RELATIVE TIME OF EMERGENCE, LEAF AREA DEVELOPMENT AND PLANT HEIGHT AS MAJOR FACTORS IN CROP-WEED COMPETITION

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ABSTRACT

Growth analysis data (dry weight, LAI and height) are presented of competition experiments with sugar beet (Beta vulgaris cv. monohill and cv. salohill), Fat hen (Chenopodium album) and Chickweed (Stellaria media), as well as with beet and early and later sown Chenopodium. Yield losses are not related to leaf area, the worst weed Chenopodium having the lower LAI. The paradox is explained by different height growth of the weed species in view of the competition for light.
A time lag of 21 days between the emergence of crop and Chenopodium still leads to yield losses; weeds emerging 30 days later than the crop no longer develop a canopy on top of the crop's and no longer lower yields.

INTRODUCTION

In open and early sown crops such as sugar beet, a group of late summer annuals tends to escape the current mechanical operations and even soil herbicides; mechanical control measures during early crop growth may only be effective between the rows. Remaining weeds in the row, even at low density, often cause substantial damage (Solanum nigrum, Chenopodium album, Echinochloa crus-galli) (Zimdahl 1980). In these circumstances the need is felt for reliable prediction of yield losses and advice for herbicide application (Cousens in prep.)

In the search for practical warning systems and thus in the development of empirical models (Spitters et al. 1983), the following characters (parameters) are put forward as useful descriptors of weed infestation:
- the time of emergence of the weed with respect to the crop emergence date (Cousens 1985, Lapointe 1985, O'donovan et al. 1985, Spitters et al. 1983),
- the weed species (provided that we have data on specific biological and physiological characters such as growth form, height and other morphological responses to competition, a.o.),
- the weed density. This parameter on its own has only a limited value, as demonstrated in many experiments on damage thresholds: large differences in yield loss - weed density relations between experiments are often found (Koch 1974, Kropff et al 1984, Poole et al. 1987, Schweizer 1981, Wahmhoff et al. 1985, Zimdahl 1980).

Plant responses to environmental factors can be quantified. For many crop species these relations are used in growth models, but data on physiological characteristics of weeds are still lacking. Present versions of the crop-weed competition models, equally based on physiological growth parameters, suggest a predominant influence of differences in the times of emergence of crop and weed, and of two biological characters, the leaf area development and plant height (Kropff et al. in prep.). However, there appear to be few complete sets of field data on growth and performance of both weed and crop in monocultures and mixtures, in well monitored environmental conditions, in different years and with different time lag between crop and weed emergence. This labourious type of field experiment is rewarding, since, apart from datasets for validation of simulation models and the testing of hypotheses generated with the models, it offers a discriminating view on competition-related processes in the course of a growing season.

In this contribution we present the analysis of two field experiments in subsequent years, in order to evaluate the influence of the relative time of emergence, and of plant height and leaf area development, given the crop and weed species and their responses to different weather conditions.

EXPERIMENTAL DESIGN

The field experiments, in split plot design with four replicates, were carried out in Wageningen on a loamy sand (4% soil organic matter) with adequate supply of water and nutrients.

In 1985 sugar beet was grown at 30 cm equidistant spacing (11 plants per m^2); the weeds were grown equally distributed between the crop plants, Fat hen at 5.5 plants per m^2 in mixture and 11 plants per m^2 in monoculture, Chickweed at 11 (clumps of) plants per m^2, both in mixture and monoculture. The plot size was 6 x 1.5 m, allowing harvest of 15 plants. The dates of 50% emergence for sugar beet, Fat hen and Chickweed were 9 May, 21 May and 20 May, respectively.

In 1986 sugar beet was grown in rows 50 cm apart, at distances of 18 cm in the row (11 plants per m^2); Fat hen was equally grown in rows at plant distances of 18 cm in monoculture or in the rows of the crop, alternating with the sugar beet plants. Plot size was 6 x 1.25 m. Fat hen was sown at crop emergence and 15 days later and had final densities of 11 plants per m^2 in monoculture, but in the mixtures of 9.1 and 9.7 plants per m^2, respectively. The dates of 50% emergence for sugar beet, Fat hen (early) and Fat hen (late) were 4 May, 25 May and 3 June, respectively.

RESULTS

The 1985 experiment produced growth curves of the type expected for the monocultures of Beta, Chenopodium and Stellaria (Fig. 1A) and illustrates the shorter life cycles of the weeds, especially Stellaria. The time lag between sugar beet and weed emergence of about 10 days leads to substantial crop losses at final harvest, but even at the beginning of July there is an influence of Beta (by then over 2 t ha-1) on the weed, especially Stellaria, and vice versa. Table 1 shows that total crop biomass was reduced with 21% by Stellaria and with 37% by Chenopodium. The time course of the height development and the leaf area index of Beta-weedfree (B), Beta with Chenopodium (Bc) and B. with Stellaria (Bs) is summarized in Table 2, as well as height and LAI for Chenopodium and Stellaria monocultures (Chm and Stm) and their mixtures with Beta (Chb and Stb). Marked differences were the height development of Chenopodium (more than twice as high as the crop) and the much higher LAI of Stellaria (LAI 2.68, against 0.96 in Chenopodium).

The 1986 experiment offers comparable results, with respect to monocultures of Beta and Chenopodium 1 (early). Apparently weather conditions (August and September being drier, colder and more clouded than 1985) were less favourable for Beta and its final production stayed well behind 1985. The weather did not affect final biomass of Chenopodium 1, emerging on May 25 (four days later than previous year), due to its shorter life cycle. Even the Chenopodium 2 (late) emerging on June 3, produced almost the same final biomass, well over 13 t ha-1.

In the mixtures only the early Chenopodium with a time lag of 21 days,

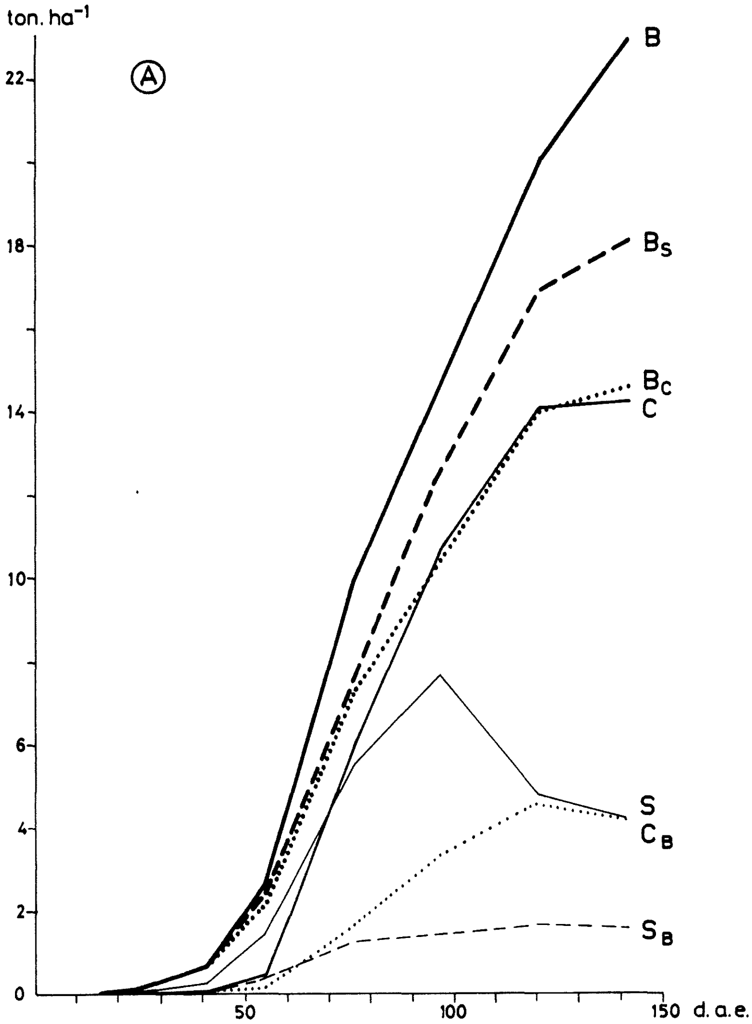

Fig. 1.A. Development of dry weight (t. ha^{-1}) in 1985 of Beta in monoculture (B), in mixture with Stellaria (B_S) and with Chenopodium (B_C). Dry weight of the weeds comprise Stellaria in monoculture (S), in Sugar beet (S_B) and Chenopodium in monoculture (C) and in Sugar beet (C_B); dae: days after emergence of the sugar beet crop.

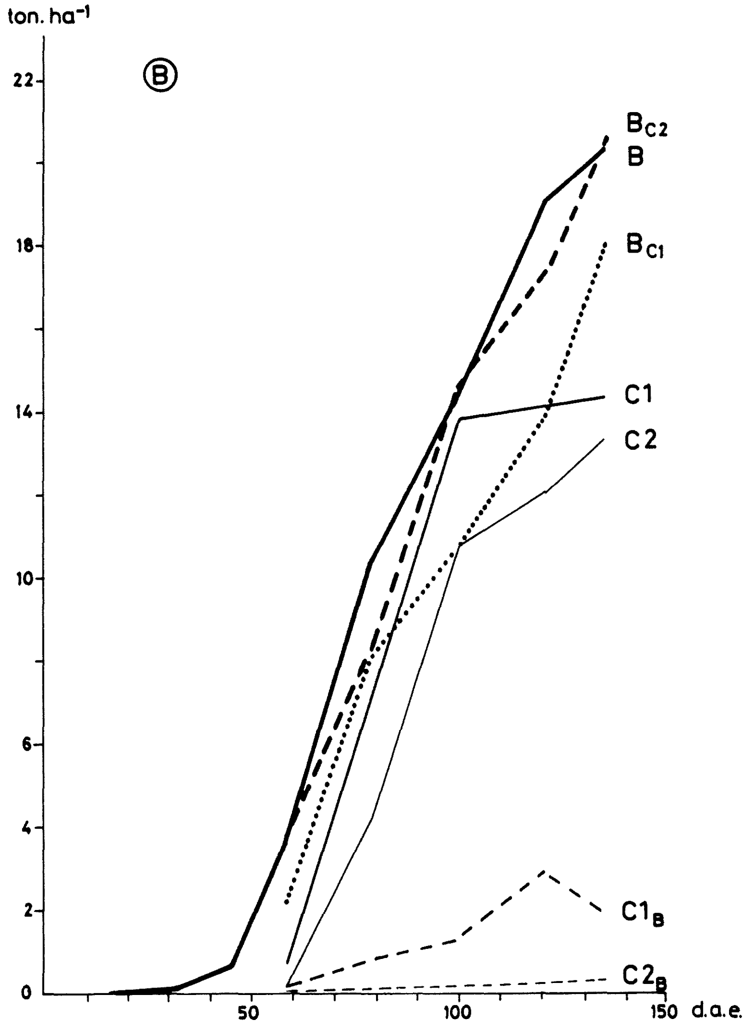

Fig. 1.B. Development of dry weight in 1986 of Beta and Chenopodium (early: C1, and late: C2) in monocultures and mixtures. (Explanation of symbols 1A).

TABLE 2

Height development in Beta (B: mono, B_C: with Chenopodium, B_S: with Stellaria), Chenopodium (C: mono, C_B: with Beta) and Stellaria (S: mono, S_B: with Beta), and development of leaf area index LAI in 1985. For 1986 height and LAI data relate to Beta and Chenopodium only, the latter sown early (C1) and late (C2). Dae: days after emergence of the crop.

	Height cm (1985)							LAI (1985)						
dae	B	B_C	B_S	C	C_B	S	S_B	B	B_C	B_S	C	C_B	S	S_B
39	18	17	17	13	13	10	9	.77	.79	.85	.09	.04	.54	.21
53	34	33	32	53	53	21	22	2.35	1.98	1.94	.81	.24	3.30	1.15
74	50	51	51	142	127	35	50	5.65	3.97	4.03	4.63	.96	10.61	2.68
95	62	57	60	159	145	29	56	5.10	4.17	3.87	4.73	.80	9.33	2.68
118	59	58	60	166	142	-	-	5.10	4.19	4.13	4.24	.59	1.26	.67
140	61	59	56	159	142	11	53	4.66	3.27	3.08	1.15	.12	.58	.17

		Height cm (1986)*				LAI (1986)						
dae C1	dae C2	C1	$C1_B$	C2	$C2_B$	B	B_{C1}	B_{C2}	C1	$C1_B$	C2	$C2_B$
28	38	28	28	12	13	2.29	2.22	2.56	.81a	.18b	.23b	.02c
48	58	136	72	101	31	3.36	2.73	2.40	3.43a	.27a	2.98b	.07c
69	79	158	74	158	43	3.77	2.89	3.34	3.75a	.29a	3.78b	.07c
90	100	159	92	156	43	3.18	2.50	3.15	3.33a	.26a	3.78b	.05c
104	114	156	81	149	45	2.85	2.79	3.11	2.64a	.05a	2.67b	.03c

* Height of Beta compare data 1985

reduced Beta production with 11% at final harvest (Table 1B); already on July 1st a lowering of Beta biomass and of Chenopodium biomass is shown (Fig. 2).

TABLE 1

The 1985 and 1986 sugar beet production at final harvest in mono- and mixed cultures, in t ha^{-1} and in (%) of weed-free.
Different letters indicate significant difference between treatments ($P < 0.05$, capitals $P < 0.01$).

1985		weed-free	with Stellaria	with Chenopodium
Total dry weight	(t ha^{-1})	23.1 (100) a(A)	18.2 (79) b(AB)	14.6 (63) b(B)
Shoot dry weight	(t ha^{-1})	8.6 (100) a(A)	6.8 (80) b(AB)	6.4 (74) b(B)
Root dry weight	(t ha^{-1})	14.5 (100) a	11.3 (78) ab	8.2 (57) b
Total fresh weight	(t ha^{-1})	61.9 (100) A	48.9 (79) B	33.1 (53) C
Sugar content (%)		15.04 a	15.43 b	15.43 b
Sugar production	(t ha^{-1})	9.3 (100) A	7.5 (81) B	5.1 (55) C

1986		weed-free	with early Chenopodium	with late Chenopodium
Total dry weight	(t ha^{-1})	20.3 a	18.1 b	20.5 a
Shoot dry weight	(t ha^{-1})	7.4 -	6.9 -	7.0 -
Root dry weight	(t ha^{-1})	12.9 a	11.2 b	13.5 a
Total fresh weight	(t ha^{-1})	53.5 a	45.4 b	56.3 a
Sugar content (%)		17.7 -	17.9 -	18.0 -
Sugar production	(t ha^{-1})	8.5 a	7.3 b	9.0 a

CONCLUSIONS

LAI and height

The results of the 1985 experiment show marked differences between the two weedspecies, Chenopodium causing by far the highest yield loss. Supply of water and nutrients taken as sufficient, the competition will have been for light exclusively. This result stands in marked contrast to the lower yield loss by Stellaria, which had a strong leaf area development (LAI 2.7 and in its monoculture even 10) compared to Chenopodium (LAI 0.96 and in monoculture 4.6). This is explained by the data on height development (Table 2). In monoculture Chenopodium plants grew up to a height of 160 cm and up to 150 cm between the sugar beets, which topped at 60 cm, and was able to use its lower LAI more effectively in the light interception. Stellaria in monoculture remained of low statue (35 cm), but part of it used the beet plants to climb up to the same height as the crop.

Relative time of emergence

The results of the 1986 experiment clearly show the strong effect of a difference of 10 days in the period between sugar beet and weed emergence. The latest sown weed did not gain a high statue, reached only modest LAI and finished its growth together with the early sown weed, at the end of a shorter life span and without seriously hampering crop production.

DISCUSSION

Height- and leaf area development, together with emergence date and two differing years, they once more revealed their serious influence on the outcome of crop-weed competition (viz. also Elberse et al. 1979, Lapointe 1985).

On the one hand the relative date of emergence proves to be an indispensible datum in any discussion of competition and it is amazing that in many publications this aspect is neglected.

The results draw attention to the germination and to developmental characteristics of the weeds and above all to the rate of leaf area development and height growth of the weeds relative to the crop canopy. Although Chenopodium is known for its capacity to increase height in a shadowy environment, the plants of the later generation in the 1986 experiment did not develop a canopy on top of the crop's. Shortening daylength urged the onset of flowering and although the weed had a substantial production including a seed crop, it did not interfere with the sugar beet.

The results of the present experiments, although permitting clear conclusions, cannot lead to causal understanding or generalization. This is only to be expected from simulation studies based upon knowledge of the underlying physiological processes, governing photosynthesis and morphological development (height growth, lateral spread, leaf development). The hypotheses generated may lead to relatively simple and less casuistic field experiments.

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