Korean J. Ecol. 8(3) : 127~132, 1985

The Development of Leaf in *Amaranthus retroflexus* and *Chenopodium album* Represented by the Plastochron

Ⅱ. The Competitive Development of Leaf in the Species

Park, Bong-Kyu and Joung-Hee Kim
(*Dept. of Biology, College of Natural Science, Ewha Womans University*)

Plastochron에 의한 *Amaranthus retroflexus*와 *Chenopodium album*의 잎의 성장 해석

Ⅱ. 잎의 경쟁적 발달

박 봉 규·김 종 희
(이화여자대학교 자연과학대학 생물학과)

ABSTRACT

In this study, the competitive development of leaf in *Amaranthus* and *Chenopodium* were investigated by the complemented plastochron index. The value of PI for *Amaranthus* was not varied with competional ratios, while for *Chenopodium* it was varied. Namely in *Chenopodium*, the plastochron 1 was increased as competitional combinations, the plastochron 2 was decreased. These results indicated *Amaranthus* had advantage in competition over *Chenopodium*. It is surmised that these results were exhibited differences in photosynthetic pathway between *Amaranthus* (C_4 plant) and *Chenopodium* (C_3 plant).

The linear patterns were clearly demonstrated by the differences in leaf arrangement between *Amaranthus* (alternate type) and *Chenopodium* (opposite type). From these results, use of plastochron seems to a useful means of evaluating plat response to various environments.

INTRODUCTION

Amaranthus retroflexus and *Chenopodium album* are annual weeds, co-occuring in ecologically similar habitats and they are similar in morphology. The mechanisms of co-occuring of both species were dimonstrated by difference of photosynthetic pathway (Pearcy *et al.*, 1981). The photosynthetic mechanisms of plants are determined by the degree of response in temperature and humidity gradients. It is certain the plants which adaptive ability to environments will have competitive advantages.

In this study, the competitive development of leaf in *Amaranthus* and *Chenopodium* was estimated by the plastochron index model. Because the use of PI is available in studies of the effects of physiological and environmental factors on developmental process in plants (Lamoreaux *et al.*, 1978).

Coleman(1976) reported the growth and development of the leaf in tomato by using PI. Silk(1980) also studied the growth of *Cantaloupe* relation to irrigation line source estimated by the PI. Freeman (1984), Maksymowch(1959, 1973), and Maksymowch *et al.*(1960, 1977) used plastochron index for their physiological, developmental research.

By using LPI, Isebrands *et al.* (1974 developed an index of cell separation for cell layers in cottonwood leaves at various stages of development.

The objectve of this study was i) to represent the utility of the plastochron index for the development of the leaf in *Amaranthus* and *Chenopodium* in order of competitional combinations, and ii) by using of the linear model of PI, to descrive the different linear patterns between both species.

MATERIALS AND METHODS

Seeds of *Amarenthus* and *Chenopodium* were collected in 1984 during October and November respectively. Collected seeds were allowed to air dry and then stored in the dark at 5°C until using in experiment.

Germination of both species were conducted in incubator at 30°C and the seedlings were transplanted into 9cm diameter plasticpotfilled with vermiculite. Seedling sizes were equal when the time of transplanting in order to eliminate any effects of time of seed germination and seedling size on the competitive interactions.

Growth Conditions The experiments were conducted in growth chamber equipped with fluorescent and incandescent lighting (3,000 Lux). Plants were grown in 16hrs photoperiod at 28/18±2°C(day/night) temperature regime and were frequently fertilized with Hoagland nutrient solution. Humidity was kept in 75%.

Competitional Combinations The seedlings were transplanted in 4 proportions of each species into a hexagonal pattern, providing equal spacing at a density of 24 plants per a pot. 4 competitional combinations for both species were pure each species, 1 : 3(*Ama.* : *Che.*), 2 : 2, and 3 : 1, and then it was conducted 5 replications.

Measurement of Leaf Length Leaf length measurements to the nearest mm were taken at 24 hr-interval for each competitional combinations in both species. For the date analysis, cotyledons and the first two leaves were excluded because they were found to have a growth pattern that differed from the other leaves.

Analysis of Data The raw data were plotted the natural logarithm of leaf length versus time. From the data, the reference length was obtained, it must be selected in early stage of development ie., the range of exponential growth and large enough to be measured accurately.

In our study, the reference length for *Amaranthus* was 5mm, for *Chenopodium* 4mm. Application of the PI to competitional combinations for both species were made by complemented plastochron index described in previous paper (Table 1).

RESULTS

Figs. 1 and 2 showed that the growth curve represented the natural logarithm of leaf length versus time for *Amaranthus* and *Chenopodium*. It showed the different growth pattern between *Ama-*

Table 1. The equation for the plastochron age of the plant. (PI: Plastochron index, L_n: The length of leaf N., *LR*: The reference length)

leaf length	$L_n > LR > L_{n+1}$	$2L_n - L_{n+1} > LR$	$2L_{n+1} - L_n > LR$
PI	$n + \frac{\ln L_n - \ln LR}{\ln L_n - \ln L_{n+1}}$	$n - \frac{\ln LR - \ln L_n}{\ln L_n - \ln L_{n+1}}$	$n + 1 + \frac{\ln L_{n+1} - \ln LR}{\ln L_n - \ln L_{n+1}}$

ranthus and *Chenopodium*. Since they have a different leaf arrangements.

The growth curve were represented the semilogarithmic plotting for each species (pure) in Figs. 3 and 4. It appeared linear types for each leaf length

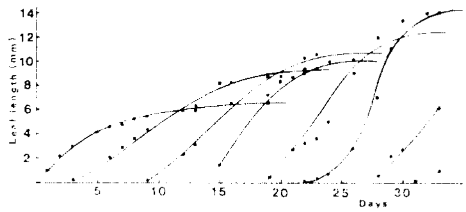

Fig. 1. The relations between leaf length (mm) and time for *Amaranthus retroflexus*.

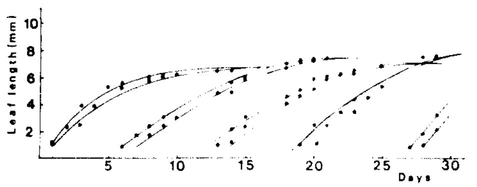

Fig. 2. The relations between leaf length (mm) time for *Chenopodium album*.

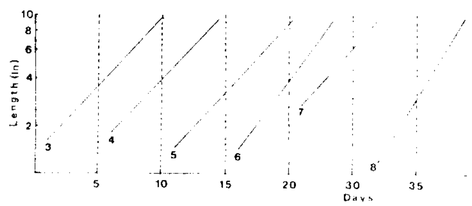

Fig. 3. Semilogarithmic graph about leaf length against time for *Amaranthus retroflexus* in early stage.

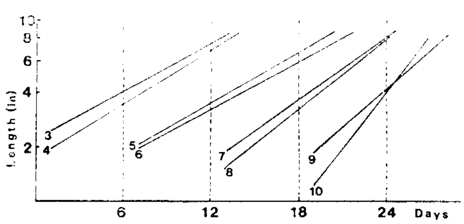

Fig. 4. Semilogarithmic graph about leaf length against time for *Chenopodium album* in early stage.

in *Amaranthus* and *Chenopodium*. By using linear model for plastochron age of the plant, the regression lines of each leaves were obtained. And then the each lines were collected, and a regression line was estimated. The lines were derived from the linear model equation, $Y_n = a-(n-1)q+rt+\varepsilon$.

As shown in Fig. 5, a family of parallel lines was generated, the equation of the first line was $Y=0.22X+0.23$, and it was occurred repeatly 4.95 times interval (ie., the value of plastochron). In Fig. 6 also, two families of parallel lines in *Chenopodium* were generated, the equation of the first line was $Y=0.20X+0.36$, and it was repeated 0.96 (P1), 4.99 (P2) interval.

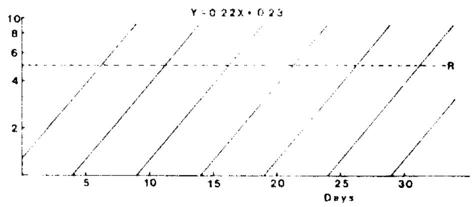

Fig. 5. The linear model of the plastochron in *Chenopodium album* (pure).

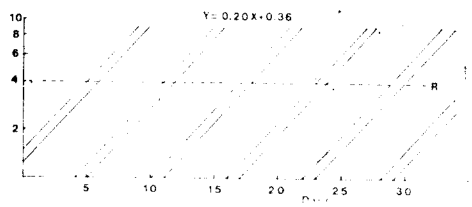

Fig. 6. The linear model of the plastochron in *Chenopodium album* (pure).

Table 2. Evaluation of the effect of competition on the plastochron. The ratios are combinations between of *Amaranthus* and *Chenopodium*

Species ratios	*Amaranthus*		*Chenopodium*		
	Plastochron	Slope	Plastochron 1	Plastochron 2	Slope
pure	4.95	0.22	0.63	4.99	0.20
3 : 1	3.65	0.22	2.34	3.24	0.11
2 : 2	4.49	0.27	1.56	4.08	0.10
1 : 3	4.68	0.31	0.87	4.78	0.12

These results demonstrated that the linear pattern of plastochron of plants was varied as leaf arrangements. These values were varied with competitional combinations (Table 2).

The results from analysis of variance indicated that there were no significant differences (0.05) between competitional combinations for *Amaranthus*. While the competitional effects on development of leaf of *Chenopodium* were significant in both plastochron 1 and 2. The competitional effects for the *Chenopodium* suggested that the values of plastochron 1 were increased and the values of plastochron 2 were decreased as for competitional combinations. The value of plastochron 1 means that the time interval between two leaves attached on one node and the value of plastochron 2 means the time interval between the node.

Comparison between the value of *Amaranthus* was increased in order of competitional ratios, for *Chenopodium* it was decreased. These results suggested that *Amaranthus* had greater competitive abilities than *Chenopodium*.

The plastochron index was estimated for the competitional effects in *Amaranthus* and *Chenopodium* (Table 3). The low value of PI means the numbers leaf occurred are few, since a fixed number of PI is estimated as serial number of leaf. Therefore, and low value of PI means that the plants grow slowly.

The values of PI of the third leaf were exhibited

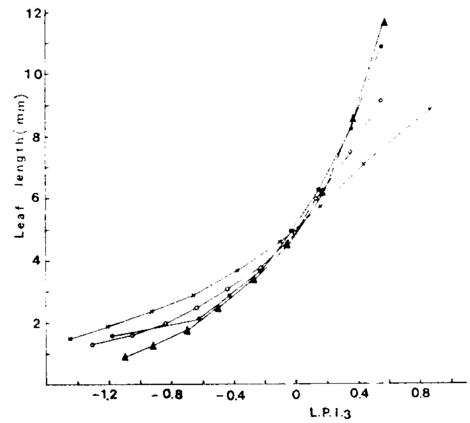

Fig. 7. The third leaf length plotted against LPI (Leaf plastochron index) in *Amaranthus retroflexus*. LPIi=PI-i, i : the serial number of i leaf.○ : pure, ▲ : 1 : 3(*Amaranthus* : *Chenopodium*), × : 3 : 1, ● : 2 : 2

Table 3. PI at 4 compitition ratios between *Amaranthus retroflexus*(*Am.*) and *Chenopodium album*(*Ch.*)

Day	Pure		1 : 3		2 : 2		3 : 1	
	Am.	*Ch.*	*Am.*	*Ch.*	*Am.*	*Ch.*	*Am.*	*Ch.*
3	2.20	4.13	2.22	4.0	2.18	1.3	1.93	1.93
6	3.05	4.59	3.0	5.12	2.99	2.45	2.85	3.45
9	3.25	6.01	3.26	5.56	3.96	3.90	4.0	4.18
10	4.18	6.09	4.20	6.03	4.17	4.05	4.05	4.33
11	4.31	6.34	4.22	6.07	4.20	4.08	4.20	4.40
12	4.47	6.53	4.24	6.16	4.22	4.14	4.36	4.62
13	4.59	6.72	4.39	6.23	4.33	4.28	4.58	4.75
14	4.66	7.32	4.69	6.34	4.48	4.30	4.69	5.0
16	5.0	8.17	5.07	6.60	5.32	5.67	5.15	6.07
19	5.48	8.29	5.38	8.01	5.36	5.97	5.98	6.36
20	6.13	8.45	5.83	8.07	6.10	6.13	6.27	
21	6.50	8.50	6.05	8.22	6.34	6.22	6.92	
24	6.61		6.74		7.13		7.56	

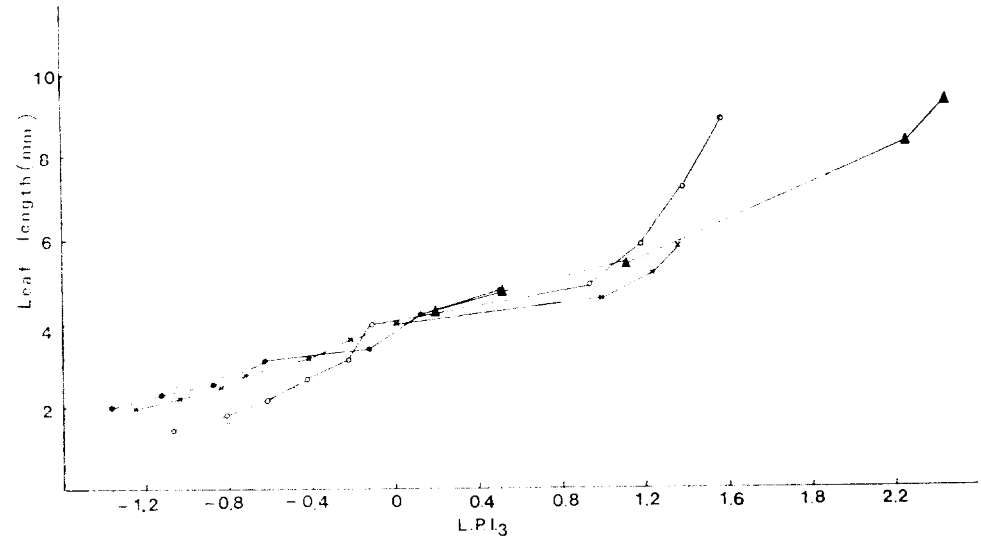

Fig. 8. The third leaf length plotted against LPI in *Chenopodium album.* ○ : pure, × : 1 : 3 (*Amaranthus* : *Chenopodium*), ▲ : 3 : 1, ● : 2 : 2.

by linear model in Figs. 7 & 8. The leaf plastochron index (LPI) can be used in developmental studies limited specifically to only one leaf in question.

LPIi=PI−i.

Where i is the serial number of the leaf in question.

Even though the lamina initiated at LPI-1.2, because it was practically started on the leaves enough to measure. LPI can also be concluded that the growth in the early plastochrons is exponential. LPI is zero value occurring only when the leaf is exactly the reference length (Fig. 7, 8).

DISCUSSION

The results clearly demonstrated that development of leaf in *Amaranthus* and *Chenopodium* was affected by the competition. The competitive effects significantly reduce the r of *Chenopodium* (Table 2). However the r of *Amaranthus* was increased as for competitive ratios.

In the analysis of plastochron model, the PI was used complemented PI of Erickson & Michelini in previous paper, it was useful to estimate the PI in experiments.

The patterns of linear model as leaf arrangement were different between *Amaranthus* and *Chenopodium.* Because the leaf arrangement of *Amaranthus* is alternate type and *Chenopodium* is opposite type.

The variation of PI for both species indicated that *Amaranthus* had competitive advantage over *Chenopodium* (Table 3). These results were considered that differences in photosynthetic pathway between *Amaranthus* (C_4) and *Chenopodium* (C_3) could be an important determinant in competitive interactions (Baskin *et al.*, 1978, Ethleringer, 1978).

The competitive effects in *Chenopodium* exhibited that the time interval between two leaves attached a node of shoot was longer than control. It considered as our experimental processes were investigated on advantage conditions for C_4 pathway. Therefore such as these experiments will be compared with these results.

In summary, measurements of the plastochron, the exponential rate of leaf elongation and the use of linear model provide a useful means of evaluating plant response to various environments (Vallejos *et al.*, 1983).

摘 要

*Amaranthus retroflexus*와 *Chenopodium album*은 形態的, 生態的으로 비슷한 生育地에서 자라는 一年生은 雜草이다.

두 植物의 잎의 競爭的 發達이 plastochron index의 값으로서 解釋되어졌다. *Amaranthus*에 대한 plastochron 값들은 *Chnopodium*과의 競爭的 比率에 따라 變異가 없는 것으로 나타났고 (0.05의 有意 水準에서 일원 배치법에 의한 分散 分析 結果) 그와 달리 *Chenopodium*에서는 *Amaranthus*와의 競爭的 比率의 增加에 따라 plastochron 1의 값들은 增加했고, plastochron 2의 값들은 減少했다. 즉 *Chenopodium*에서의 競爭的 效果는 같은 마디에 달려 있는 잎들 사이의 出現 時間 間隔이 커졌으며, 마디 사이의 出現 時間 間隔은 작아 지는 傾向을 보이는 것으로 解釋될 수 있었다. 이 같은 結果들은 *Amaranthus*가 *Chenopodium*과의 競爭的 相互 作用에 대해 有益性을 가지고 있음을 提示했다. 이것은 아마도 *Amaranthus*(C_4 식물)과 *Chenopodium*(C_3 식물) 사이의 光合成 過程의 차이로서 說明될 수도 있다.

Lamina의 出現은 LPI −1.2에서 시작되었으나 이것은 實質的으로 測定하기에 充分한 잎들에서 計算되었던 것으로 認識되었으며, LPI 값들은 또한 그 增加形態(Fig. 7, 8)가 初期 plastochrons에서는 exponential 함을 다시 結論지을 있게 한다.

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(*Received May* 30, 1985)