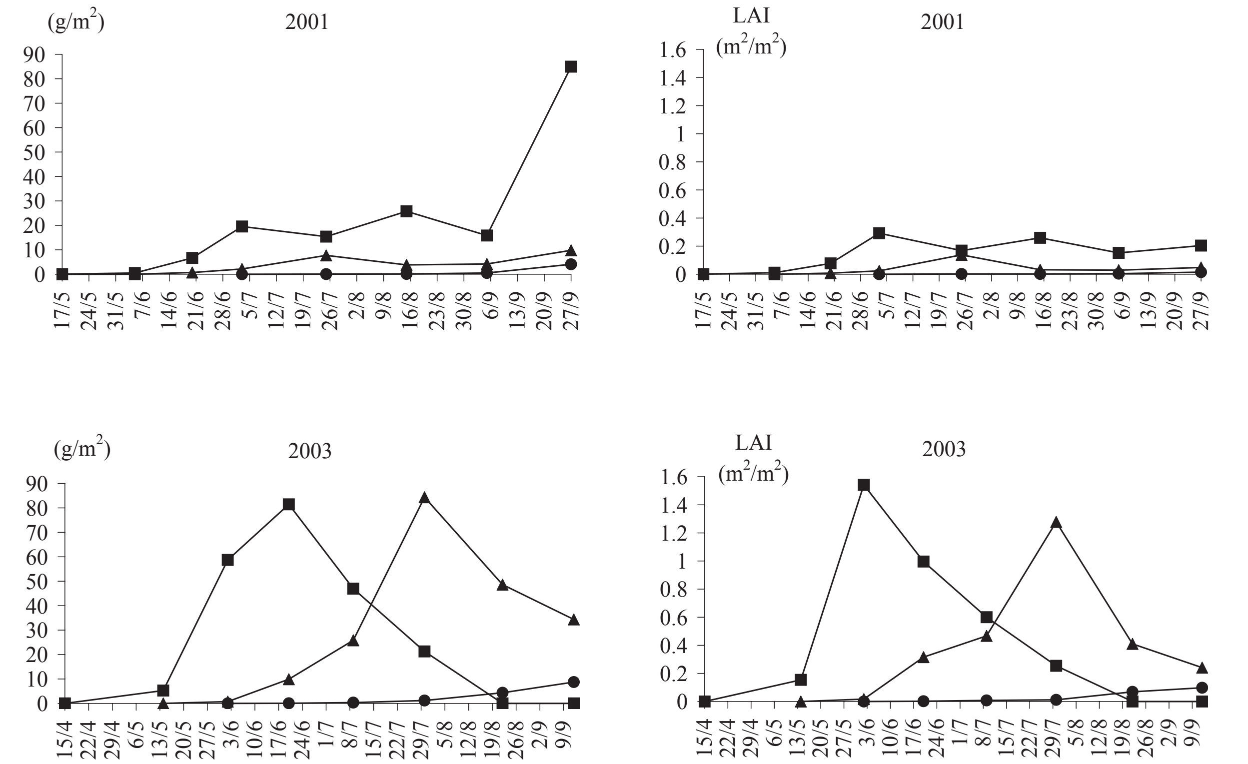


Figure 5. Development of dry weight of aboveground biomass of *Mercurialis annua* from m^2 (on the left) and LAI of *M. annua* (on the right) – treatments: ■ A, ▲ B, ● C

On primary weed infestation of sugar beet in the Czech Republic participated mainly *Chenopodium album* and some winter and spring weeds (*Galium aparine*, *Tripleurospermum maritimum*, *Fumaria officinalis*, etc.). If this primary weed infestation is not controlled, it may markedly decrease the yield of sugar beet roots and also increase weed soil seed bank. Mainly *Ch. album* has a very high

Table 2. Influence of length of weed-free period in sugar beet on seed production of weeds

Treatment	*Chenopodium album*		*Amaranthus retroflexus*		*Mercurialis annua*	
	homogenous groups	seed number from m^2	homogenous groups	seed number from m^2	homogenous groups	seed number from m^2
2001						
A	B	64 125	B	402 500	B	3 033
B	B, A	29 425	A	40 125	B	1 268
C	A	138	A	4 925	A	44
d_{min}(α = 0.05)		42 130		56 458		1 375
2002						
A	C	91 375	A	20 250	not present	
B	B	29 500	B	130 250		
C	A	3 250	A	18 500		
d_{min}(α = 0.05)		13 809		12 715		
2003						
A	B	179 425	A	4 800	B	16 560
B	A	8 875	B	53 325	B	21 102
C	A	0	A	0	A	3 075
d_{min}(α = 0.05)		15 170		7 443		4 960

Table 3. Influence of length of weed-free period on sugar beet and years on yield of sugar beet roots

Effect of length of period without weeds (treatments) on sugar beet yield			Effect of years on sugar beet yield		
treatment	homogenous groups	yield (t/ha)	year	homogenous groups	yield (t/ha)
A	A	7.99	2001	C	52.13
B	B	38.89	2002	A	36.44
C	C	62.82	2003	B	41.08
D	C	63.16			
d_{min}(α = 0.05)		5.23	d_{min}(α = 0.05)		4.11

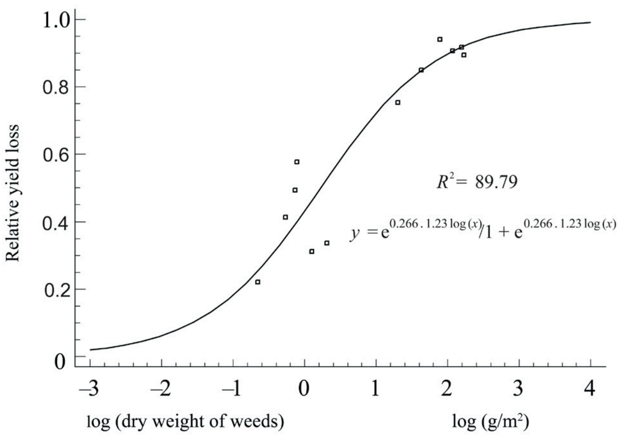


Figure 6. Effect of dry weight of aboveground biomass of weeds (g/m^2), in sugar beet BBA 25–27, on relative yield loss (0–1) – results from 2001–2003

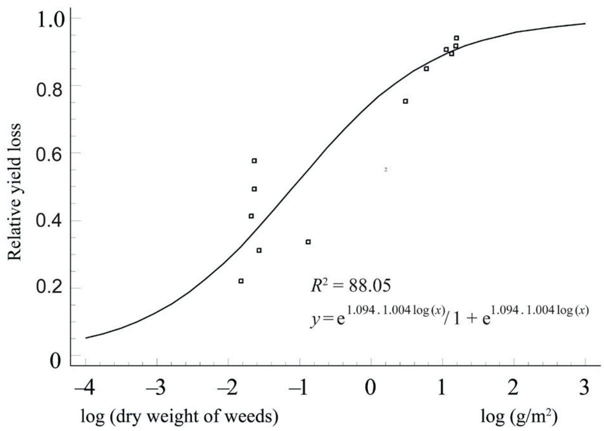


Figure 7. Effect of relative dry weight of aboveground biomass of weeds (dry weight of weeds/dry weight of top of sugar beet), in sugar beet BBA 25–27, on relative yield loss (0–1) – results from 2001–2003

reproductive ability. Late sowing canopy of sugar beet may be also markedly infested by *Amaranthus retroflexus* and *Echinochloa crus-galli*.

If primary weed infestation is controlled, mainly summer weeds that require high minimum temperature to germinate (A. *retroflexus*, *E. crus-galli*, etc.) may emerge in a number of waves (Jursík et al. 2004). This weed infestation may markedly decline yield of sugar beet roots, reduce crop quality (sugar content) and strongly increase soil seed bank (Mesbah 1993). Especially *A. retroflexus* has a very high reproductive ability in this case. The grass weeds that have large seeds and a higher investment in roots in the seedling stage (*E. crus-galli*) are usually more competitive later in the season when resources become limiting (Storkey 2004).

Late weed infestation (weeds emerged after closing of sugar beet canopy) has no negative effect on yield of sugar beet roots. Nevertheless, it should be mentioned that *A. retroflexus* and *Mercurialis annua* can assert also in well closed canopies of sugar beet and produce relatively lots of seeds. On the contrary, winter and spring annual weeds, similar to *Ch. album*, assert badly in well-closed canopy (Wellmann 1999, Jursík et al. 2003). Weed infestation by these weeds is mostly caused by choice of unsuitable herbicide, wrong term of application or bad establishment of canopy.

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